I, Bekah Lee, 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 Sleep Duration and Compliance to the DASH diet in Adolescents with High Blood Pressure

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Committee member: Abigail Pear's, Ph.D.
The Relationship between Sleep Duration and Compliance to the DASH diet in Adolescents with High Blood Pressure

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 Nutrition of the College of Allied Health by

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ABSTRACT

Purpose: To investigate the relationship between sleep duration and compliance to the Dietary Approaches to Stop Hypertension (DASH) diet in adolescents with high blood pressure.

Subjects: One hundred and eleven adolescents between 11-18 years of age with diagnosed pre-hypertension or stage 1 hypertension were enrolled in the DASH-4-Teens randomized clinical trial at the Cincinnati Children’s Hypertension Center located at Cincinnati Children’s Hospital Medical Center (CCHMC).

Methods: Subjects were randomly assigned to one of two groups: the DASH-4-Teens intervention group (n=57) or the usual care group (n=54). Only participants that had completed both baseline and 6 months (post-intervention) study assessments were included in this study. Both groups received dietary counseling on the DASH diet, including strategies to increase consumption of fruits, vegetables and low fat dairy foods and decrease consumption of sodium and fat. The DASH-4-Teens intervention included telephone based behavioral counseling and individualized treatment goals. The usual care group did not receive behavioral counseling nor were treatment goals individualized. Sleep duration was measured by 7-day recall and averaged. Dietary intake was measured by 3-day food recall and averaged. Servings of daily food groups, and sodium intake were calculated from Nutrition Data Systems Software output files and a DASH index score was derived according the method of Gunther et al [68]; a high score indicated greater adherence to the DASH diet. Multiple regression models were used to evaluate the association between sleep duration (categorized as less than recommended, recommended, and more than recommended based on hours of sleep recommended by the National Sleep Foundation [27]) and adherence to the DASH dietary pattern, measured by the change in a
DASH score from baseline to 6 months. Statistical significance was defined as $P < 0.05$ and data analysis was conducted using SAS version 9.2 (SAS Inc., Daly, NC, USA).

Results: Only 1/3 of the study participants met the recommended number of hours of sleep/day, with over half getting more than 10 hours of sleep per day. In this sample, there was no significant relationship between sleep duration and adherence to a DASH dietary pattern.

Conclusion: There is evidence from prior research to suggest that sleep deprivation is associated with increased appetite and hunger, suggesting a possible role in diet quality modification. Findings from the present study suggest that sleep duration was not related to compliance to a DASH dietary pattern among teenagers who completed a six-month dietary intervention focused on the DASH diet.
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I. INTRODUCTION

Currently, the increase in the prevalence of obesity-related hypertension in adults is reflected equally in the pediatric population. In 2000, approximately one billion people, a quarter of the adult population, were diagnosed with high blood pressure worldwide and by 2025 this number is predicted to increase to approximately 1.5 billion people [9]. With the recent augmentation in hypertension, various pediatric health behaviors such as dietary sodium intake are under study in an effort to prevent this condition from tracking into adulthood and contributing to related chronic conditions such as heart disease, congestive heart failure, stroke, and chronic kidney disease [67]. Recently, several well designed studies point to a positive influence of sleep deprivation on intake of unhealthful foods and obesity leading to the prediction among health experts that sleep patterns may influence overall diet quality, which in turn may lead to weight gain and associated adverse health conditions, e.g. hypertension. The following review of the literature will examine the relationship between pediatric sleep duration, dietary quality and hypertension, and point to a paucity of evidence in this area and the need to do the present study.
II. LITERATURE REVIEW

IIa. Hypertension

In the U.S, approximately one in every three adults, roughly 68 million people, have high blood pressure and nearly 1,000 deaths per day are high blood pressure-related diseases. [41,42]. Hypertension is also responsible for 7.6 million premature deaths, and it is also the second leading cause of disability worldwide [9]. Hypertension in adults is defined as having mean systolic BP > 140 mm Hg, or having mean diastolic BP > 90 mm Hg [24]. Many hypertensive individuals are unaware of the consequence of this major risk factor for heart disease and stroke. This unawareness results in about 36 million people not getting the proper treatment for raised blood pressure, most of them not realizing they have the condition [41]. According to the data obtained by the Center for Disease Control and Prevention (CDC), the prevalence of hypertension with age-adjustment among U.S. adults 18 and older was 28.6% in 2009-2010, which did not differ significantly from the 29.7% obtained in 2007-2008 [23].

The problem of hypertension is also detected in the younger generation, who may not realize that it is a major threat to their future health. High blood pressure in children and adolescents is defined differently from the adult definition of hypertension because it is based on the correspondence of age, gender, and height to a standardized table of blood pressure values set by the CDC and the National Heart, Lung, and Blood Institute (NHLBI) [3,23]. According to the CDC standards for children and adolescents, prehypertension is defined as having a blood pressure ≥ 90th percentile, but < 95th percentile based on age, gender and height measurements, and hypertension is defined as having blood pressure ≥ 95th percentile [3]. Ideal blood pressure levels are important during childhood because optimum cardiovascular health in adulthood is greatly depended on the achievement and maintenance of a healthy blood pressure level
throughout life. High blood pressure accounts for 62% of all strokes and 49% of all coronary-related deaths each year [9]. Research has shown that untreated pediatric hypertension tracks into adulthood and is associated with the development of heart disease, stroke, kidney disease and eventually to premature death [3,9,45,67].

