Jennifer Van Oss, hereby submit this original work as part of the requirements for the degree of Master of Science in Nutrition.

It is entitled:
The Relationship between Physical Activity and DASH Diet Adherence.

Student's name: Jennifer Van Oss

This work and its defense approved by:

Committee chair: Abigail Peairs, PhD
Committee member: Sarah Couch, PhD

University of Cincinnati
The Relationship between Physical Activity and DASH Diet Adherence

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 Nutrition
College of Allied Health Sciences

by
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December 2012

Committee Chair: Abigail Peairs, PhD
Abstract

Background: The Dietary Approaches to Stop Hypertension (DASH) diet has been shown to be effective in adolescents as a non-pharmacological treatment for elevated blood pressure. Other factors that influence adoption and adherence of the DASH diet are not yet fully understood.

Objective: To determine the relationship between physical activity and diet adherence in hypertensive adolescents receiving DASH education by evaluating the DASH Score, DASH Component Scores, and minutes of physical activity per week.

Methods: Seventy six adolescents between 11-18 years with diagnosis of prehypertension or stage 1 hypertension received initial counseling by a registered dietitian on the DASH diet. Dietary intake was assessed through three 24-hour recalls and physical activity data through a 7-day recall, both at baseline and after 6 months. DASH diet adherence was determined by computing a DASH score (0-80) based on the participants’ intakes of each DASH component.

Results: In characterizing their physical activity levels at the 6 month assessment, 52 participants did not meet national physical activity standards compared to 24 that met or exceeded these recommendations. Adolescents that met or exceeded the recommendations tended to have a higher average overall DASH score (44.09 vs. 40.22, p=0.09). The component scores with the strongest correlations to physical activity were vegetables (beta=0.264, p=0.023), total dairy (beta=0.305, p=0.006), and low-fat dairy (beta=0.208, p=0.021). Physical activity tended to be negatively associated with oils (beta=-0.199, p=0.092) although the trends did not reach statistical significance.

Conclusions: Participants who were more physically active tended to have higher total DASH scores, representing better diet adherence, than those participants with lower levels of physical activity.
# Table of Contents

Introduction 6

Literature Review 6

  Hypertension 6
  DASH Diet 7
  Physical Activity in the United States 9
  Physical Activity and Cardiovascular Disease 13
  Motivational Spill-over 14

Purpose and Hypothesis 16

Methods 17

  Participants 17
  Measurements 17
  DASH Intervention 18
  DASH Score 19
  Statistical Analysis 21

Results 21

Discussion 25

Conclusion 30

References 30
List of Tables and Figures

Table 1. DASH recommendations per food group based on 2,000 kcal daily.

Table 2. Components of DASH index.

Table 3. Mean values (SD) and number of demographic characteristics at baseline for 76 randomly assigned participants.

Table 4. Change in mean minutes of physical activity (PA), total DASH, and individual DASH component scores.

Table 5. Relationship between physical activity and DASH scores.

Figure 1. Independent t-test of total DASH score and PA level.
INTRODUCTION

The relationship between diet, exercise, and overall health is well established. Singularly, both diet and exercise have proven benefits for warding off potential health risks and prolonging life. What is less understood is the nature of the relationship between diet and exercise. It is not known whether one of these behaviors is the key to successfully adopting the other. It is also unknown if one of these behaviors positively affects the adherence of the other. Gathering information about this relationship will assist educators, professionals, and the general public better understand how diet and exercise are inherently intertwined and essentially work together for overall health.

Hypertension

It is estimated that approximately 50 million American adults have been diagnosed with hypertension\(^1\). This is equivalent to approximately 30% of adults over the age of 18\(^2\), and the prevalence increases with age. The significance of this is that having high blood pressure increases one’s risk for heart attack, heart failure, stroke, and kidney disease\(^3\), which are all components of cardiovascular disease (CVD). In fact, for individuals between the ages of 40-70 years, every 20 mmHg incremental increase in blood pressure doubles one’s risk of developing CVD\(^3\).

Alarmingly, the prevalence of hypertension in America’s youth is growing at a pace similar to that of childhood obesity, accounting for between 2-5% of the population\(^4,5\). Unfortunately, thirty-eight percent of children who suffer from untreated hypertension have indications of early target organ damage\(^6\). Further, having elevated blood pressure as a child commonly leads to hypertension in young adulthood\(^7\), making early treatment essential. It is also likely that hypertension increases the risk of CVD diagnosis at a young age, although there is a significant lack of data regarding long term effects of hypertension diagnosed in adolescence.
Accurate numbers reflecting the number of children and adolescents in the United States and worldwide with higher than normal blood pressure are more difficult to determine than those for adults because of ambiguous diagnosis guidelines. Commonly, guidelines set for adults are used, but evaluation also depends on the child’s sex, age, and height percentile. Normal blood pressure of 120/80 for adults may be considered hypertension in adolescents. For a 13-year old in the 50th percentile for height, a blood pressure of 108/62 would be considered normal. Authors of a study conducted in Northeast Ohio reported that only 37% of children who had either prehypertension or hypertension were appropriately diagnosed.

Adopting various lifestyle modifications can reverse hypertension and in turn, help prevent CVD. Positive effects have been observed in blood pressure decreases from 2-20 mmHg. Behaviors such as weight reduction, increasing physical activity, decreasing alcohol consumption, reducing dietary sodium, and adoption of healthy patterns are all good options.

