Diet Quality of Omnivores, Vegans and Vegetarians as Measured by the Healthy Eating Index 2010 and the Rapid Eating and Activity Assessment for Participants Short Version

by

Courtney Bliss

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Graduate Supervisory Committee:

Carol Johnston, Chair
Natasha Tasevska
Simin Levinson

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ABSTRACT

Diet quality is closely intertwined with overall health status and deserves close examination. Healthcare providers are stretched thin in the current stressed system and would benefit from a validated tool for rapid assessment of diet quality. The Rapid Eating and Activity Assessment for Participants Short Version (REAP-S) represents one such option. The objective of the current study was to evaluate the effectiveness of the REAP-S and Healthy Eating Index 2010 (HEI-2010) for scoring the diet quality of omnivorous, vegetarian and vegan diets. Eighty-one healthy male and female subjects with an average age of 30.9 years completed the REAP-S as well as a 24-hour dietary recall. REAP-S and HEI-2010 scores were calculated for each subject and evaluated against each other using Spearman correlations and Chi Square. Further analysis was completed to compare diet quality scores of the HEI-2010 and REAP-S by tertiles to examine how closely these two tools score diet quality. The mean HEI-2010 score was 47.4/100 and the mean REAP-S score was 33.5/39. The correlation coefficient comparing the REAP-S to the HEI-2010 was 0.309 ($p=0.005$), and the REAP-S exhibited a precision of 44.4% to the HEI-2010 for diet quality. The REAP-S significantly correlated with the HEI-2010 for whole fruit ($r=0.247$, $p=0.026$), greens and beans ($r=0.276$, $p=0.013$), seafood proteins ($r=0.298$, $p=0.007$), and fatty acids ($r=0.400$, $p<0.001$). When evaluated by diet type, the REAP-S proved to have increased precision in plant-based diets, 50% for vegetarian and 52% for vegan, over omnivorous diets (32%). The REAP-S is a desirable tool to rapidly assess diet quality in the community setting as it is significantly correlated to the HEI-2010 and requires less time, labor and money to score and assess than the HEI-2010. More studies

are needed to evaluate the precision and validity of REAP-S in a broader, more diverse population.

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CHAPTER 1

INTRODUCTION

Diet quality has serious implications for short and long-term health status. The current obesity epidemic in the U.S. and beyond has rendered the health care system overloaded. Healthcare providers would benefit from a rapid and meaningful tool to assess diet quality. The gold standard Healthy Eating Index (HEI) is not a suitable rubric for most providers or patients to implement or comprehend in a simple office visit. The Rapid Eating Assessment for Providers Short version (REAP-S) aims to quickly identify who is at risk and what easy changes can be made and discussed during the course of a typical office visit. The REAP-S questionnaire also serves as a method for identifying patients who would benefit from follow-up with a Registered Dietitian (RD). Research suggests that, for at-risk patient populations, access to an RD improved health outcomes and decreased medical costs associated with chronic illness (Weingarten, Henning & Badamgarav et al, 2002).

Measures of diet quality are used in clinical, community and research settings. Tools need to be user-friendly and practical in addition to being valid in multiple populations. With the healthcare system overloaded, it is imperative we have a tool to rapidly assess health risks due to dietary factors (Paxton, Stryker & Toobert et al, 2001).

Two of the most utilized tools for measuring diet quality of Americans are the HEI and the Diet Quality Index (DQI). In 1980, the United States Department of Agriculture (USDA) released the first Dietary Guidelines for Americans (DGA). The DGA is the official source of diet recommendations in the U.S. and is updated based on current research and intake levels every five years (U.S. Department of Health and

Human Services, 2014). In the early 1990s Patterson et al developed the DQI to rank dietary patterns indicative of diet quality (Patterson, Haines & Popkin, 1994). The DQI is also considered a tool for measuring risk of chronic disease (McCollough, Feskanich, & Stampfer et al, 2002). The DQI scores diet quality on a 16-point scale using 8 questions. Around the same time period the USDA developed the 1995 HEI (Kennedy, Ohls & Carlson et al, 1995). The HEI is a measure of diet quality that scores information collected by a self-report on a 100-point scale, with full points given for a diet that closely follows the DGA. Hence, the HEI is a measure that determines adherence to the DGA. Along with the DGA, the HEI is updated every five years based on the most recent evidence of intake patterns based on the National Health and Nutrition Examination Surveys (NHANES).

In the early 2000s the National Heart, Lung and Blood Institute developed the Nutrition Academic Award for medical education. One of the early projects developed for the award was the Rapid Eating and Activity Assessment for Patients (REAP). The REAP is a dietary assessment tool developed to quickly assess a person's physical activity and nutrient intake and assist in brief lifestyle counseling by a healthcare provider. The REAP differs from the other measures in that a patient would complete the questionnaire while in the doctors office, and the healthcare professional would immediately determine the diet score and provide appropriate counseling and diet recommendations to the patient (Gans, Ross, & Barner et al, 2003). The REAP was updated for easier administration and scoring. This updated, shortened version of the REAP, REAP-S, was validated using the 1998 Block food frequency questionnaire and showed a significant correlation with dairy, fruit and vegetables servings and fat consumption (Segal-Isaacson, Wylie-Rosett & Gans, 2004).

Diet balance is a concept that deserves attention. Instead of a focus on "good" versus "bad" foods, diet balance nutrition education and interventions emphasize a broader view of how to eat for overall health (Freeland-Graves & Zitzke, 2013). A high quality diet requires balance and variety. Diet modification to improve quality encompasses increasing consumption of whole grains, leafy green vegetables and plant protein sources, while decreasing consumption of sodium, trans and saturated fats, and added sugars.

Although many researchers focus on intake of specific nutrients as related to health, there is a movement aimed at measuring the overall quality of diet which proves a much more difficult task. It is important that tools to assess diet quality be validated for various plant types, including plant-based diets. Determining how the HEI-2010 and REAP-S assess different types of diets is a necessary and relevant task. It is also imperative to assess how the HEI and REAP-S relate to known biomarkers of health such as serum vitamin C, cholesterol, hemoglobin A1c, etc. In a 2012 study at Arizona State University (ASU) the REAP-S was validated against the HEI-2005 and DQI-R in young male omnivores (correlation r=0.367) indicating that the REAP-S and updated HEI would correctly measure diet quality in the additional diet populations, vegetarian and vegan (unpublished data). More research is needed to establish the correlation of REAP-S with other validated scores in multiple diet populations.

Purpose of the Study

The purpose of this study was to examine the agreement between the REAP-S and the HEI-2010 for scoring the diet quality of omnivorous, vegetarian, and vegan diets. Diet scores for both measures were also related to established biomarkers for disease risk in these populations. It is important to identify a measure of diet quality that is quick and appropriate for a variety of diets. Such measures can be used by healthcare providers to effectively serve patient populations and to researchers to assess diet quality of research participants.

Hypothesis

Diet quality quantified by REAP-S scores will significantly correlate to the scores of the HEI-2010 based on 24-hour dietary recalls in an adult population comprised of omnivores, vegetarians, and vegans. Diet quality scores will also relate favorably with measures of chronic disease risk.

Limitations

Limitations of this study include the source of dietary intake data, computer entry of diet data and the small sample size. The use of dietary recalls is inherently flawed due to self-report bias on the part of the participants. Another study limitations are computer entry of the diet data and subjective scoring of the HEI. Twenty-four hour dietary recalls were collected from 83 healthy males and pre-menopausal females. To minimize investigator bias at the level of diet entry, standard defaults were used for dietary items not in the database or not clearly reported.

Delimitations

This study was performed using volunteers (aged 18-50) free of chronic disease residing in the Phoenix-metropolitan area with an average BMI of 18.5 – 30. Validation of this study may not pertain to obese individuals or those with chronic diseases, those outside of the studied age range, or populations other than the Phoenix-metropolitan area.

CHAPTER 2

REVIEW OF LITERATURE

Based on the NHANES in 2000, American men consume and average of 2475 calories while American women consume an average of 1833 calories per day (Centers for Disease Control, 2003), intakes that are not calorically excessive. However, these data are self-reported by consumers and likely to have a high degree of bias due to under-reporting of foods (Ezzati, Martin & Skjold et al, 2006). Diet quality and overall eating patterns along with physical activity are better predictors of health and chronic disease risk than individual nutrients (US Department of Agriculture and US Department of Health and Human Services, 2010). The concept of diet quality refers to the variety of food groups ingested, recommended food intake patterns, and the adherence to healthy food choices (Freeland-Graves & Zitzke, 2013). Diet assessment is an inaccurate science complicating the development of public policy and diet recommendations (Archer, Hand & Blair, 2013). Currently, the definition and quantification of diet quality is very difficult not only because diet recall is inherently biased but also because the existing tools for assessing diet can be cumbersome and time-consuming.

Many healthcare providers share the goal of the US Department of Health and Human Services, which is to improve the health of the current generation and of generations to come (US Department of Agriculture and US Department of Health and Human Services, 2010). From 2003 to 2012, approximately 31% of children ages two to 20 years and over 68% of adults are overweight or obese according to pooled NHANES reports (Flegal, Carroll & Kit et al, 2012). With a current population over three hundred million, the toll of an overweight and obese population on the healthcare system is taxing.

Healthy eating recommendations should provide practical messages relating to the total diet approach and should be empowering and proactive for greatest benefit (Freeland-Graves & Zitzke, 2013). There is an urgent need for a rapid assessment tool of overall diet quality to efficiently assess patients and make referrals to skilled food and nutrition practitioners so patients can improve their health status through better diet.

Dietary Guidelines for Americans

The first DGA was created in 1980 with the main message that eating healthy was a lifestyle, not a dieting method (US Department of Agriculture and US Department of Health and Human Services, 1980). That message still rings true today. In fact, many of the DGA recommendations have remained consistent over the last few decades – increase fiber consumption, stay physically active most days, maintain a healthy body weight, and limit added sugars and sodium. The DGA report has many uses relating to public health: it is used to develop educational materials for public health communications, federal nutrition programs, and school nutrition programs, and it is used by the government for authoritative statements about nutrition and health (US Department of Agriculture and US Department of Health and Human Services, 2010). Scientists regularly assess the DGA and how adherence to the recommendations affects health status. In recent years a growing body of evidence has supported the DGA as a beneficial way to minimize risk of chronic disease and promote overall health (National Cancer Institute, 2014).

The DGA is updated every five years. Each update builds upon previous versions, using the most recent intake and health data from NHANES and sets new goals for the health of the U.S. population as a whole. The DGA was comprised of seven guidelines from 1980 through 1995. During those years, the DGA has focused on keeping a healthy body weight, eating a variety of foods from each food group, minimizing fat, cholesterol, added sodium and sugars and drinking alcohol in moderation (Dietary Guidelines for Americans, 1995). The changes made during this period shifted the goals from abstract recommendations like maintain ideal weight for your body to more quantifiable ones like maintain a healthy weight by balancing your caloric intake with physical activity. Since 2000 the DGA has been comprised of ten guidelines sorted into three basic groups: aim for fitness, build a healthy base, and choose sensibly. Also different in the 2000 version was an emphasis on food prepared at home with little added sugar and sodium, food safety, as well as an emphasis of the food pyramid as a guiding tool (Dietary Guidelines for Americans, 2000). Below is Table 1 indicating changes made from the DGA's inception in 1980 through 2000.