IIb. Association between Obesity and Hypertension

A major risk factor for hypertension is overweight and obesity. Child overweight and obesity status is assessed using the BMI-percentile standards controlled for age and gender set by the CDC. Overweight is defined as having a BMI percentile of ≥ 85th percentile and < 95th percentile; obesity is defined as having a BMI ≥ 95th percentile [23]. In 2009-2010, approximately 34% of adolescents between 12-19 years of age were considered overweight or obese in the U.S. [23]. Globally, more than 1.5 billion people are overweight and obese and over 40 million children under the age of 5 are overweight [22]. Available evidence suggests that hypertension is noted as the most prevalent condition among obese populations and obesity-related diseases; weight loss has been shown to be associated with lowering blood pressure [22,24,67].

There is substantial evidence that obesity is linked to hypertension. An analysis of data from the National Health and Nutrition Examination Survey (NHANES) for years 1999-2004, that sampled 13,745 men and women, concluded that the odds ratio for hypertension in overweight individuals was 1.7 times greater compared to normal weight individuals, and the odds ratio increased in increments of 1-1.2 as the level of obesity increased [24]. The National Health and Nutrition Examination Survey (NHANES) III, conducted from 1988 to 1994, showed a strong association between BMI and hypertension; this association was corroborated in the NHANES 1999-2004 with the finding that the prevalence of hypertension in adults increased
with increasing body mass index [24]. Association between overweight or obesity with prehypertension or hypertension was also observed in the NHANES 1999-2008 study of U.S. adolescent population aged 12 to 19 years when prevalence of hypertension, one of the CVD risk factors, were stratified by weight status of subjects [23].

With the consistent, strong association between obesity and hypertension, many experts predict that the current generation of overweight and obese children may have a shorter lifespan than the previous generation [22]. Yet, a recent study that included a follow-up of 23 years consisting of 6,328 subjects stated that if childhood obesity were treated or reduced, adult CVD risk could be reduced [22]. In this particular prospective cohort study, measurements of childhood and adult BMIs were assessed in a 23 year follow-up and risks factors for CVD. Those that reported being obese or overweight during childhood, but were no longer obese as adults, had similar CVD risks as those individuals who were never obese [22]. Therefore, it is crucial that childhood obesity is treated to prevent hypertension, which can in turn lead to increased risk of morbidity and mortality into adulthood.

The etiology of obesity at any age is considered by most health experts to be multifactorial; many factors such as changes in food intake, health behaviors, environment, and genetics likely interact and relate to the development of this major public health problem [10,67]. Most experts recommend that regardless of age, weight loss should be the cornerstone in treating obesity and related health complications including hypertension [22,67].

IIc. Association between Diet Quality and Hypertension

Experts have explored many different dietary factors in relation to blood pressure. Most recently, fruits and vegetables have been researched to assess whether high intake of these foods is associated with lower blood pressure. Fruit and vegetable consumption has been examined in
multiple studies as a weight loss strategy due to their higher fiber content, which lends satiety to the diet, and their potential use as a replacement in the diet for energy-dense foods with fewer calories [47]. Relative to blood pressure management, hypothetically, if fruits and vegetable consumption could help adolescents lose weight, their blood pressure may be favorably altered.

A longitudinal study focusing on pediatric blood pressure revealed that children who consume more than 4 servings per day of fruits and vegetables had smaller gains of blood pressure throughout childhood than those who consumed less [46]. Similarly another study conducted with adolescents showed that those who ate more fruits and vegetable (≥ twice daily) had a lower systolic blood pressure (SBP) /diastolic blood pressure (DBP) than those who ate less [47]. While these studies support a beneficial role of fruit and vegetable consumption on blood pressure control, they failed to address whether fruit and vegetable consumption mediates blood pressure by modifying body weight. To date, this question has not been addressed.

Higher intakes of fruits and vegetables may contribute to blood pressure lowering by providing a mix of vitamins and minerals that serve as antioxidants; these in turn can reduce markers of inflammation and oxidative stress such as C-reactive proteins (CPR) and interleukin-6 (IL-6), which participate in the development of atherosclerotic plaques in the blood [43]. These oxidative stress biomarkers are known to be associated with visceral fat accumulation, metabolic disturbances and arterial dysfunction, which could affect blood pressure [43,46,47,48,49]. Also, fruit and vegetable consumption has been shown to positively affect pulse wave velocity, which is a measure for arterial stiffening that affect blood pressure [49]. Therefore, great consumptions of fruits and vegetables may favorably alter the structure and function of blood vessels, and therefore beneficially modulate blood pressure [43,46,47,48,49]. Fruits and vegetables are high
in potassium. High intakes of this nutrient may result in sodium and water diuresis and participate in blood pressure lowering, especially with high sodium intakes [69,70,71].

Dairy products have also been shown to favorably influence blood pressure [46,50,51]. The QUALITY Cohort study conducted by Yuan et al. found that high dairy intake (≥ 2 servings per day) was associated with 1.74 mm Hg lower SBP and 0.87 mm Hg lower DBP in preadolescent children compared to lower intakes [50]. A cohort study of children assessed at 18 months and again at 9 years of age showed that children who met recommended intakes of dairy (≥ 2 servings per day) had a lower age-associated increase in DBP, compared to children that failed to meet the dairy recommendations [51]. Both studies support beneficial effects of meeting the recommended amount of dairy foods per day dairy products on blood pressure in youth.

