I, Krista Dangelo, hereby submit this original work as part of the requirements for the degree of:
Master of Science
in Nutritional Science
It is entitled:
Nutrient Adequacy of Low versus High Carbohydrate Diet for Older Adults

Student Signature: Krista Dangelo

This work and its defense approved by:
Committee Chair: Sarah Couch
Seung-Yeon Lee

Approval of the electronic document:
I have reviewed the Thesis/Dissertation in its final electronic format and certify that it is an accurate copy of the document reviewed and approved by the committee.

Committee Chair signature: Sarah Couch
Nutrient Adequacy of Low versus High Carbohydrate Diets for Older Adults

A thesis submitted to the
Graduate School
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE
In the Department of Nutritional Sciences
of College of Allied Health Sciences

By
Krista Dangelo
BS, Miami University, 2003
May 13, 2009

Committee Chair: Sarah C. Couch, PhD., RD
UNIVERSITY OF CINCINNATI

ABSTRACT

Nutrient Adequacy of Low versus High Carbohydrate Diets for Older Adults

By: Krista Dangelo

Chairperson of the Supervisory Committee: Sarah Couch, PhD, RD
Department of Nutritional Science

Purpose. To determine if an older adult can meet their Dietary Reference Intakes (DRI’s) for selected vitamins and minerals and achieve an adequate macronutrient distribution range after being counseled on a high carbohydrate diet compared to those counseled on a low carbohydrate diet. Methods. Twenty six older adults were randomly selected into a high carbohydrate or low carbohydrate diet group. Both groups completed food records 5 days prior to intervention as well as during the 6 week time period they were following a high or low carbohydrate diet. Nutrition information was entered from written food records and analyzed using Minnesota Nutrition Data Systems for Research software. To determine the dietary adequacy of the high carbohydrate versus low carbohydrate diet groups, mean differences for weight, body mass index (BMI), fiber, calories, macronutrients and micronutrients were compared using Students’ t-tests for each nutrient at baseline, 3-weeks, and 6-weeks. An analysis of the group prevalence of inadequacy using the Estimated Average Requirement (EAR) cutoff point method was also completed.

Results. There were no significant differences between groups for nutrient intake at baseline. The low carbohydrate group consumed greater amounts of fat and protein, while the high carbohydrate group consumed more calories and fiber during the 6-week study. At week 6 significant differences in intake of vitamin C, thiamin, niacin, vitamin B-6, folate, magnesium, iron, and potassium were observed between groups. Using the EAR cutoff, the prevalence of inadequacy of vitamin C, B-6, thiamin, niacin, folate, and magnesium was significantly higher in the low carbohydrate group compared to the high carbohydrate group. Conclusion. The results of this study suggest that a low carbohydrate diet (≤ 20 g) should not be recommended for the older adult for an extended period of time without proper supplementation.
ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Professors Couch and Lee for their assistance in the preparation on this manuscript. In addition, special thanks to Tamara Heisler whose familiarity with the Minnesota Nutrition Data Systems for Research software (NDSR, 2006 version) program was helpful during the programming and implementation phase of this undertaking.
# TABLE OF CONTENTS

Abstract .......................................................................................................................................... iii  
Acknowledgements ........................................................................................................................ iv  
List of Tables ................................................................................................................................. vi  
Introduction ..................................................................................................................................... 1  
Literature Review ............................................................................................................................. 2-11  
  - Nutrition for the Older Adult ........................................................................................................ 2-8  
  - Low Carbohydrate Diets ........................................................................................................ 8-10  
  - Low Carbohydrate Diets and the Older Adult ..................................................................... 10-11  
Statement of Problem .................................................................................................................... 11  
  - Purpose of Study ....................................................................................................................... 11  
  - Hypothesis ................................................................................................................................. 11  
Methods.................................................................................................................................... 12-15  
  - Research Design and Methods ............................................................................................. 12-15  
    - Study Population .................................................................................................................. 12-13  
    - Nutrition Intervention and Assessment Protocol ............................................................. 13-14  
      - Dietary and Statistical Analyses ......................................................................................... 15  
Results...................................................................................................................................... 15-19  
  - Descriptive Analysis ............................................................................................................ 15-19  
Discussion ................................................................................................................................... 20-24  
Summary ....................................................................................................................................... 24  
References ................................................................................................................................... 25-27
<table>
<thead>
<tr>
<th>Number</th>
<th>Table Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baseline characteristics of both intervention groups</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Changes in both group variables from baseline</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Changes in macronutrient and fiber intake in both groups from baseline</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>Changes in micronutrient (vitamin) intake in both groups from baseline</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Changes in micronutrient (mineral) intake in both groups from baseline</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>Dietary Reference Intakes (DRIs) definitions</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>Vitamin intake: Estimate of the prevalence of inadequacy at 3 and 6 weeks</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>Mineral intake: Estimate of the prevalence of inadequacy at 3 and 6 weeks</td>
<td>19</td>
</tr>
</tbody>
</table>
INTRODUCTION

The U.S. Census Bureau predicts that the number of citizens over the age of 65 will increase by 2 fold from the present day to the year 2030 (1). In 2009, American’s life expectancy reached a new record high of 78 years (2). As more, older Americans are achieving their maximum biological age, many are searching for strategies to enable a greater quality of life as they age. Diet and lifestyle programs in the popular press are often sought out as a means of reducing chronic disease risk and gaining other health benefits. However, many of these popular programs have not been scientifically evaluated, particularly for use among older individuals (3).

In the past 10 years low carbohydrate diets have resurfaced and sparked an interest among the young and the old. Low carbohydrate diets are currently being studied for weight loss, to improve glycemic control, and to prevent memory decline, all of which may benefit the older adult. Along with the potential health benefits, low carbohydrate diets may be nutritionally inadequate. It is well known that low carbohydrate diets lack whole grain breads, milk products, fruits, and some vegetables, which reduce the overall intake of vitamins C and B complex, and calcium, potassium, magnesium and iron (4). Because these vitamins and minerals are vital for the health of older adults, it is important to determine if a low carbohydrate diet can meet the nutritional needs and is appropriate for older individuals. This thesis will examine whether an older adult population can meet their Dietary Reference Intakes (DRIs) for select vitamin and minerals after being counseled on a low carbohydrate diet not exceeding 20 grams of carbohydrate per day.
LITERATURE REVIEW

Nutrition for the Older Adult

Body composition changes with the aging process and has an influence on the nutritional needs of the older individual. For both genders, as a person ages, total body fat increases by about 50% and total body water decreases by approximately 20% (5). Adipose tissue has no significant metabolic activity; therefore, the basal metabolic rate of the older individual decreases by about 2% per decade (6). Skeletal muscle mass and function also declines between the ages of 20 and 70 years (7). With the decrease in metabolism and physical activity, mean energy intake declines by approximately 1,000 to 1,200 kcal in men and by 600 to 800 kcal in women between 20 and 80 years of age (8). As overall energy intake decreases, there is a decline in micronutrient intakes, especially calcium, magnesium, iron, and B vitamins. Thus, it is particularly challenging for older adults to maintain optimal nutritional status, health, and well being (9).