**DASH diet**

Excess sodium intake plays an important role in the pathogenesis of hypertension. Accordingly, it is also attributed to promoting left ventricular hypertrophy and fibrosis of the heart, kidneys, and arteries. Average sodium intakes in the United States are about 30% higher than current dietary guidelines, and by reducing intakes to dietary guidelines could potentially prevent 11 million cases of hypertension and save billions in healthcare costs.

Due to more than 75% of sodium intakes are attributable to packaged and restaurant foods, sticking to a diet high in fruits and vegetables and other naturally low-sodium foods could be a good option to reduce blood pressure. Adults and adolescents with hypertension have shown that adhering to the Dietary Approaches to Stop Hypertension (DASH) diet have been successful in lowering
their blood pressure\textsuperscript{14, 15}. Results have been observed in adults in a period as short as 14 days\textsuperscript{14}. Long term, DASH adherence can reduce one’s 10-year coronary heart disease (CHD) risk by 11-18\%\textsuperscript{16}.

The DASH diet emphasizes fruits, vegetables, low-fat dairy, whole grains, and lean protein. Magnesium may also contribute to decreasing blood pressure by acting as a natural calcium channel blocker, competing with sodium for binding sites on vascular smooth muscle cells\textsuperscript{18, 19, 20}. Optimal levels of calcium in the body will lead to stable vascular membranes and reduce vasoconstriction\textsuperscript{21}. When it works together with magnesium, it provides an ionic balance in the vascular membrane as well as vasodilation, all of which result in decreased blood pressure. The typical American diet provides about 3.5g of sodium per day, while current recommendations are set at 2.3g per day\textsuperscript{1}. In the DASH diet, the daily amount of sodium is brought down below those recommendations to about 1.2g per day.

Following this diet will result in lower intakes of total and saturated fat and cholesterol, while increased intakes of heart healthy minerals potassium, calcium, and magnesium, along with dietary fiber than what is found in the typical American diet\textsuperscript{14}. Table 1 shows the daily recommendations for each food group for 2,000 kcal diet\textsuperscript{17}.

<table>
<thead>
<tr>
<th>Table 1. DASH recommendations per food group based on 2,000 kcal daily.</th>
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<tr>
<td><strong>Food Group</strong></td>
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<tr>
<td>Low-fat Dairy</td>
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<tr>
<td>Whole Grains</td>
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<tr>
<td>-------------</td>
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<tr>
<td>Meats, Poultry, Fish</td>
</tr>
<tr>
<td>Nuts, seeds, legumes</td>
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</tbody>
</table>

Note that the nuts, seeds, and legumes are weekly recommendation.

Adolescents require more calories per day than the typical adult due to increased needs for growth. Boys should get on average 2,800 kcal and girls 2,200 kcal per day to meet energy requirements. While many adolescents are achieving these total caloric intakes, their food sources are usually higher in processed and fast foods. Snacking on foods high in sodium, fat, and sugar and low in dietary fiber, vitamins, and minerals make up about one-fourth of the typical adolescent diet. The main source of fruits for adolescents nationally has been found to be orange and other fruit juices, not whole fruits. Fried potatoes make up about half of an average adolescent’s vegetable intake, followed by tomato products.

**Physical Activity in the United States**

Currently, there are two sets of recommendations for physical activity levels. The 2008 Physical Activity Guidelines (PAG) for Americans states adults need to engage in at least 150 minutes per week of moderate intensity activity (aerobic activity) or 300 minutes per week of vigorous intensity activity and participate in muscle strengthening activities at least 2 days per week to obtain substantial health benefits. Healthy People 2010 recommends participating in at least 30 minutes per day of moderate intensity aerobic activity at least 5 days per week or 20 minutes of vigorous aerobic activity at least 3 days per week. Overall, a majority of American adults fail to meet either of these standards. According to a study conducted by Carlson et al. in 2011 less than half (43.5%) of US adults were aerobically active,
only 21.9% met the muscle strengthening recommendations, and a mere 18.2% met both. Adolescents also fail to meet physical activity recommendations; with only 36% of high school students meeting the PAG in 2010. Notably, after age 9, trends for physical activity start to decrease significantly and by ages 13 and 14, girls and boys respectively are not reaching the recommended minutes of moderate-to-vigorous physical activity. It is significant to note that adolescents who do not eat 5 or more servings of fruits and vegetables are also more likely to not meet physical activity recommendations.

The 2008 PAG for Americans recommends children and adolescents participate in one hour or more of physical activity every day. That one hour should be made up of aerobic, muscle-strengthening, or bone-strengthening activities. It is recommended that children and adolescents take part in at least moderate-intensity aerobic activity daily, with some vigorous-intensity aerobic activity three days a week. Examples of moderate-intensity aerobic activities are hiking, bicycle riding, skateboarding, or games that require catching and throwing like baseball. Vigorous-intensity activities are those such as martial arts, running, vigorous dancing, soccer, basketball, swimming, or games that involve running and chasing like tag.

These guidelines also recommend muscle-strengthening and bone-strengthening activities at least three days a week. The muscle-strengthening activities should make the muscles work more than usual during normal daily activities, involving at least a moderate amount of effort. These activities should work each major muscle group and include activities such as tree climbing, sit-ups, push-ups, climbing walls, and resistance exercises with bands, weight machines, or hand-held weights. The bone-strengthening activities should produce enough force to encourage bone growth and strength. These kinds of activities include games like hop-scotch, jumping rope, running, and sports like gymnastics, basketball, volleyball, and tennis.
Traditionally, physical activity data has been measured by surveys and recall instruments. These techniques do not always provide reliable data, especially within the pediatric population, due to difficulty in recalling the information. There are some studies that show these methods can be accurate in reporting physical activity data (73.4-86.3% agreement between recall data and direct observation), but the gold standard for measuring such data is direct observation of the individual’s activity. However, this method is not feasible for most studies due to the time and labor intensive nature of this type of instrument. Thus, the use of devices such as heart rate monitors, pedometers, and accelerometers have increased in use as tools to accurately determine physical activity. They reduce any bias in recall data by the individual and the surveyor, yet do not require the level of personnel, time, and commitment of having youth being directly observed for an extended period of time.