DIETARY GUIDELINES FOR AMERICANS, 1980 TO 2000

1980 7 Guidelines	1985 7 Guidelines	1990 7 Guidelines	1995 7 Guidelines	2000 10 Guidelines, clustered into 3 groups	
Eat a variety of foods	Eat a variety of foods	Eat a variety of foods	Eat a variety of foods		
Maintain ideal weight	Maintain desirable weight	Maintain healthy weight	Balance the food you eat with physical activity—maintain or improve your weight	Aim for a healthy weight	Aim for Fitness
				Be physically active each day	
Avoid too mu ch fat, saturated fat, and cholesterol	Avoid too much fat, saturated fat, and cholesterol	Choose a diet low in fat, saturated fat and cholesterol		Let the Pyramid guide your food choices	Build a Healthy Base
Eat foods with adequate starch and fiber	Eat foods with adequate starch and fiber	Choose a diet with plenty of vegetables, fruits and grain projects	Choose a diet with plenty of grain products, vegetables, and fruits	Choose a variety of grains daily, especially whole grains	
				Choose a variety of fruits and vegetables daily	
				Keep food safe to eat	
			Choose a diet low in fat, saturated fat and cholesterol	Choose a diet that is low in saturated fat and cholesterol and moderate in total fat	Choose Sensibly
Avoid too much sugar	Avoid too much sugar	Use sugars only in moderation	Choose a diet moderate in sugars	Choose beverages and foods to moderate your intake of sugars	
Avoid too much sodium	Avoid too much sodium	Use salt and sodium only in moderation	Choose a diet moderate in salt and sodium	Choose and prepare foods with less salt	
If you drink alcohol, do so in moderation	If you drink alcoholic beverages, do so in moderation	If you drink alcoholic beverages, do so in moderation	If you drink alcoholic beverages, do so in moderation	If you drink alcoholic beverages, do so in moderation	

Shading indicates how the order in which the guidelines are presented has changed over time.

Center for Nutrition Policy and Promotion, USDA, May 30, 2000

The current recommendations, released in 2010, have three main pillars: balance calories with physical activity for a healthy weight, increase consumption of nutrient-dense foods, and maintain a healthy eating pattern whenever possible (Dietary Guidelines Advisory Committee, 2010). In response to the current obesity epidemic, the first guideline addresses balancing calories with needs and physical activity to maintain a healthy weight. The next guideline focuses on decreasing consumption of foods and nutrients proven to be undesirable such as sodium, solid fats, added sugars, refined grains and alcohol. Increasing consumption of nutrient-dense foods is the other piece of changing eating patterns with an emphasis on consuming whole grains, lean proteins, fruits and vegetables and low-fat or fat-free dairy. The 2010 version of the DGA also stress the importance of choosing plant sources of protein in addition to lean animal proteins such as fish and eggs. The final two guidelines address the social and environmental nature of diet and wellness – building healthy eating patterns and helping Americans make healthy choices. For building healthy eating patterns there are meal and diet plans provided through My Plate, which are based off of the DASH (dietary approaches to stop hypertension) diet and Mediterranean diet. Helping Americans make healthy choices addresses how families, communities, and businesses affect intake and overall health. The DGA suggests that these groups come together to help individuals get healthy instead of working against health efforts.

Updates to the DGA occur every five years by law, and are tackled in three phases (Dietary Guidelines Advisory Committee, 2010). First, a scientific Dietary Guidelines Advisory Committee (DGAC) is assembled to analyze recent scientific findings on diet and health. The DGAC report is a thorough review of data relating to nutrition, physical activity, and health issues. Important items featured include a population review of: energy balance and weight management, macronutrient and micronutrient adequacy, fatty acids and cholesterol, protein, whole grains, sodium, alcohol, food safety and technology (Dietary Guidelines Advisory Committee, 2010). The resultant report is used to develop public policy. Another committee, comprised of food, nutrition and public policy experts, is created to assess the scientific findings of the report and to formulate them into achievable goals for the population. The goals are then used to develop public policy messaging and communication materials to be used for public rollout.

The DGA serves as the basis of federal nutrition policy to be used in education, outreach, and food assistance programs and is intended for use by health professionals, nutrition educators, and consumers alike (Dietary Guidelines Advisory Committee, 2010). Government agencies and community associates use the DGA as the scientific foundation for various programs related to health and nutrition including food labeling and wellness initiatives. The recommendations found in the DGA are intended to help the population create a healthy diet and lifestyle – from individual recommendations to nation-wide initiatives to food labeling and assistance programs.

Diet Quality Index

The scoring of diet quality dates back to the late 1930's (Burke, 1938). The initial diet quality measures scored intake of specific nutrients compared to the optimal levels of the time. Scores were numerical and spanned the gamut from very poor intake to excellent intake. Much of the research and emphasis from the 1930s onward focused on specific nutrients or foods and their relation to health or disease status. This line of thinking continues to this day, though thanks to the work by Kant 1996 research has moved to focus on overall diet quality, not just adequacy of a specific food or nutrient.

Analysis of diet quality indices in the 1990's showed that there was room for drastic improvement (Kant, 1996). The *Diet and Health* report by the Committee on Diet and Health of the National Research Council for the Food and Nutrition Board detailed obesity and chronic disease rates and laid forth public health recommendations (Food and Nutrition Board, 1989). As a result of the Food and Nutrition Board's report, the DQI was created to measure risk of chronic disease (Patterson, Haines & Popkin, 1994).

The DQI has eight components, each category worth zero to two points, for a maximum total score of 16 points. Unlike other measures of diet quality, a low DQI score is desirable. The DQI is weighted for importance of measure by having multiple questions for each recommendation. For example, there are three questions relating to fat consumption and poor adherence to the fat recommendations would earn 6 points in only three of eight components. Table 1 below gives an overview of the components and point values per intake level.

Table 2. The Diet Quality Index, 1994

Component	Measure	0	1	2
1	Total fat	≤ 30% total kcal	30-40% total kcal	>40% total kcal
2	Saturated fat	≤ 10% total kcal	10-13% total kcal	>13% total kcal
3	Cholesterol	≤ 300 mg	300-400 mg	>400 mg
4	Fruit and Vegetable	5+ servings*	3-4 servings*	0-2 servings*
5	Starch, complex carb^	6+ servings*	4-5 servings*	0-3 servings*
6	Protein	0-100% RDA	100-150% RDA	>150% RDA
7	Sodium	≤2400 mg	2400-3400 mg	>3400 mg
8	Calcium	≥100% RDA	66.67-100% RDA	<66.67% RDA

(A lower scores denotes a higher quality diet)
^ Starch, complex carbohydrates = beans, peas, etc
*Serving size = ½ cup vegetable, fruit, cereal, legumes; 1 medium piece of fruit; 1 roll, muffin, slice of bread

The DQI was updated in 1999 to reflect the 1992 Food Guide Pyramid and the 1995 DGA (Haines, Siega-Riz & Popkin 1999). The revised DQI (DQI-R) gives full points to those who eat a variety of foods within each of the food categories and uses added sugars and fats sparingly. The DQI-R is comprised of 100 total possible points and a high score correlates with high diet quality versus the DQI that had a total of 16 points and the lower the score the better the diet. The updated components for the DQI-R are: total fat, saturated fat, dietary cholesterol, 2-4 fruit servings, 3-5 vegetable servings, 6-11 grain servings, calcium intake, iron intake, dietary diversity, and dietary moderation.

Table 3. The Diet Quality Index - Revised, 1999				
Component	Measure	Goal	Score	Criteria
1	Total fat	≤ 30% total kcal	0-10	>40 =0, ≤ 30 =10
2	Saturated fat	≤ 10% total kcal	0-10	>13 =0, ≤ 10 =10
3	Dietary cholesterol	≤ 300 mg	0-10	>400 =0, ≤ 300 =10
4	Fruit servings	2-4 servings	0-10	<2 =0, ≥ 2 = 10
5	Vegetable servings	3-5 servings	0-10	<3 =0, ≥ 3 = 10
6	Grain servings	6-11 servings	0-10	<6 =0, ≥ 6 = 10
7	Calcium	% AI level	0-10	< 50% =0, ≥ 100% =10
8	Iron	% RDA for age	0-10	< 50% =0, ≥ 100% =10
9	Dietary diversity	Number of food groups	0-10	<3 =0, ≥ 6 = 10
10	Dietary moderation	Discretionary kcal	0-10	<4 =0, ≥ 7 = 10

(A lower scores denotes a higher quality diet)
^ Starch, complex carbs = beans, peas, etc
*Serving size = ½ cup vegetable, fruit, cereal, legumes; 1 medium piece of fruit; 1 roll, muffin, slice of bread

The DQI and DQI-R were developed with goal of being used for population monitoring and research. Some researchers have used the DQI as a marker of diet quality to associate with chronic disease risk, morbidity or mortality. One such example is the Cancer Prevention Study though in this population the DQI did not show a significant correlation with short-term mortality (Seymour, Callee & Flagg et al, 2003).

Healthy Eating Index 2010

The Healthy Eating Index (HEI) was developed in 1995 by the USDA's Center for Nutrition Policy and Promotion (CNPP) as a way to measure diet quality in the general population compared to USDA recommendations (Miller, Mitchell & Harala et al, 2011). The HEI was unique in that it incorporated the DGA and Dietary Reference

Intakes in one scale (Kennedy, Ohls & Carlson et al, 1995). The ultimate goal of the HEI was to serve as a method for monitoring changes consumption patterns in the U.S. population though this is difficult due to the inherent subjectivity in scoring the HEI. The HEI was revised in 2006 using the 2005 DGA and then again in 2012 using the 2010 DGA (Guenther, Casavale & Reedy et al, 2013). After each update, the HEI is validated against a public data set – typically recent dietary intake data from the USDA NHANES. Since its inception, the HEI has focused on adequacy and moderation of nutrients though the variations with each revision are subtle.

The HEI-1995 was comprised of ten components each worth ten points, for a total score of 100 (Kennedy, Ohls & Carlson et al, 1995). The original components were based on food groups and dietary guidelines. The food group components included grains, vegetables, fruits, milk, and meat while the guideline components were total fat, saturated fat, cholesterol, sodium and variety of diet.

The HEI-2005 was comprised of nine adequacy components and three moderation components (Guenther, Reedy & Krebs-Smith, 2008). The HEI-2005 had a greater focus on whole grains, fruit and vegetable variety, types of fats consumed and a new concept of 'discretionary calories.' The moderation components of the HEI-2005 were saturated fat, sodium and discretionary calories from alcohol, added sugars and solid fats. The adequacy components of the HEI-2005 were total fruit, whole fruit, total vegetables, dark green and orange vegetables and legumes, total grains, whole grains, milk, meat and beans, and oils.

The latest version of the HEI, HEI-2010 (Appendix C) features twelve components to be scored on a one hundred-point scale (Guenther, Casavale & Reedy et al, 2013). Nine of the components are focused on adequacy and the remaining three on moderation with all measures adjusted for density. Each component has a minimum and maximum score possible, ranging from zero to twenty. Standard levels for the minimum and maximum scores were set using average levels of intake from publicly available datasets such as NHANES.

Intake levels recorded in the NHANES 2001-2002 were reviewed and used to establish the standard minimum and maximum threshold (Britten, Marco & Yamini et al, 2006). The distributions of intakes for each food group were analyzed to develop the standards for each age and gender group. When creating the HEI, developers selected the easiest requirement for intake as the low-level threshold for each food group.

In the moderation category are intake of refined grains, sodium, and empty calories (Guenther, Casavale & Reedy et al, 2013) Refined grain intake is worth 10 points and consuming less than or equal to 1.8 ounces per thousand calories gets full points while consumption greater than or equal to 4.3 ounces per thousand calories receives zero points. Intake of sodium is worth 10 points and consuming less than or equal to 1.1 grams per thousand calories receives full points while consumption greater than or equal to 2.0 grams per thousand calories gets zero points. To receive the full twenty points for adequate empty calorie consumption, calories from solid fats, alcohol and added sugars should comprise less than or equal to 19% of total energy and greater than or equal to 50% of total calories from ‘empty’ sources yields zero points. The point values for the HEI-2010 moderation component are weighted towards nutrient dense foods, fewer refined grains and added sodium as indicated by the higher points values.