Information on the health and nutritional status of older Americans from the third National Health and Nutrition Examination Survey (NHANES III) suggests that diet plays a major role in the health decline of adults aged 65 years and older. The Healthy Eating Index (HEI) is a measure of diet quality based on the Food Guide Pyramid and other established guidelines. The individual components of the HEI include an assessment of how well a person’s diet conforms to the serving recommendations in the Food Guide Pyramid, meets American Heart Association limits for total fat, saturated fat, cholesterol, and sodium, and includes a variety of different foods. The HEI provides a score out of 100 points, where a higher score indicates higher diet quality. NHANES III data were used to evaluate the diets of the older adult using HEI scoring criteria. Findings from this analysis showed that only 21% of older
Americans had diets that were rated “good” according to the HEI; 13% had diets rated “poor”, and 67% had diets that “needed improvement” (5). The mean HEI score for all persons 65 years of age and older was 67.6 out of 100, which meant that on average the diets of older persons in the U.S. needed improvement (8). To aid in enhancing the nutritional status of the older adult, in 1999 a modified Food Guide Pyramid was developed for those aged 70 years and older. The revised Pyramid was altered from the former by the replacement of selected generic food icons with nutrient dense examples; for example a fiber icon was added to appropriate food categories to facilitate achieving an adequate intake of dietary fiber to promote optimal bowel function. Also, a row of glasses at the base of the pyramid was included to remind older adults to drink adequate amounts of fluid daily, and a flag was placed at the top of the pyramid to alert some older adults that their healthcare provider should be consulted regarding the need for vitamins B12 and D or calcium supplements (10).

The epidemic of overweight and obesity is evident among all age groups including the older adult. As basal metabolic rate and physical activity level decrease among older adults, energy expenditure generally declines (6). Overweight contributes considerably to increased morbidity and disability. Data from the NHANES III survey indicated that, in the 65-74 year age group, approximately 34% of women and 44% of men were considered overweight, and an additional 27% of women and 24% of men were considered obese (11). Obesity has been shown to be associated with a greater risk for cardiovascular disease, dislipidemia, selected cancers, hypertension, stroke, sleep apnea, diabetes mellitus, osteoarthritis, and suboptimal physical functioning (8). Maintaining a healthy body weight can promote a better quality of life for the older adult.
For older adults, an adequate dietary intake of nutrients from a variety of food sources is critical because of the increased vulnerability to diseases and conditions that may impair health in this population (9, 11, 12). In the United States, approximately 80% of all persons 65 years of age and older have at least one chronic health condition, and 50% have at least two chronic conditions (8). The average 75-year old has three chronic health conditions and uses five different prescription drugs (13). Certain drugs can alter the taste of food which commonly results in decreased energy consumption. In addition, drugs can affect the absorption and metabolism of certain nutrients (6).

The Dietary Guidelines for Americans suggest that one of the most important ways to decrease the risk of chronic disease is by consuming five to nine servings per day of a variety of fruits and vegetables (13, 14). However only 32% of persons 65 years of age and older consume five or more servings of fruits and vegetables a day (8). Risk of certain types of cancers may be significantly reduced with greater intakes of fruits and vegetables (13). Types of cancer that have an increased risk with low consumption of fruits and vegetables include esophageal, oral cavity, larynx, pancreas, stomach, bladder, and colorectal (15). Greater consumption of fruits and vegetables may also reduce the progression of age related macular degeneration (14). Experimental and epidemiological studies suggest that low antioxidant intake (carotenoids, vitamins C and E, zinc) may be associated with the occurrence of age-related macular degeneration, and that adequate intake of lutein and zeaxanthin, in the form of fruits and vegetables, may reduce the risk. (8).

Elevated blood pressure may be lowered in older individuals that consume a dietary pattern high in fruits and vegetables. The Dietary Approaches to Stop Hypertension (DASH) diet, which encouraged consumption of 7 to 10 servings of fruits and vegetables per day, was
shown to lower both systolic and diastolic blood pressure in adults with hypertension and pre-hypertension. Adherence to a Mediterranean diet rich in fruits in vegetables was associated with a lower all cause mortality and lower cardiovascular-related deaths and was inversely associated with systolic and diastolic blood pressure (8). Given the fact that 60% of men and 70% of women, aged 65 to 74 years and 68% of men and 84% of women aged 75 years and older have hypertension (16), a diet high in fruits and vegetables may have substantial cardiovascular benefits in this age group.

As a person ages, nutrient intake in general may be inadequate, increasing susceptibility for compromised immune function (17). It is well recognized that omega-3 fatty acids, vitamins A and E, and trace elements such as selenium, zinc, and iron have an influence on the immune system (6). Supplementation with vitamin E has been found to significantly increase T-cell proliferation and decrease parameters indicative of oxidative stress (18). In a cross-over design, zinc-deficient women and men aged 50-80 years given 30 mg of zinc daily for 6 months improved production of the cytokine interleukin-1 (IL-6) (18). Deficiency of iron impairs secretion of cytokines and T-cell proliferation (18). Selenium, omega-3 fatty acids, and vitamin A intake from vitamins and supplements have also been correlated with an increase in T lymphocytes in vitro (17). A weakened immune system in the older adult increases their susceptibility to infections and chronic disease (17).

Seniors who routinely eat nutritious food and drink adequate amounts of fluids are less likely to have complications from chronic disease and to require care in a hospital, nursing home, or other facilities (13). The prevalence of dehydration may be as high as 60% among community dwelling older adults (19). In people with diabetes, dehydration is known to promote complications including blindness, amputations, and cardiovascular disease (19). The
macronutrient composition of the diet can influence hydration status. High protein intake increases the amount of nitrogen waste produced from protein metabolism (20). Elevations in nitrogen increase the amount of water excreted in the urine, which can then cause dehydration (20). High protein intakes have also been shown to increase the glomerular filtration rate, which can cause progressive kidney damage in those who already suffer from kidney disease (21). A significant increase in glomerular filtration rate can be seen among the older adult after being provided a high protein diet (2 g/kg/day) for 1 week (21). Due to the high risk of dehydration and kidney dysfunction in the older adult, particularly those with diabetes, high amounts of protein in the diet should be avoided.