Strong et al. completed the most intensive review to date of studies concerning the effects of physical activity on health and behavior outcomes among adolescents to develop evidence-based recommendations for this age group. After reviewing approximately 850 articles, they reported that most of the intervention studies used programs of supervised moderate to vigorous physical activity of 30-45 minutes for three to five days per week. The authors concluded that a longer duration would be necessary to observe the same results under ordinary circumstances (intermittent and unsupervised physical activity). They recommended that school-age youth should participate in 60 minutes of moderate to vigorous physical activity every day to observe beneficial changes in skeletal health, aerobic fitness, muscular strength and endurance, and adiposity in overweight youth. They suggest that the activities be varied, developmentally appropriate, and enjoyable for the participants.

In order to combat childhood obesity and other chronic diseases, the government has taken a more active role in promoting physical activity. On the state level, the Ohio Department of Education and the Ohio Department of Health have developed goals emphasizing physical activity, nutrition, and
tobacco use prevention. In terms of physical activity goals, the state of Ohio is working to increase the number of schools with physical education teachers or specialists who have received professional development on physical activity within the last 2 years. This will allow educators and policy makers to properly assess current physical activity levels and education in schools and develop appropriate curriculum to address any needs or shortcomings.

Ohio legislature has also developed the “Play More campaign” 31 in an effort to encourage healthy eating and physical activity in children and adolescents. One of the messages of this initiative is to encourage children to get out and play because it is more than just having fun with friends; it is part of the solution to ending obesity. Further, “Ohio Action for Healthy Kids” 34 is part of a national initiative to improve health and school performance through better nutrition and physical activity. The philosophy of this program is that healthy schools will produce healthy students that are more equipped to learn and reach their true potential. There are also afterschool programs such as “Ohio Kids on the Move” 35 that promote increased physical activity in children and adolescents.

Locally, Hamilton County was chosen by the CDC as a site for a program called “Communities Putting Prevention to Work” 36 that leads an effort to decrease obesity and tobacco use in order to prevent chronic disease. Developed out of that program is an initiative called “We THRIVE!” 37. This initiative also focuses on the reduction of chronic diseases by increasing access to healthy foods and physical activity opportunities where families in Hamilton County live, work, and play. The goal is to make the healthy choice the easy choice.

In summary, it is recommended that children get at least one hour of physical activity every day that incorporates aerobic, muscle-, and bone-strengthening activities to decrease chronic disease risk including hypertension. Most adolescents do not meet these recommendations, with a significant drop in physical activity seen after ages 13 and 14. It has been observed that adolescents failing to meet fruit
and vegetable recommendations are also failing to meet their physical activity recommendations, indicating a potential correlation between these two behaviors. On the national level, the PAG sets standards for normal, healthy children and adults to maintain a healthy lifestyle. In the state of Ohio, there are programs such as the “Play More” campaign, “Ohio Action for Healthy Kids”, and “Ohio Kids on the Move”, as well as initiatives for schools to bring in more qualified physical education professionals to help more children meet their physical activity goals.

**Physical Activity and Cardiovascular Disease**

The American College of Sports Medicine recommends aerobic or endurance exercise training as a non-pharmacological approach to decrease blood pressure and treat hypertension. Their recommendations are as follows: exercise on most (if not all) days of the week; exercise at a moderate intensity (40-<60% of VO₂R); exercise for a duration of ≥30 minutes continuously or cumulative per day; and should consist of primarily endurance activities supplemented by resistance activities. Reductions in blood pressure have been observed within 22 hours after exercise, with the greatest decreases in blood pressure seen in individuals with the highest baseline readings. The ACSM indicates the emphasis of any physical activity regimen should be on the factors that contribute to a permanent lifestyle change and encourage a lifetime of physical activity, in order to retain that cardio-protective benefit of aerobic fitness.

The proposed mechanisms for the observed blood pressure lowering effects are varying. Some explanations include decreased catecholamines (like epinephrine and norepinephrine) and decreased peripheral resistance in blood vessels, improved insulin sensitivity, and adaptations of vasodilators and vasoconstrictors. Norepinephrine mediates vasoconstriction and increases vascular resistance. After
exercise, norepinephrine has been shown to decrease, resulting in attenuated vasoconstriction and reductions in blood pressure in normotensive subjects. In normotensive subjects, reductions in renin and angiotensin II after exercise may contribute to lower BP as well, but this has not been consistently seen in hypertensive subjects. Vascular resistance after training may be reduced by neurohormonal and structural adaptations, altered vascular responsiveness to vasoactive stimuli, or both.

Currently, there is conflicting data on the effectiveness of chronic exercise in reducing blood pressure in adolescents. This may be due to the difficulty mentioned earlier in determining the appropriate blood pressure based on age, weight, and height. It could also be due to different physical activity assessment methods used and the inherent issues with reliability. Although there are currently lower numbers of adolescents with high blood pressure when compared to adults, this trend may increase as does the number of children becoming overweight and obese.

