ORIGINAL RESEARCH

What Is the Relationship Between Dairy Intake and Blood Pressure in Black and White Children and Adolescents Enrolled in a Weight Management Program?

Diane M. DellaValle, PhD, RDN, LDN; Janet Carter, MS, RD, LD, CLS; Molly Jones, RD, LD; Melissa Howard Henshaw, MD, MSCR

Background—The DASH (Dietary Approaches to Stop Hypertension) clinical trials and other studies have demonstrated a relationship between diet and cardiovascular outcomes in adults, yet little is known of this relationship in children. Childhood obesity has reached epidemic proportions in the United States, with similar increases in hypertension among this population. The purpose of our study was to examine the association between dairy intake and blood pressure (BP) in a cohort of children and adolescents (aged 4–17 years) enrolled in a weight management program.

Methods and Results—Dietary intake was assessed using the Block Kids 2004 food frequency questionnaire in a cross-sectional sample of participants enrolled in the Pediatric Metabolic Syndrome Study at the Children's Hospital (Charleston, SC). BP and other anthropometrics were obtained at baseline. Only children with complete baseline data and food frequency questionnaires were included in this analysis (n=117). Associations between food group/nutrient intake and BP were examined across race and sex using ANOVA and Pearson correlations. Linear regression models were controlled for body mass index and age. In the total sample, a significant inverse relationship was found between the intake of dairy and systolic BP (r=−0.24, P=0.009). The effect of dairy on systolic BP, however, differed by race. We observed a decrease of 11.2 mm Hg for each serving of dairy consumed by white children, and no decrease in systolic BP in black children (P=0.001 for the race–dairy serving interaction).

Conclusions—Nutrition professionals must consider nonnutrition factors contributing to childhood hypertension, as current dietary recommendations appear to have differential outcomes across races. **(*J Am Heart Assoc*. 2017;6:e004593. DOI: 10.1161/JAHA.116.004593.)**

Key Words: high blood pressure • hypertension • obesity • pediatrics • race and ethnicity

High blood pressure (BP) during childhood is an important risk factor for cardiovascular disease in adulthood. Current estimates of high BP in US children and adolescents (aged 8–17 years) have been reported at 6.07±0.39%.[1] We know that the prevalence of adult hypertension differs by race in the United States, with non-Hispanic black persons having a higher prevalence compared with white persons, and this racial disparity is also present in US children and teens.[1]

Although the DASH (Dietary Approaches to Stop Hypertension) pattern has been shown to be effective in managing BP in adults, the beneficial effects of the individual components of DASH (eg, fruit, vegetable, dairy intake) on the BP of children and teens have yet to be studied. Several studies have examined the DASH eating pattern (rich in fruits and vegetables and low-fat dairy) compared with usual dietary intake on BP in primarily white children and adolescents, but there have been no reports of any racial or ethnic differences in the effects of DASH dietary components on the BP of children and adolescents. The purpose of our study was to examine the association between dairy intake and BP, as well as any racial differences, in a cohort of obese children and adolescents.

Materials and Methods

Study Design and Participants

This cross-sectional analysis included 117 obese children between the ages of 4 and 17 years. Children were recruited

From the Marywood University, Scranton, PA (D.M.D.); Children's Heart Health Program of South Carolina, Charleston, SC (J.C., M.J., M.H.H.); Children's Hospital of South Carolina, MUSC, Charleston, SC (M.H.H.).

Accompanying Tables S1 through S6 are available at http://jaha.ahajournals.org/content/6/8/e004593/DC1/embed/inline-supplementary-material-1.pdf

Correspondence to: Diane M. DellaValle, PhD, RDN, LDN, Department of Nutrition and Dietetics, Marywood University, 2300 Adams Ave, Scranton, PA 18509. E-mail: ddellavalle@marywood.edu

Received August 29, 2016; accepted May 5, 2017.

© 2017 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

Clinical Perspective

What Is New?

- We observed racial differences for the effects of dairy intake on systolic blood pressure (BP) in a cohort of children and teens enrolled in a weight management program.
- Greater intakes of dairy were associated with lower systolic BP in white but not black children and teens, suggesting that greater dairy intake alone is not beneficial for all races regarding systolic BP.

What Are the Clinical Implications?