The adequacy category is scored similarly and inversely in that meeting guideline recommendations receives full points while consumption linked with increased risk of chronic disease, in the adequacy group this is a lack of intake, warrants zero points (Guenther, Casavale & Reedy et al, 2013). Fruit and vegetable consumption is broken down into total fruit, whole fruit, total vegetables, and greens and beans. Also broken down are total protein foods and seafood and plant proteins. These subgroups are necessary to evaluate how the population is doing meeting the DGA. Total fruit consumption has a maximum score of 5 points for greater than or equal to 0.8 cups per thousand calories. Whole fruit consumption also has a maximum score of 5 points for a serving size greater than or equal to 0.4 cups per thousand calories. Greens and beans consumption is assessed separately from total vegetables, though each category is worth 5 points. Consumption of greater than or equal to 0.2 cups of greens or beans per thousand calories receives full points and consumption of greater than or equal to 1.1 cups of total vegetables per thousand calories gets the full 5 points. Adequate whole grain consumption receives 10 points at greater than or equal to 1.5 ounces per thousand calories. Dairy is also worth ten points when greater than or equal to 1.3 cups per thousand calories is consumed. Total protein and seafood or plant protein sources are each worth 5 points. Greater than or equal to 2.5 ounces of total proteins per thousand calories is the standard for the maximum score. Full points for seafood and plant proteins is given if consumption per thousand calories is greater than or equal to 0.8 ounces. Consumption of fatty acids and their ratio are important to health status and as such are part of the HEI adequacy component yielding ten points. The ratio of polyunsaturated and monounsaturated fatty acids to saturated fatty acids determines the score received. If the ratio is less than or equal to 1.2, that is consumption of saturated fatty acids is higher than monounsaturated or polyunsaturated fatty acids the score for this component is zero. Conversely if the ratio is greater than or equal to 2.5, full points are given. The point values for the HEI-2010 are weighted towards plant and seafood protein, whole grains, lean dairy and a healthy ratio of fats thus indicated by the higher points values.

Rapid Eating and Activity Assessment for Participants (REAP)

In 1997 the National Heart, Lung, and Blood Institute (NHLBI) developed the Nutrition Academic Award (NAA) to improve training provided in United States medical schools (Pearson, Stone & Grundy et al, 2001). One of the early focuses of the NAA was for assessment tools to be used in the clinical setting. A team at The Alpert Medical School and Brown University developed a tool for rapid assessment of diet that addressed national priorities for adults (Gans, Ross & Barner et al, 2003). The tool was the REAP. REAP was developed using the Food Guide Pyramid and the 2000 U.S. DGA. Recent research findings consistently show that Americans are not consuming enough calcium, whole grains, or produce and are over-consuming fats, cholesterols, alcohol and sodium (Krebs-Smith, Guenther & Subar et al, 2010). There was also a marked decrease in physical activity. REAP set out to address all of those factors and enable providers to tailor lifestyle adjustments or recommendations based on answers to the questionnaire. The investigators also developed a scoring key with talking points for physicians or providers to help facilitate easy scoring and counseling.

The original version of REAP, developed in 2003 assessed several pillars of diet quality including: total and saturated fat intake, calcium-containing food consumption, fruit and vegetable intake, consumption of sugary beverages or foods, whole grains, physical activity, alcohol and excess sodium. The original questionnaire is composed of 27 questions, is written at a 6th grade level and takes an average of ten minutes for patients complete and even less time for physicians to score. As with the Healthy Eating Index, the higher the score the better the quality of diet. The REAP questionnaire was validated in 61 healthy volunteers against food frequency questionnaires, biomarkers, and a cognitive assessment test along with feasibility and calibration studies (Gans, Ross & Barner et al, 2003).

REAP-Short Version

After initial feedback from providers and students, the REAP investigators created a short version of the form for even faster assessment of diet. The REAP-Short Version (REAP-S) consists of 16 questions and in addition to taking less time to complete and score – it is also easier for working with low-literacy populations or in a fast-paced clinical setting. Unfortunately, little research testing its validity has been done since its original validation and inception (Segal-Isaacson, Wylie-Rosett & Gans, 2004). The development team validated the REAP-S against the Block 1998 FFQ in healthy volunteers. The strongest correlation in Segal-Isaacson's 2004 validation was seen in the vegetable, fruit and dairy groups while meat and added fat servings had an inverse correlation (Segal-Isaacson, Wylie-Rosett & Gans, 2004). A recent thesis project at Arizona State University validated the REAP-S measure against DQI and HEI-2005 for a group of healthy men (Fawcett, 2012).

In the project aimed at correlating REAP-S scores with HEI-2005 and DQI (revised), statistical significance was found in both comparisons. Based on the findings of this study with limited sample size, it appears the REAP-S can serve as a faster method of assessing diet quality than HEI.

U.S. Dietary Intake Recommendations

The average American makes over 200 food choices each day (Lang, 2006). The USDA and DHHS recommend following the DASH Diet or Mediterranean diet as examples of sound dietary intake. Current recommendations are based on the Dietary Reference Intakes (DRI) from the Institute of Medicine (Institute of Medicine, 2002). In 2002 the Institute of Medicine (IOM) released the Acceptable Macronutrient Distribution Ranges (AMDRs) report, which takes into account chronic disease risk and levels necessary for essential functions. These recommendations are broken up by age groups (young children, older children and adolescents, and adults) and by macronutrient.

Table 4. Dietary Reference Intakes, 2010 IOM

Life stage	Carbohydrates (g/d)	Total Fiber (g/d)	Protein (g/d)	Fat (g/d)
Infants				
0 to 6 mo	60	ND	9.1	31
6 to 12 mo	95	ND	11	30
Children				
1–3 y	130	19	13	Unknown
4–8 y	130	25	19	Unknown
Males				
9–13 y	130	31	34	Unknown
14–18 y	130	38	52	Unknown
19–30 y	130	38	56	Unknown
31–50 y	130	38	56	Unknown
51–70 y	130	30	56	Unknown
> 70 y	130	30	56	Unknown
Females				
9–13 y	130	26	34	Unknown
14–18 y	130	26	46	Unknown

19–30 y	130	25	46	Unknown
31–50 y	130	25	46	Unknown
51–70 y	130	21	46	Unknown
> 70 y	130	21	46	Unknown
Pregnancy				
14–18 y	175	28	71	Unknown
19–30 y	175	28	71	Unknown
31–50 y	175	28	71	Unknown
Lactation				
14–18	210	29	71	Unknown
19–30 y	210	29	71	Unknown
31–50 y	210	29	71	Unknown

Carbohydrates

The AMDRs for carbohydrate intake, regardless of age, is 45 – 65% of total calories or 60-210 grams, depending on gender and life stage, each day. Carbohydrates are obtained from plant sources and contribute the largest part of most diets (Mahan & Escott-Stump, 2008). The body creates energy from carbohydrates by converting it into glucose. Glucose has a very important role in energy supply because it is the primary source of energy for the brain and nervous system. Carbohydrates are the only energy source used by red blood cells and are the preferred energy source for the fetus in pregnant women. Current recommendations are to increase the amount of whole grains whilst decreasing the amounts of refined grains (give examples of each- whole/refined). Increasing daily intake of carbohydrates from fruits, vegetables and whole grains improves the likelihood of reaching the recommended consumption of dietary fiber and micronutrients while decreasing consumption of added sugars.

Fiber is part indigestible carbohydrates thus recommended intake levels are often grouped together. The IOM endorses intakes of 14 – 34 grams of fiber per day and levels are based on age and gender. Children under the age of three years require the least amount of fiber while men ages 19 – 30 years old require the most amount of fiber. Fiber can be found in fruits, vegetables and whole grains. Consumption of fiber has been connected with decreased risk of type-2 diabetes and cardiovascular disease among others (Dietary Guidelines Advisory Committee, 2010).

Protein

The AMDRs for protein intake range from 5 – 35% of total calories or 9-71 grams consumed each day depending on age range and gender (Institute of Medicine, 2002). Young children, from one to three years of age, should consume 5 – 20% of total calories. Older children, from four to eighteen years of age, should consume 10 – 30% of total calories. Adults over 19 years should consume a diet composed of 10 – 35% carbohydrates. Proteins can come from plant or animal sources and Americans typically consume excessive amounts each day. Protein food sources include poultry, eggs, meat, seafood, beans, peas, soy, nuts and seeds. Protein foods are high in vitamins and minerals but specific micronutrients vary by type of protein. Dairy sources of protein provide vitamins A and D, calcium, magnesium and potassium. Animal sources of protein provide vitamin B12 and iron among other micronutrients. Plant sources of protein, such as quinoa, provide potassium and folate among others (USDA, 2014). The DGA 2010 recommends Americans choose lean protein from a variety of sources each day to ensure a balance of amino acids and micronutrients.

Fat

Consumption of fat is crucial to a healthy diet, though choosing the right types of fats and quantities is imperative. Fats are necessary for absorbing vitamins A, D, E and

K, forming cellular membranes, providing energy and various other functions (Mahan & Escott-Stump, 2008). The IOM states the AMDRs for fat ranges from 20 – 40% of caloric intake based on age (Institute of Medicine, 2002). Children under three years of age require 30 – 40% of daily calories from fat while older children, 4 – 18 years, need 25 – 35% of calories from fat. Adults require 20 – 30% of their daily calories to come from fat sources. Trans and saturated fats, often found in solid fats, are detrimental to health while polyunsaturated and monounsaturated fats, as found in oils, are beneficial in moderate amounts (Lichtenstein, Appel & Brands et al, 2006). The DGA recommends consuming less than 10% of total calories from saturated fats. The HEI 2010 gives full points for a diet high in polyunsaturated and monounsaturated fats while low in saturated fats. This can be accomplished by consuming more liquid fats than solids, such as safflower oil, olive oil and vegetable oil instead of butter or lard.

Diet and Disease

The American Heart Association (AHA) released its most recent Diet and Lifestyle Recommendations in 2006 (Lichtenstein, Appel & Brands et al, 2006). The AHA focused on a combination of lifestyle and dietary factors in this latest report, indicated that prevention of heart disease is more desirable than efficient treatment of the disease. Lifestyle recommendations include increasing physical activity, avoiding tobacco use and or exposure and keeping blood pressure and blood lipids in the desirable ranges. The AHA recommends, similar to the DGA, that adults consume a diet rich in fruits and vegetables and whole grain foods along with fish, preferably oily fish, twice a week. Their report also indicates that maintaining a healthy body weight and a regular balanced diet, versus periods of adherence and over-indulgence, is ideal for minimizing chronic disease risk.

Measures of diet quality and relationship to chronic disease risk are an area of much interest. Epidemiologic studies are used to measure risk of chronic disease and the collection of nutrition intake along with environmental exposures years before development of disease as they provide much insight into disease risk and progression. Since the initial development of the DGA and the HEI many researchers have tried to improve upon them. Two such examples are the Alternate Healthy Eating Index (AHEI) and the Recommended Food Source (RFS).

The AHEI was created by McCullough et al and contained nine components (McCullough, Feskanich & Stampfer et al, 2002). The AHEI was designed to target nutrients with known associations to chronic disease risk such as vegetables, nuts, soy and trans fat among others. The RFS was developed as part of a study on diet quality and mortality in women (Kant, Schatzkin & Graubard et al, 2000). The RFS is composed of a 62-item food frequency questionnaire with food items divided into 23 groups and scored. Foods featured in the RFS include specific fruits and vegetables and meats cooked in a particular fashion.

McCullough used the RFS and AHEI to evaluate if these tools would predict chronic disease risk better than the HEI-2000. The investigators used over 100,000 subjects from the Health Professionals Follow Up Study and the Nurses Health Study who had diet questionnaires available. The RFS was predictive of risk for cardiovascular disease and other chronic diseases in men but not in women. The AHEI was statistically associated with risk of major chronic disease in men and women. The AHEI has not been tested much or updated since 2000 and thus was not chosen for the current study.

Another study evaluating the association of mortality with dietary recommendations was Parikh et al. This team evaluated the association between adherence to a DASH-like diet and mortality in a group of Americans with hypertension (Parikh, Lipsitz & Natarajan, 2009). Parikh et al analyzed data from the third NHANES cohort and found a significant reduction in all-cause mortality in those who followed a DASH-like diet, hazard ratio 0.69, 95% CI (p=0.01). The DGA often use the DASH diet as a recommendation of healthy intake patterns thus this study of mortality when following the recommendations provides further proof that the DGA supports an overall healthy lifestyle.

A more recent study of adherence to the DGA and stroke risk was completed in minority ethnic groups (Sharma, Sheehy & Kolonel, 2013). The purpose of this study was to assess whether fruit and vegetable intake changed stroke risk by ethnicity thus indicating a change in recommendations for certain populations. The investigators found no association between increased stroke risk and fruit or vegetable intake by ethnic group in the males studied. There was a decrease in risk of stroke for women of ethnic minority groups by amount of fruit and vegetable consumption, though it was not statistically significant (relative risk =0.84, 95% CI). This study suggests that adherence to the DGA and risk of fatal stroke is not modified by ethnicity supporting the recommendations across racial and ethnic groups.