The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents concedes that in the strongest studies conducted thus far, the conclusion is that physical activity results in a small, but not statistically significant decrease in blood pressure. It is noted that regular physical activity is an important component of childhood obesity treatment, which has been shown to be a significant factor in reducing blood pressure among children and adolescents.

Motivational Spill-over

To improve long term cardiovascular risk and health outcomes, risk-reducing lifestyle changes is a major behavioral change worth implementing. Short-term motivations are well known, and useful. Some examples of external factors that act as incentives for health-minded behavior change include fear, needing to meet expectations, and enhancing self-worth. In the long-term, lifestyle modification is more difficult to sustain because it requires the individual to motivate themselves and not to rely on external reinforcement to keep them on a healthy path. Unfortunately, there is still insufficient
information known about why people do or do not adhere to these lifestyle changes\textsuperscript{40}. One significant factor that needs to be better understood is the motivation for a behavior, which is a crucial aspect of healthy behavior adherence and maintenance\textsuperscript{40}.

The key to maintenance of a healthy behavior is the successful transition from external motivating factors to internal motivating factors. In other words, the motivation for a particular behavior is a personal one rather than a social one\textsuperscript{40}. The process for adopting health behaviors is similar to the same process adolescents undergo when they adopt social values and behaviors, with the individual’s experience being a key factor\textsuperscript{41}. At first, the motivation may come from the desire to avoid an undesirable health outcome (i.e. heart attack), satisfying a doctor, or to appease a loved one. This externally regulated behavior is not as stable, and the individual may experience a significant amount of conflict over partaking in this particular behavior. The individual may also experience motivation through guilt or shame that they need to make this behavior change, in which case, the individual’s ego can be a barrier to the full transition to internal motivation\textsuperscript{40}. The motivation has become internalized when the behavior is incorporated into the individual’s values and personal goals at which point there will be the greatest potential for long-term adherence. Once the individual has taken ownership of the behavior with the self-determination to continue the behavior, and has the support and security to overcome any struggles or temptations they may encounter he/she will be able to successfully continue the behavior\textsuperscript{42}.

Many health behaviors are similar in terms of their consequences\textsuperscript{43}. For example, physical activity and diet are both likely to influence body weight. Clustered health-promoting behaviors like these may work better together for long-term adherence through transfer effects. Transfer explains how motivations and experiences in one setting are applied to behaviors in another\textsuperscript{44}. This happens if the behaviors are similar in nature, as in the example of physical activity and diet. Diet and physical
activity are associated in cross-sectional studies and have been shown to have an interactive effect in various intervention studies. Physical activity, in particular, has been suggested to play a significant role in weight management due to its effect on several processes including energy metabolism and appetite, self-efficacy, body image, and mood. The successful adoption of a regular exercise routine has the potential to increase confidence and overall motivation to other health-related behaviors, such as a healthy diet pattern and self-regulation. If this transfer, or “motivation spill-over” stems from internal motivations, it may prove to be even more powerful because it is fueled by autonomy and self-determination. In a study conducted by Mata et al., this theory was applied in the context of a weight management intervention. The study was a randomized control trial in overweight and moderately obese women. The primary focus was to increase exercise self-motivation and exercise adherence, with a goal of long-term weight control. The intervention group participated in weekly or biweekly sessions focused on increasing physical activity and energy expenditure, adopting a diet with a moderate energy deficit, and establishing exercise and eating routines that support weight maintenance. The control group received general health education. Over the course of one year, an increase in self-determination was observed in the participants as well as exercise motivation that transferred to improvements in eating self-regulation. Due to the fact that the tenants of this transfer stem from the Self-determination Theory and it is similar to other social processes, this theory should be applicable and appropriate for adolescents as well as adults, regardless of intervention treatment.

Purpose and Hypothesis

The benefits of the DASH diet on hypertension management are well characterized. The additional inclusion of physical activity can increase benefits to hypertensive individuals, as shown in studies in adults. The adoption of healthy eating behaviors has been associated with the motivation for physical activity in adults, regardless of the method of intervention treatment. Additional data is
needed to explore the relationship between physical activity and diet adherence in adolescents. The purpose of this study was to explore the relationship between physical activity and diet adherence in hypertensive adolescents.

The question to be answered in this thesis is as follows: Is physical activity level related to or does it predict adherence to a DASH diet among adolescents with hypertension participating in a dietary intervention? The hypothesis is that a greater physical activity level predicts greater adherence to a DASH diet among adolescents with hypertension participating in a dietary intervention focused on the DASH diet.

METHODS

Participants

The data used to answer this research question were derived from a study conducted by Couch et al. Seventy-six adolescents between 11 and 18 years of age with a clinical diagnosis of prehypertension or stage 1 hypertension were recruited from the Cincinnati Children’s Hypertension Clinic (CCHC) at Cincinnati Children’s Hospital Medical Center (CCHMC) between February 2008 and March 2011. Hypertension status was determined based on criteria established by the Fourth Pediatric Report on Hypertension. Pediatric pre-hypertension was defined as an average systolic blood pressure (SBP) or diastolic blood pressure (DBP) ≥90th percentile and <95th percentile for age, gender, and height and stage 1 hypertension as an average SBP or DBP ≥95th percentile and <99th percentile plus 5 mmHg based on gender, age, and height as measured on three or more occasions. Exclusion criteria included secondary hypertension, taking blood pressure medication prior to enrollment in the study, diagnosis of Type I or Type II diabetes, prior exposure to formal dietary therapy to manage blood pressure, target organ damage, presence of an eating disorder, and lack of clearance from a physician to participate. Participants were also excluded for using blood pressure altering drugs.
medications and the unwillingness to stop taking vitamins, minerals, or antacids. Parental and subject consent was also gathered. Approval for this study was granted by the Cincinnati Children’s Hospital Medical Center Institutional Review Board (IRB) and the University of Cincinnati IRB.