Many studies have been done on sodium intake and blood pressure and the majority show an adverse effect of the mineral on vascular health [56,57,58,59,60]. National nutrition data indicate that the average sodium consumption is well above recommended levels in both normotensive and hypertensive adults and children [3,45,46]. An examination of the NHANES 2003-2008 data found that children and adolescents consumed an average of 3387 mg of sodium per day, which is about 1000 mg more than the daily recommendations for children and adolescents, determined by the 2010 Dietary Guidelines for Americans [3,]. A review analyzing a collection of over 20 observational studies demonstrated that with increased intake of sodium, increased blood pressure was evident and a meta-analysis of 10 randomized-controlled trials revealed that a reduction in sodium intake in children was associated with significant reduction in blood pressure [3,58,59,60]. These studies provide strong evidence that high sodium intake is a risk factors for hypertension in children and that lowering dietary sodium intake is beneficial relative to blood pressure modification. Given that many children and adolescents are exceeding
recommended levels of sodium, public health efforts should be directed toward sodium reduction in youth [3,46,59,60].

The Dietary Approaches to Stop Hypertension (DASH) dietary pattern was aimed to lower blood pressure in hypertensive individuals [67]. The DASH dietary pattern consists of a diet rich in fruits and vegetables (8–10 servings/d), rich in low-fat dairy products (2–3 servings/d), and reduced in saturated fat and cholesterol; this included increased intakes of whole grains, poultry, fish and nuts; and reduced intakes of fats, red meat, sweets, and sugar-containing beverages [67]. A nutrient analysis of the DASH diet showed that this pattern is rich in potassium, magnesium, calcium, and fiber and is reduced in total fat, saturated fat, and cholesterol [67]. Previous research showed that the DASH diet significantly lowered BP in many subgroups including men, women, blacks, non-blacks, hypertensive individuals, and non-hypertensive individuals compared to a Westernized diet [67].

The DASH diet has also been shown to lower BP in children and adolescents. Data on 2185 adolescent girls in the National Heart Lung and Blood Institute's Growth and Health Study with a follow-up of over 10 years studied a diet pattern similar to that of DASH to evaluate the risk of elevated blood pressure. The analysis revealed that girls who consumed ≥ 3 servings of fruits and vegetables per day and ≥ 2 servings of low-fat dairy products per day had a 36% lower risk of elevated BP in late adolescence than those who consumed less fruits, vegetables and dairy [52]. Couch et al., conducted a randomized clinical trial examining the effect of a behavioral nutrition intervention program emphasizing the DASH diet on lowering blood pressure in hypertensive adolescents compared to usual hospital-based nutrition care [8]. The DASH diet emphasized in the intervention was slightly modified from the original version for adults to cover all the requirements for adolescents. In this study, adolescents in the DASH intervention received
both face-to-face counseling on a DASH-like diet pattern as well as telephone and mail counseling and adolescents in the Usual Care (UC) group were only recommended to implement healthy eating habits. The results showed that the systolic BP z-score in adolescents in the DASH group was reduced by 58% and by post-treatment 50% of the DASH group had achieved normal BP levels compared to 36% in the UC group [8]. Although the mechanism by which the DASH diet contributes to blood pressure lowering is not clear, researchers suspect that the food combination contains key nutrients that work synergistically to reduce blood pressure in adolescents and adults alike.

IId. Association between Sleep and Factors that May Alter Blood Pressure

Current research states that shorter sleep duration is linked to increased blood pressure [20]. The National Sleep Foundation and the CDC document that the amount of sleep individuals engage in daily changes throughout one’s lifetime and tends to decrease with age, ranging from 12-18 hours in newborns to 7-9 hours in adulthood [26,27,28,29]. Although duration of sleep may vary among individuals, the National Sleep Foundation recommends 8.5-9.25 hours of sleep per night to teenagers aged 10-17 years [27]. These recommendations were set to ensure that basal sleep needs are met, which is the amount of sleep needed by one’s body regularly for optimal performance. In adults, the range of recommended basal sleep is 7 to 8 hours every night [61]. These recommendations have not been justified empirically [54].

Despite the National Sleep Foundation’s recommendations, adolescents are not meeting the recommendations for sleep duration [44] Lack of sleep may have health implications in youth, as several studies showed that sleep deprivation is associated with hypertension [20,21,62,63,64]. A recent analysis of NHANES-I data found that short sleep duration was associated with a 60%
higher risk of hypertension in middle-aged Americans (32 to 59 years old) without sleep disorders [20] than in those who obtain adequate amounts of sleep.

In some cases curtailment of sleep has been shown to be the sole factor in elevated blood pressure and sympathetic activity in both hypertensive and normotensive subjects [20,21]. The mechanism for an association between sleep and blood pressure has yet to be elucidated, but one potential pathway suggested by researchers is that shortened sleep may raise the average 24-hour blood pressure and heart rate via a longer exposure to elevated sympathetic nervous system (SNS) activity, which occurs in longer awake time [20, 21]. It is suspected that this elevation in SNS activity keeps the physical and psychosocial “stress signals” on for longer duration. When these “stress signals” persist for a long period of time, they have been shown to increase salt appetite and suppress renal salt-fluid excretion, which would increase the amount of sodium in the body through retention and intake [21]. Other mechanisms linked to sleep deprivation include over-activity of the renin-angiotensin-aldosterone system, pro-inflammatory activity, endothelial dysfunction and renal impairments [20,21]. Further exploration of these proposed mechanisms is needed.