- Nutrition professionals should assess the quality of the overall dietary pattern, as opposed to single nutrients, when providing recommendations to lower BP in the overweight and obese childhood and adolescent population.
- Nutrition and medical professionals must consider nonnutrition factors contributing to childhood hypertension and other cardiovascular disease risk factors, as current dietary recommendations appear to have differential outcomes across races in this cohort of children and teens.
- To prevent or manage high BP in children and teens, nutrition and medical professionals should use a strong evidence base and work collaboratively to design patient-focused nutrition interventions taking into account age, sex, and race.

from the greater Charleston (SC) area and from the Medical University of South Carolina (MUSC) Heart Health program, which provides pediatric weight management and preventive cardiology services to >600 patients, into the PMSS (Pediatric Metabolic Syndrome Study) from 2009 to 2014. Our weight management program is structured, family-centered, and lifestyle-oriented (eg, nutrition, physical activity, and behavioral education) and includes regular individual clinic visits as well as weekly group sessions with a registered dietitian–nutritionist (RDN) with specialized training in pediatric weight management, regular fitness sessions, monthly newsletters, and periodic physical examinations with the program medical director, who is board certified in both pediatrics and obesity medicine. The primary purpose of the PMSS was to evaluate fasting insulin levels in children and adolescents with a primary diagnosis of abnormal weight gain and to assess racial disparities by comparing results of black and white participants. Children and adolescents were included in the PMSS if they were generally healthy, aside from a primary diagnosis of abnormal weight gain and potential coexisting features of the pediatric metabolic syndrome such as insulin resistance, hypertension, and/or dyslipidemia. Patients were excluded from PMSS if they were pregnant, taking insulin, or on chronic oral steroids. Patients were included in this cross-sectional analysis if they had complete dietary, anthropometric, laboratory, and lifestyle data as of December 2014. As of December 2014, 448 children and adolescents were enrolled in the PMSS, of which different parts of the study were completed (n=207 anthropometry, n=188 laboratory tests, n=194 food frequency). There was no bias in the sample used (children with complete data for anthropometric measurements, laboratory tests, and food frequency) because there were no differences in demographic data (P=0.34 for age, P=0.11 for race, P=0.54 for ethnicity) or body weight measurements (n=393, P=0.87) obtained for those who had and did not have complete data.

This study was approved by the MUSC institutional review board. Informed parental consent and subject assent (based on child age <18 years) were obtained from all participants at the first study visit. Demographic characteristics including child age, self-reported race, and self-reported ethnicity were documented at an initial visit. An RDN or trained research assistant administered a lifestyle questionnaire that included questions about feeding history, current health behaviors, eating habits, and activity patterns. Both the child and the parent were present during the consent and administration of the lifestyle questionnaire for all children <18 years. Although all questions were directed toward the child, the parent was allowed to answer if the child was unable or unwilling to do so. All answers were recorded by the RDN verbatim in the electronic medical record. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects or patients were approved by the institutional review board of the Medical University of South Carolina. Written informed consent was obtained from all participants.

Anthropometric Measurements

Within 28.0±35.7 days of the initial visit, anthropometric measurements were taken by trained clinical staff, including height and weight measured in street clothes and stocking feet, using a wall-mounted stadiometer and a medical grade digital scale, respectively.[2] Body mass index (BMI) was calculated and used to determine the patient's percentage of the 95th percentile for BMI for age and sex, according to Centers for Disease Control and Prevention growth charts.[3] Children's severity of obesity index was calculated as BMI (kg/m^2) at the time of the survey divided by the corresponding BMI at the 95th percentile, as described previously; for example, a severity of obesity index >1.2 would be equivalent to a BMI >99th percentile.[4] This clinical index is useful when looking at change in obesity status over time, especially when BMI for age is ≥99th percentile.[5,6] Waist and hip circumference measurements were also taken using standardized methods, and waist:hip ratios were calculated for all participants.[2]

Blood Pressure

Also within 1 month of the initial visit, BP was measured using Dynamap vital sign monitors (model BP 8800; Critikon, Inc). Measurements were taken by trained nurses. Before BP measurement, mid–upper arm circumference was measured and recorded (cm) to determine appropriate cuff size, and all children and adolescents were required to sit and rest for at least 5 minutes before BP measurement was recorded. Participants were in a seated, relaxed position, with their feet resting flat on the ground. Two measurements were taken in the right arm after a 5- and 10-minute rest. The mean of these 2 measurements was considered, but if the 2 measurements differed by ≥5 mm Hg, a third measurement was taken. BP was classified according to national guidelines for children and adolescents as normal (systolic BP [SBP] and diastolic BP [DBP] <90th percentile); prehypertension (SBP or DBP ≥90th to <95th percentile or BP >120/80 mm Hg to <95th percentile); and hypertension, including stage 1 and 2 (SBP and/or DBP >95th percentile).[7] If SBP was ≥140 or if DBP ≥90 but <100 and the child had no symptoms, he or she was included in the PMSS. If the child was symptomatic or if DBP was ≥100, he or she was excluded from the study and immediately sent to the emergency department.