**Measurements**

Baseline measurements took place before in-clinic diet counseling began. Participants self-reported age, gender, race, and physical activity. Physical activity data was determined using a validated 7-day physical activity recall\(^4^7\). Each participant was asked about the amount of time they participated in physical activity every day and what type of activity they were engaged in. Only those activities with duration of 5 minutes or more were recorded. Their activities were then defined as light, moderate, hard, or very hard. Each participant was given a guide to help determine how to categorize the type of activity they participated in. Because recommendations are based on activities done at least a moderate intensity, only moderate, hard, and very hard durations were considered for this analysis. The minutes of activity for each of those three intensity levels was then added together to determine the participant’s weekly physical activity at both baseline and post-treatment (6 months).

Participants completed three 24-hour recalls (two weekdays and one weekend day) over a two week period before each assessment using the validated multi-pass method\(^4^8\). The recalls were taken over the phone by a registered dietitian and analyzed for average caloric intake, selected nutrients including total fat, saturated fat, calcium, potassium, magnesium, and sodium and number of servings of fruits, vegetables, dairy, grains, meat, oils, and sweets. These dietary recalls were used to measure the participant’s dietary changes from baseline to six months (post-treatment).

The participant’s socioeconomic status was determined with the help of their parents, who provided their family’s annual income. Weight and height were measured to determine body mass index and blood pressure was taken at each assessment. Blood pressure measurements were
performed with a mercury sphygmomanometer according to standardized procedures. Blood pressure was calculated as the mean of all available measurements at that time point: four measurements taken in clinic two weeks apart comprised the baseline assessment and two measurements at post-treatment. Post-treatment measurements were taken at 6 months after in-clinic nutrition counseling, along with a follow-up scheduled at 18 months after in-clinic nutrition counseling.

**DASH Intervention**

Participants were randomly assigned to either a phone based intensive DASH intervention or the hypertension routine care (usual care) intervention. The usual care intervention consisted of the typical nutrition counseling given to all new patients at the CCHMC hypertensive clinic, which included information about the DASH diet. The dietary recommendations provided were consistent with the National High Blood Pressure Education Program’s pediatric dietary recommendations, which include reducing dietary sodium and controlling weight by limiting high fat goods, reducing portion sizes and eating the nutrient-dense form of foods.

The DASH diet intervention used in this study was modified slightly from the original version designed for adults. Participants were encouraged to make their dietary changes gradually to achieve the DASH goals of eight servings per day of fruits and vegetables, three servings per day of low fat dairy foods, and two servings per day or less of DASH unfriendly foods. They recorded their dietary intakes for five out of seven days each week for the duration of the intervention; specifically they were encouraged to track their intake of fruit, vegetable, low fat dairy, and high fat, high sodium foods (called DASH unfriendly foods in the study) but not calories. DASH unfriendly foods were defined as those foods with greater than three grams of fat and 480 mg of sodium per serving. Weekly goals were set for fruits, vegetables, low-fat dairy foods, and DASH unfriendly foods. The participants received $50, $75, and $100 respectively for completing baseline, post-treatment and follow-up assessments. Participants
in the DASH intervention were awarded with additional incentives for meeting their weekly DASH goals ($2 for each goal met).

**DASH Score**

Adherence to the DASH diet for all subjects was assessed by computing an individual DASH Score for each participant. This index is based on one used by Gunther et al. with some modifications. Each participant’s DASH score was comprised of 11 component scores (total grains, whole grains, vegetables, fruit, total dairy, low-fat dairy, meat/poultry/fish/eggs, nuts/seeds/legumes, fats/oils, and sweets). The DASH score used by Gunther et al. did not divide grains and dairy into sub-components, but rather had one component score for total grains and total dairy. This was done because the DASH dietary pattern emphasizes the intake of whole grains and low-fat dairy versus the general food group.

For each of the DASH food groups, a maximum score of 10 could be assigned according to how well the individual’s intakes meet the recommendations. However, the grains and dairy components were divided further, and therefore each component had a maximum score of 5. The resulting component scores are then added together to determine the overall DASH score, ranging from 0 to 80. Table 2 summarizes the details of each component and score standards.

The DASH plan of the NHLBI provides recommendations for four different total energy intakes. In this analysis, the energy level closest to the estimated energy requirements for adolescents based on age, sex, and physical activity level was used.

<table>
<thead>
<tr>
<th>Table 2. Components of DASH index.</th>
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<tr>
<td><strong>Calorie Level</strong></td>
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<td>Calorie Level</td>
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### Data Analysis

Study participants included in this analysis were “completers”, meaning that they provided both baseline and post-treatment (6-month) data. Although 18 month follow-up data were collected, they were not considered in these analyses. For these analyses, since both intervention groups received initial information on the DASH diet plan, we considered both groups combined when addressing our main research question: is physical activity level related to adherence to a DASH diet among adolescents with hypertension participating in a dietary intervention? Means and standard deviations for all participants were derived at baseline and post-treatment for continuous variables and frequencies for categorical variables. Paired t-tests were used to compare the total DASH score and physical activity level for each participant at baseline and post-treatment. An independent t-test was used to compare total DASH scores at 6 months between participants who met versus those who did not meet the national physical activity recommendations. Regression analysis was done to identify the relationship between minutes of physical activity and total DASH score and physical activity as well as