Growing evidence supports the notion that shorter sleep duration is a risk factor for weight gain and obesity. The link between getting less sleep and weight gain may be related to an increased caloric intake in short sleepers, which has been documented in multiple studies [2,5,6,10,13,14]. With sleep curtailment, hormonal changes related to the appetite take place, including increasing ghrelin and reducing leptin, which lead to increased appetite. In a study conducted by Weiss and colleagues, it was observed that adolescents with mean sleep duration of less than 8 hours had a 2.7% higher proportion of energy derived from dietary fats and were 2.1 times more likely to consume high caloric foods from snacks than those with sleep duration of
greater than 8 hours [15]. Shorter compared to longer sleep duration was associated with higher consumptions of calories from snacks among adolescents in several studies [5,15]. These findings suggest that decreased sleep is a risk factor for increased caloric intake, which may lead to weight gain. Increase caloric intake may be influenced by changes in appetite regulating hormones (leptin and ghrelin), stimulating the body to increase consumption, especially for high-caloric foods [15].

Sleep is essential in the control of two hormones secreted from the hypothalamus that affect appetite and hunger: ghrelin and leptin [44]. Leptin, the satiety signaling hormone, is derived from adipocytes and inhibits hunger and food intake, increases energy expenditure and promotes fat utilization [2]. Leptin levels decrease during fasting and increase after a meal [2]. This in contrast to ghrelin, the hunger signaling hormone, which is predominantly derived from the stomach and acts to stimulate hunger and food intake, reduce energy expenditure, and promote fat retention [2]. Ghrelin levels increase before meal time and decrease after a meal. In humans, leptin and ghrelin are inversely correlated throughout the day; however, studies have shown that for those with deprivation of sleep this relationship is altered due to metabolic dysregulation [1].

In a randomized cross-over study, daytime leptin and ghrelin were assessed after two nights of 4 hours of sleep and again after two nights of 10 hours of sleep in similar environmental conditions. The result obtained indicated a decrease of leptin level by 18%, an increase of ghrelin level by 28% and an increase in the ghrelin/leptin ratio by more than 70% when comparing levels after 10 hours versus 4 hours of sleep per night [2]. This study also showed that about 70% of the variance in hunger was due to the change in the ghrelin/leptin ratio. These findings highlighted the significant negative effect that sleep loss has on leptin and ghrelin
Evidence suggests that short sleep duration increases the likelihood of obesity; changes in hypothalamic hormones induced by sleep deprivation suggest that modification in the ghrelin/leptin ratio may be a contributing factor related to increasing appetite and related weight gain [21].

Another hormone that may be related to reduced sleep hours is cortisol. In a study conducted by Van Cauter et al., sleep deprivation was associated with an increased subjective rating of hunger and appetite, especially morning cravings for high-fat, high-carbohydrate foods [15]. Increased cortisol and SNS activities were observed in those with fewer hours of sleep per night compared to those with more. Researchers suggest that sleep deprivation has a negative feedback influence on the hypothalamus and pituitary gland, which stimulate food intake [64]. Peptide YY (PYY) is a gut peptide that has been observed to inhibit appetite and levels vary inversely with ghrelin over a 24-hour period. Although this peptide has not been assessed in sleep-related research, the relationship with ghrelin may suggest that sleep could potentially have an effect on altered levels of this peptide, and consequently on appetite [2].

Researchers have also observed an association between short sleep duration and poor diet quality. Several studies have documented that individuals that sleep for shorter periods of time at night compared to those who sleep more had higher intakes of carbohydrates, fats, sodium, and lower intakes of vegetables and fruits, along with irregular eating patterns overall [6,7,14]. Additionally, higher fat intake was associated with less sleep in postmenopausal women [18], as well as in American adolescents ages 16-19 years old [15,16]. Interestingly, in the study of the American adolescents, the association between shorter sleep duration and higher intake of fat was significant in girls but not in boys [15].
Recently, Krueger et al. examined the association between diet quality and sleep duration [53]. These researchers found that adolescents with fewer sleep hours had lower odds of consuming fruits and vegetables, and greater odds of consuming fast food compared to adolescents who slept more [53]. Among female students in Iran, researchers have recently shown that consumption of fruits, whole grains and beans was lowest among short sleepers compared to those who slept for longer duration [6]. In this same study, the lowest mean intake of nutrients including niacin, vitamin C, and vitamin B12 were observed in the sleep deprived individuals compared to those who got adequate sleep [6]. Although little data is available examining the association between diet quality and sleep in adolescents, available studies provide evidence that shortened sleep duration is associated with making poor dietary choices.

IIe. Gaps in the Literature

Several researchers have studied the effects of sleep in relation to diet quality. However, most of the research that has been done to-date is in older age groups with under-powered studies. There is a paucity of research on sleep and diet quality in the adolescent population. Given the increasing demands from school, sports and family for this age group, data point to many adolescents not meeting the recommendation for number of hours of sleep per day [73]. In adults, sleep deprivation is associated with poor diet quality, increased weight status and elevated blood pressure. These same relationships need further investigation in youth. Furthermore, no studies have examined the influence of sleep patterns on changes in diet quality associated with a dietary intervention targeted toward at risk youth. It would be useful to understand the relationship between sleep and diet quality measures as they changed through dietary intervention to determine whether sleep is a factor that needs to be accounted for in statistical models examining associations between change in diet and health outcomes in youth.
This thesis will help to fill this gap by examining the relationship between sleep duration and changes in diet quality associated with a nutrition intervention conducted to improve blood pressure in adolescents with hypertension.