Impaired absorption of certain micronutrients is common in the elderly (5). With increasing age, the stomach tends to decrease its secretion of hydrochloric acid. This condition known as hypochloridia can alter the absorption of iron and folate. The stomach also secretes intrinsic factor, which is necessary for optimal vitamin B12 absorption. The aging process can lead to a significant decreased in intrinsic factor production and secretion, thereby decreasing overall vitamin B12 status. Folate is a B vitamin used in the fortification process of many common grains, such as ready to eat cereals. Inadequate folate status can lead to changes in DNA that may result in procarcinogenic effects, especially colon and breast cancers (8). Fortified ready-to-eat cereals contribute a significant amount of folic acid to the diets of older adults (8). Anemia is common among the older adult population. Survey data from the 2003 NHANES III report indicated that 11% of men and 10.2% of women aged 65 years and older were anemic (8). The Recommended Dietary Allowance (RDA) for folate is 400 ug, vitamin B12 is 2.4 ug, and iron is 8 mg for both men and women aged 51-70 years (22).
Calcium and vitamin D are two additional examples of nutrients whose absorption and status is influenced by age (6). This is important as bone mass decreases with age especially after menopause in women, making them prone to osteoporosis. In the U.S., osteoporosis along with low bone mass affects almost 44 million women and men aged 50 years and older and is expected to affect half the population over the age of 50 years by 2020 (8). In a survey of 1,740 US adults 51 to 85 years of age, vitamin D was inadequately consumed by more than 90% of responders and calcium intakes were substandard for more than 80% (23). For both vitamin D and calcium, an age related decrease of receptor expression in the duodenum has been observed in women (6). Also, the synthesis of vitamin D in the skin decreases with age (6). An inadequate intake of vitamin D and calcium along with decreased uptake and synthesis of the nutrient are a major concern for bone health in older adults. The AI for vitamin D for men and women aged 51-70 years is 10 micrograms (22). The Adequate Intake (AI) for calcium in men and women aged 51-70 years is 1200 mg (22).

Physiological and functional changes that occur with aging can result in modifications in nutrient needs. Taste, smell, dentition, as well as the loss of lean body mass are all facets of the aging process. About 45% of older adults have some degree of muscle loss (24). Compounding these changes, there may be environmental, social, financial, and functional barriers faced by older adults as well that may interfere with adequate dietary intake (25). Consuming a wide variety of foods is considered the best way to ensure a balance of nutrients. There have been many government funded programs put into place such as the Food Stamp Program, Meals on Wheels, and the Senior Farmers Market Nutrition program that promote and enhance nutrition among the elderly. One study found that formal meal programs can prevent further declines in nutritional risk as measured by diet history questionnaire (26). A Morning Meals on Wheels
program found that their participants consumed greater amounts of total calories, protein, carbohydrate, fat, fiber, potassium, folate, calcium, iron, magnesium, and zinc (27). While these programs have been found to improve the nutritional status of the older adult, more work needs to be done to improve access to these programs for all older Americans.

**Low Carbohydrate Diets**

Low carbohydrate diets are generally considered to contain less than 100 grams of carbohydrate per day with an average macronutrient distribution of 50-60% from fat, less than 30% from carbohydrate, and 20-30% from protein (4). A low carbohydrate diet that has received a lot of public press is the Atkins diet, which describes a dietary plan that does not exceed 20 g of carbohydrate per day during the first 2 weeks in order to induce ketosis. Ketosis is a state of metabolism where the liver converts fat to ketones to be used by the body for energy. During ketosis induction (Phase I of the program), protein foods such as beef, chicken, pork, fish, turkey, and eggs are encouraged in large portions and fat is allowed in unlimited quantities. After ketosis is achieved, the Atkins Diet recommends a gradual increase in carbohydrate intake to a level that maintains ketosis and promotes weight loss. The Atkins diet does encouraged intake of good fats (ie, unsaturated, polyunsaturated, and monounsaturated), yet there are no limits put on intake of saturated fats (28). Phase I of the diet restricts fruits, fruit juices, breads, grains, starchy vegetables, or dairy products, except for cheese (3-4 ounces per day), butter and cream (4). However, non-starchy vegetables are allowed such as lettuce, tomatoes, cucumber, yet only in amounts of 2-3 cups per day (29). The Atkins plan refers to fiber and sugar alcohols as non-impact carbohydrates, and thus not part of the total carbohydrate allotment for the day (28). As carbohydrate intake is gradually increased to maintain ketosis and weight loss, a range of carbohydrates from 25 grams per day up to 90 g per day is allowed depending on an
individuals’ metabolic needs (4). The amount of carbohydrate each individual can consume yet remain in ketosis is not height or weight based, but based the body’s resistance to gain weight (29).

With the exclusion of fruits, most dairy products, and some vegetables, it would be expected that an Atkins type diet would be deficient in some nutrients. Data from the Continuing Survey of Food Intake by Individuals (CSFII 1994-1996) were used to examine the nutrient quality (as assessed by HEI score) of diets consumed by adults in the U.S. that met the definition of a low versus high carbohydrate distribution relative to protein and fat. Findings from this study showed that high carbohydrate diets (greater than 55% of energy from carbohydrate) gave the highest HEI scores, e.g., > 82.9. Low carbohydrate diets (less than 30% of energy from carbohydrate) gave the lowest scores, e.g. < 44.6 (4). In another study examining the nutrient adequacy of low carbohydrate diets among overweight adults, diets were found to be deficient (less that 2/3 of the RDA or AI values) for vitamins A, B6, C, and E, thiamine, folate, calcium, magnesium, iron, potassium, and fiber (30).

Low carbohydrate, ketogenic diets for medical purposes have been commonly used to treat seizure disorders among children (31). John Hopkins Medical Center, Baltimore, MD, and the Mayo Clinic, Rochester, MN, developed the classic ketogenic diet for this purpose in the 1920s (32). The diet consisted of approximately 70% to 90% of energy from fat, with the remaining energy coming from protein and carbohydrate (31). In a study done with 30 pediatric patients, both growth and nutrient analyses were done to determine if any ill effects of the ketogenic diet were seen after a 4 month period on the diet (31). After 4 months it was found that linear growth was not adversely effected by the diet, yet body weight decreased, which likely was the result of inadequate energy intake. The diet was found to be inadequate in most
micronutrients; however the addition of a sugar free multivitamin and mineral supplement, a
calcium tablet with magnesium and zinc, and an iron supplement remedied this problem (31). All
biochemical lab values for children in this study remained within normal limits during the 4
month diet period. Short term studies of 6 to 12 months suggest that low carbohydrate diets do
not negatively impact cardiovascular lipid profiles, and have actually been found to help reduce
fasting insulin and glucose levels, improve blood pressure, and positively impact blood lipid
levels (4). The relatively low fiber intake of those on low carbohydrate diets raises concerns
about long term risks of diverticular disease and bowel cancer. Common side effects of a low
carbohydrate diet include constipation, diarrhea, dizziness, halitosis, headaches, insomnia,
kidney stones, and nausea (30). Additionally, short term trials of low carbohydrate diets suggest
that the diets are nutritional inadequate. Nutritional supplementation to ensure that nutrient
needs are met is generally advised.

