Self-Reported Total Vegetable Intake, but not Fruit, is Associated with Higher Cognitive Test Scores Among University Students

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by
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Authorization to Submit Thesis

This thesis of Meredith A. LaFrance, submitted for the degree of Master of Science with a Major in Family and Consumer Sciences and titled "Self-Reported Total Vegetable Intake, but not Fruit, is Associated with Higher Cognitive Test Scores Among University Students," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

Fruit and vegetable (F/V) consumption throughout the lifespan plays an important role in maintaining optimal physical health; however, additional research focusing on college students is needed. University of Idaho students (n=23) participated in this cross-sectional study to investigate relationships between dietary F/V intake and 1) cognitive outcomes, 2) psychological well-being, and 3) skin carotenoid concentrations. Dietary F/V intake was assessed using the Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool (version 2018). Cognitive and emotional outcomes were assessed via the NIH Toolbox® for Assessment of Neurological and Behavioral Function (NIH Toolbox). Skin carotenoid concentrations were estimated using Resonance Raman spectroscopy (RRS). Spearman's correlations (with and without an income adjustment) were used to evaluate relationships between variables using SAS software. Cognitive scores were adjusted for age, gender, race, ethnicity, educational attainment, and parent education.

Higher processing speed was associated with higher total vegetable intake (R^2=0.56, p=0.01) and higher combined F/V intake (R^2=0.43, p=0.04) with the added income adjustment. Intake of dark-green vegetables positively correlated with executive function (R^2=0.42, p=0.05), as well as processing speed (R^2=0.45, p=0.04) and fluid cognition (R^2=0.48, p=0.02). Additionally, consumption of foods rich in lycopene positively correlated with processing speed (R^2=0.43, p=0.05) and fluid cognition (R^2=0.41, p=0.05). While there was no significant relationship between F/V consumption and skin carotenoid scores, there was a significant positive relationship between skin carotenoid scores and dietary intake of beta-carotene (R^2=0.50, p=0.01), lycopene (R^2=0.42, p=0.05), and total carotenoids (R^2=0.72, p=0.0001).

There was no association between total dietary F/V intake and emotional health measures; however, consumption of dark-green vegetables, consumption of legumes, and skin carotenoid sores were inversely related to negative affect (R^2=-0.45, p=0.04; R^2=-0.42, p=0.05; R^2=-0.50, p=0.02, respectively). Legume intake and skin carotenoid scores were also positively related to psychological well-being (R^2=0.44, p=0.04; R^2=0.48, p=0.02, respectively). Results of this study suggest a relationship between dietary intake of total vegetables and higher processing speed scores, but no relationship between total fruit and cognitive outcomes. Further research with larger sample sizes is needed to comprehensively evaluate these relationships among university students.

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Dedication

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I also dedicate this accomplishment to my grandmother, Dolores Schmidt, for setting an example early on in my life as a strong-willed, self-motivated, and resilient woman.

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List of Abbreviations

AD	Alzheimer's disease
ASA24	Automated Self-Administered 24-hour Dietary Assessment Tool
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CFC	Cognition Fluid Composite
CHD	Coronary Heart Disease
COMPASS	Computerized Mental Performance Assessment System
DCCS	NIH Toolbox Dimensional Change Card Sort Test
ECF	Executive Cognitive Function
FFQ	Food Frequency Questionnaire
FICA	NIH Toolbox Flanker Inhibitory Control and Attention Test
F/V	Fruit and Vegetable
IQR	Interquartile Range
LSWM	NIH Toolbox List Sorting Working Memory Test
NIH	National Institutes of Health
PCPS	NIH Toolbox Pattern Comparison Processing Speed Test
PSM	NIH Toolbox Picture Sequence Memory Test
PWI-SF	Psychosocial well-being index-short form
RRS	Resonance Ramen Spectroscopy
SAS	Statistical Analysis Software
SCOPE	Student Coping Scale
SD	Standard Deviation
SHS	Subjective Happiness Scale
USDA	United States Department of Agriculture
WHO	World Health Organization

Chapter 1: Research Purpose and Overview

Problem Statement

Fruit and vegetable (F/V) consumption throughout the lifespan (including pregnancy, early childhood, adolescence, young adulthood, middle adulthood, and older adulthood) plays an important role in maintaining optimal physical health. Among the general population, F/V intake is associated with a reduced risk of cardiovascular disease (Dauchet et al., 2006; Tanaka et al., 2013), type 2 diabetes (Cooper et al., 2012; Wang et al., 2016), stroke (Chuang et al., 2016; Hu et al., 2014; Larsson et al., 2013), and certain types of cancer (Farvid et al., 2019; Key, 2011). Some studies attribute the reduction in disease incidence to the dietary fiber (Casiglia et al., 2013; Wang et al., 2016). Fruits and vegetables, especially legumes, contribute the most dietary fiber. Plant-based diets in particular are associated with a range of positive health outcomes, including decreased risk of coronary heart disease (CHD) (Satija et al., 2017), type 2 diabetes, dementia, hypertension, hyperlipidemia, gastrointestinal disease, and cancer (Marsh et al., 2012; Satija & Hu, 2018; Segasothy & Phillips, 1999). Those adhering to vegan (no meat, poultry, fish, or animal products) and lacto-ovo vegetarian (no meat, poultry, or fish; includes diary and eggs) diets appear to have approximately half the risk of developing type 2 diabetes when compared to those following nonvegetarian diets (Tonstad et al., 2009). Research also demonstrates an association between F/V intake and emotional well-being across age groups (Boehm et al., 2018; Conner et al., 2017; Rooney et al., 2013).

Young adulthood is a pivotal period, as habits developed during this time tend to be carried on into middle and older adulthood (Nelson et al., 2008). It is also a peak time for certain types of learning and recall (Myers, 2014), and is marked by increased independence as individuals leave the parental home, complete their formal education, and establish a career (J. E. Brown, 2017). Research suggests that diet quality, in conjunction with physical activity, stress, and sleep, also plays an important role in helping college students maintain a healthy weight (Nelson et al., 2008). Research also demonstrates that dietary patterns during adolescence impact brain development and cognition (Taki et al., 2010). The increased academic pressure characteristic of this lifecycle stage further amplifies the importance of a healthy diet (Chung et al., 2012). Yet, there is minimal research to date that shows a positive relationship between whole F/V intake and cognition in this population (Whyte et al., 2019).

Research on dietary intake of fruits and vegetables and cognition tends to center on middle to older adults and addresses the impact on cognitive decline and risk of developing Alzheimer's and dementia. Among middle-aged and older adults, high F/V intake has been shown to delay cognitive impairment (Nooyens et al., 2011; Yuan et al., 2019) and improve emotional well-being (Nguyen et al., 2017). Studies on F/V intake and cognitive outcomes that include younger populations emphasize academic performance. Children (aged 4 years) have performed higher on verbal intelligence tests (Gale et al., 2009) and adolescents (aged 12-15 years) have demonstrated improved cognitive function and overall academic performance (Abudayya et al., 2011; Nyaradi et al., 2014) with increased F/V consumption. A small number of studies demonstrate a positive relationship between supplementation with fruit juices and extracts (Haskell-Ramsay et al., 2017; Watson et al., 2015) and varying cognitive outcomes (e.g., episodic memory, attention, and reaction time) among young adults. One study also indicates that greater F/V intake among undergraduate students positively influences academic performance (Wald et al., 2014). Another study found a relationship between drinking a smoothie containing mixed berries and faster response times based on certain tasks measuring aspects of cognition (Whyte et al., 2019). However, there is limited research available on the association between whole fruits and vegetables, specifically vegetable subgroups, and cognitive and emotional outcomes among college-age adults. Additional research regarding the relationship between F/V intake and cognitive function among university students is needed.

Statement of Purpose

The purpose of this study is to determine the impact of reported fruit and vegetable (F/V) intake on cognitive functioning and emotional well-being among undergraduate students (18-26 years) at the University of Idaho in Moscow.

Study Objectives

i. Assess usual dietary intake of University of Idaho Students (18-26 years) by facilitating the completion of three 24-hour dietary recalls.
ii. Determine average daily F/V intake among University of Idaho students (18-26 years).
iii. Compare average F/V intake of University of Idaho students (18-26 years) with the *2015-2020 Dietary Guidelines for Americans*.
iv. Measure cognitive and emotional outcomes of University of Idaho students (18-26 years).
v. Determine the relationship, if any, between F/V intake and cognitive functioning among University of Idaho students (18-26 years).
vi. Determine the relationship, if any, between F/V intake and emotional well-being among University of Idaho students (18-26 years).

Hypotheses

Null Hypotheses (H_0):

i. One hundred percent of participants will meet the recommended daily intake for fruits and vegetables as outlined in the *2015-2020 Dietary Guidelines for Americans*.
ii. One hundred percent of participants will have a normative unadjusted scale score for cognition.
iii. There will be no relationship between F/V intake and cognitive outcomes.
iv. There will be no difference in cognitive outcomes among those in highest and those in lowest quartile of F/V intake.
v. There will be no relationship between F/V intake and measures of emotional well-being.

Alternative Hypotheses (H_a)

i. Less than one hundred percent of the participants will meet the recommended daily intake for fruits and vegetables as outlined in the *2015-2020 Dietary Guidelines for Americans*.

ii. Less than one hundred percent of participants will have a normative unadjusted scale score for cognition.

iii. There will be a positive relationship between F/V intake and cognitive outcomes.

iv. There will be a significant difference in cognition among those in highest and those in lowest quartile of F/V intake.

v. There will be a positive relationship between F/V intake and measures of emotional well-being.

Chapter 2: Review of Literature

Brain Development in Adolescence and Young Adulthood

Preadolescence and adolescence are characterized by significant structural and cognitive brain development (Taki et al., 2010). The accelerated growth that occurs between 11 and 13 years of age is followed by a period of "pruning" (elimination of unnecessary connections), which is thought to explain the decrease in grey matter (Giedd, 2004). Increased white matter volume (in the temporal, frontal, parietal, and occipital areas of the brain) reflects the rapid myelination of axons, which is believed to enhance processing speed and more complex cognitive abilities (Giedd, 2004). Research involving cognitive outcomes among individuals in this age range primarily focuses on aspects of executive cognitive function (ECF).

The frontal lobe is considered the center for ECF, as it is responsible for judgement, strategic thinking, and impulse control (Anderson, 2016). ECF also encompasses a diverse set of control processes that influence planning (especially goal-oriented planning), (Takeuchi et al., 2013) sequencing, inhibition, working memory, attention, assembling, and coordinating (Salthouse et al., 2003). Interactions between the prefrontal cortex and the limbic system enhance ECF, improving problem solving and goal-directed behavior (Riggs et al., 2010). Planning and the ability to transition from one task or mental set to another are also categorized as types of ECF. Studies involving adolescents and their performance on tasks related to emotional and inhibitory control, (Blakemore & Choudhury, 2006; Leon-Carrion et al., 2004) processing speed, (Luna, 2004) working memory, and decision-making (Hooper et al., 2004; Luciana et al., 2005) demonstrate the ongoing developing of executive functions throughout adolescence.

Research on ECF applies to social development as well as academic performance (Blakemore & Choudhury, 2006). These executive functions aid in the separation of important and unimportant information, as well as the ability to resist impulses. (Blakemore & Choudhury, 2006). Furthermore, psychological, social, and environmental changes during this stage lead to more independent lifestyle choices (e.g., eating out more frequently) and can influence dietary habits and food selection (Reichelt & Rank, 2017; Story et al., 2002). Added peer pressure and heightened anxiety about body image can also affect food-related behaviors among adolescents (Story et al., 2002).

The frontal lobe continues to develop throughout young adulthood, reaching peak maturity between 23 and 25 years of age (Anderson, 2016). A 2016 study involving 178 university students evaluated the impact of planning and working memory, which are components of ECF. Performance on a series of planning tests (e.g., *Planned Connections, Planned Codes,* and *Planned Patterns)* and working memory tests (e.g., *Listening Span, Digit Span Backward*, and *Digit Memory*) indicated that planning exerted a significant effect on reading comprehension (Georgiou & Das, 2016). Planning was also the primary contributor to ECF among a separate group of 30 university students with a reading deficit (Georgiou & Das, 2016). While no relationship between working memory and reading compression was found in these studies, the correlation between planning and reading comprehension highlights the important role cognition plays in academic success among college-age adults (Georgiou & Das, 2016).

Established Guidelines for Fruit and Vegetable Intake

Fruit and vegetables are components of a healthy diet. The most recent recommendations for F/V intake among U.S. adults are based on the *2015-2020 Dietary Guidelines for Americans*, which is issued every five years by the United States Department of Agriculture (USDA). According to the Healthy U.S.-Style Eating Pattern at the 2,000-calorie level, U.S. adults should consume 2.5 cup-equivalents of vegetables per day and 2 cup-equivalents of fruit per day. Vegetables are divided into five subgroups: Dark-green, red and orange, legumes (beans and peas), starchy, and other. Vegetables from these different subgroups provide key nutrients, such as vitamin A, vitamin K, and fiber. The dietary guidelines state that, on a weekly basis, U.S. adults should consume 1.5 cup-equivalents of dark-green vegetables, 5.5 cup-equivalents of red and orange vegetables, 1.5 cup-equivalents of legumes, 5 cup-equivalents of starchy vegetables, and 4 cup-equivalents of other vegetables. Table 2.1 lists examples from each vegetable subgroup.

Table 2.1: Vegetable Subgroups from the *2015-2020 Dietary Guidelines for Americans*

Vegetable Subgroup	Examples
Dark-Green Vegetables	Broccoli, Spinach, Leafy Salad Greens (Including Romaine Lettuce), Collards, Bok Choy, Kale, Turnip Greens, Mustard Greens, Green Herbs (Parsley, Cilantro)
Red & Orange Vegetables	Tomatoes, Carrots, Tomato Juice, Sweet Potatoes, Red Peppers (Hot and Sweet), Winter Squash, Pumpkin
Legumes (Beans & Peas)	Pinto, White, Kidney, and Black Beans; Lentils, Chickpeas; Limas (Mature, Dried); Split Peas; Edamame (Green Soybeans)
Starchy	Potatoes, Corn, Green Peas, Limas (Green, Immature, Plantains, Cassava
Other	Lettuce (Iceberg), Onions, Green Beans, Cucumbers, Celery, Green Peppers, Cabbage, Mushrooms, Avocado, Summer Squash (Includes Zucchini), Cauliflower, Eggplant, Garlic, Bean Sprouts, Olives, Asparagus, Peapods (Snowpeas), Beets

(U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015)

Energy intake recommendations vary according to age, sex, weight, height, and level of physical activity, which means there are also variations in the recommended servings of fruits and vegetables. An all-encompassing recommendation for adults is a total of five or more F/V servings per day. This is slightly higher than the 4.5 servings outlined in the Healthy U.S.-Style Eating Pattern at the 2,000-calorie level. This makes sense, as F/V recommendations increase as caloric intake increases. In addition to recommendations based on caloric intake, there are also guidelines for specific age-sex groups: Males/Females 1-3 years, 4-8 years, 9-13 years, 14-18 years, 19-30 years, 31-50 years, 51-70 years, and 70+ years. According data provided in the *2015-2020 Dietary Guidelines for Americans*, males and females aged 19-30 years are not meeting the age-sex guidelines for total F/V. They are also below the recommended range for vegetables from each of the vegetable subgroups.

MyPlate (choosemyplate.gov) is commonly used to establish general parameters for F/V consumption, as well as other important parts of a healthy diet. An image of a table setting is used to reflect the USDA’s recommendations. The plate is divided into four sections, with half the plate consisting of fruits and vegetables and the other half consisting of grains, and protein. A circle in the upper right represents dairy.

MyPlate focuses on increasing consumption of whole fruits and vegetables, whole grains, and low-fat/fat-free dairy, in addition to reducing intake of saturated fat, sodium, and added sugars (U.S. Department of Agriculture, n.d.). As with the *2015-2020 Dietary Guidelines for Americans*, MyPlate recommendations for F/V consumption vary according to calorie requirements related to age, sex, and physical activity level (Kimmons et al., 2009).