IIf. Purpose

The purpose of this thesis was to study the relationship between sleep duration and change in diet quality as measured by DASH index among adolescents with prehypertension or hypertension who completed a 6 month intervention emphasizing the DASH diet for blood pressure control.

IIg. Hypothesis

Adolescents with prehypertension or hypertension who meet the recommended number of hours (9-10 hours) of sleep per night will have a greater positive change in diet quality (greater improvement in DASH score index) compared to adolescents who do not attain the recommended number of hours of sleep (either < 9 hours or >10 hours).

III. METHODS

IIIa. Participants

All participants included for this research study were selected from the total participant population enrolled in the ongoing DASH-4-Teens dietary intervention being conducted at the Cincinnati Children’s Hospital Medical Center (CCHMC) located in Cincinnati, Ohio by SC Couch and colleagues. The age range of the participants for this study was 11-18 years. All participants had diagnosed pre-hypertension or stage 1 hypertension. Physician and Institutional Review Board approval was required for participation in the study. All subjects under the age of 18 were required to sign an assent form and their parents signed an informed consent prior to
their participation in the program. Subjects ≥ 18 years of age signed an informed consent prior to study participation.

Exclusion criteria for the study included having stage 2 hypertension, taking medication that altered blood pressure levels, not being able to speak English, and having a diagnosed eating disorder that may influence their eating habits. Participants who were already enrolled in a diet counseling program were also excluded from the study as were those with secondary hypertension.

All participants were randomly assigned to either the DASH-4-Teens intervention group or the usual care group. Study groups were matched for age, gender, race and hypertension status. Study participants were assessed at baseline, 6 months, and 18 months for dietary intake and health status. For this sub-study (thesis), only data for subjects that completed both baseline and 6 months assessments were considered.

**IIIb. Intervention**

The goal of the DASH-4-Teens intervention was to alter adolescent’s blood pressure via having them modify their dietary pattern to include a greater number of servings of fruits, vegetables, and low fat dairy products while decreasing dietary fat and sodium. The DASH-4-Teens program was slightly modified from the original DASH dietary pattern for adults, to ensure participants met the dietary requirements for their age group. Participants were randomly assigned to the DASH-4-Teens intervention or the usual care intervention. Both groups included counseling from a trained registered dietitian to develop a DASH-like dietary pattern consisting of 8 servings of fruits and vegetables per day, 3 servings of low fat dairy per day and 2 servings or less of foods high in fat and sodium per day (goal was to enable participants to choose foods
with < 3g fat and/or 480mg of sodium per serving). Both interventions provided a 60 minute face-to-face counseling session in the hypertension center with the participant.

Participants received different instructional and follow-up approaches depending on their randomization assignment. Participants randomized to the DASH-4-Teens group received a 10 module, illustrated manual containing individualized dietary instructions on the DASH diet, which was reviewed during the clinic visit, whereas the usual care group received a pamphlet on the DASH diet and general guidelines for dietary approaches to lower blood pressure with no individualized instruction. During the follow-up, participants in the DASH-4-Teens group received a weekly phone call from a registered dietitian for 8 weeks, followed by 7 biweekly calls. These calls provided dietary instruction, guidance in setting weekly DASH dietary goals and in action planning towards reaching goals. The calls also provided other behavioral strategies toward promoting DASH dietary adherence such as meal planning, self-rewarding, and handling high risk situations. After every call, participants received educational material related to the content of the call via the mail. Also self-monitoring dietary booklets (trackers) were provided to participants to keep track of their dietary goal achievements. Participants set 4 DASH food related goals each week. Participants were awarded monetary incentives ($1 per goal met), based on the level of compliance to the dietary goals.

The usual care group received the usual dietary advice provided to all new hypertensive patients at the Cincinnati Children’s Hospital Medical Center (CCHMC) hypertension clinic. This included one counseling session with the dietitian and print material summarizing the national dietary guidelines to lower blood pressure. Food tracking was not requested and no behavioral phone calls or follow-up print materials were made available as is standard care at
Both groups received instruction on the DASH dietary pattern as part of their respective interventions.

IIIIc. Measurements

Blood Pressure

For eligibility into the study, patients had to have diagnosed pre-hypertension or stage 1 hypertension, which was based on blood pressure measurements taken three times on 3 different days. At study assessments, blood pressures were taken 3 consecutive times on one day after the participant had rested for 5 minutes. Blood pressures were taken according to standard pediatric guideline [65] using an appropriate size cuff with a clinical sphygmomanometer. Pre-hypertension was defined as having blood pressure level ≥ 90th percentile but < 95th percentile based on the gender, age and height of the subject. Stage 1 Hypertension was defined as having a blood pressure level of ≥95th percentile but <99th percentile + 5 mmHg based on the gender, age and height of the subject.

Anthropometrics

Measurements were taken for height using a wall mounted stadiometer and for weight using a calibrated triple-beam balance scale, both located at the CCHMC hypertension clinic. The height and weight were used to calculate the Body Mass Index (BMI), defined as weight in kilograms divided by height in meters squared (BMI = weight (kg) / [height (m)]². BMI z-scores were calculated using the growth chart provided by the Center for Disease Control for children and teens [24].

Sleep Hours

A 7-day physical activity recall was collected from all participants by a trained research assistant. As part of this recall, each subject was asked about their bed-time and their wake-up
time over the last 7 days working backward from the present day through the past 7 days. This method of recalling physical activity and sleep has been validated by others [66]. In order to obtain the average number of hours for sleep time, the number of sleep hours for the week was summed up and divided by 7, giving average daily sleep duration. Only bedtime hours were obtained; naptimes were not included in the data collection or in these analyses.