Health Benefits

The benefits of fruit and vegetable consumption have been noted for years. A recent review of health benefits touched on the relatively new field of phytonutrients (Slavin & Lloyd, 2012). Unfortunately very few randomized controlled trials have been published showing the health benefits of increasing fruit and vegetable intake using biomarkers. Much of the evidence researchers pull from stems from epidemiologic studies. Fruits and vegetables are known to vary greatly in nutrient content and energy level though all have high levels of phytonutrients (Beecher, 1999). It is also known that fruits and vegetables supply large amounts of dietary fiber, vitamins, minerals and antioxidants. Dietary fiber is helpful in reducing the risk of obesity and cardiovascular disease while antioxidants help relieve stress on the body and protect against natural-forming free radicals (Abete, Goyenechea & Zulet et al, 2011).

Ample whole grain intake has been linked to reduced risk of cardiovascular disease and visceral adiposity. The combination of soluble and insoluble fibers found in whole grains work to reduce low-density lipoprotein levels in the blood (Lichtenstein, Appel & Brands et al, 2006).   Large-scale epidemiological cohort studies have shown an inverse association between consumption of whole grains and the incidence of cardiovascular disease (Mellen, Liese & Tooze et al, 2007).

Visceral adiposity and abdominal fatness are also associated with cardiovascular disease and other chronic diseases. Researchers have hypothesized that refined-grain intake was associated with visceral adiposity (KcKeown, Troy & Jacques et al, 2010). This study compared abdominal subcutaneous adipose and visceral adiposity as related to whole or refined grain intake. The investigators found that higher whole-grain intake is associated with lower visceral adiposity in adults. Admittedly, this study could not elucidate the mechanism where-by refined grains favor fat storage and whole grains do not, but the evidence was helpful in tailoring recommendations for improved dietary intake.

In recent years there has been a push by professional organizations to increase the amount of nutrition research completed to further knowledge relating to disease control and prevention. The American Society of Nutrition formed a committee to look at those specific issues (American Society of Nutrition, 2015). Their goals were to focus on the individual variability in food and diet response, further knowledge relating to healthy growth, development and reproduction along with health maintenance. Also of importance was improved medical management of nutrition-related diagnoses, a better understanding of nutrition-related behaviors and of the food supply (Ohlhorst, Russell & Bier et al, 2013). Validation of a rapid assessment tool would aid their mission of improving knowledge and treatment of various conditions.

Diet Analysis

The analysis of diet is one of the most difficult measures in research. Diet is a strong part of everyday life and subtle changes can make a large difference. Measuring and analyzing data in large populations is cumbersome and the use of self-reported data often entails recall bias or some degree of misreporting. Several common methods for collecting dietary intake data include 24-hour dietary recall and food frequency questionnaire. Each type of measure has it’s own strengths and weaknesses. Food frequency questionnaires do not indicate meal patterns, and the subject can under-report negative foods and over-report positive foods. Biomarkers also provide a method for analyzing data without the use of self-reported data.

Twenty-four hour recalls are time-consuming and labor intensive even on small scales. In the early 2000's the USDA created the AMPM, or Automated Multiple-Pass Method to increase the efficiency of dietary intake collection and ease the workload on the researchers. Since it's inception, the AMPM has been validated in women using doubly labeled water, total energy expenditure, food frequency questionnaires and a 2-week estimated food record (Blanton, Moshfegh & Baer et al, 2006). The USDA's AMPM was validated again in healthy adults, men and women, using total energy expenditure, doubly labeled water and three 24-hour dietary recalls during the course of the study (Moshfegh, Rhodes & Baer et al, 2008). Moshfegh et al found that AMPM reduced recall bias by providing respondents with multiple cues to remember and describe items consumed.

Adequate diet assessment is such a problem that researchers often use multiple measures to assess quality and intake. It is not uncommon for a single study to collect data-related information via food frequency questionnaire, diet recall or diary as well as biochemical markers of intake. Thirty-seven studies were examined to develop a meta-analysis reviewing the extent, nature and determinants of misreporting in diet (Poslusna, Ruprich & de Vries et al, 2009). Poslusna et al found that approximately 30% of subjects under-estimated their intake by 15%. There was also a tendency for low-energy reporters to have higher micronutrient densities, possibly due to lower reported energy intake. The researchers also found an inverse relationship between body mass index (BMI) and the probability of under-reporting dietary intake. This meta-analysis reaffirms the need to collect multiple measures of diet intake to paint a clear picture of actual status.

Assessment Needs

The HEI is a thorough and validated tool for assessing diet quality though it has weaknesses. The HEI does not assess physical activity, a known risk factor for chronic disease, and it is cumbersome to score and analyze. As a result of the HEI shortcomings, many investigators have developed their own tools specific to their needs and tried to validate them. Most of the adjustments to the HEI (prior to the 2010 revision) focused on ease of execution and equal weighting for plant and animal protein sources to adequately assess vegetarian and vegan diets. The REAP or REAP-S have been widely-used among researchers, more so than some other rapid diet quality assessment tools such as the DDS-R or the RFS-24 (Gans, Roos & Barner et al 2003).

Assessing and addressing other risk-increasing behaviors is necessary for meaningful interventions (Babor, Sclamanna & Pronk, 2004). The analysis by Babor et al confirmed what many public health experts have purported – that the tools you use are not nearly as important as the act of screening patients regularly for unhealthy lifestyles. In large-scale research settings it is common for investigators to have access to a nutrition expert with time and money available to measure HEI in study populations. In the community setting this is not the case. Community physicians require a rapid measure of risk due to lifestyle and dietary factors to quickly and efficiently assess their patients and make necessary recommendations or referrals.

Types of Diets

In 2008, approximately 3.7% of the American population identified themselves as vegetarian or vegan (Vegetarian Times, 2014). A 2013 survey indicated over 13% of the United States population identifies themselves as vegetarian or vegan (Vegetarian Times, 2014). With such a large portion of the population omitting animal proteins from their diet, diet assessment tools should be validated for vegetarians, vegans and omnivores.

Omnivore

Approximately 87% of the US population follows an omnivorous diet. Omnivores can consume a variety of meats, fish, produce and dairy. As with all eating patterns, the way Americans follow an omnivorous diet will vary by individual preference and cultural norms.

Vegetarian

As recently as 2013, approximately six percent of Americans follow a vegetarian diet (Vegetarian Times, 2014). Vegetarians do not eat meat, fish or poultry and follow a plant-based diet. Vegetarians can follow one of several eating patterns usually grouped as vegan, lacto-ovo vegetarian, or lacto vegetarian. Vegan diets will be described below. Lacto-ovo or lacto vegetarians consume dairy and egg products or just egg products, respectively (Medline Plus, 2014).

Vegan

Vegans are a type of vegetarians and represent approximately seven percent of the US population (Vegetarian Times, 2014). Vegans differ from vegetarians in that they do not consume or use any animal products or by-products including eggs, honey, leather, fur, silk, or wool among others (Medline Plus, 2014). The motivation behind consuming a vegan diet is a combination of health and promotion of a more humane world.

Benefits of Plant-Based Diets

Over the past few decades much research has been completed on the health benefits of plant-based diets. Most of this work has been done as part of a systematic review of epidemiological cohort studies (Hu, 2003). Predominantly plant-based diets have been associated with decreased risk of all cause mortality, cardiovascular disease, diabetes and obesity in multiple studies and cohorts.

Plant-based diets are higher in folate, potassium, dietary fiber, flavonoids, carotenoids, monounsaturated and polyunsaturated fats while also being lower in cholesterol, saturated and trans fats (Fung & Hu, 2003). In 2005 a team of researchers completed a randomized control trial comparing a traditional low-fat diet with a predominantly plant-based low-fat diet (Gardner, Coulston & Chatterjee et al, 2005). This trial found a significant reduction in total cholesterol ($p=0.001$) and low-density lipoprotein ($p=0.02$) in both arms. The Gardner trial did not find any significant increase in high-density lipoprotein or reduction in triglycerides, nor was there a significant difference between the traditional and plant-based low-fat diets. Findings also suggested increased weight and blood sugar control associated with the whole grains and increased fiber consumed as part of a plant-based diet. Plant sources of omega-3 fatty acids such as alpha-linoleic acid found in flax seeds and walnuts have been linked to cardiovascular protection (Fung & Hu, 2003).

These reviews support an emphasis on fruits, vegetables, whole grains and plant proteins as outlined by the DGA. A successful diet quality measurement tool should effectively score all types of diets, including plant-based diets considering these health benefits and current rate of adherents to plant-based diets. To date, HEI scoring (arguable the 'gold-standard for diet quality) has not been correlated to nutrient intake or health assessments in a population composed of both omnivores and vegetarians in the United States. A European study recently published assessed the nutritional quality of different diet types as measured by the HEI-2010, the Mediterranean Diet Score, and a food frequency questionnaire (Neuhouser, Patterson & King et al, 2014). The data indicate that plant-based diets are more healthful than their omnivorous counterparts. This European cohort of 1800 subjects shows the timeliness of the current study and the need for a better understanding of diet quality by diet type. The current study examines diet quality scoring, via HEI-2010 and REAP-S, in a population composed equally of omnivores, vegetarians, and vegans to compare and contrast how well these measures relate to nutrient intake and biomarkers of the respondents as well as to each other.

CHAPTER 3

METHODOLOGY

This study will use dietary data that were collected from 81 participants of a previously conducted cross-sectional study that examined substrate utilization as a function of omnivorous versus vegetarian diets. Recruitment took place at a large university in the Southwest and the surrounding community. This study was approved by the Arizona State University Institutional Review Board (Appendix A) and all participants gave written consent for the procedures including REAP-S questionnaire and diet analyses.

Participant Selection

Participants of the study were healthy, non-smoking adults between the ages of 18 and 50 years who had been following their current diet (omnivore, vegetarian or vegan) for at least six months. Participants were asked to provide a twenty-four hour urine sample, wear a facemask for 30 minutes to measure resting energy expenditure, and provide a fasting blood sample. Volunteers were excluded if they had a BMI greater than 30 kg/m^2, were pregnant or lactating within the six months prior to screening, had irregular menstrual cycles, were endurance-trained or were on medications that could potentially influence body weight (e.g. insulin, corticosteroids, sulfonylureas, sodium valproate, thyroid replacement therapy, beta-blockers, ACE inhibitors, diphenhydramine, lithium carbonate, thiazolidinediones, or cyproheptadine).

Participants were recruited using emails, flyers and online forums for local vegetarian and vegans. Individuals interested in participating were directed to complete an online screening questionnaire ensure all inclusion criteria were met. Eligible volunteers had in person meetings to learn more about the study and the investigators further screened for exclusion criteria. Individuals who confirmed interest in the study and met none of the exclusion criteria were invited to participate and asked to provide written consent.

The original study included 83 participants but one did not complete the REAP-S questionnaire and another subject did not provide a 24-hour dietary recall; hence, the total subjects analyzed for the current project was 81. In the final analysis for the current project there were 27 omnivores, 26 vegetarians and 27 vegans resulting in an even distribution of participants across diet types

Study Design

The previous study collected anthropometric data, blood, urine, and self-administered questionnaires as well as 24-hour dietary recalls. Anthropometric data collected included: waist circumference measured by centimeters, height measured in inches by scale, weight using a calibrated scale was recorded in kilograms. Body mass index (BMI) was calculated from the height and weight as kg/m^2. Bone mineral density (BMD) was evaluated using a DEXA scanner and results were reported in Z-scores. Handgrip strength was measured as pounds per square inch (psi) using a Smedley hand dynamometer. Twenty-four hour urine samples were collected and pH was assessed using a pH meter. The previous study collected several blood and plasma biomarkers though for this study only plasma vitamin C was used. The fresh plasma was mixed with cold 10% tichloroacetic acid and then centrifuged at 3500g and 0 degrees C for 20 minutes. The resultant supernatant was stored at -80 degrees C until ready for analysis. Vitamin C was analyzed using the 2,4-dinitrophenylhydrazine colorimetric method (Omaye, Turnbull & Sauberlich, 1979).