Fruit and Vegetable Intake Among Young Adults

According to the Centers for Disease Control (CDC) (2017), one in 10 adults consumes the recommended amount of fruits and vegetables, which (depending on age and sex) is 1.5 to 2 cups per day of fruit and 2 to 3 cups per day of vegetables (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). Research suggests that, based on the U.S. dietary guidelines, the vast majority of college students do not consume an adequate amount of fruits and vegetables (Anding et al., 2001). There is some research on vegetable consumption among young adults relative to other guidelines such as those established by the World Health Organization (WHO) (Rodrigues et al., 2019). A meta-analysis of 71 studies revealed that the majority of college-university students assessed (n=65,9710) did not meet the WHO's recommended minimum F/V intake of 400 grams (5 portions) per day (Rodrigues et al., 2019; World Health Organization, 2015). In their review, Rodrigues et al. (2019) also found that females tended to consume higher amounts of vegetables compared to males. In a longitudinal study looking at predictors of F/V intake among college students in Minneapolis/St. Paul, average daily intake of whole fruit was only 0.9 servings and average daily intake of vegetables (excluding potatoes) was 1.8 servings (Larson et al., 2012). Both of these amounts are below the average recommended two servings of fruit and 2.5 servings of vegetables per day. The Healthy Eating Index or the Alternate Healthy Eating Index (based on the U.S. dietary guidelines) are often used in studies involving a range of populations to assess health characteristics and adherence to specific diets (Ervin, 2008; McCullough & Willett, 2006). However, specific studies evaluating the number of U.S. college students that meet the U.S. dietary guidelines are minimal.

Research indicates that F/V intake decreases during the transition to adulthood. According to the American College Health Association's 2009 National College Health Assessment, only 5.9 percent of college students reported consuming five or more servings of fruits and vegetables each day (American College Health Association, 2009). In a 2016 study, college students (aged 18-25 years) recalled greater preference for fruits and vegetables during childhood and reported a decreased intake as adults (Ramsay, 2016). Overall, research shows that young adults typically are not consuming the recommended amount of fruits and vegetables.

Factors Influencing Fruit and Vegetable Intake

F/V intake may vary based on culture, geographical location, and family preference (Morgan et al., 2016). Availability (e.g., seasonality) could also play a role. In a qualitative study of urban Fijians, researchers found that differences in traditional dietary patterns among Hindus and members of the iTaukei community accounted for many variations in the types of fruits and vegetables consumed (Morgan et al., 2016). F/V consumption also tends to be higher among those with higher income, education, and social status (Johansson & Andersen, 1998). Furthermore, women tend to consume more fruit and vegetables compared to men, and older adults have a higher intake than younger individuals (Pollard et al., 2002; Riediger & Moghadasian, 2013). A longitudinal study of college students in Minneapolis/St. Paul found that intake of fruits and vegetables was higher among those more concerned about their health and with fewer perceived time barriers to including healthier items (Larson et al., 2012).

Other factors that may influence F/V intake across the lifespan include: sensory appeal, familiarity, social pressures, cost, time constraints related to preparation time, and media influences (Pollard et al., 2002). Videos promoting F/V consumption and demonstrating preparation techniques can also affect F/V intake. One study found a significant increase in reported intake of asparagus from 0.02 ± 0.36 servings each day to 0.03 ± 0.19 servings each day ($p=0.016$), though no significant change in total F/V intake was noted (K. N. Brown et al., 2011). Similar results have been found in other studies. Cooking classes and certain types of nutrition education are associated with increased F/V vegetable intake among adults (B. J. Brown & Hermann, 2005), as well as elementary- and middle school-aged youth (Jarpe-Ratner et al., 2016).

Fruit and Vegetable Intake and Cognition

Carbohydrates, protein, fat, vitamins, and minerals are obtained through the diet and contribute to the brain's structure and functions (Nurliyana et al., 2014). Nutrients are critical for DNA synthesis and cell proliferation and drive metabolic processes (Nyaradi et al., 2013). A diet that is nutritionally deficient can lead to long-term cognitive impairment (Nurliyana et al., 2014). Due to the fact that fruits and vegetables are rich in nutrients and comprise half of the USDA's MyPlate, their impact on cognitive outcomes is worth investigating.

Previous studies have investigated the impact of F/V intake on cognition, though many focus on academic performance in younger populations (MacLellan et al., 2008) and slowing cognitive decline in middle-aged to elderly populations (Nooyens et al., 2011; Nurk et al., 2010). Other studies have evaluated the relationship between specific micronutrients (e.g., vitamin B_{12}, iodine, and iron) and neurocognitive development (Nyaradi et al., 2013). However, individuals tend to consume various combinations of nutrients, which differ in their interaction with one another (Nurliyana et al., 2014). Thus, it is important to look at cognitive impacts of whole foods. Furthermore, Nyaradi review addressed some nutrients not found in significant amounts in fruits and vegetables. For example, while certain fruits and vegetables contain iron, they are not significant sources of vitamin B_{12}.

There are a number of studies relating F/V intake and cognition among younger and older populations. There are also studies that suggest a relationship between specific bioactive compounds found in fruits and vegetables and cognition across the lifespan, including among young adults. However, to date there is no research available demonstrating an association between daily/weekly whole F/V consumption and cognition among college-age adults. The following section addresses research that is currently available on F/V vegetable intake throughout the lifespan and the impact on cognition.

Fruit and Vegetable Intake and Cognitive Outcomes Throughout the Lifespan

Older Adulthood (>60 Years)

A rapidly growing aging population (over the age of 60 years) (J. E. Brown, 2017) and increased incidence of cognitive decline have prompted considerable interest in the impacts of dietary factors on neurodegenerative diseases (Lamport et al., 2014). Research has shown diets rich in vegetables and plant-based foods to be protective against negative impacts on cognition (Ashby-Mitchell et al., 2015). One study found that a diet high in vegetables, fruits, legumes, soy products was associated with reduced cognitive impairment in older Chinese women (> 65 years) (Chan et al., 2013). Among Puerto Rican adults (n=1412) aged 45-75 years, there was a positive relationship between the consumption of a wide variety of fruits and vegetables and a higher Mini Mental State Examination (MMSE) score, which is a measure of global cognition (Ye et al., 2013). There was also a significant relationship between greater F/V variety and measures of executive function, memory function, and attention (Ye et al., 2013). Results from a study involving Chinese adults aged 65 years and older indicate that higher intake of fruits and vegetables may reduce the risk of global cognitive decline (based on the Taiwanese version of the Montreal Cognitive Assessment, or MoCA-T) and decline in measures of attention (based on the Wechsler Memory Scale-Third Edition digit span-forward and backward) (Chou et al., 2019). In another study involving individuals aged 60-75 years, participants who received a beverage containing approximately 600 mg of flavonoids derived from blueberries maintained sustained cognitive performance over the course of the day compared to the control group (Dodd et al., 2019).

Studies involving specific plant-based dietary patterns, such as the Mediterranean Diet, inversely correlate with risk of Alzheimer's disease (AD), dementia, and mild cognitive impairment (Scarmeas et al., 2006; Yannakoulia et al., 2015). Other studies have evaluated the quantity and frequency of F/V consumption in terms of significant cognitive benefits. Based on a meta-analysis of 25 epidemiological and dietary intervention studies, chronic intake of whole fruits and vegetables, as well as 100% fruit juices may have protective effects on cognition (Lamport et al., 2014).

In Norwegian study, 2031 participants (aged 70-74 years) completed a comprehensive Food Frequency Questionnaire (FFQ) and a series of six cognitive tests, designed to assess executive function, episodic memory, perceptual speed, and global cognition, among others (Nurk et al., 2010). Researchers found that those consuming up to 500 grams per day of fruits and vegetables performed better on all six cognitive tests (Nurk et al., 2010). Cognitive improvements were seen in individuals consuming a maximum of 50-200 grams per day of vegetables alone, while the amount of fruits and mushrooms consumed was not associated with increased or decreased cognitive performance (Nurk et al., 2010). Findings from these studies highlight the strong association between F/V consumption and cognition among older adults. Diets high in fruits and vegetables have also been shown to be beneficial to individuals in middle adulthood.

Middle Adulthood (35-60 Years)

Fewer studies evaluate the correlation between F/V intake and cognition among middle-aged adults (J. E. Brown, 2017; Nooyens et al., 2011). In a study of 2533 French men and women (aged 45-66 years) researchers used six 24-hour dietary recalls and a series of verbal memory and executive function tests (Péneau et al., 2011) to determine a correlation between higher combined F/V intake, as well as fruit intake alone, and verbal memory scores (Péneau et al., 2011). Conversely, higher combined F/V intake, as well as consumption of vegetables alone, was associated with decreased executive functioning. (Péneau et al., 2011). Furthermore, in one study, adherence to a plant-based food pattern correlated with higher cognitive scores for executive function, learning, and memory (Pearson et al., 2016). In addition to the relationship between high F/V intake and improved cognition, some studies also indicate a correlation between low consumption of fruits and vegetables (< 2 servings per day) and decreased cognitive function (Sabia et al., 2009). Similar to older adults, relationships between cognitive functioning and juice consumption have also been found among middle-aged adults. A study involving 24 males (aged 30-65 years) demonstrated improved cognitive function and psychomotor speed after consuming 240 mL of flavonoid-rich orange juice (Alharbi et al., 2016).

Certain types of vegetables have also been associated with cognition among middle-aged adults. In a study using data from the Nurse's Health Study, intake of cruciferous vegetables, dark-green leafy vegetables, and soybeans correlated with slower cognitive decline among females aged 30-55 years (n=121700) and a diet rich in soybeans and soybean products was associated with a reduced risk of dementia (Kang et al., 2005). In another study, researchers used an FFQ with 178 food items to assess the diets of 2613 men and women (aged 43-70 years) in the Netherlands (Nooyens et al., 2011). At the beginning of the study, participants consuming greater amounts of nuts, mushrooms, and cabbage performed better on four cognitive tests aimed at measuring memory function, cognitive flexibility, and information processing speed (Nooyens et al., 2011). Five years later, individuals with a higher intake of cabbage, root vegetables, or total vegetables exhibited a smaller decline in cognitive function (Nooyens et al., 2011).

Young Adulthood (18-35 Years)

The number of studies evaluating the relationship between F/V intake and cognition among young adults is limited. Research indicates that better adherence to lifestyle recommendations (e.g., consuming at least five servings per day of fruits and vegetables) is associated with a higher grade point average among undergraduate students (n=16,095) ages 18-24 years (Wald et al., 2014). In a randomized, single blinded, placebo-controlled study, that included adults aged 20-30 years (n=40), researchers found that participants who consumed a 400-mL blended drink consisting of 75 grams each of whole blueberries, blackberries, strawberries, and raspberries demonstrated improved executive function compared to the placebo group. This included significantly better accuracy after six hours based on the Modified Attention Network Task (MANT) and improved response times on Task Switch Task (TST) (Whyte et al., 2019).

Other research suggests an association between fruit juice and cognitive outcomes among young adults. In a randomized, placebo-controlled, double-blind study (n=20, mean age=21.05 years) adults receiving 230 mL purple grape juice achieved a higher score for reaction time on a measure of composite attention compared to the group given a sugar-matched control beverage (Haskell-Ramsay et al., 2017).

Cognitive outcomes were measured using the Computerized Mental Performance Assessment System (COMPASS, Northumbria University, Newcastle upon Tyne, UK), which consisted of domains to assess episodic memory and working memory in addition to attention (Haskell-Ramsay et al., 2017). In another intervention study using 36 young adults (18-35 years), researchers found that acute supplementation with 142 mL of cold-pressed blackcurrant juice correlated with sustained attention on the digit vigilance tasks and supplementation with a weight-based dose of anthocyanin-enriched blackcurrant extract correlated with greater accuracy on the rapid visual information processing (RVIP) task, components of the aforementioned COMPASS (Watson et al., 2015). Another study found an association between acute supplementation with 35 grams of dark chocolate (rich in coco-flavanols) and visual system function among young adults (aged 18-25 years). While these results provide some support for a relationship between cognition and consumption of fruits and vegetables, particularly blended fruit beverages and fruit juice, more research involving the consumption of whole fruits and vegetables is needed.

Adolescence (12-18 Years)

Compared to middle and older adulthood, research on the relationship between F/V intake and cognition in teenagers is minimal. However, it is understood that F/V intake tends to decrease during adolescence (11-21 years) (J. E. Brown, 2017). In a 2017 study, data on F/V consumption among individuals aged two to 23 years (n=2131) was collected from previous UK National Diet and Nutrition Survey (NDNS) (Albani et al., 2017). The average vegetable intake for females was 1.3 portions per day (approximately 100 grams per day) and 0.9 portions per day (approximately 72 grams per day) for males (Albani et al., 2017). Results showed that participants consumed fewer total F/V portions during adolescence, compared to early childhood (Albani et al., 2017). Conversely, while adolescence may be a period characterized by low F/V consumption, a 2015 report involving 33 predominantly European and North American countries found that, overall, there has been a positive trend in F/V intake between 2002 and 2010 (Vereecken et al., 2015). Researchers speculate that this pattern may be due to the educational messages and subsidization of fruits and vegetables (Vereecken et al., 2015). More research is needed to determine the long-term changes in F/V consumption among this age group.

Studies evaluating the relationship between F/V consumption and cognition during adolescence tend to focus on academic performance. Adolescents (aged 12-15 years) in the Gaza Strip who ate fruits and vegetables more than three times per week were more likely to have better overall grade (average of >70%) over the course of one academic school year (Abudayya et al., 2011). In a study of Norwegian adolescents (n=2432) aged 15-17 years of age, researchers found that girls and boys who consumed higher amounts of fruit and girls who consumed higher amounts of vegetables had increased odds of better academic performance in three core required classes (Norwegian, English, and Math) (Stea & Torstveit, 2014). Research exploring the relationship between F/V intake and specific cognitive outcomes, such as executive function, episodic memory, and attention are needed in order to draw more informed conclusions on the impact of these types of foods on cognition.

Childhood and Infancy (0-11 Years)

As with other age groups, F/V intake throughout childhood, including early childhood and infancy, falls short of the recommended amount. In one study (n=6513 children and adolescents) 50.2% of children aged 2-5 years did not meet the guidelines for daily fruit intake and 78.3% did not meet the recommendations for daily vegetable intake (Lorson et al., 2009). Of those 6-11 years of age, 74.1% did not meet the recommendations for fruit and 83.8% did not meet the recommendations for vegetables (Lorson et al., 2009). F/V consumption may begin to decrease at certain points throughout early childhood (birth to eight years) (UNESCO, 2019) as a result of the stages of food neophobia (negative response to new food) (Contento, 2016).

In a 2007 study that included FFQs and a modified version of the Scale for Assessing Emotional Disturbance, Fu et al. (2007) found that unhealthful eating patterns (i.e., diets low in nutrient-dense foods, such as fruits and vegetables) correlated with lower academic performance among elementary school children (n=2222). Researchers measured intellectual and academic functioning, in addition to other outcomes related to familial and peer support and motivation to complete coursework (Fu et al., 2007).

In another study, researchers utilized age-specific FFQs to demonstrate a relationship between a dietary pattern characterized by more frequent intake of fruits and vegetables during infancy and higher scores for full-scale and verbal IQ as well as memory performance (measured by the Wechsler Pre-School and Primary Scale of Intelligence, 3rd edition) at four years of age (Gale et al., 2009). No relationship was found between diet and neuropsychological or cognitive function (attention, memory, language, etc.) (Gale et al., 2009).

Prenatal

According to a 2016 study, high fruit intake during pregnancy correlates with improved cognitive performance in the infant, including memory, attention, visual preference, and concept formation (Bolduc et al., 2016). Similar to other age groups, the amount and variety of fruits and vegetables consumed during pregnancy may impact cognitive measures differently. While previous research indicates that exposure in utero to a variety of foods may increase infants' enjoyment and acceptance of certain foods (Mennella et al., 2001), one study found that maternal diet after pregnancy had a greater influence on children's (ages 2-3 years) diet quality and F/V variety when compared with the maternal diet during pregnancy (Ashman et al., 2016). This indicates that adequate and varied consumption of fruits and vegetables once the child is born is more likely to promote optimal F/V intake during early childhood when compared to pregnancy. This could be due the child's observation of his/her mother's eating behaviors. More studies are required to further evaluate the impact of fruit consumption during pregnancy on a child's cognition later in life, as cognitive development at age one is not closely related to cognitive development at age three (Bolduc et al., 2016). Additional studies that focus on vegetable consumption in particular during pregnancy and a child's cognition would also provide more insight.