**Low Carbohydrate Diets and the Older Adult**

Low carbohydrate diets are high in protein, and protein needs increase with age (25). However, with advancing age, glomular filtration rate, which is a direct correlation of renal
function, decreases. At the age of 50 the weight of the kidneys progressively falls by about 20-
30%, reflecting a decrease in the number of intact glomeruli (6). Extreme amounts of protein
intake can promote kidney failure in the older adult, or cause kidney stone formation (4). The
possibility of additional renal decline is a reason why large protein intakes such as those
recommended on a low carbohydrate diet are generally not recommended for the older adult
(21).

It has been established that low carbohydrate diets are deficient in thiamine, folate,
calcium, magnesium, iron, potassium, and fiber, as well as vitamins A, B6, and E (30, 33). As
discussed throughout this literature review, the older adult (greater than 65 years of age) would derive health and wellness benefits from consuming nutrient dense foods with high levels of a diverse array of vitamins and minerals. Low carbohydrate diets are advocated by some in the medical community as a means of achieving glucose control, and treating obesity, and cardiovascular disease. In the present study, a low carbohydrate diet (20 g per day) was used to halt the symptoms of early onset Alzheimer’s disease in individuals greater or equal to 65 years of age. Traditionally low carbohydrate diets for weight loss have not been studied in a population over the age of 65 years, nor have they commonly been studied for longer than 12 months in any population (34). It is possible that low carbohydrate diets prevent memory decline in older adults; however, given the potential risk of the diet for nutritional inadequacies it would be important to examine dietary adequacy in older individuals following a low carbohydrate diet for an extended period of time.

**STATEMENT OF PROBLEM**

**Purpose of Study**

To determine if a greater number of older adults can meet their DRI’s for selected vitamins and minerals and achieve an adequate macronutrient distribution range after being counseled on a high carbohydrate diet compared to those counseled on a low carbohydrate diet.

**Hypothesis**

It was hypothesized that a greater number of older adults could meet their DRI’s for selected vitamins and minerals and achieve an adequate macronutrient distribution range after being counseled on a high carbohydrate diet compared to those counseled on a low carbohydrate diet.
METHODS

Research Design and Methods

Study Population

This study was carried out as a part of a more comprehensive project by Dr. Robert Krikorian, Department of Psychology, of the University of Cincinnati on the relationship between Cognitive Aging on Energy Metabolism. Nutrition data was collected from March 2007 through March 2009. Both male and female participants aged 60 years and older were recruited throughout the Cincinnati and Northern Kentucky Tri-State area. Data for 12 males and 14 females are included in this study.

Before subjects were enrolled in the study, participants underwent a screening process including an Academic and Medical History Questionnaire, a Clinical Dementia Rating Scale, and a phone survey. Current health status, memory level, and food preferences of the subjects were determined by these questionnaires.

Subjects were excluded from the study if: 1) they had current dementia or a neurological disorder, such as provable Alzheimer’s Disease, Parkinson’s Disease, multi-infarct dementia, and leukoencephalopathy; 2) they used medications containing adrenal hormone modulators, insulin, or insulin sensitizing agents or psychoactive medications that could affect the outcome measures; 3) they abused recreational drugs; 4) there was current or past neurological or psychiatric disorder causing a substantial and persisting decline in occupational or social functioning; 5) they had diabetes, kidney or liver disease; and/or 6) they had mental retardation. Due to an added Magnetic Resonance Imaging component included in the larger study, two participants were also excluded on the basis of claustrophobia and/or having any metal devices in their bodies. Subjects who met the inclusion criteria and were willing to participate were enrolled. Participants were
then randomly assigned to either a high carbohydrate (HC) diet group or low carbohydrate (LC) diet group.

**Nutrition Intervention and Assessment Protocol**

Subjects enrolled in the study were sent out an education packet by mail which included a 5-day diet diary, instructions on how to complete the diet diary, a portion poster (from Nutrition Consulting Enterprises), and instructions on how to estimate amounts of food and beverages consumed using the portion poster. Participants were asked to write down all foods and beverages they consumed in a 24-hour period for 5 days prior to their baseline visit with the Registered Dietitian and research assistant. The packet also included a contact number for the Registered Dietitian and research assistant if questions arose.

During the baseline visit, participants were asked to come to the University of Cincinnati and bring their completed 5 day food record. Baseline labs and anthropometric data were obtained at that time along with memory testing and nutrition education regarding diet group assignment (high versus low carbohydrate diet). The duration of each dietary intervention was 6 weeks. Subjects randomized into the LC group were instructed to limit their carbohydrate intake to 20 grams per day (based on total grams of carbohydrate). The LC group was asked to avoid all grains, fruit, fruit juice, milk, yogurt, starchy vegetables (corn, potatoes, lima beans, peas), beans, sweets and sweetened beverages. This group was encouraged to consume pork, beef, chicken, turkey, fish, and eggs, along with plenty of non-starchy vegetables at each meal. Suggested snacks included nuts (not peanut butter), seeds, cheese, cottage cheese (full fat variety), and non-starchy vegetables. Subjects were encouraged to consume lean cuts of meats if they were concerned with overall fat and cholesterol intake. Also, participants were educated on food label reading to determine total amount of carbohydrate in packaged foods. Urine ketone
strips were provided to subjects in this group to use daily during the 6 week study. Presence of urinary ketones was used by the research team as an indication of compliance to the diet.

Participants randomized to the HC group were encouraged to consume many grains, fruits, fruit juices, and all vegetables. Whole grain as compared to refined grain choices within the breads and cereals group were not emphasized unless the subject asked for more information on this topic. To ensure a difference between the groups in intake of grams of total daily carbohydrates, the HC group was asked to have at least one meatless meal per day.

Subjects received 30 to 45 minutes of diet education. Due to the complexity of the LC diet, individuals in this diet group typically required the full 45 minutes of diet instruction. Meal suggestions were provided to each participant regardless of random assignment. Each subject was provided a dietary supplement containing 80mg of calcium citrate, 80 mg magnesium citrate, and 99mg potassium aspartate, and 21mg of vitamin C (ascorbyl palminate) to be taken daily. Subjects were then provided with 6-weeks of 24-hour diet record forms to be filled out daily. Participants were encouraged to call either the Registered Dietitian or research assistant with any questions.