Three self-reported questionnaires were completed for the previous study – the REAP-S, a 24-hour dietary recall and the Godin-Leisure Time Exercise Questionnaire. The leisure questionnaire requires participants to detail the number of hours of low, moderate and high exertion activity for a typical week. The hours for each exertion level are multiplied by a coefficient and then tallied for an overall metabolic equivalent score (Godin & Shephard, 1985). For the previous study, the REAP-S (Appendix C) was self-reported based on the previous week's intake and, on the same day, an unannounced 24-hour dietary recall was conducted by a trained nutrition professional. Diet quality was scored using the HEI-2010 (Appendix C) and REAP-S for each subject as described below. Micronutrient and macronutrient intake was assessed using a food and nutrient processing system.

Self-reported 24-hour-recalls were collected by a trained nutrition professional along with REAP-S questionnaires completed by the subjects.

Scoring the HEI-2010

The HEI 2010 is a rubric for quality of diet as compared to the federal dietary guidelines (Guenther, Casavale & Reedy et al, 2013). In 2010 the HEI was updated based on the release of the *Dietary Guidelines for Americans, 2010* (US Department of Agriculture and US Department of Health and Human Services, 2010).

The HEI-2010 is composed of one hundred possible points across twelve categories. The twelve categories are divided into two groups: adequacy and moderation. The categories address consumption of fruits, vegetables, whole and refined grains, dairy, protein, fatty acids, sodium and empty calories. Scores for each component are calculated on a sliding scale based on the adherence to the DGA recommendations. Zero consumption of the food group in question yields zero points, consumption at 100% of the standard per thousand kilocalories yields full points and any intake between these receives an incremental score. Specific categories of the adequacy component are: total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and fatty acids. Scores for each of the adequacy components range from 5-10. Specific categories of the moderation component are: refined grains, sodium and empty calories. Scores for the moderation component range from 10-20 points and are scored inversely of the adequacy groups; the lower the consumption of each food groups in question the higher the score. See Appendix C for the full rubric.

The 24-hour dietary recalls were entered into The Food Processor® Nutrition and Fitness Software by ESHA Research, Inc. (version 10.11, ©2012) for scoring of the HEI-2010 and nutrient analysis. Once the data was collected and entered into the food processor software, the investigator spent several hours reviewing records and entering data to format the food processor output into a formatted HEI-2010 spreadsheet. Each data point was checked for accuracy against the 24-hour dietary record and known nutrition facts. Food Processor automatically calculates servings by food groups via MyPlate. The investigator used the auto-populated MyPlate servings as the basis but then spot-checked each food against the MyPlate website. Several foods were shown to not calculate correctly in the food processor, specifically for food groups. For example, fuji apples did not trigger the fruit serving so anyone who consumed a fuji apple was not credited with a fruit serving for that apple. Any foods that were not in the Food Processor database were looked up online and manually added to the 24-hour dietary record. If the nutrition facts for foods listed were not easily found through an Internet search, the investigator looked up three similar products and took the average of the three measures as the surrogate.

Many dishes commonly eaten by Americans contain items from multiple food groups. The investigator discovered that Food Processor did not always account for mixed foods as the USDA and CNPP had intended. For mixed foods and dishes containing dairy products, such as casseroles and pizza, the investigator accounted 20% of the fat calories to dairy. Any out of range measures, for example four bananas in one day, the investigator went back to the paper copy of the subject's 24-hour dietary recall for careful review. In all but one instance, the 24-hour dietary record matched that which was entered in Food Processor.

Dairy and soymilk were assessed for fat and sugar content. Fat calories for one percent (25 kilocalories/cup) milk through whole (80 kilocalories/cup) milk were added to the empty calories component. Additional calories for flavored dairy (80 kilocalories/cup) or soymilk (50 kilocalories/cup) were also added to account for the increased sugars. Fortified soymilk was counted towards the dairy point but other nondairy milks, such as rice or almond milk, were allotted to the plant protein section per the HEI (USDA, 2010). Alcohol consumption was assessed per drink, not per grams of alcohol, to adhere to the HEI rubric of one drink per 1000 kilocalories or one drink for women and two drinks for men.

Scoring the REAP-S

The REAP-S is a questionnaire consisting of sixteen items regarding food intake. The participant completes the questionnaire based on their food intake the previous week. Thirteen of the questions are answered ‘usually/often, sometimes, or rarely/never’ and three of the thirteen can also be answered as ‘does not apply to me.’ The additional option of ‘does not apply to me’ relates to the consumption of meat, poultry, seafood, and processed snacks. For this study, only the first thirteen questions were scored as the last three questions are not measured in the HEI-2010 and thus could not be correlated. Responses of usually/often received 1 point, sometimes = 2 points, and rarely/never or does not apply to me received 3 points (Segal-Isaacson, Wylie-Rosett & Gans, 2004). For the thirteen questions scored, a total possible score ranged from 13 to 39 points.

Statistical Analysis

To assess the study population and validate the REAP-S as a surrogate for the HEI-2010 multiple analyses were performed. All data were checked for normality. The HEI-2010 and REAP-S data was skewed, thus nonparametric tests were used for analysis. Descriptive statistics were run for participant characteristics such as age, height, weight, body mass index (BMI), waist circumference and body fat percentage, all results reported as mean ± SD with minimum and maximum values. Chi-square testing was used to compare gender differences in groups and to assess the grouping of diet quality tertiles between REAP-S and HEI-2010. One-way ANOVA was performed to compare participant characteristics such as weight, age, height, BMI, blood pressure, hand grip, waist circumference, visceral fat, body fat percentage, physical activity, bone mineral density, blood glucose, total energy, plasma vitamin C, and urinary pH between diet groups. Descriptive statistics were run to assess mean HEI-2010 and REAP-S scores overall and by diet type as well as significance, all results reported as mean ± SD with minimum and maximum values and p-value significance. Histograms were used to visually display score frequencies for HEI-2010 and REAP-S for the entire study population. Box plots were used to visually display score frequencies for HEI-2010 and REAP-S by diet type. HEI-2010 and REAP-S scores of study participants were assessed for normality visually and with Kolmogorov-Smirnov test. The data were not normally distributed necessitating the use of nonparametric tests. The total HEI-2010 and REAP-S scores were compared using Spearman correlational coefficient analyses instead of transforming the data to use parametric tests. In additional to assessing correlation between the total scores, REAP-S scores were also tested for correlations against the HEI-2010 subgroups. To further assess the adequacy of REAP-S as a surrogate for diet quality, Spearman correlational analysis was run for each score against known health markers including: age, BMI, blood pressure, hand grip, waist circumference, visceral fat, body fat percentage, physical activity, bone mineral density, urinary pH and plasma vitamin C. The investigators also used Spearman correlations to assess diet quality scores by intake of individual nutrients such as: energy, fats (total, saturated, trans, monounsaturated, and polyunsaturated), protein, carbohydrates and total and soluble fibers, total sugars, cholesterol, vitamins A through K, calcium, iron, magnesium, selenium, etc. Another important aspect to measure was how well REAP-S classified diet quality compared to HEI-2010. To assess this, scores for REAP-S and HEI-2010 were separated into tertiles. The tertiles of REAP-S scores and HEI-2010 scores were compared using crosstabulation statistics to determine if subjects were grouped similarly by diet quality across the two measures. For further assessment of inter-rater reliability of the REAP-S and HEI-2010, kappa statistics was run to measure the level agreement between the two scales.

All data are reported as the mean ± SD and correlations reported with correlation coefficient (r) and p-values. The REAP-S scores were correlated to the HEI-2010 for each diet type. All analyses were conducted using IBM© SPSS© Statistics by IBM Corporation (version 20, © 2011). $P<0.05$ indicates significance.

CHAPTER 4

RESULTS

Participant Characteristics

A total of 81 subjects (27 omnivores, 26 vegetarians and 27 vegans) were included in this analysis. There were 23 males and 58 females assessed for the current study. The mean age of participants was 30.9 ± 6.7 years with a range of 19 to 50 years of age. The mean weight of the subjects was 65.1 ± 11.2 kilograms (range: 46.2 to 93.4), mean height was 66.3 ± 0.4 inches (range: 59.7 to 75), and the mean BMI was 22.8 ± 2.8 (range: 18.3 to 29.0). Participant characteristics are displayed in Tables 5 and 6.

Table 5. Participant characteristics

Characteristics	Mean ± SD	Minimum	Maximum
Age, y	30.9 ± 6.7	19	50
Weight, kilograms	65.1 ± 11.2	46.2	93.4
Height, inches	66.3 ± 0.4	59.7	75
BMI, kg/m^2	22.8 ± 2.8	18.3	29
Waist Circumference, cm	80.4 ± 9.9	62.4	106.5
Body Fat, %	29.8 ± 7.9	13.5	47.2

n = 81
SD = standard deviation
BMI = body mass index (calculated as kg/m^2).

Our three diet groups were differed significantly from each other in five items at baseline – age ($p= 0.013$), gender ($p=0.540$), urinary pH ($p= 0.001$), plasma vitamin C ($p= 0.010$) and REAP-S score ($p \leq 0.05$). Our groups did not significantly differ in total energy intake ($p=0.712$).

Table 6. Participant characteristics by diet group*

	OMN	LOV	VEGAN	*P*
Age, years	**27.2 ±6.7***	**31.6 ± 8.9***	**33.9 ± 8.7***	**0.013***
Gender (M/F)	7/19	6/20	10/17	0.540^
Weight, kg	66.8 ± 11.9	63.4 ± 9.8	65.1 ± 11.8	0.552
Height, inches	66.1 ± 4.1	65.9 ± 2.8	65.7 ± 3.5	0.683
BMI, kg/m²	23.4 ± 3.1	22.5 ± 2.7	22.4 ± 2.5	0.326
sBP, mmHg	116.5 ± 8.9	114.6 ± 10.7	114.6 ± 9.4	0.698
dBP, mmHg	69.7 ± 7.3	70.7 ± 6.8	72.4 ± 8.0	0.385
Hand Grip, psi	29.9 ± 9.6	25.3 ± 7.8	27.7 ± 7.5	0.138
Waist Circumference, cm	80.4 ± 10.5	80.2 ± 9.8	80.4 ± 9.6	0.995
Visceral Fat, cm²	245.9 ± 237.9	262.3 ±300.9	449.3 ± 430.3	0.051
Body Fat, %	29.1 ± 8.7	31.7 ± 7.7	28.8 ± 7.4	0.348
METS, total kcal/kg	50.1 ± 38.9	37.5 ± 29.3	40.2 ± 28.0	0.331
Bone Mineral Density, Z-score	1.2 ± .1	1.1 ± .1	1.1 ± .1	0.1
Glucose, mmol/L	86.0 ± 7.2	85.5 ± 6.9	85.0 ± 7.2	0.876
Urinary pH	**6.2 ± .4***	**6.5 ± .4***	**6.7 ± .4***	**0.001***
Total energy, kcal#	2153 ± 736	2042 ± 558	2195 ± 684	0.712
Plasma vitamin C, mg/dL	**.524 ± .163***	**.592 ± .143***	**.651 ± .140***	**0.010***

n=81, SD = standard deviation, psi = pounds per square inch, sBP= systolic blood pressure, dBP = diastolic blood pressure, METS = metabolic equivalents; ^p= chi-square statistic, *Data are mean ± SD; P represents oneway ANOVA: means with different superscript differ significantly; # determined by food processor; OMV = omnivore, LOV = vegetarian, VEG = vegan

Characteristics of Indices by Diet Group

Mean scores for the HEI-2010 and the REAP-S were calculated overall and by diet group. The mean REAP-S score was 33.5 ± 3.1 (p=0.402) 95% CI: 44.3, 50.5, while the mean HEI-2010 score was 47.4 ± 14.1 (p<0.001) 95% CI: 32.9, 34.2. The highest HEI-2010 score was seen in the omnivore group while the highest REAP-S score was seen in the vegan group. Mean scores of each diet were also calculated and are displayed in Table 6. All HEI and REAP-S scores and measure distributions were checked for normality. Neither the HEI-2010 nor the REAP-S was normally distributed thus nonparametric tests were used for analysis. Figure 1 and 2 show the distribution of total HEI-2010 and REAP-S scores, respectively, as histograms.