Fruit and Vegetable Intake and Emotional Well-being

An abundance of literature is available on the determinants of psychological health and subjective emotional well-being. The strong evidence base for the numerous physiological benefits associated with F/V intake has given rise to a growing body of research analyzing the effect of such foods on both positive and negative aspects of psychological well-being (Rooney et al., 2013). One cross-sectional study of university students in Iran demonstrated a positive association between happiness (determined by Oxford Happiness Questionnaire scores) and consumption of four or more servings each of fruit and vegetables per day (Lesani et al., 2016). In another study, results from a survey of Chilean college students (n=3461) aged 17 to 24 years demonstrated a relationship between F/V intake and greater likelihood of being classified as "very happy" on the Subjective Happiness Scale (SHS) (Piqueras et al., 2011).

Research also supports this relationship across the lifespan. A cross-sectional study involving Koreans (n=1530) aged 30 to 69 years found that a well-balanced diet consisting of adequate quantities of vegetables and fruits correlated with a higher level of happiness, based on psychosocial well-being index-short form (PWI-SF) (Kye & Park, 2014). In a study with healthy Japanese adults (n=521) aged 21-67 years, those consuming high amounts of fruit, vegetables, mushrooms, and soy products reported fewer depressive symptoms based on the Center for Epidemiologic Studies Depression (CES-D) Scale (Nanri et al., 2010). However, the relationship may have something to do with the types of fruits and vegetables, which were considered to be components of a "healthy Japanese dietary pattern." A larger cross-sectional study of approximately 80,0000 individuals in Great Britain found a dose-dependent relationship between daily servings of fruits and vegetables and both mental health and happiness, with individuals consuming seven to eight servings reporting the highest levels of psychological well-being (Blanchflower et al., 2012). Though it is important note that confounding factors such as income and social support may also contribute to improved psychological well-being. Additionally, the relationship between F/V intake and emotional well-being could be explained by greater F/V consumption among individuals who report higher levels of happiness and life satisfaction. While the results of these studies are suggestive in nature, they do emphasize the important role that sufficient F/V intake plays in the psychological well-being of individuals across the lifespan.

Green vegetables are high in B vitamins, such as vitamin B_6, vitamin B_{12}, and folate. Dietary folate is associated with reduced depressive symptoms in young Japanese women aged 18-28 years (Watanabe et al., 2012). Among middle-aged adults, a 12-week trial of a mixed vitamin B supplement was associated with reduced stress/dejected mood compared to the placebo (Stough et al., 2011). This suggests that the B vitamins in green vegetables likely play a significant role in the relationship between dark-green vegetables and emotional well-being.

It is also important to consider the ways in which stress can impact cognition. Research has shown that stress can impair cognitive functioning processes. In a study comprised of 203 college students, researchers assessed participants' academic stress, coping skills (using a modified COPE scale, referred to as the Student Coping Scale, or SCOPE), motivation, and academic performance (Struthers et al., 2000). The SCOPE scale evaluated academic planning (e.g., "I think about how I might best handle the problem"), efficacy (e.g., "I feel competent"), and emotional venting (e.g., "I let my feelings out"), among others (Struthers et al., 2000). Results from another study suggests an inverse relationship between college students' stress and academic performance (Struthers et al., 2000). However, some research indicates no relationship between stress, specifically Post-Traumatic Stress Disorder (PTSD) and ECF (Leskin & White, 2007). These findings demonstrate that stress levels may modulate cognition to a certain degree.

Skin Carotenoids as a Biomarker of Fruit and Vegetable Intake

Carotenoids are red, yellow, and orange pigments derived from certain types of plants and algae (Higdon, 2004). Fruits and vegetables are the primary sources of the 40 to 50 different types of carotenoids prominent in the human diet (Higdon, 2004). As antioxidants, they may help reduce the risk of certain diseases, such as heart disease and cancer (Scarmo et al., 2012).

While serum carotenoid concentrations are the most accurate biological markers of F/V intake, obtaining plasma measurements is invasive and time-consuming and results can vary considerably according to daily consumption (Aguilar et al., 2014; Al-Delaimy et al., 2005). Resonance Raman Spectroscopy (RRS) is considered less invasive and data may even be used to predict certain cancers (breast and prostate) due to its association with overall carotenoid status (Ermakov et al., 2005). A higher Raman intensity count indicates a higher concentration of carotenoid molecules at the measurement site (Aguilar et al., 2015). Skin carotenoids have also been found to be highly correlated with serum carotenoid status among healthy children (5-17 years) (Aguilar et al., 2014). Over the course of four weeks, participants in the Aguilar study completed three 24-hour dietary recalls (two weekdays and one weekend day) using the ASA24-Kids-2012 multiple-pass method, as well as a 27-item FFQ (Aguilar et al., 2014). Results showed that skin carotenoid levels correlated with reported F/V consumption, including those high in carotenoids (Aguilar et al., 2014). RRS intensity increased by 3504 units with each reported cup of averaged total F/V intake (Aguilar et al., 2014). A 2017 study involving college students (n=251) also found a relationship between self-reported F/V intake and skin carotenoid concentrations at baseline (R^2=0.448, p<0.001) and again at follow-up (R^2=0.439, p<0.001) (Wengreen et al., 2017). Skin carotenoid concentrations increased by 1545 units for every half cup of fruits and vegetables consumed (Wengreen et al., 2017)

Conclusion

In general, F/V intake throughout the lifespan is associated with a range of health benefits, including improved cognitive ability (indicated by academic performance, as well measures of executive function, attention, response time, etc.) and better outcomes for emotional well-being. Research also shows that F/V consumption correlates with skin carotenoid levels. While there is a growing body of research on the relationship between F/V intake and cognition among children and middle and older adults, as well as fruit juices and cognitive measures among young adults, few studies evaluate the impact of whole F/V intake on cognition in young adults, specifically college students. Thus, the purpose of this study is to provide more insight regarding F/V consumption among college students aged 18-26 years and to explore any relationships with cognition and emotional well-being.

Chapter 3: Methods

Recruitment

Recruitment was performed via paper distribution of flyers on campus and within the Moscow community, electronic dissemination of flyers to university faculty and staff, announcements in the *University of Idaho Daily Register* and *My UI Student Newsletter*, classroom presentations, and word of mouth. Individuals signed up via the email address provided. Inclusion criteria specified that participants must be 18 to 26 years of age, a full-time student at the University of Idaho, and attending classes at the Moscow, ID campus. Individuals were also screened for any major illness (e.g., flu or cold) within two weeks prior to data collection; however, prospective participants that did not meet the criteria were not excluded from the study.

Study Design and Protocol

For this cross-sectional study, participants attended a single one-on-one visit with a researcher on the University of Idaho campus. Prior to the visit, an electronic copy of the Informed Consent was emailed to each participant, as well as directions to the building designated for data collection. Upon arrival, a trained researcher reviewed the protocol and Informed Consent with the participant. Both the researcher and the participant signed two copies of the Informed Consent. One copy was provided to the participant. Participants also completed a short, online questionnaire via the 2019 Qualtrics Survey Software, which contained demographic and lifestyle questions related to household income, smoking, physical activity, chronic illness, current illness, and sun exposure.

After reviewing the Informed Consent and completing the Qualtrics questionnaire, researchers asked additional demographic questions from the NIH Toolbox ® for Assessment of Neurological and Behavioral Function (NIH Toolbox), which were related to race, ethnicity, the highest level of education completed at the time of the visit, highest maternal education, and handedness (e.g., right or left). Administration of the first cognitive assessment followed. All participants were provided with a timed 5-minute break following the second assessment, at which point they were offered a snack bar and water. The researcher then proceeded to administer the third, fourth, and fifth cognitive assessments. Next, participants completed a self-assessment of emotional health. The researcher first read the written explanation and then moved to a separate, but nearby area to allow the participant some privacy. The researcher answered questions pertaining to the emotional assessment as needed.

Once the assessment was complete, the participant was asked to wash his/her hands with soap and water and then three separate skin carotenoid scans were performed. Height and weight were also measured. Finally, the researcher used the electronic demonstration tool provided by the 24-hour dietary recall program to explain the dietary recall procedure. The researcher also provided each participant with a paper listing his/her three assigned recall dates. A follow-up email with these dates was also sent. Participants completed the three assigned recalls at home. In total, the in-person visit took approximately and hour to an hour-and-a-half to complete. Upon completion of all components of the study, including the three 24-hour dietary recalls, participants received a $10 Amazon gift card via email.

Cognitive Assessment

Cognitive testing was performed using the NIH Toolbox ® for Assessment of Neurological and Behavioral Function (NIH Toolbox) (Gershon et al., 2013). The NIH Toolbox is approved for participants aged 3-85 years. Researchers administered a custom battery consisting of five cognitive tests, as well as the complete NIH Toolbox Emotion Battery (ages 18+) (see Table 3.1). The cognitive battery of the NIH Toolbox was first validated in an adult sample (ages 20-85 years) by Weintraub et al. (2014). The five tests used in this study were: The Flanker Inhibitory Control and Attention Test, the List Sorting Working Memory Test, the Dimensional Change Card Sort Test, the Pattern Comparison Processing Speed Test, and the Picture Sequence Memory Test. These tests were selected because they all measure fluid cognition, which this study aimed to assess. Fluid intelligence is the ability to use reason and logic to solve problems (Myers, 2014). Cognitive test scores were based on patient-reported-outcome (PRO) measures (otherwise known as T-Scores), which have a mean of 50 and a standard deviation (SD) of 10.

Table 3.1: NIH Toolbox Cognition Battery

Construct	Test	Description
Executive Functioning & Attention	Flanker Inhibitory Control and Attention Test	Measures attention and inhibitory control. Participant focuses on a given stimulus while inhibiting attention to stimuli flanking it.
Working Memory	List Sorting Working Memory Test	Measures working memory. Participant recalls and sequences visually and orally presented stimuli.
Executive Function	Dimensional Change Card Sort Test	Measures cognitive flexibility and attention. Pictures are presented varying along two dimensions (e.g., shape and color). The dimension for sorting is indicated by a cue word on the screen.
Processing Speed	Pattern Comparison Processing Speed Test	Measures processing speed. Participants discern whether two side-by-side pictures are the same or not, with 85 seconds to respond to as many items as possible. Items are simple so as to purely measure processing speed.
Episodic Memory	Picture Sequence Memory Test	Measures episodic memory. Participants are asked to reproduce a sequence of pictures that is shown on the screen. Different practice sequences and test items for participants of different ages.

(National Institutes of Health & Northwestern University, 2020a)

Emotion Measures

Table 3.2 describes the components of the NIH Toolbox emotion battery used in this study, which measured negative affect, social satisfaction, and psychological well-being. Negative affect describes unpleasant emotions and feelings such as fear, anger, and sadness. Social satisfaction is based on perceived social support, friendship, loneliness, social distress, and positive peer interactions. Psychological well-being encompasses both hedonic (e.g., happiness and serenity) and eudaimonic (e.g., life satisfaction and meaning) components of well-being.

Table 3.2: NIH Toolbox Emotion Battery

Construct	Measure	Description	# of Items
Negative Affect			
Anger	Anger-Affect CAT [1]	Attitudes of hostility and cynicism often associated with experiences of frustration impeding goal-directed behavior.	CAT
	Anger-Hostility FF[2]		5
	Anger-Physical Aggression FF		5
Fear	Fear-Affect CAT	Symptoms of anxiety that reflect autonomic arousal and perceptions of threat.	CAT
	Fear-Somatic Arousal FF		6
Sadness	Sadness CAT	Low levels of positive affect; comprised of symptoms that are primarily affective (poor mood) and cognitive (negative perceptions of self, the world, and the future) indicators of depression.	CAT
Psychological Well-being			
Positive Affect	Positive Affect CAT	Feelings that reflect a level of pleasurable engagement with the environment, such as happiness, joy, excitement, enthusiasm, and contentment.	CAT
General Life Satisfaction	General Life Satisfaction CAT	One's cognitive evaluation of life experiences and whether one likes his/her life or not.	CAT
Meaning & Purpose	Meaning and Purpose CAT	The extent to which people feel their lives matter or make sense.	CAT
	Meaning and Purpose FF		
Social Relationships			
Social Support	Emotional Support FF	The perception that people in one's social network are available to listen to one's problems with empathy, caring, and understanding.	8
	Instrumental Support FF	The perception that people in one's social network are available to provide material or functional aid in completing daily tasks, if needed.	8
Companionship	Loneliness FF	Perceptions that one is alone, lonely, or socially isolated from others.	5

	Friendship FF	Perceptions of the availability of friends or companions with whom to interact or affiliate.	8
Social Distress	Perceived Hostility FF	The extent to which an individual perceives his/her daily social interactions as negative or distressing. This can include aspects of perceived hostility (e.g., how often people argue with me, yell at me, or criticized me) and perceived insensitivity (e.g., how often people don't listen when I ask for help, or don't pay attention to me).	8
	Perceived Rejection FF		8

(National Institutes of Health & Northwestern University, 2020b)
[1]CAT = Computer Adaptive Test
[2]FF = Fixed Form

Dietary Assessment

Participants completed three 24-hour dietary recalls at home. Dietary intake data for the 24-hour recalls were collected and analyzed using the Automated Self-Administered 24-hour (ASA24) Dietary Assessment Tool, version 2018, developed by the National Cancer Institute, Bethesda, MD. Estimates of intake from 24-hour recalls were collected on two non-consecutive weekdays (Monday through Friday) and one weekend day (Saturday or Sunday) and averaged (National Cancer Institute, n.d.). A number of studies demonstrate the effectiveness of utilizing 24-hour dietary recalls to assess dietary intake among various populations (Kimmons et al., 2009; Péneau et al., 2011). A total of three dietary recalls have been used in previous studies assessing diets of various populations (Aguilar et al., 2014; Ettienne-Gittens et al., n.d.). Most NHANES (National Health and Nutrition Examination Survey) participants complete two separate 24-hour recalls, collected within three to 10 days of one another (Lee & Nieman, 2010). Compared to other methods, such as FFQ's, 24-hour dietary recalls provide more accurate intake data with minimal bias (Timon et al., 2016). ASA24 was used to assess total servings of fruits and vegetables consumed, as well as intake of the five vegetable subgroups outlined in the *2015-2020 Dietary Guidelines for Americans*. Total dietary intake of carotenoids was also measured with ASA24. The researcher used the demonstration version of ASA24-2018 on the ASA24 demonstration website to familiarize participants with the process for reporting the foods, beverages, and supplements consumed within a 24-hour period. All participants also received both a paper and electronic copy (sent via email) of the ASA24 login instructions and assigned recall dates.

Skin Carotenoid Measurements

The researcher tested participants' skin carotenoid concentrations using the patented Pharmanex BioPhotonic S3 Scanner from NuSkin Enterprises (S3 Scanner). The S3 Scanner non-invasively measures carotenoid levels in living tissue via RRS. The scanner emits a safe, blue light onto the palm and displays a score in Ramen counts, which correlate with the carotenoid antioxidant levels in the skin. After washing their hands vigorously with soap and water, which was a process used by Wengreen et al. (2017), participants placed the palm of their right hand against the light window of the scanner and held it there for 30 seconds. Each participant had their hand scanned a total of three times consecutively and an average was taken.

Data Analysis

Data analysis was carried out using SAS software and results were considered significant at $p \leq 0.05$. The percentage of individuals who met and did not meet the *2015-2020 Dietary Guidelines for Americans* was determined by comparing the recommended servings per day (cup-equivalents) of fruits and vegetables with the reported cup-equivalents from ASA24. Weekly intake of the vegetable subgroups was determined by multiplying reported serving sizes of legumes and dark-green, red and orange, starchy, other vegetables by a factor of seven. This number was then compared to the weekly vegetable subgroup recommendations for the Healthy U.S.-Style Eating Pattern at the 2,000-Calorie Level, outlined in the *2015-2020 Dietary Guidelines for Americans*.