Six weeks after the baseline visit, subjects were asked to come back to the University of Cincinnati and bring with them their completed 6-weeks of food records. Biochemical labs and anthropometric data were collected at this time, and memory testing was completed. Baseline and final data include height, weight, waist circumference, hip circumference, blood pressure, pulse, fasting insulin, fasting glucose, and C-reactive protein. Only height and weight and dietary outcomes will be presented and discussed as part of this thesis.
Dietary and Statistical Analyses

Nutrition information was entered from written food records into the Minnesota Nutrition Data Systems for Research software (NDSR, 2006 version) program. One weekend day and one week day were selected and averaged from food records collected at baseline, during week #3, and during week #6 of the intervention. This provided 3 values for each subject representing dietary changes over time for macro/micronutrients. Nutrient changes relative to baseline were analyzed from both the HC and LC diet groups.

Statistical analyses were performed using the Statistical Analysis System (SAS) software, version (SAS Institute Inc, Cary, NC). To determine the dietary adequacy of the HC versus LC diet groups, mean differences for weight, body mass index (BMI), fiber, calories, macronutrients and micronutrients were compared using Students’ t-tests after conformation of normal distribution of means for each nutrient at baseline, 3-weeks, and 6-weeks. An analysis of the group prevalence of inadequacy using the Estimated Average Requirement (EAR) cutoff point method was also completed (reference for the RDA). Adequate Intakes (AI) were used for comparative purposes for those nutrients where data are not sufficient to establish EARs. Results are reported for significance levels at p≤0.05 and p≤0.01.

RESULTS

Descriptive Analysis

Of the initial 30 mildly cognitively impaired older adults who were randomly assigned to either the HC group (n=11) or the LC group (n=15), 26 completed the 6 week study. All 4 subjects that dropped out were from the LC group. Reasons for dropping out included, dizzy spells (n=1), non-compliance (n=1), and finding the diet too difficult to follow (n=2). The gender distribution in the study was 12 males and 14 females with a mean age of 70.4 years (age
There were no significant differences between the HC group and LC group at baseline for anthropometric variables or age (Table 1).

### Table 1: Baseline characteristics of both intervention groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>HC (n=11)</th>
<th>LC (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>71.6 (8.2)</td>
<td>69.5 (4.5)</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>66.6 (3.6)</td>
<td>66.1 (3.2)</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>174.2 (41.1)</td>
<td>181.0 (39.3)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.5 (5.23)</td>
<td>28.9 (4.84)</td>
</tr>
</tbody>
</table>

Mean +/- (standard deviation); HC= High Carbohydrate; LC= Low Carbohydrate

Table 2 shows the change in weight (pounds) and BMI (kg/m²) post-intervention (at 6 weeks) from baseline. The LC group lost significantly more weight and had a greater decrease in BMI compared to the HC group.

### Table 2: Changes in both group variables from baseline

<table>
<thead>
<tr>
<th>Variable</th>
<th>HC (n=11)</th>
<th>LC (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (pounds)</td>
<td>-1.2 (2.6) a</td>
<td>-10.8 (4.7) a</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>-0.9 (2.6) a</td>
<td>-2.0 (1.1) a</td>
</tr>
</tbody>
</table>

a Significant differences (p<0.001) between groups at baseline; Mean +/- (standard deviation)

HC= High Carbohydrate; LC= Low Carbohydrate

Table 3 compares means (+/-, standard deviation) for macronutrients and fiber between groups at baseline, 3-weeks, and 6-weeks. Significant differences were seen between groups at the 3rd week for carbohydrates (% of kcals and gms), protein (% of kcals and gms), fat (% of kcals and gms), and fiber (g). Significant differences were seen between groups at the 6th week for calories, carbohydrates (% of kcals and gms), protein (% of kcals and gms), fat (% of kcals and gms), and fiber (g). The LC group consumed greater amounts of fat and protein, while the HC group consumed more calories and fiber during the 6-week study. There were no significant differences between groups for nutrient intake at baseline.
Table 3: Changes in macronutrient and fiber intake in both groups from baseline

<table>
<thead>
<tr>
<th>Variable per day</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>Energy (kilocalories, kcal)</td>
<td>1697 (417)</td>
<td>1521 (395)</td>
<td>1592 (395)</td>
<td>1693 (504)</td>
<td>1214 (539)</td>
<td>1067 (316)</td>
</tr>
<tr>
<td>Carbohydrates % of kcal</td>
<td>50.3 (13.7)</td>
<td>55.8 (10.8)</td>
<td>50.6 (11.1)</td>
<td>45.5 (8.04)</td>
<td>28.1 (5.2)</td>
<td>12.4 (4.6)</td>
</tr>
<tr>
<td>Protein % of kcal</td>
<td>14.2 (3.5)</td>
<td>14.3 (4.7)</td>
<td>15.0 (3.9)</td>
<td>15.5 (3.4)</td>
<td>28.1 (5.2)</td>
<td>26.9 (5.2)</td>
</tr>
<tr>
<td>Fat % of kcal</td>
<td>32.4 (9.1)</td>
<td>27.7 (7.9)</td>
<td>34.1 (8.6)</td>
<td>38.4 (9.1)</td>
<td>58.5 (6.0)</td>
<td>59.9 (4.7)</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>207.4 (63.7)</td>
<td>210.6 (58.5)</td>
<td>197.6 (53.4)</td>
<td>189.8 (60.9)</td>
<td>36.5 (18.1)</td>
<td>33.0 (17.7)</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>60.9 (21.7)</td>
<td>52.3 (15.6)</td>
<td>58.0 (12.7)</td>
<td>63.5 (17.0)</td>
<td>84.5 (38.2)</td>
<td>70.5 (20.3)</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>61.5 (24.3)</td>
<td>46.9 (18.9)</td>
<td>61.6 (25.9)</td>
<td>74.2 (28.8)</td>
<td>81.25 (43.0)</td>
<td>71.9 (24.7)</td>
</tr>
<tr>
<td>Dietary Fiber (g)</td>
<td>17.3 (7.8)</td>
<td>19.3 (10.0)</td>
<td>19.2 (7.3)</td>
<td>15.7 (7.21)</td>
<td>7.4 (4.3)</td>
<td>6.5 (3.3)</td>
</tr>
</tbody>
</table>

a Significant differences (p<0.05) between groups at 3rd week; b Significant differences (p<0.01) between groups at 3rd week; c Significant differences (p<0.01) between groups at 6th week; Mean +/- (standard deviation); HC= High Carbohydrate; LC= Low Carbohydrate

Mean micronutrient changes are shown in Tables 4 and 5 for the HC group and LC group. At week 3 significant differences in intake of vitamin C, thiamin, magnesium, iron, and potassium were observed between groups. At week 6 significant differences in intake of vitamin C, thiamin, niacin, vitamin B-6, folate, magnesium, iron, and potassium were observed between groups. There were no significant differences in nutrient intake between the groups at baseline.