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<td><strong>Fats, Oils</strong></td>
<td>10</td>
<td>≤2</td>
<td>≤2</td>
<td>≤3</td>
<td>≥4</td>
<td>≥4</td>
<td>≥6</td>
</tr>
<tr>
<td><strong>Sweets</strong></td>
<td>10</td>
<td>≤1</td>
<td>≤1</td>
<td>≤1</td>
<td>≥2</td>
<td>≥2</td>
<td>≥2</td>
</tr>
<tr>
<td><em><em>Sodium</em> (mg)</em>*</td>
<td>10</td>
<td>≤2300</td>
<td>≤2300</td>
<td>≤2300</td>
<td>≥3300</td>
<td>≥3300</td>
<td>≥3300</td>
</tr>
</tbody>
</table>

Intakes are servings per day unless noted otherwise. *Sodium was included in Gunther et al., but not included in the computation of the DASH score in this analysis.
each individual DASH component score adjusted for income which was previously identified as significantly related to the outcome measure. Statistical analyses were done using IBM SPSS Statistics 19 and SAS 9.2 software. P values of <0.05 were considered statistically significant.

RESULTS

At baseline, there were no significant differences between any of the participants for age, gender, race, BMI, BMI z-score, BP category, by intervention group, physical activity, total DASH score, and component DASH scores (Table 3). Family income (p=0.001) and group were included into the linear regression model due to their effect on the outcome measures.

Table 3. Mean values (SD) and number of demographic characteristics at baseline for 76 randomly assigned participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>14.64 (±2.09)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>48</td>
</tr>
<tr>
<td>Female</td>
<td>29</td>
</tr>
<tr>
<td>Race</td>
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</tr>
<tr>
<td>White</td>
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</tr>
<tr>
<td>Black</td>
<td>28</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>Family Income</td>
<td></td>
</tr>
<tr>
<td>&lt;$20,000</td>
<td>17</td>
</tr>
<tr>
<td>$20,000-50,000</td>
<td>27</td>
</tr>
<tr>
<td>$50,000-80,000</td>
<td>13</td>
</tr>
<tr>
<td>&gt;$80,000</td>
<td>17</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
</tr>
<tr>
<td>Body mass index (BMI)</td>
<td>31.19 (±9.91)</td>
</tr>
<tr>
<td>BMI z-score</td>
<td>1.64 (±0.788)</td>
</tr>
<tr>
<td>Blood Pressure category</td>
<td></td>
</tr>
<tr>
<td>Prehypertension</td>
<td>47</td>
</tr>
<tr>
<td>Stage 1</td>
<td>36</td>
</tr>
</tbody>
</table>

As a part of the DASH education provided to the participants, there was an emphasis was placed on both whole grains (+0.37, p=0.021) and low-fat dairy (+1.84, p=0.000), which both increased at the 6
month assessment. Fruits (+3.88, p=0.005) and vegetables (+5.20, p=0.000) were also emphasized, and increased more than the other components at the 6 month assessment (Table 4). Meat consistently had the highest component score, and comprised the highest percentage of the total DASH score. Whole grains increased (p=0.021), representing a larger proportion of the total gain intake. Fruits and vegetables increased the most at the 6 month assessment, followed by sweets (+1.03, p=0.029) and low-fat dairy (+0.82, p=<0.01). At the 6 month assessment, the average total DASH score increased by 5.18 points (p=<0.01) while physical activity, on the other hand, decreased by an average of 19.53 minutes per week (p=<0.01).

| Table 4. Change in mean minutes of physical activity (PA), total DASH, and individual DASH component scores. |
|-------------------------------------------------|-----------------|-----------------|-----------------|       |
| Minutes per week of PA                          | Baseline (SD)   | 6 Month (SD)    | Absolute Change | p    |
| Total DASH                                      | 36.23 (7.32)    | 41.41 (9.29)    | 5.18 (9.07)     | 0.000*|
| Total Grains                                    | 3.91 (1.02)     | 3.85 (1.04)     | -0.06 (1.17)    | 0.665 |
| Whole Grains                                    | 1.60 (1.23)     | 1.97 (1.34)     | 0.37 (1.38)     | 0.021*|
| Vegetables                                      | 3.94 (2.28)     | 5.20 (2.75)     | 1.26 (2.66)     | 0.000*|
| Fruits                                          | 2.70 (2.83)     | 3.88 (3.36)     | 1.18 (3.57)     | 0.005*|
| Total Dairy                                      | 2.57 (1.31)     | 3.21 (1.26)     | 0.64 (1.43)     | 0.000*|
| Low-fat Dairy                                    | 1.02 (1.29)     | 1.84 (1.66)     | 0.82 (1.73)     | 0.000*|
| Meat                                            | 9.46 (1.01)     | 9.55 (1.22)     | 0.09 (1.42)     | 0.566 |
| Nuts                                            | 1.06 (2.00)     | 0.86 (1.82)     | -0.20 (2.07)    | 0.403 |
| Oils                                            | 6.09 (2.86)     | 6.23 (3.06)     | 0.14 (3.46)     | 0.719 |
| Sweets                                          | 3.78 (2.97)     | 4.81 (3.75)     | 1.03 (4.03)     | 0.029*|

n=76; mean (SD);*p=<0.05; Paired t-test to compare averages for each component score. Percent of total DASH demonstrates the proportion of the total DASH score each component contributes. Percent difference refers to the difference in the proportion of the total DASH score at 6 months from baseline.