**Dietary Intake Assessment**

Dietary intake was obtained via three random 24-hr dietary recalls, 2 of which were done on weekdays and 1 on a weekend. Participants were instructed to use food portion size models to aid in the reporting of food portions more accurately, which were reported through telephone interviews administered by trained registered dietitians (RD) at CCHMC. RDs collecting the dietary data were blinded to participant intervention groups to minimize recording bias. Dietary data were analyzed for average caloric intake, overall nutrient quality, and average daily servings of fruits, vegetables, regular and low fat dairy products, meats, nuts/seeds/legumes, fats/oils and sweets.

**Diet Quality**

Change in diet quality was measured by the change in DASH score index from baseline to 6 months. The DASH score index was calculated by the measurements of 8 different food components assessed through the dietary intake assessment completed by the subjects. The 8 components included grain, fruits, vegetables, dairy, meat, nuts/seeds/legumes, fats/oils and sweets and sodium. Goals of intake for each food group were based on recommendations specified by the Dietary Guidelines for Americans [19], the DASH Collaborative Research Group [38], and on calorie levels specific for age, gender, and sedentary activity level [39]. A maximum score of 10 was achieved within each food group when a teen’s intake met the food
group recommendation, whereas lower intakes were scored proportionately. If lower intakes were favored by the dietary recommendation, reverse scoring was applied and a score of 0 was applied to intakes >200% of the recommended upper level. The resulting food group component scores were totaled to create an overall DASH Score, which ranged between 0 and 90, with a higher score indicating a higher diet quality.

III.d. Statistical Analysis

Participants that had completed both the baseline and 6 month study assessments were included in these analyses. Means and standard deviations were derived for continuous variables and frequencies were calculated to summarize categorical variables. Comparisons between sleep duration categories were made for DASH score and DASH component scores using analysis of covariance. Multiple linear regression models were generated to evaluate the association between the independent variable (sleep hours) and the dependent variable (change in DASH score index). Models were adjusted for age, gender, race, intervention group, parent income, participant BMI z-score, and hypertension status. The statistical significance used for this study was p<0.05 with the use of SAS version 9.2 for data analysis (SAS Inc., Daly, NC, USA).

IV. RESULTS

IVa. DASH-4-Teen Participant Characteristics at Baseline

The present study included 111 adolescents who completed either the DASH-4-teens (n=57) or usual care (n=54) intervention. Completion of the intervention was defined as participating in both the baseline and post-intervention (6-month) study assessments. Study participants were between the ages of 11 to 18 years (Table 1). Over 60% of the participants were white males with pre-hypertension status. The percentage of adolescents sleeping less than the recommended number of hours (<9hrs), the recommended number of hours (9-10hrs), and
more than the recommended number of hours (>10rs) was 12.6%, 32%, and 55.3%, respectively.

Additional participant characteristics are listed in Table 1.

**Table 1. DASH-4-Teens Participant Characteristics at Baseline (n=111)¹**

<table>
<thead>
<tr>
<th>Participant Characteristic</th>
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<tr>
<td><strong>Gender, n(%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>69</td>
<td>(62.2)</td>
</tr>
<tr>
<td>Females</td>
<td>42</td>
<td>(37.8)</td>
</tr>
<tr>
<td><strong>Intervention, n(%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DASH-4-Teens</td>
<td>57</td>
<td>(51.4)</td>
</tr>
<tr>
<td>Usual Care</td>
<td>54</td>
<td>(48.7)</td>
</tr>
<tr>
<td><strong>Race, n(%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>67</td>
<td>(60.4)</td>
</tr>
<tr>
<td>Other</td>
<td>44</td>
<td>(39.6)</td>
</tr>
<tr>
<td><strong>Hypertension Status, n(%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-hypertension</td>
<td>63</td>
<td>(56.7)</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>48</td>
<td>(43.2)</td>
</tr>
<tr>
<td><strong>Income, n(%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; $20,000</td>
<td>25</td>
<td>(22.7)</td>
</tr>
<tr>
<td>$20,000-$50,000</td>
<td>41</td>
<td>(37.3)</td>
</tr>
<tr>
<td>$50,000-$80,000</td>
<td>21</td>
<td>(19.1)</td>
</tr>
<tr>
<td>&gt;$80,000</td>
<td>23</td>
<td>(20.9)</td>
</tr>
<tr>
<td><strong>Age, years, mean (SD)</strong></td>
<td>14.55</td>
<td>(2.0)</td>
</tr>
<tr>
<td><strong>BMI z-score, mean (SD)</strong></td>
<td>1.83</td>
<td>(0.8)</td>
</tr>
<tr>
<td><strong>Sleep Time, n(%)²</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than Recommended</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep &lt; 9hrs.</td>
<td>13</td>
<td>(12.6)</td>
</tr>
<tr>
<td>Recommended hours²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep 9-10hrs.</td>
<td>33</td>
<td>(32.0)</td>
</tr>
<tr>
<td>More than Recommended</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep &gt; 10hrs.</td>
<td>57</td>
<td>(55.3)</td>
</tr>
</tbody>
</table>

¹All values are n(%) unless otherwise indicated
²Recommended hours derived from averages obtained from standard sleep charts provided by various health institutes [26,27,28,29]
DASH= Dietary Approaches to Stop Hypertension
BMI= Body Mass Index

IVb. Changes in DASH score indices by sleep groups
Table 2 shows a comparison of mean change in DASH score and DASH component scores from baseline to post-treatment by sleep duration group. Although, DASH score and most DASH component scores were modified in a favorable direction (e.g., increased) across groups from pre to post-intervention, the sleep groups did not differ from each other with respect to change in DASH score or component score after adjustment for age, gender, race, intervention group, parent income, participant BMI z-score, and hypertension status.