Spearman's correlations were used to evaluate associations between variable pairs because values were not normally distributed and because values were both continuous and ordinal. Variable pairs included relationships between cognitive scores (for attention and executive functioning, episodic memory, working memory, executive function, and processing speed) and 1) total fruit intake, 2) total vegetable intake, 3) vegetable subgroup intake, 4) dietary intake of carotenoids, and 5) skin carotenoid concentration (RRS average). Spearman's correlations were also used to evaluate the relationships between the aforementioned variables (1-5) and emotional constructs: negative affect (anger, fear, sadness), psychological well-being (positive affect, general life satisfaction, and meaning and purpose), and social relationships (social support, companionship, and social distress). Spearman's correlations were also used to assess relationships between skin carotenoid concentration (RRS average) and 1) total fruit intake 2) total vegetable intake, 3) vegetable subgroup intake, and 4) dietary intake of carotenoids.

Fully corrected T-scores for cognitive outcomes were used in the data analysis process. These scores are given in terms of the national average after accounting for age, gender, race, ethnicity, participant education, and maternal education. Unadjusted T-scores for emotional well-being were used in the analysis, as these were the ones provided by the NIH Toolbox. An additional adjustment for income was added for correlations involving cognition and psychological well-being due to the fact that income may predict education attainment, psychological well-being, and ability to purchase fruits and vegetables. One of the hypotheses proposed a relationship between quartiles of fruits and vegetables consumed and cognitive scores. However, due to the small sample size, it was not possible to compare across quartiles.

Chapter 4: Results

Demographics and General Findings Related to Dietary Intake and Carotenoids

Sample demographic characteristics are shown in Table 4.1. A total of 27 participants enrolled in the study, but only 23 participants completed all components. Overall, there were eight males (35%) and 15 females (65%), aged 18-26 years (M=21.2, SD=2.3). Twenty participants reported ethnic and racial information as "Not Hispanic or Latino" and "White" (87%). Nine participants (39%) reported a household income of less than $35,000 per year and the remaining participants reported. Eight participants (35%) reported a household income of $35,000 or more per year, while the remaining six participants (26%) reported an annual income over $74,000. If listed as a dependent for tax purposes, participants reported household income based on parent/guardian income; otherwise, income was based on student's reported income. Four participants (17%) identified as a "High School Graduate," one participant reported having completed an "Associates Degree," two participants (9%) reported having completed a "Bachelor's Degree (e.g., BA, AB, BS)," and 16 participants (70%) reported completing between one and three years of a college at a 4-year program. The highest reported level of maternal education was a "Doctorate Degree (e.g., PhD, EdD)."

Table 4.1: Demographic Summary

Sample Size	23
Age (years) (Mean ± Standard Deviation)	21.17 ± 2.25
BMI (kg/m2)	24.83 ± 5.02
Gender (%)	
Male	35
Female	65
Race (%)	
White	87
Asian	4
Other	9
Ethnicity (%)	
Hispanic or Latino	4
Not Hispanic or Latino	96
Highest Education (%)	
Some High School	0
GED or High School Diploma	17

Some College (<1 year)	0
Associates Degree	4
Bachelor's Degree	9
1 Year of College at a 4-year Program	17
2 Years of College at a 4-year Program	48
3 Years of College at a 4-year Program	4
Master's Degree	0
Professional Degree	0
Doctoral Degree	0
Highest Maternal Education (%)	
Some High School	4
GED or High School Diploma	9
Some College (<1 year)	0
≥1 Year of College at a 2-year Program, No Degree	4
Associates Degree	9
Bachelor's Degree	48
Master's Degree	22
Professional Degree	0
Doctoral Degree	4
Household Income (%)	
Less than $35,000/Year	39
$35,000-$41,999/Year	4
$42,000-$51,999/Year	9
$52,000-$58,999/Year	0
$59,000-$73,999/Year	22
Over $74,000/Year	26

Additionally, participants answered questions regarding lifestyle and illness. Four participants (17%) reported an existing chronic illness, including primary hypogonadism, chronic gastritis, and a history of leukemia (in remission since 2014). One of these participants stated eczema as a chronic illness, resulting from a peanut allergy. The remaining 19 participants (83%) reported no chronic illness. One participant (4%) noted recently suffering from cold, flu, or allergy symptoms, while the remaining 22 participants (96%) participants reported no symptoms. Two participants (9%) reported smoking, while the remaining 21 participants (91%) indicated that they were non-smokers. Options provided for physical activity responses were based on the recommendations made in the *2015-2020 Dietary Guidelines for Americans*, as well as the *Physical Activity Guidelines for Americans, 2nd Edition,* which state that adults aged 18 to 64 years should strive for least 150 minutes (two hours and 30 minutes) of moderate-intensity physical activity each week (U.S. Department of Health and Human Services, 2018; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). Three participants (13%) reported engaging in less than 30 minutes of moderate physical activity per day, 13 participants (57%) reported between 30 and 60 minutes of moderate physical activity per day, and seven participants (30%) reported greater than 60 minutes of physical activity per day. Seven participants (30%) reported less than one hour of sun exposure per day, while the remaining 16 participants (70%) reported at least one hour of sun exposure per day.

Table 4.2 exhibits the average number of calories consumed overall, as well as the percentage of participants that met the USDA dietary guidelines for fruits, vegetables, and the five vegetable subgroups. It also shows the average intake for each category (in cup-equivalents) ± the standard deviation. Dietary guidelines for total combined fruits and vegetables are provided in terms of a 2,000-calorie diet (4.5 servings per day), as well as in terms of diets consisting of 2,200 calories or more (≥5 servings per day). This is due to the fact that calorie recommendations vary according to factors such as age, sex, height, weight, and physical activity.

Less than half of the participants met the dietary guidelines for combined fruits and vegetables, based on both recommendations; however, 57% of participants met/exceeded the dietary guidelines for dark-green vegetables. Only 13% of participants met the dietary guidelines for starchy vegetables and legumes.

Table 4.2: Calories and Dietary Guidelines

Variable	DG (cup-eq.)	Meets DG (%)	Mean ± SD (cup-eq.)
Total Fruits	2/day	13	1.1 ± 0.5
Total Vegetables	2.5/day	17	2.0 ± 1.6
Total Fruits and Vegetables	4.5/day[1]	22	3.1 ± 1.8
	≥5/day[2]	17	
Dark-Green Vegetables	1.5/week	57	3.29 ± 7.67
Red and Orange Vegetables	5.5/week	17	3.48 ± 6.57
Starchy Vegetables	5/week	13	3.27 ± 9.27
Other Vegetables	4/week	39	4.21 ± 7.44
Legumes	1.5/week	13	1.03 ± 3.68

[1]Based on 2,000-calorie diet
[2]Based on diets consisting of 2,200 calories or more

Table 4.3 summarizes descriptive characteristics related to diet, such as caloric intake, dietary intake of fruits, vegetables, and vegetable subgroups. Skin carotenoid concentration results from previous studies are also provided as a comparison. Similar to this study, Aguilar et al. (2014) and Wengreen et al. (2017) also used RRS to assess skin carotenoid concentration. As there is not an established Recommended Dietary Allowance (RDA) for carotenoids, intake of specific carotenoids from another study that also included college-age adults (though only female) are also included. The dietary intake of carotenoids is provided in terms of the mean ± SD for this study. However, it is provided as the median and interquartile Range (IQR) for the Pezdirc et al. (2015) study. This makes it difficult to directly compare results; however, it does provide some insight as to where participants from this study stand in relation to adults of a similar age range.

Table 4.3: Skin Carotenoid Concentration (RRS Average) and Dietary Intake of Carotenoids

Variable	**Mean ± Standard Deviation**	**Mean ± Standard Deviation from Other Studies**
Skin Carotenoid Concentration (RRS Average)	34565.22 ± 11553.75	28676 ± 3397[2] 26054 ± 9856[3]
Carotenoids (average mcg/day)	**Mean ± Standard Deviation**	**Median and IQR[1] from Other Studies**
β-carotene	4087.19 ± 6494.91	6872.4 (4462.6-8918.6)[4]
α-carotene	486.16 ± 593.87	1988.6 (1220.2-2611.6)[4]
Cryptoxanthin	102.91 ± 116.09	
Lycopene	5816.17 ± 5030.07	5054.8 (2975.1-7,488.5)[4]
Lutein + Zeaxanthin	3869.10 ± 7466.83	2276.8 (1523.-2895.1)[4]
Total Carotenoids	14361.54 ± 14341.99	

[1]Interquartile Range
[2](Aguilar et al., 2014)
[3](Wengreen et al., 2017)
[4](Pezdirc et al., 2015)

Table 4.4 shows the normative unadjusted, age-adjusted, and fully adjusted scores, as well as the percentage of participants who achieved a normative unadjusted scale score and age-adjusted score for each cognitive test. The age-adjusted FICA, LSWM, DCCS, PCPS, PSM, and CFC scores were derived from a comparison of the study participants with the NIH Toolbox nationally representative sample from the same age bracket. Any participants with an age-adjusted score greater than or equal to 100 were considered to have a normative score. For majority of the tests, more than half of the participants achieved normative, age-adjusted scores for each cognitive test. The fully adjusted cognitive scores were all comparable to the NIH Toolbox nationally representative sample (mean of 50 with a SD of 10). These were adjusted for age, gender, race, ethnicity, education, and maternal education.

Table 4.4: Normative Unadjusted, Age-Adjusted, and Fully Adjusted Scores for Cognitive Tests, with Percentage of Participants with Normative Unadjusted and Age-Adjusted Scores

Cognitive Test	Unadjusted Scale Score (Mean ± SD)	% Participants with Normative Unadjusted Scale Score	Age-Adjusted Score (Mean ± SD)	% Participants with Normative, Age-Adjusted Score	Fully Adjusted Score (Mean ± SD)
FICA	104.74 ± 6.94	78	92.52 ± 16.41	30	43.83 ± 10.88
LSWM	106.87 ± 6.61	87	99.22 ± 9.07	52	46.65 ± 6.83
DCCS	111.35 ± 7.27	96	105.48 ± 18.44	61	52.83 ± 12.49
PCPS	124.70 ± 10.81	100	114.52 ± 12.72	87	59.13 ± 8.40
PSM	117.13 ± 11.61	91	109.43 ± 15.03	74	56.70 ± 11.26
CFC	116.74 ± 8.52	100	106 ± 15.29	65	52.57 ± 11.32

FICA (Flanker Inhibitory Control and Attention), LSWM (List Sorting Working Memory), DCCS (Dimensional Change Card Sort), PCPS (Pattern Comparison and Processing Speed), PSM (Picture Sequence Memory), CFC (Cognition Fluid Composite).

Table 4.5 shows the unadjusted T-scores for the emotional constructs. In general, scores that are less than or equal to 40 (with 1 SD below the mean) are considered low and scores greater than or equal to 60 (with 1 SD above them mean) are considered high. Based on these criteria, participants' scores were comparable to the nationally representative normative sample for emotion.

Table 4.5: Unadjusted T-Scores for Emotional Outcomes

Emotion Construct	Mean ± Standard Deviation
Negative Affect	57.04 ± 10.50
Social Satisfaction	44.57 ± 10.63
Psychological Well-being	48.04 ± 8.11

Fruit and Vegetable Intake and Cognition

Spearman's correlations were used to assess the relationship between F/V intake and cognitive measurements of executive function, attention, working memory, episodic memory, processing speed, and fluid cognition. Table 4.6 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between measures of cognition and servings of fruits, vegetables, and combined fruits and vegetables (cup-equivalents). A significant positive relationship was found between total vegetable intake and processing speed, based on scores for the Pattern Comparison Processing Speed (PCPS) test without adjusting for income (R^2=0.44, p=0.03) and when adjusted for income (R^2=0.56, p=0.01). A significant positive relationship was also found between total combined F/V intake and processing speed when values were adjusted for income (R^2=0.43, p=0.04).

Table 4.6: Spearman Correlations Between Total Daily Fruit and Vegetable Intake and Fully Corrected Cognitive Scores, Unadjusted and Adjusted for Income

	Total Fruit		Total Vegetable		Combined Total Fruit & Vegetable	
	R^2	p-value	R^2	p-value	R^2	p-value
FICA[1]	0.06	0.79	0.12	0.58	0.22	0.32
FICA[2]	0.00	1.00	0.07	0.76	0.17	0.44
LSWM[1]	0.16	0.45	0.04	0.85	0.34	0.11
LSWM[2]	0.14	0.54	0.01	0.95	0.33	0.14
DCCS[1]	-0.25	0.24	0.23	0.29	-0.002	0.99
DCCS[2]	-0.26	0.24	0.24	0.28	-0.0002	1.00
PCPS[1]	-0.08	0.70	0.44	**0.03**	0.33	0.12
PCPS[2]	-0.005	0.98	0.56	**0.01**	0.43	**0.04**
PSM[1]	0.10	0.65	0.06	0.78	0.06	0.80
PSM[2]	0.02	0.95	-0.02	0.92	-0.02	0.92
CFC[1]	-0.04	0.85	0.27	0.21	0.22	0.32
CFC[2]	-0.07	0.76	0.26	0.25	0.20	0.37

N=23
FICA (Flanker Inhibitory Control and Attention), LSWM (List Sorting Working Memory), DCCS (Dimensional Change Card Sort), PCPS (Pattern Comparison and Processing Speed), PSM (Picture Sequence Memory), CFC (Cognition Fluid Composite).
[1] Adjusted for age, gender, race, ethnicity, education, and maternal education
[2] Adjusted for age, gender, race, ethnicity, education, maternal education, and income

Spearman's correlations were also used to evaluate the association between vegetable subgroups (dark-green, red/orange, starchy, legumes, and other) and cognitive outcomes. Table 4.7 lists Spearman's correlation coefficients and corresponding p-values representing the relationships between each of the five vegetable subgroups and cognition. There was a significant positive association between consumption of dark-green vegetables and fully corrected measures of executive function based on the Dimensional Change Card Sort (DCCS) test (R^2=0.42, p=0.05) both with and without the additional income adjustment. There was also a significant positive correlation between intake of dark-green vegetables and processing speed (R^2=0.47, p=0.02 without income adjustment; R^2=0.45, p=0.04 with income adjustment), as well as fluid cognition (R^2=0.46, p=0.03 without income adjustment; R^2=0.48, p=0.02 with income adjustment).

Table 4.7: Spearman Correlations Between Weekly Intake of Vegetable Subgroups and Fully Corrected Cognitive Scores, Unadjusted and Adjusted for Income

	Dark-Green Vegetables		Red and Orange Vegetables		Starchy Vegetables		Other Vegetables		Legumes	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
FICA[1]	0.16	0.48	0.03	0.89	0.04	0.87	-0.03	0.88	0.25	0.26
FICA[2]	0.20	0.38	-0.04	0.85	-0.06	0.79	-0.05	0.81	0.17	0.44
LSWM[1]	0.32	0.14	-0.15	0.49	0.01	0.96	0.09	0.67	0.20	0.37
LSWM[2]	0.34	0.12	-0.20	0.37	-0.04	0.86	0.08	0.71	0.16	0.47
DCCS[1]	0.42	**0.05**	0.04	0.87	-0.08	0.73	0.10	0.66	0.28	0.20
DCCS[2]	0.42	**0.05**	0.04	0.85	-0.08	0.72	0.10	0.67	0.30	0.17
PCPS[1]	0.47	**0.02**	-0.07	0.76	0.19	0.39	0.34	0.11	-0.03	0.88
PCPS[2]	0.45	**0.04**	0.03	0.89	0.36	0.10	0.39	0.08	0.10	0.65
PSM[1]	0.23	0.29	-0.08	0.72	-0.06	0.78	0.12	0.58	0.08	0.71
PSM[2]	0.31	0.17	-0.20	0.37	-0.22	0.31	0.10	0.66	-0.06	0.79
CFC[1]	0.46	**0.03**	-0.01	0.97	0.03	0.89	0.15	0.51	0.18	0.41
CFC[2]	0.48	**0.02**	-0.04	0.85	-0.01	0.96	0.14	0.54	0.16	0.49

N=23

FICA (Flanker Inhibitory Control and Attention), LSWM (List Sorting Working Memory), DCCS (Dimensional Change Card Sort), PCPS (Pattern Comparison and Processing Speed), PSM (Picture Sequence Memory), CFC (Cognition Fluid Composite).