When comparing physical activity data at baseline and at 6 months, there was an average decrease in minutes per week of approximately 20 minutes (19.54 minutes, SD 393.83). However, when assessing the relative change by individual (using the average percent change), there was actually an
average increase in activity of 136% (SD 483.88) in minutes per week of physical activity. An examination of individual changes in physical activity over 6 months, for those participants who increased their physical activity, their percent increase averaged 288%, while the average percent decrease for participants that decreased their minutes of physical activity was 60%.

To compare total DASH score and physical activity level, participants were divided into those that did vs. those that did not meet national physical activity recommendations of an average of 60 minutes per day or a total of 420 minutes per week (Figure 1). Although the majority of participants did not meet national recommendations (n=52), the participants that met or exceeded national recommendations (n=24) tended to have a higher total DASH score (p<0.09). Those who accumulated less than 420 minutes per week averaged a total DASH score of 40.22 (SD 9.21), while those that did 420 minutes or more per week had an average total DASH score of 44.09 (SD 9.45, p<0.09).

![Figure 1. Independent t-test of total DASH score and PA level. p=0.088 Weekly recommendations for adolescents is 420 minutes per week (or 60 minutes per day)](image)

Included in this linear regression model were income and group, after being identified as covariates significantly correlated to the outcome measures (total DASH score and physical activity). We
adjusted for group because of the different intervention treatments in order to see if that would influence the relationship between physical activity and DASH diet adherence. Age, gender, race, BMI, BMI z-score, and BP category were not significantly related to the outcome measures (total DASH score or physical activity). Physical activity was a continuous variable in this model, not categorical. Many component scores and the total DASH score had a positive beta coefficient, representing a positive relationship between the score and physical activity, but few were of statistical significance (Table 5). The strongest relationships were found with vegetables (beta=0.267, p=0.021) and total dairy (beta=0.296, p=0.010). Although they did not meet the criteria for statistical significance in this analysis, a positive trend was observed with low-fat dairy (beta=0.192, p=0.075) and oils (beta=0.203, p=0.086). The only component became significant after adjusting for group was low-fat dairy (beta=0.208, p=0.021), meaning low-fat dairy had a stronger relationship than in the adjusted for income model, which only indicated a positive trend.

### Table 5. Relationship between physical activity and DASH scores.

<table>
<thead>
<tr>
<th></th>
<th>Adjusted for Income</th>
<th></th>
<th>Adjusted for Income and Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>SE</td>
<td>P</td>
<td>Beta</td>
</tr>
<tr>
<td>Total DASH score</td>
<td>0.138</td>
<td>0.003</td>
<td>0.212</td>
<td>0.151</td>
</tr>
<tr>
<td>Total Grains</td>
<td>0.072</td>
<td>0.000</td>
<td>0.539</td>
<td>0.069</td>
</tr>
<tr>
<td>Whole Grains</td>
<td>0.109</td>
<td>0.000</td>
<td>0.340</td>
<td>0.116</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.267</td>
<td>0.001</td>
<td>0.021*</td>
<td>0.264</td>
</tr>
<tr>
<td>Fruits</td>
<td>0.120</td>
<td>0.001</td>
<td>0.261</td>
<td>0.131</td>
</tr>
<tr>
<td>Total Dairy</td>
<td>0.296</td>
<td>0.000</td>
<td>0.010*</td>
<td>0.305</td>
</tr>
<tr>
<td>Low-fat Dairy</td>
<td>0.192</td>
<td>0.001</td>
<td>0.075†</td>
<td>0.208</td>
</tr>
<tr>
<td>Meat</td>
<td>-0.115</td>
<td>0.000</td>
<td>0.334</td>
<td>-0.114</td>
</tr>
<tr>
<td>Nuts</td>
<td>-0.144</td>
<td>0.001</td>
<td>0.229</td>
<td>-0.143</td>
</tr>
<tr>
<td>Oils</td>
<td>-0.203</td>
<td>0.001</td>
<td>0.086†</td>
<td>-0.199</td>
</tr>
<tr>
<td>Sweets</td>
<td>0.073</td>
<td>0.001</td>
<td>0.543</td>
<td>0.080</td>
</tr>
</tbody>
</table>

n=76; *=p<0.05; †=p<0.10 (trend); Linear regression model to determine relationship of physical activity to DASH scores.

**DISCUSSION**
In this study, 76 adolescents with hypertension were studied to explore whether physical activity level was related to DASH diet adoption/adherence. Participants were given instruction on the DASH diet and then followed for 6 months to track their progress on adhering to the diet. The importance of physical activity for blood pressure reduction was mentioned at the first counseling session with all patients, but no specific instructions for increasing physical activity were given to any of the participants. The results of this study provide evidence that without specific instruction, those adolescents who were more physically active had, on average, a higher total DASH score. This analysis also found modest relationships and trends with physical activity as a predictor of DASH component scores including vegetables, total dairy, low-fat dairy, and oils.

Interestingly, while the average DASH scores increased over time, the average minutes of physical activity of this group of adolescents actually decreased over the 6 month period. There are several possible explanations for this finding. The decrease in average physical activity from baseline to 6 months in this study could be due to participation on an organized athletic team. Physical activity requirements vary from in-season to off-season and from sport to sport. For those who are possibly multi-sport athletes, one sport may require more intense activities than another, accounting for the change. It is also possible that upon hypertension diagnosis, some athletes became ineligible to participate in their sport, thereby decreasing their level of training (and thus, minutes of physical activity). The average physical activity decrease could also be the result of season changes. Warmer months are generally more conducive to promoting activity, especially outdoors.