Table 4: Changes in micronutrient (vitamin) intake in both groups from baseline

<table>
<thead>
<tr>
<th>Variable per day</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td>Vitamin A (RE, mcg)</td>
<td>1049 (798)</td>
<td>912 (684)</td>
<td>924 (576)</td>
<td>1093 (654)</td>
<td>711 (517)</td>
<td>754 (390)</td>
</tr>
<tr>
<td>Vitamin D (calciferol, mcg)</td>
<td>4 (3)</td>
<td>4 (3)</td>
<td>4 (4)</td>
<td>4 (2)</td>
<td>3 (1)</td>
<td>5 (10)</td>
</tr>
<tr>
<td>Vitamin E (total alpha tocopherol, mg)</td>
<td>6 (2)</td>
<td>9 (6)</td>
<td>8 (8)</td>
<td>7 (3)</td>
<td>5 (3)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>Vitamin K (phyloquinone, mcg)</td>
<td>68 (29)</td>
<td>77 (25)</td>
<td>101 (91)</td>
<td>136 (146)</td>
<td>168 (237)</td>
<td>138 (135)</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>99 (94)</td>
<td>118 (62)</td>
<td>105 (61)</td>
<td>75 (46)</td>
<td>34 (31)</td>
<td>32 (29)</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.4 (0.4)</td>
<td>1.6 (0.7)</td>
<td>1.7 (0.9)</td>
<td>1.5 (0.6)</td>
<td>0.9 (0.5)</td>
<td>0.8 (0.4)</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.8 (0.5)</td>
<td>2.0 (1.1)</td>
<td>2.1 (1.2)</td>
<td>2.2 (0.9)</td>
<td>1.7 (0.7)</td>
<td>1.6 (0.5)</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>18.1 (6.7)</td>
<td>20.2 (11.2)</td>
<td>22.0 (11.9)</td>
<td>19.7 (6.3)</td>
<td>17.1 (7.8)</td>
<td>14.8 (5.5)</td>
</tr>
<tr>
<td>Vitamin B-6 (mg)</td>
<td>1.6 (0.6)</td>
<td>1.82 (1.1)</td>
<td>2.0 (1.5)</td>
<td>1.7 (0.4)</td>
<td>1.2 (0.5)</td>
<td>1.0 (0.3)</td>
</tr>
<tr>
<td>Vitamin B-12 (mcg)</td>
<td>3.5 (1.6)</td>
<td>3.8 (3.6)</td>
<td>5.0 (4.0)</td>
<td>4.7 (3.0)</td>
<td>4.3 (2.8)</td>
<td>4.7 (2.6)</td>
</tr>
<tr>
<td>Folate (mcg)</td>
<td>363 (111)</td>
<td>467 (246)</td>
<td>420 (237)</td>
<td>393 (186)</td>
<td>175 (57)</td>
<td>184 (80)</td>
</tr>
</tbody>
</table>

a Significant differences (p<0.05) between groups at 6th week; b Significant differences (p<0.01) between groups at 3rd week; c Significant differences (p<0.01) between groups at 6th week; Mean +/- (standard deviation); HC= High Carbohydrate; LC= Low Carbohydrate
### Table 5: Changes in micronutrient (mineral) intake in both groups from baseline

<table>
<thead>
<tr>
<th>Variable per day</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>HC (n=11)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
<th>LC (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (mg)</td>
<td>Baseline</td>
<td>644 (266)</td>
<td>593 (319)</td>
<td>517 (152)</td>
<td>725 (265)</td>
<td>454 (243)</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>Baseline</td>
<td>272 (114)</td>
<td>267 (113)</td>
<td>255 (80)</td>
<td>252 (73)</td>
<td>177 (73)</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>Baseline</td>
<td>12 (4)</td>
<td>16 (9)</td>
<td>16 (10)</td>
<td>14 (7)</td>
<td>7 (3)</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>Baseline</td>
<td>2468 (614)</td>
<td>2466 (724)</td>
<td>2407 (727)</td>
<td>2396 (616)</td>
<td>1787 (466)</td>
</tr>
</tbody>
</table>

a Significant differences (p<0.05) between groups at 3rd week;
b Significant differences (p<0.01) between groups at 3rd week;
c Significant differences (p<0.01) between groups at 6th week;

Mean +/- (standard deviation); HC= High Carbohydrate; LC= Low Carbohydrate

The Institutes of Medicine (IOM) recommends that nutrient comparisons for groups are to be done by comparing the prevalence of inadequacy using the Estimated Average Requirements (EAR), rather than by comparing mean intakes (26). When no RDA is available to determine the EAR, the AI is used in its place to signify the amount of intake of a selected nutrient that is assumed to be sufficient in a group of healthy people. Table 6 defines each of the current DRI measures. The proportion below the EAR was counted to determine the prevalence of adequacy; therefore, the higher the proportion, the higher the prevalence of inadequacy. In this study, the prevalence of inadequacy of nutrient intake from food was indicated by a level of >0.50 at 6 weeks. The data were analyzed for differences between diet intervention groups. The analysis for nutrients with an established EAR or AI is shown in Tables 7-8.

### Table 6: Dietary Reference Intakes (DRI) definitions

<table>
<thead>
<tr>
<th>Estimated Average Requirement (EAR):</th>
<th>The average daily nutrient intake level that is estimated to meet the requirements of half of the healthy individuals in a particular stage and gender group.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended Dietary Allowance (RDA):</td>
<td>The average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97-98 percent) healthy individuals in a particular life stage and gender group.</td>
</tr>
<tr>
<td>Adequate Intake (AI):</td>
<td>The recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate, used when an RDA cannot be determined.</td>
</tr>
<tr>
<td>Tolerable Upper Intake Level (UL):</td>
<td>The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, potential risk of adverse effects may increase.</td>
</tr>
<tr>
<td>Acceptable Macronutrient Distribution Ranges (AMDR):</td>
<td>The range of intake of an energy source that is associated with a reduced risk of chronic disease, yet can provide adequate amounts of essential nutrients. The AMDR is expressed as a percentage of total energy intake.</td>
</tr>
<tr>
<td>Estimated Energy Requirements (EER):</td>
<td>The average dietary energy intake that is predicted to maintain energy balance in a healthy individual of a defined age, gender, height, weight, and level of physical activity consistent with good health.</td>
</tr>
</tbody>
</table>

References #35, #36
Table 7 and 8 report the prevalence of inadequacy of vitamin intake from food at 3 and 6 weeks in both the HC and LC diet groups. At six weeks the HC group was inadequate in vitamin D, E, K, calcium, magnesium, and potassium. For the LC group, at 6 weeks the prevalence of inadequacy was found with vitamin D, E, K, C, B-6, thiamine, folate, calcium, magnesium, iron, and potassium. The prevalence of inadequacy of vitamin C, B-6, thiamin, niacin, folate, and magnesium was significantly higher in the LC group compared to the HC group. The HC group was found to have significantly higher prevalence of inadequacy for vitamin K.