[1] Adjusted for age, gender, race, ethnicity, education, and maternal education

[2] Adjusted for age, gender, race, ethnicity, education, maternal education, and income

Fruit and Vegetable Intake and Emotional Measures

Associations between emotional well-being and 1) total F/V intake and 2) vegetable subgroup intake were also assessed. Table 4.8 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between intake of fruits and vegetables and emotion measures. No significant relationships were found.

Table 4.8: Spearman Correlations Between Daily Total Fruit and Vegetable Intake and Emotion T-Scores, Unadjusted and Adjusted for Income

	Total Fruit		Total Vegetable		Combined Total Fruit & Vegetable	
	R^2	p-value	R^2	p-value	p-value	R^2
Negative Affect Summary T-Score[1]	-0.12	0.59	-0.40	0.06	-0.35	0.10
Negative Affect Summary T-Score[2]	0.02	0.94	-0.32	0.14	-0.28	0.21
Social Satisfaction Summary T-Score[1]	0.10	0.64	0.19	0.38	0.04	0.86
Social Satisfaction Summary T-Score[2]	0.03	0.91	0.13	0.58	-0.03	0.88
Psychological Well-Being Summary T-Score[1]	0.23	0.30	0.11	0.61	0.18	0.40
Psychological Well-Being Summary T-Score[2]	0.17	0.44	0.05	0.82	0.13	0.56

N=23
[1] Unadjusted T-Scores
[2] Adjusted for income

Table 4.9 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between emotion measures and intake of items from each of the vegetable subgroups. While there were no significant relationships between total F/V intake and negative affect, social satisfaction, or psychological well-being, there was an inverse correlation between intake of dark-green vegetables and negative affect when adjusted for income (R^2=-0.45, p=0.04). There was also an inverse relationship between intake of legumes and negative affect without an adjustment for income (R^2=-0.42, p=0.05). Results also showed a positive relationship between consumption of legumes and psychological well-being prior to adjusting for income (R^2=0.44, p-0.04).

Table 4.9: Spearman Correlations Between Weekly Intake of Vegetable Subgroups and Emotion T-Scores, Unadjusted and Adjusted for Income

	Dark-Green Vegetables		Red and Orange Vegetables		Starchy Vegetables		Other Vegetables		Legumes	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
NAS[1]	-0.30	0.17	-0.32	0.14	-0.29	0.17	-0.06	0.77	-0.42	**0.05**
NAS[2]	-0.45	**0.04**	-0.20	0.38	-0.11	0.62	-0.02	0.92	-0.27	0.23
SSS[1]	0.10	0.66	0.25	0.26	-0.06	0.78	0.09	0.68	0.35	0.10
SSS[2]	0.15	0.50	0.17	0.45	-0.21	0.35	0.07	0.76	0.26	0.23
PWBS[1]	0.08	0.71	0.17	0.43	0.19	0.39	-0.09	0.68	0.44	**0.04**
PWBS[2]	0.13	0.57	0.10	0.66	0.09	0.68	-0.12	0.60	0.38	0.08

N=23
NAS (Negative Affect Summary T-Score), SSS (Social Satisfaction Summary T-Score), PWB (Psychological Well-Being Summary T-Score)
[1] Unadjusted T-Scores
[2] Adjusted for income

Dietary Intake and Skin Carotenoid Measurements

This study also measured skin carotenoids. Intake of total fruits, total vegetables, and vegetable subgroups were compared with RRS average scores using a Spearman's correlation. Table 4.10 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between RRS counts and 1) dietary intake of total fruits, 2) total vegetables, and 3) each of the vegetable subgroups. This study did not find a significant correlation between total F/V intake and skin carotenoid status. However, results from this study do indicate a positive association between red and orange vegetables and skin carotenoid scores (R^2=0.50, p=0.01).

Table 4.10: Spearman Correlations Between Skin Carotenoid Concentration (RRS Average) and Fruit, Vegetable, and Vegetable Sub-Group Intake

	RRS Average	
	R^2	p-value
Total Vegetable	0.13	0.56
Total Fruit	0.35	0.10
Combined Total Fruit and Vegetable	0.35	0.10
Dark-Green Vegetables	0.27	0.21
Red & Orange Vegetables	0.50	**0.01**
Starchy Vegetables	-0.22	0.31
Other Vegetables	-0.08	0.71
Legumes	0.54	0.01

N=23

Table 4.11 shows Spearman's correlation coefficients and corresponding p-values representing the relationship between RRS counts and dietary intake of carotenoids. Skin carotenoid levels as measured by RRS were positively associated with total carotenoids (R^2=0.72, p=0.0001), beta-carotene (R^2=0.50, p=0.01), and lycopene (R^2=0.42, p=0.05).

Table 4.11: Spearman Correlations Between Skin Carotenoid Concentration (RRS Average) and Dietary Carotenoid Intake

	RRS Average	
	R^2	p-value
Total Carotenoid	0.72	**0.0001**
β-carotene	0.50	**0.01**
α-carotene	0.35	0.11
Cryptoxanthin	0.40	0.06
Lycopene	0.42	**0.05**
Lutein + Zeaxanthin	0.35	0.10

N=23

Skin Carotenoids, Dietary Intake of Carotenoids, and Cognitive and Emotional Measures

Table 4.12 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between cognition and skin carotenoid concentrations (RRS counts) as well as dietary intake of carotenoids. Higher intakes of lutein and zeaxanthin corresponded with higher processing speed based on the PCPS Test with (R^2=0.43, p=0.05) and without (R^2=0.43, p=0.04) adjusting for income.

Table 4.12: Spearman Correlations Between Skin Carotenoid Concentration (RRS Average) or Dietary Carotenoid Intake and Fully Corrected Cognitive Scores, Unadjusted and Adjusted for Income

	RRS Average		**Total Carotenoids**		**β-carotene**		**α-carotene**		**Crypto-xanthin**		**Lycopene**		**Lutein + Zeaxanthin**	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
FICA[1]	0.25	0.25	0.30	0.17	0.06	0.80	-0.03	0.89	0.09	0.67	0.21	0.34	0.15	0.48
FICA[2]	0.19	0.41	0.25	0.26	0.05	0.82	-0.07	0.75	0.04	0.86	0.17	0.45	0.18	0.42
LSWM[1]	0.39	0.07	0.08	0.73	0.17	0.43	-0.04	0.85	0.11	0.61	-0.19	0.37	0.28	0.20
LSWM[2]	0.37	0.09	0.05	0.84	0.17	0.45	-0.06	0.78	0.09	0.71	-0.22	0.32	0.29	0.19
DCCS[1]	0.25	0.24	0.25	0.25	0.09	0.67	-0.08	0.72	-0.07	0.77	0.09	0.68	0.32	0.14
DCCS[2]	0.27	0.22	0.26	0.24	0.09	0.68	-0.08	0.73	-0.07	0.77	0.09	0.68	0.32	0.15
PCPS[1]	-0.03	0.90	0.001	1.00	0.08	0.73	0.06	0.79	0.04	0.86	-0.002	0.99	0.43	**0.04**
PCPS[2]	0.09	0.69	0.09	0.70	0.09	0.69	0.12	0.59	0.12	0.58	0.06	0.78	0.43	**0.05**
PSM[1]	0.13	0.56	0.15	0.48	0.07	0.74	0.02	0.94	0.37	0.08	-0.12	0.59	0.24	0.27
PSM[2]	0.02	0.94	0.08	0.74	0.07	0.77	-0.05	0.84	0.32	0.15	-0.20	0.38	0.29	0.20
CFC[1]	0.27	0.21	0.26	0.24	0.14	0.52	0.004	0.99	0.16	0.47	0.02	0.94	0.41	**0.05**
CFC[2]	0.25	0.26	0.24	0.28	0.14	0.54	-0.01	0.95	0.14	0.54	-0.002	0.99	0.42	**0.05**

N=23

FIC (Flanker Inhibitory Control and Attention), LSWM (List Sorting Working Memory), DCCS (Dimensional Change Card Sort), PCPS (Pattern Comparison and Processing Speed), PSM (Picture Sequence Memory), CFC (Cognition Fluid Composite).

[1] Adjusted for age, gender, race, ethnicity, education, and maternal education

[2] Adjusted for age, gender, race, ethnicity, education, maternal education, and income

Table 4.13 shows Spearman's correlation coefficients and corresponding p-values representing the relationships between emotion measures and RRS counts as well as dietary intake of carotenoids. Results indicate that skin carotenoid scores are inversely associated with negative affect scores (R^2=0.50, p=0.02) and positively associated with psychological well-being (R^2=0.48, p=0.02 without income adjustment; R^2=0.43, p=0.04 with income adjustment).

Table 4.13: Spearman Correlations Between Skin Carotenoid Concentration (RRS Average) or Dietary Carotenoid Intake and Emotion T-Scores, Unadjusted and Adjusted for Income

	RRS Average		**Total Carotenoids**		**β-carotene**		**α-carotene**		**Crypto-xanthin**		**Lycopene**		**Lutein + Zeaxanthin**	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
NAS[1]	-0.50	**0.02**	-0.35	0.10	-0.23	0.29	-0.22	0.31	-0.20	0.36	-0.14	0.51	-0.20	0.36
NAS[2]	-0.40	0.07	-0.27	0.23	-0.25	0.26	-0.15	0.50	-0.09	0.69	-0.05	0.82	-0.29	0.20
SSS[1]	0.37	0.08	0.27	0.21	0.11	0.62	0.005	0.98	0.17	0.44	0.22	0.32	0.03	0.88
SSS[2]	0.30	0.18	0.21	0.35	0.10	0.65	-0.05	0.82	0.10	0.65	0.17	0.46	0.06	0.78
PWBS[1]	0.48	**0.02**	0.19	0.39	0.04	0.85	0.10	0.66	0.29	0.18	0.22	0.32	0.01	0.96
PWBS[2]	0.43	**0.04**	0.13	0.56	0.03	0.88	0.05	0.82	0.24	0.28	0.18	0.43	0.03	0.88

N=23
NAS (Negative Affect Summary T-Score), SSS (Social Satisfaction Summary T-Score), PWB (Psychological Well-Being Summary T-Score)
[1] Adjusted for age, gender, race, ethnicity, education, and maternal education
[2] Adjusted for age, gender, race, ethnicity, education, maternal education, and income

Chapter 5: Discussion, Limitations, and Implications

Discussion

Data collected from this study supports previous research that shows young adults are not meeting the recommended dietary guidelines for fruits and vegetables (Anding et al., 2001). Findings also add to a growing body of research suggesting that F/V intake may influence aspects of cognition (Wald et al., 2014; Whyte et al., 2019), particularly processing speed, executive function, and fluid cognition. While no relationship between total fruit intake and cognition was observed, there was a significant positive correlation between total vegetable consumption and processing speed. A significant positive association between total combined F/V intake and fluid cognition was also observed, though only with an added adjustment for income. Higher intake of dark-green vegetables positively correlated with processing speed and fluid cognition as well, in addition to executive function. Significant positive relationships were also found between dietary intake of combined lutein and zeaxanthin and both processing speed and fluid cognition, though there was no significant correlation between skin carotenoid status and measures of cognition. This study does not demonstrate a link between total F/V intake and emotion measures; however, higher intake of dark-green vegetables and legumes in particular correlated with lower negative affect (e.g., fear, anger, and sadness). Greater legume intake was also associated with higher scores for psychological well-being (e.g., happiness and life satisfaction). There was not a significant relationship between dietary carotenoid intake and measures of emotion, skin carotenoid scores were inversely associated with negative affect and positively associated with psychological well-being. Overall, this study suggests that vegetables in particular are associated with measures of cognition and emotion, while fruit alone is not.

Sample Population

Only 13% of the university students from this study met the recommended daily intake of fruits, as outlined in the *2,000-calorie Healthy U.S.-Style Eating Pattern* from the *2015-2020 Dietary Guidelines for Americans* (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). A greater percentage of students met the guidelines for vegetables, though 83% of individuals still fell short of the recommended 2.5 cups per day. More than half of participants (n=13) met the guidelines for the dark-green vegetable subgroup. Food preferences, a busy schedule, level of food preparation knowledge, and budget considerations have been identified as factors that may hinder American consumers' ability and/or willingness to follow the dietary guidelines established by the USDA (Sogari et al., 2018). Daily total combined F/V intake in this study was also compared to the recommendation of five or more servings per day that used in other studies. Anding et al. (2001) noted that only 15% of total participants (n=20) consumed five or more servings of fruits and vegetables per day. The American College Health Association's 2009 National College Health Assessment (2009) also used these same parameters, noting that only 5.9% of college students reported five or more servings of fruits and vegetables per day. In contrast, 17% of participants in this study met the total F/V guidelines of ≥5 servings per day, suggesting that college students in Moscow, ID may have a higher total F/V intake compared to national representative samples.

More than half of the participants in this study met the recommended weekly servings of dark-green vegetables. Vegetable subgroups were not assessed in the Anding study, nor were they reported in the American College Health Association's 2009 assessment. However, the fact that less than 100% of participants met the recommendations for all vegetable subgroups aligns with data presented in the *2015-2020 Dietary Guidelines for Americans* (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015), which shows that both males and females aged 19-30 years are consuming less than the recommended amount of each.

Though fully correct T-scores were ultimately used in the analysis because factors such as age and educational attainment can influence performance on cognitive tests, the percentage of participants who achieved normative unadjusted scores for cognition was also assessed, as these scores were referenced in the original hypothesis. Less than one hundred percent of participants had a normative unadjusted scale score for certain tests, meaning that some participants scored lower than those in the NIH Toolbox nationally representative normative sample (unadjusted for age or any other variable). However, 100% of participants had a normative unadjusted scale score for the Pattern Comparison Processing Speed Test and fluid cognition, which shows that sample participants were at least on par with the nationally representative sample in terms of processing speed and fluid cognition. Less than 100% of participants had normative age-adjusted scores for each of the cognitive tests, as well as for fluid cognition. Fully correct T-scores for the cognitive tests and for fluid cognition were all within range based on the NIH Toolbox nationally representative sample, which has a mean of 50 and a SD of 10.

Cognitive Outcomes

F/V Intake

This study found a significant positive relationship between total vegetable intake and processing speed and fluid cognition, as well as a significant positive relationship between combined total F/V intake and processing speed when income was included in the analysis. However, there was not a significant relationship between consumption of total fruit alone and cognitive outcomes. This was not expected, as other studies (e.g., Haskell-Ramsay) demonstrated a significant relationship between acute supplementation with grape juice and attention-related tasks among a population of young adults. This variation in significant results may be attributed to the concentration of the fruit beverages used in the Haskell-Ramsay study. Grape juice may have a greater impact on cognitive measures compared to whole fruits or other types of juices, perhaps due to a higher nutrient (e.g., carotenoid, polyphenol, etc.) concentration. Whole fruits were used in the Whyte study, which found a significant relationship with accuracy and response time; however, this also involved acute supplementation and the fruits were blended and consumed as a beverage. Again, the higher concentration of certain nutrients may have influenced this association with cognition.

The lack of a relationship between total fruit intake and cognition in this study could be explained by the way in which cognition was assessed. Research among younger populations has focused on the relationship between dietary patterns and school performance (in terms of cumulative grades), which is an example of crystalized intelligence. Grades and other comprehensive measures of school performance cannot be directly compared to specific aspects of fluid cognition, such as those measured in this study (e.g., processing speed, executive function, episodic memory, etc.). The academic-focused approach to assessing cognition used in previous studies may explain why no relationship was found between total vegetable intake and attention, executive function, and episodic memory. Other studies (e.g., Nooyens and Haskell-Ramsay) used tests measuring similar cognitive outcomes, including the Computerized Mental Performance Assessment System and the Letter Digit Substitution Test. While these tests measure similar cognitive outcomes, they vary slightly in the test style and administration duration, making it difficult to compare.