Another observation from this analysis is that the majority of participants that met the national physical activity recommendations at the 6 month assessment increased their minutes of physical activity from baseline. In addition, the average percent increase was larger than those participants that decreased their minutes of physical activity from baseline. This observation, in conjunction with the
participants who met or exceeded physical activity recommendations having higher average total DASH scores, seems to suggest that a positive relationship between physical activity and diet exits in adolescents. Considering physical activity in future studies in addition to diet goals may greatly influence future results. In this age group, physical activity levels can be highly variable, as was demonstrated here. By addressing that in the beginning, these two behaviors may provide support for the individuals who may be struggling with adopting one of the behaviors. Their success in one may give them the encouragement they need to not give up on the other. Currently, information regarding this is lacking. However, there is significant information regarding motivation for just physical activity. There is recent, consistent evidence supporting internal motives as positive predictors for participation in physical activity across a variety of populations and settings. Unfortunately, a majority of these studies have been cross-sectional, and there is a lack of truly empirical studies lasting longer than three months that investigate this relationship.

Most DASH component scores, as well as the total DASH score, increased at the 6 month assessment. While there was no change in total grain intake, there was an increase in whole grain intake. This is of note because the whole grain component score is a percentage of the total grain intake, meaning that, a greater majority of the intake was represented by whole grains. Other components emphasized by the DASH diet (low-fat dairy, fruits, and vegetables) also increased, with fruits and vegetables increasing the most in their individual component scores. This seems to indicate the participants understood and successfully incorporated the major DASH diet tenants. Many of the DASH component scores at baseline were far below the maximum score possible except for total grains, total dairy, meat, and oils. Evaluating the individual component scores and their relationship to the total DASH score can provide researchers and professionals with insight as to how the diet tenants are being received by the participants.
This analysis provides more evidence for the effectiveness of the motivational transfer theory as related to diet and physical activity. In this analysis, regardless of the intervention group, at 6 months from baseline the more physically active participants had better adherence to the DASH diet. Thus there is a trend that this theory works for either target behavior. In previous studies, the target behavior has been physical activity\textsuperscript{52}, but here the target behavior was diet related, and physical activity was used as a predictor. Although there were a fewer number of participants who met or exceeded national physical activity recommendations, that should not diminish the potential of these results. There is a trend that would indicate these two behaviors, diet and physical activity, are indeed related, although there is currently not enough evidence to determine if one behavior in fact causes the other. It does, however, provide data to suggest that these clustered health-promoting behaviors warrant being addressed together in future studies. Lippke and colleagues also investigated the relationship between different health behaviors to see how they group and if there are any behavior clusters in three distinct populations in the United States and Germany\textsuperscript{44}. These studies were conducted by telephone and internet surveys and assessed using correlational analyses, factor analyses, and cluster analyses. The authors consistently observed strong correlations between nutrition and physical activity and that success in one behavior can be used to assist changes in highly correlated behaviors like nutrition and physical activity. They stipulate it may be more useful to target interventions toward clustered behavior patterns rather than single behaviors due to the success of motivational transfer within behavior clusters.

There are both strengths and limitations to this study. In terms of strengths, this analysis uses a population of adolescents that accurately represents the racial makeup of the greater metropolitan area the participants are from. There was no statistical difference between the subjects except for income. Our participants’ average family income was representative of the greater metropolitan area the participants lived in, with the median household income being $33,681\textsuperscript{53}. 

However, a limitation of this analysis is that this study did not exclude participants based on physical activity level or based on participation on an organized athletic team. This is a limitation because some participants may have already been involved in well-established physical activity regimens (ex. high school athletic team). Physical activity level was not a factor that was controlled for because it was not the intent of the original study. The data was collected for descriptive purposes via a 7 day recall and did not delve into any previous physical activity history or identify athletes participating in sports.

In addition, there are several lifestyle factors not considered in this analysis. One of those lifestyle factors was sleep time. Physical activity and sleep patterns are known to be associated and since physical activity and diet quality seem to be related, it would not be unreasonable to group them all together as associated lifestyle factors. It seems to reason that higher diet quality promotes regular physical activity (or vice versa), which would in turn promote better sleep patterns. Better sleep patterns would result in feeling more rested and having enough energy to maintain regular physical activity and healthy eating routines. A study on the association between sleep duration and hypertension conducted by Guo et al. found that short sleep duration (sleep of <9 hours) was independently associated with hypertension (OR, 1.5; 95% CI, 1.04-2.15) in Chinese boys ages 11-14. Bansil et al. also report a relationship between hypertension and sleep, but in adults, after reviewing data from NHANES 2005-2008. Their study found that hypertension in adults is associated with sleep disorders, short sleep, and poor sleep (OR, 1.84; 95% CI, 1.13-2.98), but at this time there are no prospective studies investigating this relationship. This would be an interesting area for further studies to explore how these behaviors are related. Physical activity should also be considered at the beginning of future interventions. Because physical activity is highly variable among the adolescent population, it may determine the response to the intervention. By promoting both physical activity and a healthy diet
pattern (like DASH), it may encourage the participant to not give up if they are struggling with one of the behaviors.

Even with the limitations, the major implication of this study is that one healthy behavior may have the ability to influence another and contribute to an overall healthy lifestyle. Future investigations should investigate how to appropriately combine physical activity into established, successful DASH interventions in order to maximize potential heart healthy benefits.

CONCLUSION

The results from this analysis provide support that physical activity level may relate to diet adherence among adolescents. There was a strong trend for those participants who are more physically active to have better total DASH scores, representing better diet adherence than those with lower levels of physical activity.

References

3. JNC 7
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