Table 2. Changes (6-month-baseline) in DASH score and DASH component scores of intervention completers by sleep duration groups

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Sleep time &lt; 9hr Less than Recommended hours (n=13)</th>
<th>Sleep time 9-10hr More than Recommended hours (n=33)</th>
<th>Sleep time &gt; 10hr More than Recommended hours (n=57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in DASH score</td>
<td>3.71 ± 15.8</td>
<td>6.31 ± 15.2</td>
<td>4.22 ± 14.0</td>
</tr>
<tr>
<td>Change in sodium score</td>
<td>-0.24 ± 6.0</td>
<td>0.40 ± 5.5</td>
<td>0.12 ± 4.4</td>
</tr>
<tr>
<td>Change in vegetable score</td>
<td>1.39 ± 3.2</td>
<td>1.16 ± 3.2</td>
<td>1.19 ± 3.3</td>
</tr>
<tr>
<td>Change in fruit score</td>
<td>1.16 ± 4.1</td>
<td>1.59 ± 3.9</td>
<td>0.79 ± 3.8</td>
</tr>
<tr>
<td>Change in low fat dairy score</td>
<td>0.85 ± 1.7</td>
<td>0.64 ± 2.1</td>
<td>0.83 ± 1.8</td>
</tr>
<tr>
<td>Change in meat score</td>
<td>-0.59 ± 2.1</td>
<td>-0.16 ± 1.1</td>
<td>-0.39 ± 2.6</td>
</tr>
<tr>
<td>Change in oil and fat score</td>
<td>-0.68 ± 5.0</td>
<td>0.34 ± 5.0</td>
<td>0.28 ± 5.3</td>
</tr>
<tr>
<td>Change in sweets score</td>
<td>0.58 ± 3.8</td>
<td>1.28 ± 5.4</td>
<td>1.10 ± 5.1</td>
</tr>
</tbody>
</table>

1 All values are mean ± SD (n=111)
2 Adjusted for age, gender, race, intervention group, parent income, participant BMI z-score, and hypertension status
3 Recommended hours derived from averages obtained from standard sleep charts provided by various health institutes [26,27,28,29]

No significant differences between groups for any of the dependent variables.

IVc. Associations between sleep duration and change in diet quality

The results of the multiple linear regression analyses examining the associations between sleep duration and change in DASH score and DASH component scores can be found in Table 3. The table contains the model estimates and standard errors for the analysis of the association between more versus less sleep duration and change in diet quality as measured by change in
DASH score and component scores. No significant relationships were detected between category of sleep duration and changes in DASH score or component scores.

**Table 3.** Associations between sleep duration and change in DASH score and DASH component scores among intervention completers

<table>
<thead>
<tr>
<th>Independent Outcomes</th>
<th>Sleep time &gt; 10hr vs. Sleep time 9-10hr</th>
<th>Sleep time &lt; 9hr vs. Sleep time 9-10hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommended hours(^3)</td>
<td>Recommended hours(^3)</td>
</tr>
<tr>
<td>Change in DASH score</td>
<td>5.69 (3.98) 0.16</td>
<td>2.22 (2.74) 0.42</td>
</tr>
<tr>
<td>Change in sodium score</td>
<td>1.11 (1.31) 0.40</td>
<td>0.91 (0.90) 0.32</td>
</tr>
<tr>
<td>Change in vegetable score</td>
<td>-0.34 (1.02) 0.74</td>
<td>-0.83 (0.70) 0.24</td>
</tr>
<tr>
<td>Change in fruit score</td>
<td>0.68 (1.03) 0.51</td>
<td>0.53 (0.70) 0.45</td>
</tr>
<tr>
<td>Change in low fat dairy score</td>
<td>0.68 (0.46) 0.14</td>
<td>0.05 (0.32) 0.87</td>
</tr>
<tr>
<td>Change in meat score</td>
<td>0.05 (0.67) 0.94</td>
<td>-0.01 (0.46) 0.99</td>
</tr>
<tr>
<td>Change in oil and fat score</td>
<td>1.84 (1.38) 0.19</td>
<td>0.99 (0.94) 0.30</td>
</tr>
<tr>
<td>Change in sweets score</td>
<td>1.60 (1.40) 0.26</td>
<td>-0.16 (0.96) 0.87</td>
</tr>
</tbody>
</table>

\(^1\)All values are estimate (standardized beta coefficients and standard errors) p-value; SE: standard error

\(^2\)Comparisons were adjusted for age, gender, race, intervention group, parent income, participant BMI z-score, and hypertension status

\(^3\)Recommended hours derived from averages obtained from standard sleep charts provided by various health institutes [26,27,28,29]

No significant associations were detected between sleep duration group and change in diet quality measures.

**V. DISCUSSION**

The present study showed that meeting versus not meeting the recommended number of hours of sleep at nighttime among adolescent with elevated blood pressure was not associated with greater improvements in diet quality as measured by change in DASH score and DASH component scores from baseline to post-treatment. Although DASH and DASH component scores showed generally consistent improvement across sleep groups from pre to post-
intervention, based on our findings meeting sleep recommendations did not appear to be a factor related to these dietary improvements.