As previously mentioned, other research related to F/V intake and cognition has explored diet and cognition using FFQs instead of 24-hour recalls. These types of dietary assessments differ from 24-hour recalls in that they offer a limited list of foods and are presented in terms of a standardized portion size (Lee & Nieman, 2010). In a study involving adults aged 70-74 years, researchers that found a positive relationship between cognition and consumption of carrots, cruciferous vegetable, and citrus 169-item FFQ to assess dietary habits (Nurk et al., 2010). There is some controversy regarding the use of FFQ's versus multiple 24-hour dietary recalls. Mertens et al., (2019) found that, compared to an FFQ, 24-hour recalls more accurately reflected the environmental impact of diet. However, 24-hour recalls are not without their own set of limitations, including the possibility that participants could withhold or alter information regarding foods/beverages they consume and variability in intake from day to day (Lee & Nieman, 2010).

Vegetable Subgroups

Results from this study also support a positive relationship between weekly intake of dark-green vegetables and both processing speed and executive function, as well as a positive relationship between dark-green vegetables and fluid cognition. The limited research currently available on vegetable subgroups and cognition focuses on reducing cognitive decline, rather than improving aspects of fluid cognition measured in this study (Kang et al., 2005; Morris et al., 2018). A study by Morris et al., (2018) found that eating approximately one serving of green leafy vegetables each day was associated with slower cognitive decline among adults ages 57-99. This association was only seen with the global cognitive function score, not any specific domain. Thus, it is unclear exactly how intake of green leafy vegetables impacted specific cognitive outcomes. Perhaps intake of green leafy vegetables is more likely to influence processing speed and executive function among younger adults.

While certain green leafy green vegetables used in the Kang study fall under the dark-green vegetable subgroup in the *2015-2020 Dietary Guidelines for Americans* (e.g., spinach and kale), other dark-green vegetables were not included (e.g., green herbs and broccoli), making it difficult to directly compare (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). It could be said that, with a wider array of green vegetables evaluated in this study, perhaps greater variety has something to do with the impact on cognition.

Dietary Intake of Carotenoids

There was not a significant relationship between total F/V intake and skin carotenoid concentration. These results differ from another study involving adolescents that did find significant relationship between F/V intake reported via three 24-hour recalls (R^2=0.31, p<0.001) (Aguilar et al., 2014). Possible reasons for the lack of a significant relationship could be exposure to solar UV radiation, smoking, or low intake of carotenoid-rich fruits and vegetables (Darvin et al., 2011). However, the association between intake of red and orange vegetables and skin carotenoid scores (R^2=0.50, p=0.01) aligns with research from the 2014 Aguilar study, which demonstrated a significant relationship between intake of high-carotenoid vegetables (reported via three 24-hour recalls) and skin carotenoid status (R^2=0.25, p<0.01).

Dietary intake of some types of carotenoids are comparable to those in another study of young women. Compared to individuals in the 2015 Pezdirc study, participants in this study consumed a higher amount of lycopene and lutein + zeaxanthin. However, on the other hand, participants in this study consumed lower amounts of alpha- and beta-carotene when compared to participants in the Pezdirc study. While Pezdirc included young adults within a similar age range (18.1-29.1 years) as the ones in this study (18-26 years), the sample consisted only of women. The fact that this particular study was predominantly made up of women makes it somewhat comparable to the findings by Pezdirc et al., male and female skin carotenoid concentration may vary.

This study also found positive relationships between both processing speed and fluid cognition and combined daily intake of lutein and zeaxanthin (mcg). This supports previous research on dietary intake of carotenoids and cognition. Bovier et al., (2014) found that supplementation with lutein (8 mg), zeaxanthin (26 mg), and a mixture of omega-3 fatty acids was significantly associated with improved processing speed. The age range of the subjects was somewhat similar (18-32 years), but carotenoids delivered in pill form may not have the same cognitive effects as carotenoids derived from whole food sources. Participants in the Bovier study received nearly nine times the amount of combined lutein and zeaxanthin reported by participants in this study, which was only 4 mg/day. Additionally, due to the fact that ASA24 combines the lutein and zeaxanthin amounts, it is difficult to say which carotenoid was being consumed in higher amounts and whether or not the amount matched results from Bovier et al. It could also be argued that the 190 mg of omega-3 fatty acids were primarily responsible for the cognitive benefits. Furthermore, Bovier et al. did not evaluate other aspects of cognition such as episodic memory, attention, and executive function. Tasks measuring episodic memory improved in another intervention study involving a sample of middle-aged men and women (mean age of 45.4 years) following supplementation of lutein, zeaxanthin, and meso-zeaxanthin, but no significant associations were found with executive function (Power et al., 2018). This research indicates that the impact of lutein and zeaxanthin may vary with the type of cognitive measure being assessed and that supplemental forms of carotenoids may have different effects on cognition compared to whole foods rich in these types of carotenoids.

A study by Kesse-Guyot et al. (2020) found that a dietary pattern rich in carotenoids was associated with a higher composite cognitive score, as well as better scores for episodic memory, semantic memory, and working memory based on the backward digit span task. However, this study only compared foods/food groups associated with carotenoid-rich dietary patterns and did not measure the effects of the types of carotenoids (e.g., lutein and zeaxanthin) on cognition. Thus, it is difficult to determine which carotenoids might have played a role in the overall association between diet and cognition.

Skin Carotenoid Status

Results from this study did not support an association between skin carotenoid scores and cognitive outcomes. In the only study to date that evaluates the relationship between skin carotenoid status and cognition, Edwards et al. (2019) demonstrated that skin carotenoid are positively correlated with reading and math scores, but not with measures for selective attention or interference control (based on scores on the modified Erikson flanker task) in children (n=50) aged 7-12 years. Academic achievement was determined by the Woodcock-Johnson IV test, which is a comprehensive cognitive set of batteries that evaluated progress in specific school subjects (e.g., reading, mathematics), cognitive abilities such as working memory and perceptual speed, and oral language skills (Riverside Insights, 2020). Due to the fact that academic performance is more of a broad measure of cognition, it cannot be directly contrasted alongside specific cognitive domains. The relationship between skin carotenoid status and selective attention may not occur until young adulthood. Or, perhaps a greater number of covariates (e.g., mental fatigue, hunger) could have influenced performance on the modified Erikson flanker task.

While this study did not find a significant relationship between skin carotenoid status and cognition, there was a significant positive association between skin carotenoid scores and consumption of red and orange vegetables (R^2=0.50, p=0.01) and legumes (R^2=0.54, p=0.01). This supports findings from Aguilar et al. (2014), which demonstrated that higher self-reported intake of carotenoid-rich vegetables (three 24-hour recalls) positively correlated with skin carotenoid status (R^2=0.21, $p<0.05$) among children (n=45) aged 5 to 17 years. The Aguilar study did not list vegetables categorized as "high-carotenoid"; however, red and orange vegetables in particular tend to be rich in carotenoids, especially beta-carotene. The fact that a significant relationship between red and orange vegetable and cognition was found in the present study suggests that red and orange vegetables (and perhaps legumes) may have been driving the relationship between high-carotenoid vegetable intake and skin carotenoid status in the Aguilar study.

Similar to the Aguilar study, this study also found a relationship between skin carotenoid levels and reported dietary intake of both total carotenoids (R^2=0.72, p=0.0001) and beta-carotene (R^2=0.42, p=0.05). The higher coefficient of determination and lower p-value for the relationship between total carotenoids and skin carotenoid status in this study compared to the Aguilar study (R^2=0.25, $p<0.01$) may imply that total carotenoids have a greater impact on skin carotenoid levels in young adulthood. Variations in reporting may also explain the different correlation coefficients. Young adults may be better at reporting their diet compared to children and adolescents, due in part to the increased likelihood that they are preparing meals themselves. This study also found that dietary intake of lycopene positively correlated with skin carotenoid status, while the Aguilar study reported no statistically significant relationship. Perhaps a greater amount of lycopene-rich foods is necessary to demonstrate an effect, which would mean that young adults in this sample consumed more than those in the Aguilar study. However, the specific amounts (mcg) of the different types of carotenoids are not provided.

Emotional Outcomes

F/V Intake

While previous research indicates that total F/V intake correlates with emotional well-being, results from this study do not support such findings. This variation may be due to the fact that the Conner study involved an intervention. This study only measured cognition at one point in time, prior to the completion of the three dietary recalls. Perhaps a significant relationship would be present if University of Idaho students had been asked to consume at least two or more F/V servings (one fruit and one vegetable) each day, as the Conner study participants were asked to do. This likely would have resulted in an increase in the average total F/V intake, as well as a greater variety of fruits and vegetables. In the Conner study, F/V consumption among participants in the intervention group was 3.7 servings per day, which is slightly higher than the average 3.1 servings of fruits and vegetables consumed in this study.

The significant associations between total F/V intake and emotional well-being found in two cross-sectional studies (Blanchflower and Piqueras) may have been due to differences in the assessments/questionnaires that researchers administered. In the Piqueras study, participants took a self-report questionnaire that utilized the Subjective Happiness Scale (SHS). Participants who reported feeling very happy were more likely to always consume fruits and vegetables on a daily basis (Odds Ratio=1.34, p=0.00). Significant associations may have been found if negative affect and overall psychological well-being were also evaluated. The variation in measures used to assess psychological well-being makes it difficult to compare results.

Vegetable Subgroups

While no relationships were found between total vegetable or total fruit intake and emotion measures, results from this study suggest that increased consumption of dark-green vegetables and legumes is associated with a lower negative affect. Furthermore, higher intake of dark-green vegetables was also correlated with higher scores for psychological well-being. This indicates that dark-green vegetables and legumes may play an important role in supporting emotional health. Conversely, it may mean that more feelings of anger, sadness, and fear could drive students to select fewer dark-green vegetables and legumes.

This type of relationship was demonstrated in the Boehm et al. (2018) study, which found that higher psychological well-being correlated with a less rapid decline in F/V intake over time.

Dietary Intake of Carotenoids

This study found no relationship between total carotenoids or subgroups of carotenoids and emotional well-being. The was surprising considering that specific types of vegetables correlated with certain emotional constructs. Dark-green vegetables such as spinach and kale are high in lutein and zeaxanthin and baked beans are good sources of lycopene (Higdon, 2004). Thus, a relationship between these types of carotenoids and emotional well-being would have been expected.

There is minimal research available on the impact of carotenoids alone and measures of psychological well-being. In one study, supplementation with both 13 mg/day and 27 mg/day of macular carotenoids (lutein, zeaxanthin, and meso-zeaxanthin) over the course of a six-month period did significantly improve levels of psychological stress and measures of emotional health among college students (18-25 years) (Stringham et al., 2018). A greater quantity of carotenoid-rich fruits and vegetables would likely be needed to match the concentrated level of carotenoids in the supplement. Perhaps the addition of the zeaxanthin isomer added to the effect.

Skin Carotenoid Status

This study also supports evidence for a positive relationship between skin carotenoid scores and psychological well-being, as well as an inverse relationship between skin carotenoid scores and negative affect. Results from a study of middle-aged U.S. adults demonstrated a relationship between serum carotenoid concentration and self-reported optimism, which was measured by the revised Life Orientation Test (Boehm et al., 2013). Other studies have shown that the levels of skin carotenoids and serum carotenoids are highly correlated (Aguilar et al., 2014), so this relationship is comparable to the results of the Boehm study. Studies involving younger adults would provide more insight regarding the relationship between skin carotenoid status and emotional health.

Limitations

The sample is limited to a specific region (northern Idaho) and a specific age group (18-26 years) and may not accurately reflect the consumption of fruits and vegetables among students in other geographical areas. F/V intake may vary in terms of food availability (e.g., access to foods and seasonality), as well as income, taste preference, stress, and food preparation knowledge. Additionally, dietary recalls may not accurately capture participants' typical intake as they are an estimate of only a single day's diet. Even when an average of multiple days is taken, as in the case of this study, infrequently eaten foods may be missed. It is also understood that participants may withhold, overreport, or otherwise alter information due to memory failure, fear of embarrassment, or a desire to impress the researcher with positive results.

Furthermore, unlike in the *2020 Dietary Guidelines for Americans*, vegetables categorized as "Other" are not listed in detail in ASA24. However, ASA24 does note that vegetables labeled as "Other" consist of vegetables not categorized as dark-green, red/orange, or starchy. Additionally, while legumes are considered a vegetable in the *2020 Dietary Guidelines for Americans*, they are not accounted for under the servings of total vegetables in ASA24. It is also unclear whether or not ASA24 differentiates between vegetables at certain stages of maturity. For example, in the dietary guidelines, mature, dried lima beans are listed in legume vegetable subcategory and green, immature lima beans are listed starchy vegetable category.

Another limitation to this study is that weekly intake of the vegetable subgroups was provided in daily cups-equivalents in ASA24, so each value was multiplied by seven to obtain a weekly amount that could be directly compared to the *2015-2020 Dietary Guidelines for Americans*, which are listed in weekly recommended cup-equivalents. As one of the objectives of this study was to compare reported intake with the dietary guidelines, it seemed more appropriate to adjust the reported cup-equivalents rather than dividing the weekly cup-equivalents in the dietary guidelines by seven. Due to this post-data collection adjustment, the calculated weekly cup-equivalents may not accurately reflect actual weekly intake of the vegetable subgroups.

Cognitive assessments also vary, depending on the outcome being measured (e.g., cognitive decline, IQ, academic performance, executive function, etc.). Thus, a direct comparison of studies may not be appropriate. Additionally, while questions regarding perceived stress and self-efficacy were included in the emotional assessment, a corresponding score specific to this construct was not provided in the NIH Toolbox report. A physiological test for stress (e.g., salivary cortisol) would be a more accurate determinant of stress levels and, if administered prior to the cognitive tests, could be accounted for as a confounding variable for cognitive outcomes. Sleep was not included as a covariate in this study either. Due to the impact of sleep deprivation on cognitive performance, most notably working memory and attention (Alhola & Polo-Kantola, 2007) (both measured in this study), it would be important to include this information in future studies.

The small sample size for this study (n=23) did not allow for analysis using evenly distributed F/V groups (e.g., tertiles). Instead, Spearman's correlations were used to assess linear relationships between F/V intake and cognitive and emotional outcomes. Comparisons across groups have been used in other studies assessing F/V intake and similar measures (Fu et al., 2007; Kang et al., 2005; Nanri et al., 2010). In an effort to assess for non-linear relationships and to follow data analysis processes similar the ones used in other cross-sectional F/V studies, groupings by tertiles should be used if this study is replicated in a larger sample size.

Implications and Future Directions

While this pilot study suggests that there is a relationship between total vegetable and total combined fruit and vegetable intake and certain cognitive outcomes, additional research is needed. Based on these results, higher consumption of fruits and vegetables (dark-green vegetables in particular), among university students aged 18-26 years may be even more important than previously thought in terms of cognition and emotional well-being. In the future, this protocol should be replicated, with a larger sample size, a more diverse demographic (in terms of socioeconomic status, race, and ethnicity), as well as in a variety of college and university settings and geographical locations. If a significant relationship between fruit and vegetable intake, cognition, and emotion continues to exist in this particular population, researchers may wish to consider implementing an intervention to encourage increased dietary intake of fruit and vegetables. Interventions may involve, but are not limited to, cooking classes applicable to students living in both campus and off-campus housing, as well as additional funding for low-cost or free fruit- and vegetable-rich meals and snacks during midterm and finals weeks. Administration of the two remaining tests in the NIH Toolbox Cognitive Battery designed to assess language (Picture Vocabulary Test and Oral Reading Recognition Test) may also be used in future studies to provide further insight into any relationship between dietary intake of fruits and vegetables and other areas of cognition. Relationships between groups could also be assessed using tertiles in a larger sample. Additional covariates could also be included, such as physiological markers for stress and average reported hours of sleep per night.

Chapter 6: Conclusions

Increased consumption of vegetables was associated with higher scores for processing speed and fluid cognition among university students. Dark-green vegetables in particular were positively associated with these aspects of cognition, in addition to executive function. While total combined fruit and vegetable intake was positively correlated with processing speed, no evidence was found supporting a significant association between total fruit intake and cognition. This study also demonstrated a positive relationship between daily intake of lutein and zeaxanthin (mcg) and both processing speed and fluid cognition scores, though there was no significant association between skin carotenoid status and cognition.