Table 7. Index characteristics by diet*

Index	Mean ± SD	Minimum	Maximum	Range for measure*	95% Confidence Interval	*P*
HEI-2010,total	47.4 ± 14.1	15	80.9	0-100	44.3, 50.5	0.402
HEI-2010,omv	44.7 ± 13.0	27.2	80.9	0-100	39.7, 49.6	
HEI-2010, lov	47.7 ± 13.4	23.1	70.1	0-100	42.3, 53.1	
HEI-2010, veg	49.8 ± 15.7	15	72.4	0-100	43.5, 56.0	
REAP-S, total	34 ± 3.1	26	39	13-39	32.9, 34.2	**<0.001**
REAP-S, omv	33 ± 3.1	26	38	13-39	30.6, 33.2	
REAP-S, lov	36 ± 2.3	28	36	13-39	31.8, 33.7	
REAP-S, veg	33 ± 2.0	32	39	13-39	35.3, 36.9	

n=81,*Higher score indicates higher quality diet; data are mean ± SD (standard deviation)
^Median ± SD (data not normally distributed)
P represents one-way ANOVA: means with different superscript differ significantly
OMV = omnivore, LOV = vegetarian, VEG = vegan

Figure 1. HEI-2010 Distribution of Scores

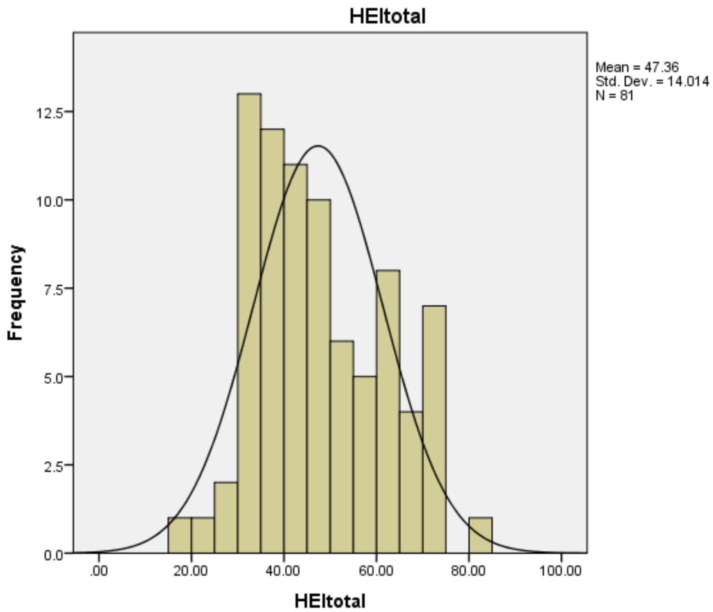
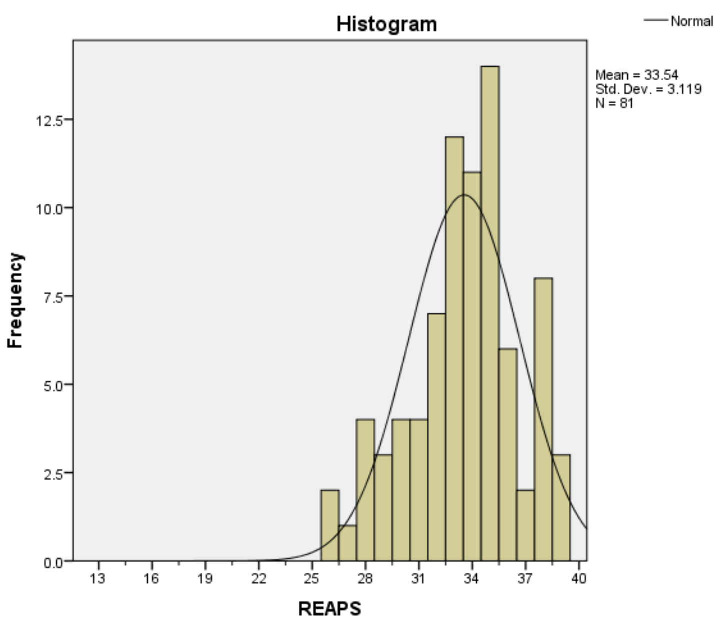
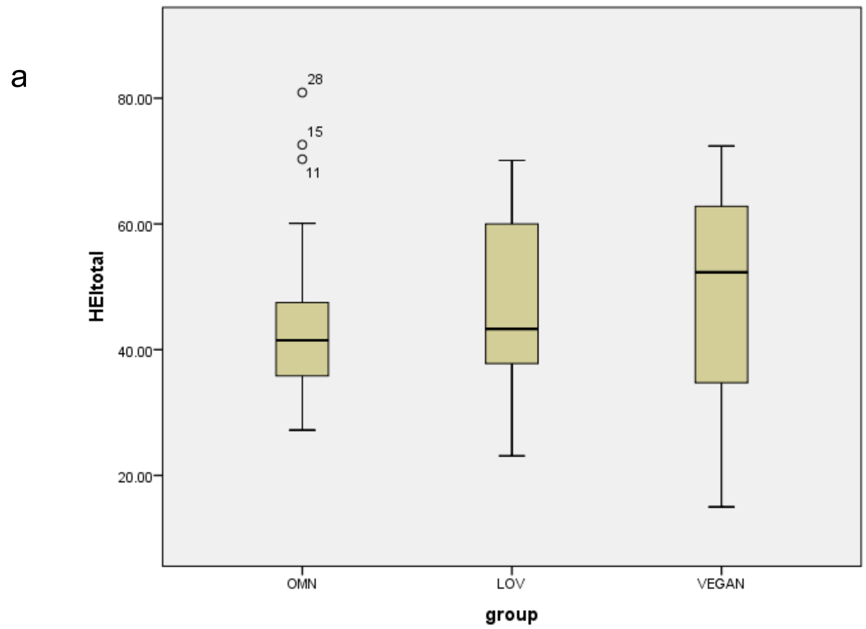


Figure 2. REAP-S Distribution of Scores



The mean HEI score for omnivores was 44.7 ± 13.0 while the mean score for vegetarians was 47.7 ± 13.4 and the mean score for vegans was 49.8 ± 15.7. The median REAP-S score for omnivores was 33, 95% CI (30.6, 33.2) while the median score for vegetarians was 36, 95% CI (31.8, 33.7) and the median score for vegans was 33, 95% CI (35.3, 36.9). Figures 3a and 3b show the distribution of HEI-2010 and REAP-S scores by diet type as box plots.



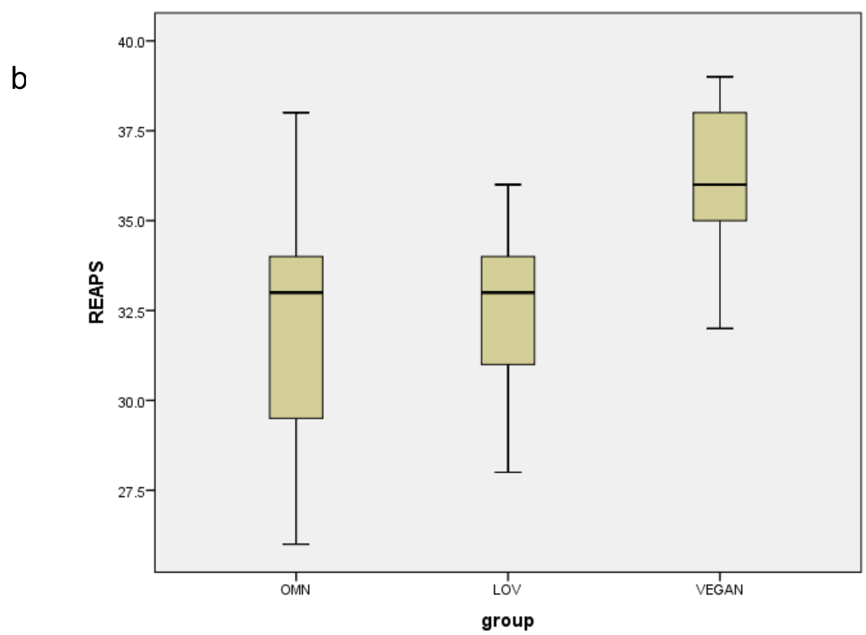


Figure 3. Distribution of HEI-2010 Scores (a) and Distribution of REAP-S Scores (b) by Diet Type. Box and Whisker Plots display the median (heavy middle line), the middle 50 percent of scores for the group (within the box) and the upper and lower 25% scores by the whiskers. Outliers are displayed as dots.

Correlations of Indices

For the purpose of this analysis, HEI-2010 and REAP-S scores were analyzed continuously and categorized into tertiles. HEI was also analyzed as total and component scores. Table 8 details the correlations for HEI and REAP-S scores. The HEI-2010 and REAP-S were correlated with a correlation coefficient of 0.309, significant to the 0.01 level (p = 0.005). Significant relationships between HEI subgroups and total REAP-S scores were seen in the consumption of: whole fruit, greens and beans, seafood protein, and fatty acids. Controlling for diet type did not affect the strength or significance of the relationship.

Table 8. Correlation coefficients for HEI and REAP-S scores*

	Correlation Coefficient	*P*
HEI (total) vs. REAP-S (total)	**0.309**	**0.005**
HEI total fruit vs. REAP-S	0.186	0.097
HEI whole fruit vs. REAP-S	**0.247**	**0.026**
HEI total vegetable vs. REAP-S	0.155	0.167
HEI greens/beans vs. REAP-S	**0.276**	**0.013**
HEI whole grains vs. REAP-S	0.014	0.899
HEI dairy vs. REAP-S	-0.042	0.708
HEI total protein vs. REAP-S	-0.049	0.666
HEI seafood protein vs. REAP-S	**0.298**	**0.007**
HEI fatty acids vs. REAP-S	**0.400**	**<0.001**
HEI refined grains vs. REAP-S	0.057	0.613
HEI sodium vs. REAP-S	-0.01	0.927
HEI empty kcals vs. REAP-S	-0.046	0.685

n=81, **P* for Spearman's correlation; controlling for diet group did not impact significance of the relationship

Controlling for diet type did not affect the strength or significance of the relationship though the HEI was significantly correlated to the REAP-S for the vegan group (r=0.384, p=0.048), further results can be seen in Table 9. The HEI and REAP-S scores were analyzed for the presence of correlations with common health markers. HEI was significantly correlated with handgrip (r=-0.255, p=0.022), waist circumference (r=-0.251, p=0.025) and urinary pH (r=0.287, p=0.010) while REAP-S was significantly correlated with serum vitamin C (r=0.487, p<0.001) and urinary pH (r=0.289, p=0.009). Complete correlation results between diet quality and health markers are shown in Table 10.

To further measure diet quality intake of individual nutrients was analyzed to ensure the REAP-S appropriately measures both macronutrient and micronutrient intake. Table 5 details the correlation between nutrients, REAP-S and HEI scores. The subgroups showed significance for both HEI and REAP-S in the following: calories from fat, calories from saturated fat, grams of soluble fiber, grams of fat, grams of saturated fat, milligrams of cholesterol, vitamins A, C and K, potassium and omega-3 fatty acids. Worth noting is that the HEI is calculated per 1000 kilocalories while the REAP-S assesses diet as a whole and thus significance should be evaluated with this adjustment in mind. Controlling for diet type did not affect the strength or significance of the relationship.