Dietary Data

Dietary intake was also assessed within 1 month of the initial visit using the Block Kids 2004 food frequency questionnaire (FFQ). Children and adolescents self-reported their dietary intake using the semiquantified FFQ adapted for children.[8] The 75-item questionnaire was administered verbally and verbatim in English by the RDN or trained research assistant to each child, with a serving size visual provided for reference.[8] The RDN was available to clarify any questions posed by the children, and children were encouraged to answer all questions. Both the child and the parent were present during the administration of the FFQ for all children <18 years. Although all questions were directed toward the child, the parent was allowed to answer if the child was unable or unwilling to do so. All answers were recorded by the RDN verbatim in the electronic medical record. All FFQs were analyzed by Nutrition Quest (Berkeley, CA). Servings per day of dairy as well as calcium, vitamin D, and other micronutrient, macronutrient, and energy intakes were obtained from the FFQ analysis. Dairy-related questions inquired about milk as a beverage, milk on cereal, cheese consumed alone or as part of sandwiches or mixed dishes (eg, macaroni and cheese, pizza), and ice creams. Examples of a single serving of dairy include a 1.5-oz slice of natural cheese, 2 oz processed cheese, 1 cup frozen yogurt, 1.5 cups of ice cream, or an 8 fl oz glass or half-pint carton of dairy milk (or calcium-fortified soy milk). If able, children were asked to specify the type and fat content of their "usual" milk items in the following manner: whole, nonfat, reduced fat (2%), low fat (1%), Lactaid, soy milk, or rice milk.

Statistical Analyses

Descriptive analyses were performed to summarize child demographic information. Continuous variables were normally distributed, and differences in continuous variables were examined using ANOVA; χ^2 tests were used with categorical variables. We used Pearson correlations to examine associations between continuous variables. Linear regression models were controlled for BMI and age, and all analyses were stratified by race. All analyses were conducted using SPSS statistical software version 24 (IBM Corp). $P<0.05$ was considered statistically significant. This study was originally powered to detect differences in fasting insulin levels between black and white participants (240 participants [n=120 black, n=120 white] were required to have 80% power to detect a small to medium effect size of 0.36 using a 2-group t test with a 0.05 significance level). The current study, however, is an analysis of baseline data, and to detect differences in dairy intake between black and white children, a sample size of 102 (n=51 black, n=51 white) would be required to have 80% power to detect a medium effect size of 0.50 using a 2-group t test with a significance level of 0.05.

Results

Sample Characteristics

Characteristics of our participants are presented in Table 1. The majority of the total sample (n=117) was non-Hispanic (93.2%), black (61.5%), and female (65.0%). There was no difference in age (12.0±3.1 years) between black and white children (n=5, ages 4–11 years; n=3, ages 12–14 years; n=2, ages 15–17 years). Although the severity of obesity index was similar for both groups (1.38±0.2), waist:hip ratio was significantly greater in white participants compared with black participants (P=0.007).

SBP was not significantly different between white and black children (112±16 mm Hg), nor was there a difference between groups in DBP (61±8 mm Hg). Although 59% of the total sample was classified as normotensive, black children and adolescents were more likely to be classified as prehypertension or hypertension (29.9% versus 11.1% of whole sample) compared with white children and adolescents (P=0.02).

Average daily dietary intake calculated from the FFQ is also presented in Table 1. There was no difference between groups in reported energy or macronutrient intake; however, white children reported greater amounts of saturated fat than

Table 1. Demographic, Anthropometric, BP, and Daily Dietary Intake Characteristics of Obese Children and Adolescents Enrolled in a Weight Management Program