While no significant relationship was found between total F/V intake and emotional measures, there was a negative correlation between weekly consumption dark-green vegetables and legumes and negative affect, as well as a positive correlation between legumes and psychological well-being. Similarly, skin carotenoid scores were negatively associated with negative affect and positively associated with psychological well-being. Studies of larger sample sizes and with more diverse racial and ethnic representation are needed to more conclusively assess these relationships among young adults in a college setting. It would also be interesting to include questions related to sleep duration and to examine physiological parameters for stress (e.g., salivary cortisol or blood pressure) prior to initiating the cognitive tests so that sleep deprivation and stress levels may be included as covariates.

Appendix A: Total Fruits Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Fruit salad, fresh or raw, (including citrus fruits), no dressing	2	2.68 ± 2.45
Apple cider	2	2.30 ± 3.06
Pineapple, cooked or canned, drained solids	1	2.07 ± 0
Apple, raw	10	2.06 ± 1.69
Cranberry juice, 100%, not a blend	1	2.02 ± 0
Strawberries, frozen, unsweetened	2	1.67 ± 0.79
Fruit, NS as to type	1	1.33 ± 0
Applesauce, stewed apples, NS as to sweetened or unsweetened; sweetened, NS as to type of sweetener	2	1.05 ± 0.74
Fruit mixture, dried (mixture includes three or more of the following: apples, apricots, dates, papaya, peaches, pears, pineapples, prunes, raisins)	1	0.97 ± 0
Orange, raw	9	0.96 ± 0.52
Fruit smoothie drink, NFS	1	0.94 ± 0
Alcoholic malt beverage, sweetened	1	0.76 ± 0
Tangerine, raw	3	0.71 ± 0.20
Fruit leather and fruit snacks candy	1	0.70 ± 0
Banana, raw	12	0.68 ± 0.18
Plum, raw	3	0.67 ± 0.46
Orange juice, with calcium added, canned, bottled or in a carton	1	0.60 ± 0
Strawberries, raw	3	0.52 ± 0.26
Peach, frozen, unsweetened	1	0.52 ± 0
Cherries, frozen	1	0.50 ± 0
Watermelon, raw	1	0.41 ± 0
Grapes, raw, NS as to type	2	0.39 ± 0.17
Sweet and sour chicken or turkey	2	0.38 ± 0.11
Nut mixture with dried fruit and seeds	1	0.35 ± 0
Kiwi fruit, raw	2	0.34 ± 0.07
Blueberries, frozen, unsweetened	2	0.32 ± 0.28
Date candy	2	0.23 ± 0
Apple, baked, unsweetened	1	0.21 ± 0
Pear, dried, cooked, unsweetened	1	0.16 ± 0
Yogurt, Greek, fruit, low fat	1	0.15 ± 0
Jam, preserves, all flavors	2	0.11 ± 0.13
Pancakes, with fruit	1	0.11 ± 0
Lemon juice, freshly squeezed	2	0.09 ± 0.04
Yogurt, fruit variety, whole milk	3	0.09 ± 0

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
Raisin bran, NFS	1	0.09 ± 0
Cookie, fig bar	3	0.09 ± 0.03
Jelly, reduced sugar, all flavors	1	0.08 ± 0
Fruit juice drink, with high vitamin C	1	0.07 ± 0
Yogurt, fruit variety, low-fat milk	3	0.07 ± 0.04
Orange chicken	1	0.06 ± 0
Pineapple, raw	1	0.06 ± 0
Jelly, all flavors	2	0.05 ± 0
Vegetable and fruit juice drink, with high vitamin C	1	0.04 ± 0
Granola, NFS	3	0.02 ± 0.01
Breakfast bar, cereal crust with fruit filling, low-fat	1	0.02 ± 0
Raisins, cooked	1	0.01 ± 0
Special K Red Berries	1	0.01 ± 0
Fruit flavored drink (formerly lemonade)	1	0.01 ± 0

Appendix B: Total Vegetables Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
White potato, NFS	4	2.44 ± 0.54
Broccoli, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	2.09 ± 0
Beans, string, green, cooked, from fresh, fat not added in cooking	1	2.00 ± 0
White potato, roasted, fat added in cooking	2	1.84 ± 1.86
Vegetable and pasta combinations with cream or cheese sauce (broccoli, pasta, carrots, corn, zucchini, peppers, cauliflower, peas, etc.), cooked	1	1.68 ± 0
Stew, NFS	1	1.66 ± 0
White potato, stuffed, baked, peel eaten, NS as to topping	1	1.44 ± 0
White potato, roasted, fat not added in cooking	2	1.42 ± 0.46
Spaghetti with tomato sauce and meatballs or spaghetti with meat sauce or spaghetti with meat sauce and meatballs	1	1.34 ± 0
Pasta with tomato sauce and cheese, canned	1	1.31 ± 0
Mixed salad greens, raw	2	1.28 ± 0.90
Kale, cooked, from fresh, fat not added in cooking	3	1.25 ± 0.43
White potato, baked, peel eaten, fat not added in cooking	1	1.15 ± 0
White potato chips, ruffled, rippled, or crinkle cut	1	1.12 ± 0
Spaghetti with tomato sauce, meatless	3	1.06 ± 0.61
Asparagus, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	1.04 ± 0
Asparagus, cooked, from fresh, fat not added in cooking	1	1.01 ± 0
Pepper, raw, NFS	1	0.99 ± 0
Beef, potatoes, and vegetables (including carrots, broccoli, and/or dark-green leafy), cream sauce, white sauce, or mushroom soup-based sauce (mixture)	1	0.98 ± 0
Broccoli, raw	3	0.96 ± 0.24
Pizza with meat and vegetables, NS as to type of crust	1	0.96 ± 0
White potato, hash brown, from frozen	2	0.94 ± 0
Squash, summer, yellow or green, cooked, from fresh, fat not added in cooking	3	0.92 ± 0.97
Sweet potato, baked, peel eaten, fat not added in cooking	3	0.91 ± 0.16

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
Sweet potato, baked, peel not eaten, fat not added in cooking	1	0.90 ± 0
Broccoli, cooked, from frozen, fat not added in cooking	4	0.90 ± 0.24
Beans, string, green, cooked, NS as to form, with mushroom sauce	1	0.87 ± 0
Vegetable lasagna (frozen meal)	1	0.86 ± 0
Squash, winter type, mashed, fat added in cooking, no sugar added in cooking	1	0.86 ± 0
Pepper, sweet, red, raw	2	0.83 ± 0.13
Avocado, raw	7	0.83 ± 0.40
White potato, french fries, from frozen, deep fried, from fast food / restaurant	5	0.82 ± 0.19
Pizza with meat and vegetables, regular crust	2	0.82 ±0.77
Broccoli, cooked, from fresh, NS as to fat added in cooking	1	0.78 ± 0
Beans, string, green, cooked, from fresh, NS as to fat added in cooking	1	0.78 ± 0
Mushrooms, batter-dipped, fried	1	0.78 ± 0
Egg omelet or scrambled egg, with vegetables other than dark-green and/or tomatoes, fat added in cooking	1	0.77 ± 0
Taco or tostada with meat, from fast food	1	0.76 ± 0
Vegetable combination (including carrots, broccoli, and/or dark-green leafy), cooked, with soy-based sauce	2	0.74 ± 0
Peppers, green, cooked, fat not added in cooking	2	0.71 ± 0.64
Lasagna with cheese and meat sauce (diet frozen meal)	2	0.68 ± 0.36
Broccoli, cooked, from frozen, fat added in cooking	6	0.66 ± 0
White potato, puffs	2	0.66 ± 0.15
Spinach, cooked, NS as to form, NS as to fat added in cooking	1	0.65 ± 0
Tomatoes, cooked, from fresh, NS as to method	2	0.63 ± 0.53
Spinach, raw	10	0.63 ± 0.45
Chili con carne with beans	1	0.61 ± 0
Broccoli, cooked, from fresh, fat not added in cooking	5	0.60 ± 0.30
Squash, winter type, mashed, no fat or sugar added in cooking	1	0.59 ± 0
Pizza with meat and vegetables, prepared from frozen, thick crust	1	0.58 ± 0
Endive, chicory, escarole, or romaine lettuce, raw	5	0.58 ± 0.41
Beans, string, green, cooked, from canned, fat not added in cooking	1	0.57 ± 0

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
White potato, chips, restructured, baked	1	0.56 ± 0
White potato, french fries, from fresh, deep fried	1	0.56 ± 0
Dumpling, vegetable	1	0.55 ± 0
Greens, cooked, NS as to form, fat added in cooking	1	0.52 ± 0
Cauliflower, cooked, from fresh, fat not added in cooking	4	0.50 ± 0.27
Vegetable combination (excluding carrots, broccoli, and dark-green leafy), cooked, with soy-based sauce	1	0.50 ± 0
White potato chips, regular cut	4	0.49 ± 0.11
Carrots, cooked, from fresh, fat not added in cooking	5	0.49 ± 0.20
Chicken burritos (diet frozen meal)	1	0.45 ± 0
Potato soup, NS as to made with milk or water	3	0.44 ± 0
Burrito with meat	1	0.44 ± 0
Tomatoes, raw	10	0.43 ± 0.22
White potato, french fries, from frozen, oven baked	2	0.42 ± 0.07
Onion soup, French	1	0.41 ± 0
Pepper, sweet, green, raw	2	0.40 ± 0.13
White potato, from dry, mashed, made with milk and fat	1	0.40 ± 0
Egg omelet or scrambled egg, with dark-green vegetables, fat added in cooking	1	0.39 ± 0
Sweet and sour chicken or turkey	2	0.38 ± 0.11
Lentil soup, home recipe, canned, or ready-to-serve	3	0.37 ± 0.20
Gordita, sope, or chalupa with chicken and sour cream	1	0.37 ± 0
Cucumber pickles, dill	6	0.36 ± 0.27
Spaghetti sauce, meatless	6	0.35 ± 0.21
Spaghetti sauce, meatless, reduced sodium	1	0.34 ± 0
Gordita, sope, or chalupa with meat	1	0.34 ± 0
Burrito with chicken and beans	1	0.33 ± 0
Pizza with extra meat, NS as to type of crust	1	0.33 ± 0
Squash, summer, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	4	0.32 ± 0.13
Pepper, banana, raw	2	0.32 ± 0.09
White potato, chips, restructured	1	0.32 ± 0
Cold cut submarine sandwich, with cheese, lettuce, tomato, and spread	1	0.31 ± 0
Gnocchi, potato	1	0.31 ± 0
Chicken patty sandwich, with lettuce and spread	1	0.30 ± 0

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
Guacamole	4	0.30 ± 0.08
Carrots, raw	4	0.29 ± 0.13
Rice, brown, with tomatoes (and/or tomato-based sauce), fat not added in cooking	2	0.29 ± 0
Mushrooms, cooked, from fresh, fat not added in cooking	1	0.29 ± 0
Lettuce, arugula, raw	2	0.28 ± 0.31
Pasta with pesto sauce	1	0.27 ± 0
Pizza with pepperoni, from restaurant or fast food, regular crust	2	0.27 ± 0.14
Soft taco with chicken, from fast food	1	0.27 ± 0
Cabbage, green, cooked, fat not added in cooking	1	0.26 ± 0
Peppers, green, cooked, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	2	0.26 ± 0
Collards, raw	1	0.26 ± 0
Tomatoes, cooked, from canned, NS as to method	2	0.25 ± 0
Lettuce, raw	8	0.25 ± 0.25
Lettuce, Boston, raw	1	0.25 ± 0
Corn, yellow, canned, low sodium, fat not added in cooking	1	0.25 ± 0
Onions, young green, raw	1	0.25 ± 0
White potato, from fresh, mashed, made with milk, and sour cream and/or cream cheese and fat	1	0.25 ± 0
Rice, white, with dark-green vegetables and tomatoes (and/or tomato-based sauce), NS as to fat added in cooking	1	0.24 ± 0
Cabbage salad or coleslaw, made with coleslaw dressing	1	0.22 ± 0
Salsa, red, commercially prepared	15	0.21 ± 0.19
Salsa, pico de gallo	2	0.20 ± 0.10
Egg omelet or scrambled egg, with meat and dark-green vegetables, fat added in cooking	1	0.20 ± 0
Mushrooms, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	2	0.20 ± 0.09
Peppers, green, cooked, NS as to fat added in cooking	2	0.20 ± 0.09
Salsa, red, homemade	1	0.19 ± 0
Onions, mature, cooked, from fresh, fat not added in cooking	8	0.18 ± 0.15
Tomatoes, canned, low sodium	1	0.17 ± 0
Tomato catsup	6	0.15 ± 0.04

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Burrito with meat and beans, from fast food	1	0.14 ± 0
Rice, white, with tomatoes (and/or tomato-based sauce), NS as to fat added in cooking	1	0.14 ± 0
Carrots, cooked, NS as to form, fat not added in cooking	1	0.14 ± 0
Onions, mature, cooked, NS as to form, NS as to fat added in cooking	1	0.13 ± 0
Cabbage, red, raw	1	0.12 ± 0
Cucumber, raw	1	0.12 ± 0
Onions, mature, raw	3	0.12 ± 0.05
General Tso chicken	1	0.12 ± 0
Peppers, hot, cooked, from fresh, fat not added in cooking	1	0.11 ± 0
Turnover, meat- and cheese-filled, tomato-based sauce	2	0.09 ± 0
Vegetable and fruit juice drink, with high vitamin C	1	0.09 ± 0
Egg roll, with beef and/or pork	1	0.08 ± 0
Meat loaf made with beef	1	0.07 ± 0
Beef stroganoff with noodles	1	0.06 ± 0
Onions, mature, cooked or sautéed, from fresh, fat added in cooking	1	0.06 ± 0
Onions, mature, cooked or sautéed, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	0.06 ± 0
Chicken or turkey with barbecue sauce, skin not eaten	1	0.05 ± 0
Rice, fried, meatless	1	0.03 ± 0
Muffin, pumpkin	1	0.03 ± 0
Barbecue sauce	1	0.02 ± 0
Quesadilla with chicken	1	0.02 ± 0
Garlic, cooked	1	0.01 ± 0
Dip, sour cream base	1	0.01 ± 0
Basil, fresh	1	0.01 ± 0
Cheese, processed, with vegetables	1	0.00 ± 0
Bean dip, made with refried beans	1	0.00 ± 0

Appendix C: Vegetables – Dark-Green Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Broccoli, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	2.09 ± 0
Kale, cooked, from fresh, fat not added in cooking	3	1.25 ± 0.43
Mixed salad greens, raw	2	1.08 ± 0.76
Broccoli, raw	3	0.96 ± 0.24
Broccoli, cooked, from frozen, fat not added in cooking	4	0.90 ± 0.24
Broccoli, cooked, from fresh, NS as to fat added in cooking	1	0.78 ±
Broccoli, cooked, from frozen, fat added in cooking	6	0.66 ± 0
Spinach, cooked, NS as to form, NS as to fat added in cooking	1	0.65 ± 0
Spinach, raw	10	0.63 ± 0.45
Broccoli, cooked, from fresh, fat not added in cooking	5	0.60 ± 0.30
Endive, chicory, escarole, or romaine lettuce, raw	5	0.58 ± 0.41
Greens, cooked, NS as to form, fat added in cooking	1	0.52 ± 0
Vegetable lasagna (frozen meal)	1	0.45 ± 0
Vegetable and pasta combinations with cream or cheese sauce (broccoli, pasta, carrots, corn, zucchini, peppers, cauliflower, peas, etc.), cooked	1	0.42 ± 0
Egg omelet or scrambled egg, with dark-green vegetables, fat added in cooking	1	0.39 ± 0
Dumpling, vegetable	1	0.30 ± 0
Lettuce, arugula, raw	2	0.28 ± 0.31
Pasta with pesto sauce	1	0.27 ± 0
Collards, raw	1	0.26 ± 0
Lettuce, Boston, raw	1	0.25 ± 0
Vegetable combination (including carrots, broccoli, and/or dark-green leafy), cooked, with soy-based sauce	2	0.21 ± 0
Egg omelet or scrambled egg, with meat and dark-green vegetables, fat added in cooking	1	0.20 ± 0
Rice, white, with dark-green vegetables and tomatoes (and/or tomato-based sauce), NS as to fat added in cooking	1	0.12 ± 0
Salsa, pico de gallo	2	0.01 ± 0.01
Basil, fresh	1	0.01 ± 0