Table 9. Correlation coefficients for HEI and REAP-S scores by diet *

	Correlation Coefficient	*P*
HEI (total) vs. REAP-S (total)	**0.309**	**0.005**
HEI OMV vs. REAP-S (OMV)	0.27	0.174
HEI (LOV) vs. REAP-S (LOV)	0.272	0.178
HEI (VEG) vs. REAP-S (VEG)	**0.384**	**0.048**

n=81, **P* for Spearman's correlation; bold indicates significance

Table 10. Correlations between diet quality scores and health markers				
	R (HEI)	p value (HEI)	R (REAP-S)	p value (REAP-S)
Age, years	-0.013	0.911	-0.09	0.425
BMI, kg/m^2	-0.161	0.153	-0.134	0.235
sBP, mmHg	-0.254	**0.023***	-0.039	0.732
dBP, mmHG	-0.1	0.375	0.058	0.612
Hand Grip, psi	-0.255	**0.022**	-0.102	0.369
Waist circumference, cm	-0.251	**0.025**	-0.189	0.094
Visceral Fat, cm^2	-0.185	0.101	-0.039	0.731
Body Fat, %	-0.047	0.677	-0.165	0.144
METS, total kcal/kg	-0.104	0.358	0.15	0.185
Bone mineral density, Z-score	-0.218	0.052	-0.116	0.303
Urinary pH	0.287	**0.010**	0.289	**0.009***
Plasma Vitamin C, mg/dL	0.22	**0.049***	0.487	**<0.001**

n=81, METS = metabolic equivalents, sBP= systolic blood pressure, dBP= diastolic blood pressure; *P* for Spearman's correlation; *controlling for diet group impacted significance of the relationship

Table 11. Correlations between diet quality scores and individual nutrients*				
	R (HEI)	p value (HEI)	R (REAP-S)	p value (REAP-S)
Energy, kcal	-0.489	**<0.001**	-0.097	0.422
Total Fat, kcals	-0.453	**<0.001**	-0.353	**0.003**
Saturated Fat, kcals	-0.538	**<0.001**	-0.52	**<0.001**
Protein, g	-0.316	**0.007**	-0.118	0.327
Carbohydrates, g	-0.316	**0.007**	0.168	0.161
Fiber, g	0.148	0.217	0.455	**<0.001**
Soluble Fiber, g	0.323	**0.006**	0.461	**<0.001**
Total Sugars, g	-0.227	0.057	-0.117	0.333
Total Fat, g	-0.452	**<0.001**	-0.354	**0.002**
Saturated Fat, g	-0.535	**<0.001**	-0.521	**<0.001**
Monounsaturated Fat, g	-0.12	0.321	-0.029	0.811
Polyunsaturated Fat, g	-0.076	0.527	0.135	0.261
Trans Fat, g	-0.163	0.176	-0.221	0.064
Cholesterol, mg	-0.356	**0.002**	-0.577	**<0.001**
Vitamin A, RAE	0.487	**<0.001**	0.382	**0.001**
Vitamin B1, mg	-0.108	0.369	0.372	**0.001**
Vitamin B2, mg	-0.174	0.15	0.307	**0.010**
Vitamin B3 NE, mg	-0.091	0.451	0.231	0.052
Vitamin B6, mg	-0.011	0.926	0.387	**0.001**
Vitamin B12, mcg	-0.27	**0.024**	0	1
Vitamin C, mg	0.277	**0.019**	0.242	**0.042**
Vitamin D, mcg	0.119	0.325	0.088	0.465
Vitamin E a-tocopherol, mg	0.192	0.111	0.265	**0.026**
Folate DFE, mcg	0.135	0.267	0.441	**<0.001**
Vitamin K, mcg	0.326	**0.006**	0.271	**0.023**
Calcium, mg	-0.19	0.112	0.079	0.51
Iodine, mcg	-0.176	0.153	-0.009	0.942
Iron, mg	-0.127	0.29	0.325	**0.006**
Magnesium, mg	0.16	0.182	0.433	**<0.001**
Potassium, mg	0.237	**0.047**	0.342	**0.004**
Selenium, mcg	-0.214	0.075	0.115	0.343
Sodium, mg	-0.43	**<0.001**	-0.023	0.849
Zinc, mg	-0.029	0.811	0.251	**0.036**
Omega-3, g	0.14	0.243	0.234	**0.050**
Omega-6, g	0.054	0.655	0.042	0.726
Alcohol, g	-0.192	0.108	-0.082	0.497
n=81, P for Spearman's correlation				

Identifying Poor versus Good Quality Diets

In addition to correlational analysis, REAP-S and HEI-2010 scores were divided into tertiles and crosstabulation of scores was performed to assess how well the REAP-S identified poor, moderate, and good quality diets as compared to the HEI-2010. The scores for each index, HEI-2010 and REAP-S, were divided into three categories – poor diet, moderate diet, and good diet. Crosstab statistics were run to determine the accuracy rate for the scores of the overall study population. Next, each diet type was analyzed using crosstab statistics to identify the difference in accuracy rates between diets. The precision of the REAP-S to the HEI-2010 for diet quality of the study population was 44.4%, e.g., similarly categorizing 44 of 81 subjects. Further review of the diet groups reveals that, using HEI results, the REAP-S may be better suited to categorize the diet quality of plant-based diets as the scores for vegans and vegetarians matched at 50% compared to 32% for the omnivores.

Table 11 shows the cross tabulation of HEI and REAP-S scores by tertiles. Overall, approximately 44% (36/81) of subjects were grouped in the same tertile for each score. Thirteen of the subjects or 46% were similarly identified in the lowest tertile of both scores. The score ranges per tertile for all diet groups are displayed within Table 11.

Table 12. Cross tabulation of HEI and REAP-S tertiles for all diet groups

		HEI tertiles			Total
		1 (15-38.5)	2 (38.6-53.5)	3 (53.6-80.9)	
REAP-S tertiles	1 (26-32)	13	8	4	25
	2 (33-34)	7	8	8	23
	3 (35-39)	8	10	15	33
Total		28	26	27	81

n=81

Further analysis was done comparing score tertiles by diet type. The results are displayed in tables 12, 13, and 14. Only nine of the 28 total omnivores were correctly categorized in the same tertile for REAP-S and HEI accounting for an accuracy rate of 32%. The accuracy rate for vegetarians is much better, 13 of 26 vegetarians or 50% were correctly categorized. The vegan group showed the highest accuracy rate, 52%, with 14 of 27 vegans being correctly categorized by tertile.

Table 13. Cross tabulation of HEI and REAP-S tertiles for omnivores

		HEI tertiles			Total
		1	2	3	
REAP-S tertiles	1	7	6	1	14
	2	3	2	3	8
	3	0	6	0	6
Total		10	14	4	28
n (omnivores)=28					

Table 14. Cross tabulation of HEI and REAP-S tertiles for vegetarians

		HEI tertiles			Total
		1	2	3	
REAP-S tertiles	1	5	2	3	10
	2	3	4	3	10
	3	1	1	4	6
Total		9	7	10	26
n (vegetarians)=26					

Table 15. Cross tabulation of HEI and REAP-S tertiles for vegans					
		HEI tertiles			Total
		1	2	3	
REAP-S tertiles	1	1	0	0	1
	2	1	2	2	5
	3	7	3	11	21
Total		9	5	13	27
n (vegans)=27					

Cohen's Kappa was also run to determine the level of agreement between the HEI-2010 and the REAP-S. There was agreement between the two scoring methods by tertile (K=.164, p=0.033). However when Cohen's Kappa was calculated for individual raw scores, point-by-point agreement was low (K=-.004, p=0.541).

CHAPTER 5

DISCUSSION

A simple and efficient tool is needed to assess diet quality. The current standards for diet quality measurement, HEI-2010 and DQI-R, are time and labor intensive. Furthermore, these measures suffer from bias related to diet assessment and entry subjectivity. The data presented in the current study indicate that the REAP-S correlates significantly with the HEI-2010 overall (r=0.309, p=0.005). The data also indicate that the REAP-S has a precision of 44% for overall scores and over 51% for plant-based diets based on tertile scoring for both measures. Assessment of tertiles using Cohen's Kappa showed a moderate agreement indicating that these measures group people similarly by diet quality.

The fact that these two measures have a degree of agreement is important. One measure (HEI) is labor-intensive and requires hours to complete; the other measure (REAPS) is completed in minutes and quickly identifies areas of concern to the practitioner/researcher, which can then be communicated to the individual in a timely manner. Furthermore, HEI is inherently biased as it entails a diet recall, data entry, and interpretation – all which are subject to manual error and subjectivity. Because of these issues, HEI scores cannot be compared between laboratories or clinical practices. REAPS is objectively scored and does not rely on data entry and subjective interpretation; hence, REAPS scores can more confidently be compared between populations. Finally, since approximately 75 hours of data entry, checking and calculation was required by a trained nutrition professional to score the HEI-2010 for 81 subjects, outside of a research setting, this level of detail and time is not reasonable for a community health provider who desires to counsel patients. And these patients are no less deserving than research participants of an adequate diet assessment. Even in the research setting a more efficient manner to assess diet quality would be welcomed for smaller projects that require diet quality assessment. Also, the variability in scoring of the HEI-2010 from one lab to another due to the highly subjective nature of certain components decreases inter-rater reliability. An ideal surrogate tool for diet quality would: be simple and fast to complete and score, come with a rubric for counseling patients, significantly correlate with each of the major components of the HEI-2010, accurately group individuals by diet quality as the HEI-2010 would, and be readily available to healthcare providers and the public.

The DGA and HEI were developed in part to help measure and assess chronic disease risk (US Department of Agriculture and US Department of Health and Human Services, 2010). Various researchers have looked to detail the association between diet quality and chronic disease risk as measured by HEI. As cardiovascular disease is one of the leading killers of Americans many groups have measured the effect of the DASH diet in effecting chronic disease risk as measured by HEI and incidence of hypertension. One such researcher completed a randomized controlled diet to assess how adherence to the DASH diet affected diet quality and the metabolic syndrome among other health biomarkers (Azadbakht, Mirmiran & Esmaillzadeh et al, 2005). The DASH study reported beneficial effects on symptoms of the metabolic syndrome after six months of the prescribed diet versus six months of usual diet. Subjects following the DASH diet reported increased high-density lipoproteins, decreased triglycerides, decreased systolic and diastolic blood pressures and decreased weight, compared to the control group

($p<0.05$). When testing for correlation with chronic disease risk using a prior version of the HEI, investigators found mixed results (McCullough, Feskanich & Stampfer et al, 2000a; McCullough, Feskanich & Rimm et al, 2000b). There was no significant association with risk of chronic disease in women (RR=0.97, 95% CI: 0.89 – 1.06) using the HEI based on data from the Nurses' Health Study (McCullough, Feskanich & Stampfer et al, 2000a). There was a significant association with risk of chronic disease in men (RR=0.89, 95% CI: 0.79 – 1.00, $p<0.001$) using the HEI based on data from the Health Professionals Study (McCullough, Feskanich & Rimm et al, 2000b). Further analysis of this significance revealed an association between diet quality and cardiovascular risk but not with cancer risk.

The REAP-S only correlated with a portion of the HEI-2010 pillars suggesting that these measures are capturing different diet attributes. The REAP-S correlated with the HEI for total fruits, greens and beans, seafood or plant proteins, fatty acids and total HEI-2010 score ($p < 0.05$). The REAP-S did not correlate with whole or refined grains, empty calories or sodium intake ($p > 0.05$). Among nutrition researchers the HEI is often considered the gold standard for diet quality assessment. As with many other gold standard tests or assessments, the HEI-2010 is not a realistic tool for small-scale rapid assessments such as a doctor's visit, nor was it intended to be so. The REAP-S appears to be a suitable surrogate for assessing diet quality rapidly and easily to meet the needs of purposes including community services and smaller-scale research projects.

The HEI-2010 and REAP-S correlated with urinary pH and intake of fat (total kilocalories from and grams of), saturated fat (total kilocalories from and grams of), soluble fiber, cholesterol, vitamins A, C and K, potassium and omega-3 fatty acids in the current study. The HEI-2010 correlated with handgrip (negatively), waist circumference, and consumption of total energy, protein, carbohydrate, vitamin B12, sodium and alcohol in the current study. The REAP-S correlated with serum vitamin C and intake of folate, fiber, iron and magnesium all aspects of a healthful diet. These findings mimic those from NHANES III that found that biomarkers of fruit and vegetable intake positively correlated with the HEI (Weinstein, Vogt & Gerrior, 2004). Serum folate correlated with the HEI ($r=0.25$) as did serum vitamin C ($r=0.30$). The current study assessed folate intake and serum vitamin C as correlated to the HEI-2010 and REAP-S. The current study did not show significant correlation between the HEI-2010 and folate intake though the findings showed HEI correlation at $r=0.220$ ($p=0.049$) for serum vitamin C, which was in line with Weingarten's correlation. The current study demonstrated a stronger correlation between plasma vitamin C and the REAP-S ($r=0.498$, $p<0.001$) and between folate and REAP-S ($r=0.441$, $p<0.001$). Weinstein argued that the positive correlation of fruit and vegetable biomarkers (carotenoids, folate and vitamin C) with the HEI was a good indicator of intake and showed the potential of the HEI to be used in epidemiological studies of intake and chronic disease risk. As the markers of fruit and vegetable intake were more strongly correlated with the REAP-S than the HEI-2010 in the current study it is fair to say that the REAP-S could serve as a surrogate marker for dietary intake and risk of chronic disease.