A positive change in diet quality was expected in this study in response to the intervention and was expected to be more significant in those meeting versus not meeting the recommended number of hours of sleep for several reasons. First, it was predicted that those with adequate nighttime sleep would be more attentive and alert during the day to concentrate on the nutrition education provided as part of the intervention; studies have shown that children who sleep fewer hours at night have a harder time concentrating during the day. These children also have increased perceived rating of sleepiness and tiredness, which may lead them to poor performances in school and other attention requiring tasks like dietary planning [30,31,32]. A higher perceived fatigue and weariness has been linked to more subjective eating stimulated by energy-rich or salty snack cravings and eating at more unconventional hours [16,18]. Also, with a longer awake time, teens may increase caloric intake either by increased hunger or increased opportunity to eat more energy-rich foods in order to satisfy cravings as others have shown [6,4,16,18]. Our findings do not support these associations.

Second, studies have shown that a deprivation of sleep accounts for appetite-influencing hormonal changes. The appetite-stimulating hormone leptin and the appetite-suppressing hormone ghrelin have been found to be greatly influenced by the amount of sleep one get per night [4,18]. The results from The Wisconsin Sleep Cohort Study indicated that sleep time was negatively associated with ghrelin levels and at the same time sleep time was positively associated with leptin levels independent of BMI [12]. These results suggest that sleep loss may alter the ability of leptin and ghrelin levels to correctly signal hunger/appetite and satiety levels as well as caloric needs.
Third, it was suspected that with shorten sleep duration adolescents would make poor diet choices as observed in the National Longitudinal Study of Adolescent Health (ADD). In this study, teenagers who slept fewer hours consumed fewer fruits and vegetables and more fast food [53]. Prior studies have also observed that greater feeling of hunger and certain cravings were associated with sleep deprivation such as cravings for salty or high-caloric snacks [5,16,17,18]. It was hypothesized that inadequate sleep might be related to increased hunger and cravings for high calorie processed foods making it difficult to comply with the DASH dietary goals. Our findings do not support his hypothesis.

One reason why our study results may not have supported our major hypothesis is that our hypothesis was based on cross-sectional findings that showed associations between sleep duration and diet quality. In our study, we examined sleep durations as it relates to change in diet quality in response to an intervention. There are many factors associated with the behavioral, nutrition intervention that may have had a stronger influence on change in diet quality than sleep duration, such as diet monitoring, goal setting and action planning. These behaviors might have allowed teens to overcome any cravings or hunger pangs that might have been brought on by lack of sleep.

Another reason why our study results may not have supported our major hypothesis is that we classified sleep into 3 categories based on whether teens were meeting or not meeting established recommendations. To our knowledge, no prior studies with adolescents have classified sleep in this manner when examining associations with dietary intake. Most studies in adolescents compared adequate (≥ 9hours) versus inadequate (< 9hours) sleepers for dietary outcomes. In our view, the method we employed for classifying sleep was clinical relevance,
since both inadequate sleeping (< 9hours) and extensive sleeping (> 10 hours) are viewed as having negative health implications [5,6,20,21].

This study had several limitations. The assessment of sleep duration was made through a self-recorded 7-day sleep log. Although sleep hours were determined by recording the time before going to bed and after waking up, self-reported information can be over- or underestimated depending on the subject’s memory [6]. Also, naptime was not assessed, which may have contributed to an underestimation of sleep time in this study [18]. The number of subjects who completed the intervention was small, particularly for those who were categorized as inadequate sleepers (< 9hours, n=13). This small number may have prevented us from finding significant associations if they existed. It also prevented us from conducting a more detailed and comprehensive examination of the present data in relations to effects of gender and perhaps age. These factors had significant associations with outcomes in statistical models in the present study. A study among children in Finland aged 10-11 years showed that the association between sleep duration and dietary intake differed between girls and boys. A significantly higher intake of nutrient-dense foods was observed in sleep deprived girls, while a significantly higher intake of energy-rich foods was observed in sleep deprived boys [4]. In a different study, shorter sleep duration in boys had a significant association with decreased carbohydrate consumption, where shorter sleep duration among girls showed a significant association with increased consumption of calories from fats [15]. The age group examined in this study was quite broad. Researchers often describe youth 11-18 years of age as being in early, middle, and late adolescence. These phases of growth may have very different metabolic and nutritional requirements and sleep needs and patterns, which may have negatively influenced our ability to find associations with diet [27,72].
Future studies regarding sleep duration and compliance to any diet program should consider the limitations of this study. A greater sample should be used for the future study to work with a more representative data of all age groups. The data should also be analyzed by stratifying and examining the relationship between age and gender groups. Moreover, in future studies examining the association between sleep hours and diet, sleep should be assessed with greater precision. Sleep time should be assessed multiple times on different occurrences like the dietary intake assessment and naptime should be included.

VI. CONCLUSION

In conclusion, the present study did not find an association between meeting versus not meeting national sleep recommendations and diet quality among adolescents who completed a dietary intervention to lower blood pressure. Several study design issues may have precluded us from finding associations, such as small sample size within sleep groups, poor sleep recall ability among adolescents, and intervention effects on dietary intake measures. A larger study, with direct assessment of sleep hours, and control over intervention effects might allow us to better understand the relationship between sleep duration and diet intake so as to determine whether this factor might be a point of intervention in dietary intervention programs to control blood pressure.
VII. REFERENCES


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