Appendix D: Vegetables – Red and Orange Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Spaghetti with tomato sauce and meatballs or spaghetti with meat sauce or spaghetti with meat sauce and meatballs	1	1.34 ± 0
Pasta with tomato sauce and cheese, canned	1	1.31 ± 0
Spaghetti with tomato sauce, meatless	3	1.06 ± 0.61
Sweet potato, baked, peel eaten, fat not added in cooking	3	0.91 ± 0.16
Sweet potato, baked, peel not eaten, fat not added in cooking	1	0.90 ± 0
Squash, winter type, mashed, fat added in cooking, no sugar added in cooking	1	0.86 ± 0
Pepper, sweet, red, raw	2	0.83 ± 0.13
Lasagna with cheese and meat sauce (diet frozen meal)	2	0.66 ± 0.35
Tomatoes, cooked, from fresh, NS as to method	2	0.63 ± 0.53
Squash, winter type, mashed, no fat or sugar added in cooking	1	0.59 ± 0
Vegetable and pasta combinations with cream or cheese sauce (broccoli, pasta, carrots, corn, zucchini, peppers, cauliflower, peas, etc.), cooked	1	0.58 ± 0
Stew, NFS	1	0.55 ± 0
Carrots, cooked, from fresh, fat not added in cooking	5	0.49 ± 0.20
Tomatoes, raw	10	0.43 ± 0.22
Chili con carne with beans	1	0.42 ± 0
Pizza with meat and vegetables, NS as to type of crust	1	0.40 ± 0
Chicken burritos (diet frozen meal)	1	0.37 ± 0
Spaghetti sauce, meatless	6	0.35 ± 0.21
Pizza with meat and vegetables, regular crust	2	0.35 ± 0.33
Spaghetti sauce, meatless, reduced sodium	1	0.34 ± 0
Pizza with meat and vegetables, prepared from frozen, thick crust	1	0.33 ± 0
Pizza with extra meat, NS as to type of crust	1	0.33 ± 0
Carrots, raw	4	0.29 ± 0.13
Rice, brown, with tomatoes (and/or tomato-based sauce), fat not added in cooking	2	0.29 ± 0
Pizza with pepperoni, from restaurant or fast food, regular crust	2	0.27 ± 0.14
Tomatoes, cooked, from canned, NS as to method	2	0.25 ± 0

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
Vegetable combination (including carrots, broccoli, and/or dark-green leafy), cooked, with soy-based sauce	2	0.22 ± 0
Burrito with meat	1	0.22 ± 0
Sweet and sour chicken or turkey	2	0.19 ± 0.05
Tomatoes, canned, low sodium	1	0.17 ± 0
Tomato catsup	6	0.15 ± 0.04
Vegetable lasagna (frozen meal)	1	0.15 ± 0
Gordita, sope, or chalupa with meat	1	0.14 ± 0
Rice, white, with tomatoes (and/or tomato-based sauce), NS as to fat added in cooking	1	0.14 ± 0
Carrots, cooked, NS as to form, fat not added in cooking	1	0.14 ± 0
Beef, potatoes, and vegetables (including carrots, broccoli, and/or dark-green leafy), cream sauce, white sauce, or mushroom soup-based sauce (mixture)	1	0.13 ± 0
Burrito with chicken and beans	1	0.13 ± 0
Lentil soup, home recipe, canned, or ready-to-serve	3	0.12 ± 0.07
Salsa, pico de gallo	2	0.12 ± 0.06
Rice, white, with dark-green vegetables and tomatoes (and/or tomato-based sauce), NS as to fat added in cooking	1	0.12 ± 0
Salsa, red, homemade	1	0.12 ± 0
Salsa, red, commercially prepared	15	0.10 ± 0.09
Gordita, sope, or chalupa with chicken and sour cream	1	0.09 ± 0
Turnover, meat- and cheese-filled, tomato-based sauce	2	0.09 ± 0
Vegetable and fruit juice drink, with high vitamin C	1	0.09 ± 0
Chicken patty sandwich, with lettuce and spread	1	0.09 ± 0
Cold cut submarine sandwich, with cheese, lettuce, tomato, and spread	1	0.07 ± 0
General Tso chicken	1	0.06 ± 0
Chicken or turkey with barbecue sauce, skin not eaten	1	0.05 ± 0
Burrito with meat and beans, from fast food	1	0.05 ± 0
Muffin, pumpkin	1	0.03 ± 0
Egg roll, with beef and/or pork	1	0.02 ± 0
Barbecue sauce	1	0.02 ± 0
Cabbage salad or coleslaw, made with coleslaw dressing	1	0.02 ± 0
Cheese, processed, with vegetables	1	0.00 ± 0
Bean dip, made with refried beans	1	0.00 ± 0

Appendix E: Vegetables – Starchy Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Dumpling, vegetable	1	0.18 ± 0
White potato, from fresh, mashed, made with milk, and sour cream and/or cream cheese and fat	1	0.25 ± 0
Corn, yellow, canned, low sodium, fat not added in cooking	1	0.25 ± 0
Gnocchi, potato	1	0.31 ± 0
White potato, chips, restructured	1	0.32 ± 0
Vegetable and pasta combinations with cream or cheese sauce (broccoli, pasta, carrots, corn, zucchini, peppers, cauliflower, peas, etc.), cooked	1	0.36 ± 0
White potato, from dry, mashed, made with milk and fat	1	0.40 ± 0
White potato, french fries, from frozen, oven baked	2	0.42 ± 0.07
Potato soup, NS as to made with milk or water	3	0.44 ± 0
White potato chips, regular cut	4	0.49 ± 0.11
White potato, french fries, from fresh, deep fried	1	0.56 ± 0
White potato, chips, restructured, baked	1	0.56 ± 0
Beef, potatoes, and vegetables (including carrots, broccoli, and/or dark-green leafy), cream sauce, white sauce, or mushroom soup-based sauce (mixture)	1	0.60 ± 0
White potato, puffs	2	0.66 ± 0.15
White potato, french fries, from frozen, deep fried, from fast food / restaurant	5	0.82 ± 0.19
White potato, hash brown, from frozen	2	0.94 ± 0
Stew, NFS	1	1.01 ± 0
White potato chips, ruffled, rippled, or crinkle cut	1	1.12 ± 0
White potato, baked, peel eaten, fat not added in cooking	1	1.15 ± 0
White potato, roasted, fat not added in cooking	2	1.42 ± 0.46
White potato, stuffed, baked, peel eaten, NS as to topping	1	1.44 ± 0
White potato, roasted, fat added in cooking	2	1.84 ± 1.86
White potato, NFS	4	2.44 ± 0.54

Appendix F: Vegetables – Other Itemized List

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Beans, string, green, cooked, from fresh, fat not added in cooking	1	2.00 ± 0
Asparagus, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	1.04 ± 0
Asparagus, cooked, from fresh, fat not added in cooking	1	1.01 ± 0
Pepper, raw, NFS	1	0.99 ± 0
Squash, summer, yellow or green, cooked, from fresh, fat not added in cooking	3	0.92 ± 0.97
Beans, string, green, cooked, NS as to form, with mushroom sauce	1	0.87 ± 0
Avocado, raw	7	0.83 ± 0.40
Beans, string, green, cooked, from fresh, NS as to fat added in cooking	1	0.78 ± 0
Mushrooms, batter-dipped, fried	1	0.78 ± 0
Egg omelet or scrambled egg, with vegetables other than dark-green and/or tomatoes, fat added in cooking	1	0.77 ± 0
Taco or tostada with meat, from fast food	1	0.76 ± 0
Peppers, green, cooked, fat not added in cooking	2	0.71 ± 0.64
Beans, string, green, cooked, from canned, fat not added in cooking	1	0.57 ± 0
Pizza with meat and vegetables, NS as to type of crust	1	0.56 ± 0
Cauliflower, cooked, from fresh, fat not added in cooking	4	0.50 ± 0.27
Vegetable combination (excluding carrots, broccoli, and dark-green leafy), cooked, with soy-based sauce	1	0.50 ± 0
Pizza with meat and vegetables, regular crust	2	0.48 ± 0.45
Onion soup, French	1	0.41 ± 0
Pepper, sweet, green, raw	2	0.40 ± 0.13
Cucumber pickles, dill	6	0.36 ± 0.27
Vegetable and pasta combinations with cream or cheese sauce (broccoli, pasta, carrots, corn, zucchini, peppers, cauliflower, peas, etc.), cooked	1	0.32 ± 0
Squash, summer, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	4	0.32 ± 0.13
Pepper, banana, raw	2	0.32 ± 0.09
Vegetable combination (including carrots, broccoli, and/or dark-green leafy), cooked, with soy-based sauce	2	0.31 ± 0
Guacamole	4	0.30 ± 0.08

Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Mushrooms, cooked, from fresh, fat not added in cooking	1	0.29 ± 0
Gordita, sope, or chalupa with chicken and sour cream	1	0.28 ± 0
Soft taco with chicken, from fast food	1	0.27 ± 0
Vegetable lasagna (frozen meal)	1	0.27 ± 0
Cabbage, green, cooked, fat not added in cooking	1	0.26 ± 0
Peppers, green, cooked, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	2	0.26 ± 0
Beef, potatoes, and vegetables (including carrots, broccoli, and/or dark-green leafy), cream sauce, white sauce, or mushroom soup-based sauce (mixture)	1	0.25 ± 0
Lettuce, raw	8	0.25 ± 0.25
Onions, young green, raw	1	0.25 ± 0
Lentil soup, home recipe, canned, or ready-to-serve	3	0.25 ± 0.13
Pizza with meat and vegetables, prepared from frozen, thick crust	1	0.25 ± 0
Cold cut submarine sandwich, with cheese, lettuce, tomato, and spread	1	0.24 ± 0
Burrito with meat	1	0.22 ± 0
Chicken patty sandwich, with lettuce and spread	1	0.21 ± 0
Burrito with chicken and beans	1	0.21 ± 0
Cabbage salad or coleslaw, made with coleslaw dressing	1	0.20 ± 0
Gordita, sope, or chalupa with meat	1	0.20 ± 0
Mixed salad greens, raw	2	0.20 ± 0.14
Mushrooms, cooked, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	2	0.20 ± 0.09
Peppers, green, cooked, NS as to fat added in cooking	2	0.20 ± 0.09
Chili con carne with beans	1	0.19 ± 0
Sweet and sour chicken or turkey	2	0.19 ± 0.05
Onions, mature, cooked, from fresh, fat not added in cooking	8	0.18 ± 0.15
Onions, mature, cooked, NS as to form, NS as to fat added in cooking	1	0.13 ± 0
Cabbage, red, raw	1	0.12 ± 0
Cucumber, raw	1	0.12 ± 0
Onions, mature, raw	3	0.12 ± 0.05
Salsa, red, commercially prepared	15	0.11 ± 0.10
Peppers, hot, cooked, from fresh, fat not added in cooking	1	0.11 ± 0

Food Description	**Frequency**	**Mean ± Std Dev (cup-equiv.)**
Stew, NFS	1	0.10 ± 0
Burrito with meat and beans, from fast food	1	0.10 ± 0
Chicken burritos (diet frozen meal)	1	0.09 ± 0
Salsa, red, homemade	1	0.07 ± 0
Dumpling, vegetable	1	0.07 ± 0
Salsa, pico de gallo	2	0.07 ± 0.03
Meat loaf made with beef	1	0.07 ± 0
General Tso chicken	1	0.06 ± 0
Beef stroganoff with noodles	1	0.06 ± 0
Onions, mature, cooked or sautéed, from fresh, fat added in cooking	1	0.06 ± 0
Onions, mature, cooked or sautéed, from fresh, fat added in cooking W/ VEGETABLE OIL, NFS (INCLUDE OIL, NFS)	1	0.06 ± 0
Egg roll, with beef and/or pork	1	0.06 ± 0
Rice, fried, meatless	1	0.03 ± 0
Lasagna with cheese and meat sauce (diet frozen meal)	2	0.02 ± 0.01
Quesadilla with chicken	1	0.02 ± 0
Garlic, cooked	1	0.01 ± 0
Dip, sour cream base	1	0.01 ± 0
Bean dip, made with refried beans	1	0.00 ± 0

Appendix G: Vegetables – Legumes Itemized List

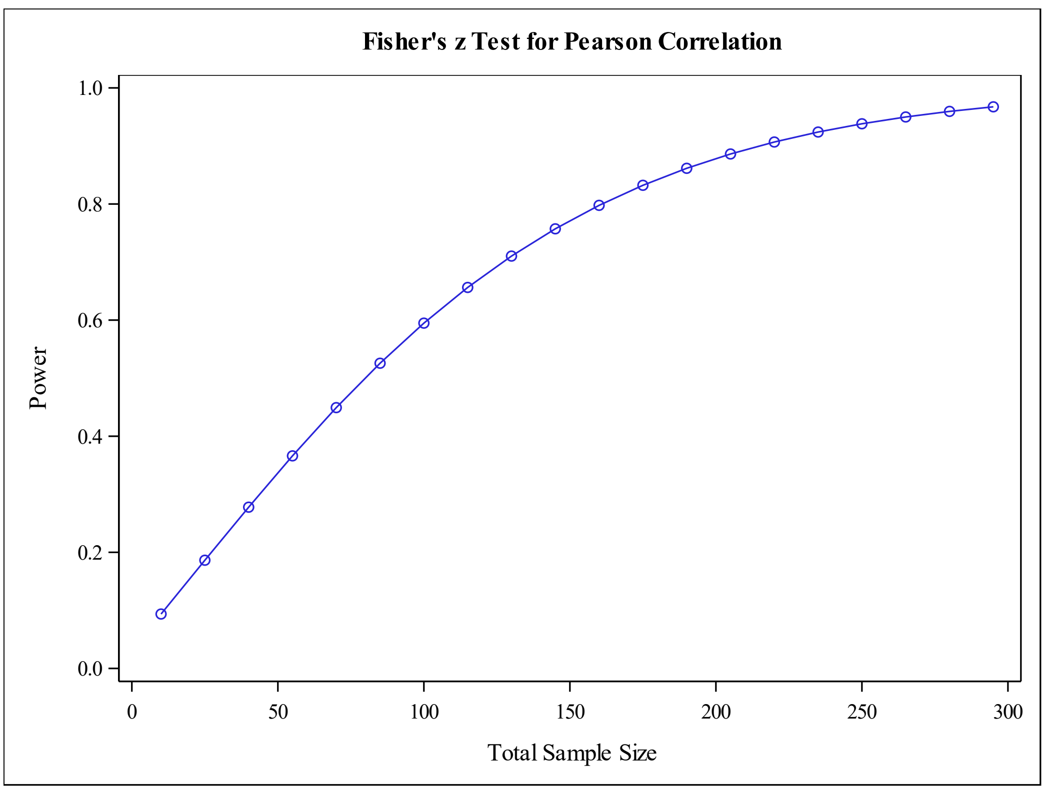
Food Description	Frequency	Mean ± Std Dev (cup-equiv.)
Beans, dry, cooked, NS as to type and as to fat added in cooking	1	3.08 ± 0
Lentil soup, home recipe, canned, or ready-to-serve	3	1.36 ± 0.72
Burrito with chicken and beans	1	0.54 ± 0
Chili con carne with beans	1	0.53 ± 0
Black, brown, or Bayo beans, dry, cooked, fat not added in cooking	3	0.41 ± 0.14
Black, brown, or Bayo beans, dry, cooked, fat added in cooking	1	0.25 ± 0
Burrito with meat and beans, from fast food	1	0.24 ± 0
Clif Bar	3	0.05 ± 0
Bean dip, made with refried beans	1	0.04 ± 0

Appendix H: Power Analysis

The Fisher's z Test for Pearson Correlation demonstrates that, in order to see a significant positive relationship between total combined F/V intake and fluid cognition (power of 0.80), approximately 160 participants would be needed.

Fixed Scenario Elements	
Distribution	Fisher's z transformation of r
Method	Normal approximation
Null Correlation	0
Correlation	0.21865
Total Sample Size	23
Number of Sides	2
Nominal Alpha	0.05
Number of Variables Partialled Out	0

Computed Power	
Actual Alpha	**Power**
0.0498	0.174



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