**Table 7: Vitamin intake: Estimate of the prevalence of inadequacy at 3 and 6 weeks**

<table>
<thead>
<tr>
<th>Variables per day</th>
<th>EAR cutoff</th>
<th>HC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
<th>HC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
<th>LC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
<th>LC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A (RE, mcg)</td>
<td>625/500</td>
<td>0.18</td>
<td>0.27*</td>
<td>0.36</td>
<td>0.27</td>
<td>0.53*</td>
<td>0.33</td>
<td>0.91</td>
<td>1.0</td>
<td>0.91</td>
<td>1.0</td>
<td>1.0</td>
<td>0.93</td>
</tr>
<tr>
<td>Vitamin D (calciferol, mcg)</td>
<td>15/10*</td>
<td>0.91</td>
<td>1.0</td>
<td>0.91</td>
<td>1.0</td>
<td>0.93</td>
<td>1.0</td>
<td>0.82</td>
<td>0.82</td>
<td>0.93</td>
<td>0.93</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Vitamin E (total alpha tocopherol, mg)</td>
<td>12/12</td>
<td>0.90</td>
<td>0.73*</td>
<td>0.73</td>
<td>0.53</td>
<td>0.53</td>
<td>0.53</td>
<td>0.36</td>
<td>0.54</td>
<td>0.66</td>
<td>0.66</td>
<td>0.86</td>
<td>0.86</td>
</tr>
<tr>
<td>Vitamin K (phyloquinone, mcg)</td>
<td>120/90*</td>
<td>0.45</td>
<td>0.27*</td>
<td>0.27*</td>
<td>0.53</td>
<td>0.86*</td>
<td>0.86*</td>
<td>0.18</td>
<td>0.20</td>
<td>0.60*</td>
<td>0.60*</td>
<td>0.80*</td>
<td>0.80*</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>75/60</td>
<td>0.91</td>
<td>0.27*</td>
<td>0.27*</td>
<td>0.53</td>
<td>0.86*</td>
<td>0.86*</td>
<td>0.09</td>
<td>0.18</td>
<td>0.06</td>
<td>0.13</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.0/0.9</td>
<td>0.27*</td>
<td>0.27*</td>
<td>0.27*</td>
<td>0.53</td>
<td>0.86*</td>
<td>0.86*</td>
<td>0.09</td>
<td>0.18</td>
<td>0.06</td>
<td>0.13</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.1/0.9</td>
<td>0.91</td>
<td>0.18</td>
<td>0.18</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.36</td>
<td>0.54</td>
<td>0.66</td>
<td>0.66</td>
<td>0.86*</td>
<td>0.86*</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>12/11</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18*</td>
<td>0.20</td>
<td>0.20</td>
<td>0.33</td>
<td>0.45</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
</tr>
<tr>
<td>Vitamin B-6 (mg)</td>
<td>2/2</td>
<td>0.91</td>
<td>0.18</td>
<td>0.18</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.45*</td>
<td>0.54*</td>
<td>0.54*</td>
<td>0.54*</td>
<td>0.54*</td>
<td>0.54*</td>
</tr>
<tr>
<td>Folate (mcg)</td>
<td>320/320</td>
<td>0.45</td>
<td>0.45*</td>
<td>0.45*</td>
<td>0.20</td>
<td>0.20</td>
<td>0.93</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*a* Significant differences (p≤0.01) between groups at 3rd week;  
*b* Significant differences (p≤0.05) between groups at 6th week  
*c* Significant differences (p≤0.01) between groups at 6th week

Mean +/- (standard deviation); HC = High Carbohydrate; LC = Low Carbohydrate

**Table 8: Mineral intake: Estimate of the prevalence of inadequacy at 3 and 6 weeks**

<table>
<thead>
<tr>
<th>Variables per day</th>
<th>EAR cutoff</th>
<th>HC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
<th>LC Baseline</th>
<th>3rd week</th>
<th>6th week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (mg)</td>
<td>1000*</td>
<td>0.82</td>
<td>0.91</td>
<td>1.0</td>
<td>0.86</td>
<td>0.93</td>
<td>1.0</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>265</td>
<td>0.54</td>
<td>0.54*</td>
<td>0.54</td>
<td>0.66</td>
<td>0.86*</td>
<td>0.86*</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>8.1</td>
<td>0.18*</td>
<td>0.09*</td>
<td>0.18*</td>
<td>0.86*</td>
<td>0.60*</td>
<td>0.60*</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>4700*</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*a* Significant differences (p≤0.05) between groups at 3rd week;  
*b* Significant differences (p≤0.01) between groups at 3rd week  
*c* Significant differences (p≤0.01) between groups at 6th week

Mean +/- (standard deviation); HC = High Carbohydrate; LC = Low Carbohydrate
DISCUSSION

The purpose of this study was to determine if the older adult could meet their macronutrient and micronutrient needs after being counseled on a low carbohydrate diet. It is well known that a low carbohydrate diet lacks adequate amounts of vitamin A, B6, C, E, thiamin, folate, calcium, magnesium, iron, potassium and fiber (30, 33). However, there are limited studies that determine the necessary dose of a supplement required for an older adult who follows a low carbohydrate diet for an extended period of time. Currently, there are no biochemical data to support that a low carbohydrate diet leads to an impaired nutritional status when followed for any length of time (4).

Older adults often have a difficult time obtaining and consuming appropriate amounts of macronutrients and micronutrients in their diet, which may result in deficiency. Many older adults have poor diet quality due to physical limitations that impair their ability to prepare meals, poor dentition, lack of transportation to a grocery store, and financial struggles. It is challenging for the older adult to meet their nutritional needs with a traditional diet, and it is often difficult for them to meet their nutrient needs when following a specialized diet, in which many well accepted and common foods may be restricted. Insufficient daily intakes of vegetables, bread and cereals, milk and milk products are observed among older individuals living at home and in long term care facilities, whereas intakes of meat and meat products, fat and sugar are often too high when compared to established guidelines (37).