The REAP-S and HEI-2010 correlated on many variables though no relationship was found with certain key variables. The REAP-S did not significantly correlate with waist circumference, total energy consumed, sodium or alcohol as the HEI-2010 did in the current study. This is an area of concern due to the known health risks associated with these variables.

The significance levels found in the current study should be used as a description of the study population (non-obese, healthy adults in the metropolitan Phoenix area) and a rough guide for possible patterns in the larger community. Larger studies of the REAP-S in communities across the country should be conducted to ensure reliability and validity in a broader population. The use of REAP-S in the community as a marker for diet quality should be regularly evaluated to ensure patients are being correctly scored.

An area of great interest is how closely the REAP-S identifies diet quality compared to the HEI-2010. As reported, the REAP-S significantly correlated with serum vitamin C ($R=0.498$, $p<0.0001$), a known marker for health and diet quality (Neuhouser, Patterson & King et al, 2003). The ideal tool will be able to classify diet quality in a similar fashion to the HEI-2010 with less time and effort in taking and scoring. The REAP-S had a precision of 44.4% (48 of 81 subjects) when assessed as tertiles for the current study population. The REAP-S had a higher precision for plant-based diets, 50% (13/26) for vegetarians and 52% (17/27) for vegans. While a higher precision rate would be desirable, the modest rate demonstrated in the current study indicates the REAP-S could be a strong stand-in for the rapid patient assessment completed by most physicians. The REAP-S is also a more desirable tool in the community setting due to the high inter-rater reliability versus the HEI-2010. While the questionnaire is self-reported data and is thus inherently biased like 24-hour-dietary recalls, the scoring of the REAP-S is far less subjective than scoring of the HEI-2010. This indicates that the use of REAP-S may be a reliable tool overall for diet quality assessment than other available indices readily available to healthcare professionals.

There is large overlap between the HEI-2010 and the REAP-S in terms of questions to assess diet quality though the HEI-2010 does not address how or where meals are prepared or physical activity as REAP-S does. These two omissions could be seen as shortcomings of the HEI though they are not in line with the goal of the HEI. Therefore the REAP-S may prove to be a more balanced tool for diet quality assessment.

While the REAP-S questionnaire is valid for each diet group as demonstrated by the current study, there are areas of concerns as well. For instance, the REAP-S appears to not capture intake or risk of certain foods, beverages or nutrients. These issues can be corrected by making a point to discuss these common risk factors during the brief patient assessment and counseling. When using the REAP-S a provider should be advised to focus diet recommendations on type of grain consumption, minimizing or avoiding alcohol content, and decreasing intake of sodium and empty calories. Also, healthcare providers using the REAP-S to assess patients should use the results as an opportunity to refer their patients to a RD for further screening and complete nutrition assessment and counseling.

CHAPTER 6

CONCLUSION

As diet quality is so closely intertwined with both short-term and long-term health outcomes a tool is needed that can efficiently screen for diet quality in the overburdened healthcare system. The REAP-S has again proven an acceptable tool for rapid diet quality assessment. The REAP-S demonstrated a significant, moderate correlation to the HEI-2010 in the current study. The precision with which the REAP-S identified high-quality diets increased with plant-based diets indicating it is a suitable tool in today's population with over 10% of the American population following a primarily plant-based diet. Our hypothesis was accepted based on the correlation and Cohen's Kappa for tertile grouping. The current study utilized data from 81 young adults living in the Phoenix area with a modest weight and BMI; therefore more research studies are required to appraise the strength and validity of the REAP-S in a more diverse patient population. The REAP-S could also be modified to better correlate with all food groups and diet quality recommendations which would likely increase overall precision, though further research would be needed to identify which changes would be most successful in identifying overall diet quality.

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APPENDIX A

IRB APPROVAL

ASU Knowledge Enterprise Development

APPROVAL:CONTINUATION

Carol Johnston
SNHP - Nutrition
602/827-2265
CAROL.JOHNSTON@asu.edu

Dear Carol Johnston:

On 11/5/2013 the ASU IRB reviewed the following protocol:

Type of Review:	Continuing Review
Title:	
Investigator:	Carol Johnston
IRB ID:	1211008557
Category of review:	(8)(a) Long-term follow-up, (8)(c) Data analysis
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	None

The IRB approved the protocol from 11/5/2013 to 11/4/2014 inclusive. Three weeks before 11/4/2014 you are to submit a completed "FORM: Continuing Review (HRP-212)" and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 11/4/2014 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc:

APPENDIX B

RAPID EATING AND ACTIVITY ASSESSMENT OF PARTICIPANTS – SHORT VERSION (REAP-S)

REAPS (Rapid Eating Assessment for Participants - Shortened Version)

CJSegal-Isaacson, EdD RD, Judy-Wylie-Rosett, EdD RD, Kim Gans, PhD, MPH

In an average week, how often do you:	**Usually/ Often**	**Sometimes**	**Rarely/ Never**	**Does not apply to me**
1. Skip breakfast?	O	O	O	
2. Eat 4 or more meals from sit-down or take out restaurants?	O	O	O	
3. Eat less than 2 servings of whole grain products or high fiber starches a day? **Serving** = 1 slice of 100% whole grain bread; 1 cup whole grain cereal like Shredded Wheat, Wheaties, Grape Nuts, high fiber cereals, oatmeal, 3-4 whole grain crackers, ½ cup brown rice or whole wheat pasta, boiled or baked potatoes, yuca, yams or plantain.	O	O	O	
4. Eat less than 2 servings of fruit a day? **Serving** = ½ cup or 1 med. fruit or ¾ cup 100% fruit juice.	O	O	O	
5. Eat less than 2 servings of vegetables a day? **Serving** = ½ cup vegetables, or 1 cup leafy raw vegetables.	O	O	O	
6. Eat or drink less than 2 servings of milk, yogurt, or cheese a day? **Serving** = 1 cup milk or yogurt; 1½ - 2 ounces cheese.	O	O	O	
7. Eat more than 8 ounces (see sizes below) of meat, chicken, turkey or fish per day? ***Note**: 3 ounces of meat or chicken is the size of a deck of cards or ONE of the following: 1 regular hamburger, 1 chicken breast or leg (thigh and drumstick), or 1 pork chop.*	O	O	O	Rarely eat meat, chicken, turkey or fish O
8. Use regular processed meats (like bologna, salami, corned beef, hotdogs, sausage or bacon) instead of low fat processed meats (like roast beef, turkey, lean ham; low-fat cold cuts/hotdogs)?	O	O	O	Rarely eat processed meats O
9. Eat fried foods such as fried chicken, fried fish, French fries, fried plantains, tostones or fried yuca?	O	O	O	
10. Eat regular potato chips, nacho chips, corn chips, crackers, regular popcorn, nuts instead of pretzels, low-fat chips or low-fat crackers, air-popped popcorn?	O	O	O	Rarely eat these snack foods O
11. Add butter, margarine or oil to bread, potatoes, rice or vegetables at the table?	O	O	O	
12. Eat sweets like cake, cookies, pastries, donuts, muffins, chocolate and candies more than 2 times per day.	O	O	O	
13. Drink 16 ounces or more of non-diet soda, fruit drink/punch or Kool-Aid a day? ***Note:** 1 can of soda = 12 ounces*	O	O	O	

	YES	**NO**
14. You or a member of your family usually shops and cooks rather than eating sit-down or take-out restaurant food?	O	O
15. Usually feel well enough to shop or cook.	O	O

	1	**2**	**3**	**4**	**5**
16. How willing are you to make changes in your eating habits in order to be healthier?	**Very willing**				**Not at all willing**

APPENDIX C

HEALTHY EATING INDEX 2010 (HEI-2010)

The Healthy Eating Index (HEI) is a measure of diet quality in terms of conformance to Federal dietary guidance. It is used to monitor the quality of American diets; to examine relationships between diet and health-related outcomes and between diet cost and diet quality; to determine the effectiveness of nutrition intervention programs; and to assess the quality of food assistance packages, menus, and the U.S. food supply. The HEI is a scoring metric that can be applied to any defined set of foods, such as previously collected dietary data, a defined menu, or a market basket, to estimate a score. The HEI-2010, which assesses diet quality as specified by the 2010 Dietary Guidelines for Americans, is made up of 12 components, as shown below. The total HEI-2010 score is the sum of the component scores and has a maximum of 100 points.

HEI- 2010[1] component	Maximum	Standard for maximum score	Standard for minimum score of zero
▲ Adequacy *(higher score indicates higher consumption)*			
Total Fruit[2]	5	≥ 0.8 cup equiv. / 1,000 kcal[10]	No fruit
Whole Fruit[3]	5	≥ 0.4 cup equiv. / 1,000 kcal	No whole fruit
Total Vegetables[4]	5	≥ 1.1 cup equiv. / 1,000 kcal	No vegetables
Greens and Beans[4]	5	≥ 0.2 cup equiv. / 1,000 kcal	No dark-green vegetables, beans, or peas
Whole Grains	10	≥ 1.5 ounce equiv. / 1,000 kcal	No whole grains
Dairy[5]	10	≥ 1.3 cup equiv. / 1,000 kcal	No dairy
Total Protein Foods[6]	5	≥ 2.5 ounce equiv. / 1,000 kcal	No protein foods
Seafood and Plant Proteins[6,7]	5	≥ 0.8 ounce equiv. / 1,000 kcal	No seafood or plant proteins
Fatty Acids[8]	10	(PUFAs + MUFAs) / SFAs ≥ 2.5	(PUFAs + MUFAs) / SFAs ≤ 1.2
▼ Moderation *(higher score indicates lower consumption)*			
Refined Grains	10	≤ 1.8 ounce equiv. / 1,000 kcal	≥ 4.3 ounce equiv. / 1,000 kcal
Sodium	10	≤ 1.1 gram / 1,000 kcal	≥ 2.0 grams / 1,000 kcal
Empty Calories[9]	20	≤ 19% of energy	≥ 50% of energy

[1] Intakes between the minimum and maximum standards are scored proportionately.
[2] Includes 100% fruit juice.
[3] Includes all forms except juice.
[4] Includes any beans and peas not counted as Total Protein Foods.
[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.
[6] Beans and peas are included here (and not with vegetables) when the Total Protein Foods standard is otherwise not met.
[7] Includes seafood, nuts, seeds, soy products (other than beverages) as well as beans and peas counted as Total Protein Foods.
[8] Ratio of poly- and monounsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs).
[9] Calories from solid fats, alcohol, and added sugars; threshold for counting alcohol is > 13 grams/1,000 kcal.
[10] Equiv. = equivalent, kcal = kilocalories.

Further details on the HEI- 2010 and scores for the U.S. population are available at http://www.cnpp.usda.gov/HealthyEatingIndex.htm and http://riskfactor.cancer.gov/tools/hei/.

Authors: Patricia M. Guenther, PhD, RD[1]; Kellie O. Casavale, PhD, RD[2]; Jill Reedy, PhD, RD[3]; Sharon I. Kirkpatrick, PhD, RD[3]; Hazel A.B. Hiza, PhD, RD[1]; Kevin J. Kuczynski, MS, RD[1]; Lisa L. Kahle, BA[4]; Susan M. Krebs-Smith, PhD, RD.[3]
[1]Center for Nutrition Policy and Promotion, U.S. Department of Agriculture; [2]Office of Disease Prevention and Health Promotion, U.S. Department of Health and Human Services; [3]National Cancer Institute, U.S. Department of Health and Human Services; [4]Information Management Services, Inc.

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