Consuming a well-balanced, nutritionally adequate diet is vital to the older adult, as risk for many nutrition related diseases, such as osteoporosis, anemia, cardiovascular disease, macular degeneration, diabetes, hypertension, cancer, and neurological disorders increases with age. Potential long term health implications of low carbohydrate diets are unknown, yet have
been speculated. Consumption of a high percentage of total energy in the form of fat may contribute to overweight or obesity, which may increase the risk of cardiovascular disease, diabetes, and hypertension (4). Low carbohydrate diets score poorly on indices that evaluate dietary factors that reduce risk for chronic diseases, such as cardiovascular disease (28). It has been hypothesized that low carbohydrate diets may increase the risk for osteoporosis because of an increase in urinary calcium loss. Short term studies show that high protein diets do not cause bone loss; however, long term studies are not available (33). Based on bone mineral density studies, it is common to find individuals with osteoporosis who have low intakes of calcium, which is consistent with a low carbohydrate diet (38). There are many epidemiological studies that support a protective role of fruits, vegetables, and whole grains against certain types of cancer, including colorectal, breast, pancreatic, lung, stomach, esophagus, and bladder (4, 39). More specifically, it should be noted that a potential link between increased intakes of meat and the incidence of colorectal cancers has been observed in some studies (40). Fruits and vegetables contain antioxidants, fiber, and polyphenols which provide protection against cancer. Alzheimer’s disease is thought to be caused by oxidative stress in the body; this condition has also seen beneficial results when increased amounts of antioxidants are provided through the diet (41).

Results from this study show that older individuals that consume a LC diet had poor intakes of vitamin C, vitamin B6, thiamin, folate, calcium, magnesium, iron, and fiber compared to the HC group. Low carbohydrate diets commonly lack these nutrients because fruits, fruit juices, dairy, and grains are restricted. The LC diet group consumed more fat and protein than the HC group, and significantly less calories. As observed in many other short term low carbohydrate diet studies, the LC group lost significantly more weight, with an average loss of
10.8 pounds in 6 weeks compared to a 1.2 pound average loss among the HC group. It was not unforeseen to find a large weight loss in the LC diet group. During the 6th week study, participants in the LC diet group were consuming on average 1069 kcal, which was 626 kcal less than their baseline average. Commonly when LC diet studies are done for longer periods of time, e.g., 6 to 12 months, the HC or comparison diet groups tend to have similar weight loss at the end of the study. Initial rapid weight loss with a low carbohydrate diet may be partially explained by a reduction in overall caloric intake, which may be the result of the limitation of food choices (4). One 2-year study found no significant differences in weight loss between a low fat, average protein, high carbohydrate diet and a high fat, high protein, low carbohydrate diet at the end of the study (42).

In the present study, consistently low intakes of vitamin D, vitamin E, calcium, magnesium, and potassium were visible among both HC and LC diet groups. Low intakes of vitamin D were anticipated among both groups. It is well known that vitamin D is extremely difficult to obtain from diet alone (43). Foods containing vitamin E, vegetable oils, nuts, and green leafy vegetables, were encouraged in both groups, and low intakes of this vitamin were unexpected. Intakes of any dairy products were infrequent in both groups. Based on national survey data, dairy intake is typically low among older individuals and below established nutrition guidelines; therefore it was not surprising to find suboptimal levels of this food group in the diet of older individuals in this study. Lower intakes of calcium were observed in the LC group, most likely due to decreased consumption of milk, which is considered a carbohydrate. It was unexpected to have low intakes of potassium in the HC diet groups since increased amounts of fruits and vegetables were strongly encouraged.
The EAR cutoff levels demonstrate the average daily nutrient intake level that is estimated to meet the requirements of half of a healthy group of individuals. When no RDA is available the AI is used in its place to signify the amount of intake of a selected nutrient that is assumed to be sufficient in a group of healthy people. The EAR cutoff values are compared with means and presented as a percentage to determine which vitamins and minerals the half of the older adults failed to meet. Knowing which vitamins and minerals are lacking from the low carbohydrate diet of an older adult can help to prevent inadequacy. From the results of this study, it would be advised that older adults following a low carbohydrate diet supplement their dietary intake with vitamin D, vitamin E, vitamin C, thiamin, vitamin B-6, folate, calcium, magnesium, and potassium with a level adequate to achieve the DRI for each nutrient. Because baseline data for both HC and LC groups were low for vitamin D, vitamin E, calcium, magnesium and potassium, it is recommended that all older adults supplement with a multivitamin containing 100% of the DRI values for these nutrients or seek out additional ways to increase these nutrients in their diet. Obtaining adequate vitamins and minerals through food versus supplements is always the optimal choice.

It is important to note the following limitations in this study. Due to the thorough screening process and compliance necessary for the 6-week diet trial, participants were difficult to enroll in the study. This resulted in a small sample size (n=26). Furthermore, all participants were classified as mildly cognitively impaired, which made it challenging to provide diet counseling. Further research is recommended on this topic inclusive of a larger sample size, without cognitive impairment. Another limitation was the occasional poor diet records kept by participants. Intermittently, portion sizes would be incorrectly documented or not completely described on the diet records. It was then left up to the discretion of the graduate student (in the
MS Nutrition Program) to enter the data based on their best judgment. During the 6-week study, some participants were contacted via telephone as part of another research project regarding their intake. At this time those subjects could ask questions on how to appropriately fill out their diet record. Participants were not provided with follow up calls for any questions about their diet regimen or filling out diet records. De-briefing of diet records would be recommended for subsequent studies on this topic. Lastly, differences in reported intake between week 3 and week 6 are present among both groups. It is possible that subjects become more familiar with the process of recording their food records as time passed, thus making week 6 a better reflection of their dietary intake.

**SUMMARY**

The results of this study suggest that a low carbohydrate diet (≤ 20 g) should not be recommended for the older adult for an extended period of time without proper supplementation. Further studies using participants with no cognitive impairment, a larger sample size, and longer duration using appropriate supplementation are suggested.

Low carbohydrate diets are studied for weight loss, improving glycemic control, and preventing further memory decline; however, low carbohydrate diets are at a greater risk of being nutritionally inadequate. Due to the fact that risk for many nutrition-related chronic diseases increase with age, such as cardiovascular disease, cancer, and diabetes, it is vital for the older adult to meet their nutrient requirements. The results of this study stress the importance of proper supplementation and supervision for those older adults following low carbohydrate diet regimens.
REFERENCES