	Complete Sample (n=117)	Black (n=72)	White (n=45)	*P* Value for Difference Between Black and White Children
Age, y	12.0±3.1	11.8±3.1	12.3±3.2	0.42
Male, %	35.0	31.9	40.0	0.25
Female, %	65.0	68.1	60.0	
Black, %	61.5			N/A
White, %	38.5			
Non-Hispanic, %	93.0	100	82.2	<0.001
Hispanic, %	6.8	0	17.8	
Severity of obesity index	1.38±0.24	1.40±0.22	1.35±0.26	0.33
Waist:hip ratio	0.87±0.10	0.85±0.11	0.90±0.08	0.007
SBP, mm Hg	112±16	114±15	110±17	0.24
Diastolic blood pressure, mm Hg	61±8	61±8	60±8	0.82
Normal blood pressure, %*	59.0	51.4	71.1	0.02
Prehypertension or hypertension, %*	41.0	48.6	28.9	
Energy intake, calories/d	1356±505	1330±502	1400±513	0.47
Protein, g/d	47±18	45±18	51±18	0.08
CHO, g/d	182±70	181±69	183±72	0.94
Fat, g/d	51±22	49±23	54±21	0.29
Saturated fat, g/d	17±7	16±7	19±7	0.05
Calcium, mg/d	588±275	541±269	662±269	0.02
Vitamin D, IU/d	111±78	102±77	125±79	0.13
Dairy servings per d	1.1±0.8	0.9±0.8	1.3±0.8	0.02
Fruit servings per d	1.0±0.7	1.0±0.8	0.9±0.7	0.49
Vegetable servings per d	1.1±0.8	1.2±0.9	1.0±0.7	0.38

Data are shown as mean±SD or percentage. BP indicates blood pressure; CHO, Carbohydrate; DBP, diastolic blood pressure; HTN, hypertension; SBP, systolic blood pressure.
*BP was classified according to national guidelines for children and adolescents as normal (SBP and DBP <90th percentile); pre-HTN (SBP or DBP ≥90th to <95th percentile or BP >120/80 mm Hg to <95th percentile); or HTN, including stage 1 and 2 (SBP and/or DBP >95th percentile).[7]

black children (P=0.05). No differences were reported in intake of sodium (2218±811 mg) or potassium (1516±596 mg), but white children reported higher intake of calcium (P=0.02) and tended to report higher intake of vitamin D compared with black children (P=0.13). Although no differences were found between black and white children in daily servings of fruits (1.0±0.7 servings per day) or vegetables (1.1±0.8 servings per day) consumed, white children reported consuming significantly more servings of dairy than black children (P=0.02).

Correlation coefficients between BP and dietary variables are shown in Table 2. In the total sample, there was a significant inverse relationship between the intake of dairy and SBP (r=−0.24, P=0.009), but the relationship between dairy consumption and SBP was significantly different by race; this relationship existed for whites but not black participants. We observed similar inverse relationships between SBP and the separate nutrients found in dairy (calcium, vitamins D and A) within the total sample and subsamples of white, but not black, children. In the total sample, although the relationship between dairy servings and DBP was weaker compared with SBP (r=−0.13, P=0.15) and remained significant only for the relationship between DBP and vitamin D intake (r=−0.20, P=0.03), all subgroup analyses were all nonsignificant.

The relationship between the number of dairy servings consumed per day and SBP by racial subgroups is shown in Figure. For each serving of dairy consumed by white children, we observed a decrease of 11.2±3.3 mm Hg in SBP, but no such decrease in SBP in black children was noted (P=0.001 for the race–dairy serving interaction, R^2=0.22). There was no significant effect of dairy on DBP (−1.2, P=0.18, R^2=0.04), and no significant race-by-dairy interaction on DBP (−1.4, P=0.43, R^2=0.04). Additional regression models controlling for potential confounders were run and are presented in

Table 2. Correlation Coefficients Between SBP, DBP, and Selected Dietary Intake Variables in Obese Children and Adolescents Enrolled in a Weight Management Program

	Total Sample, N=117		White, n=45		Black, n=72	
	r	*P* Value	*r*	*P* Value	*r*	*P* Value
Dairy servings/d						
SBP, mm Hg	−0.24	0.009*	−0.49	0.001*	−0.02	0.86
DBP, mm Hg	−0.13	0.15	−0.19	0.21	−0.09	0.43
Calcium, mg						
SBP, mm Hg	−0.18	0.06	−0.39	0.009*	0.005	0.97
DBP, mm Hg	−0.10	0.28	−0.18	0.24	−0.05	0.70
Vitamin D, IU						
SBP, mm Hg	−0.22	0.02*	−0.41	0.005*	−0.06	0.64
DBP, mm Hg	−0.20	0.03*	−0.23	0.13	−0.18	0.14
Vitamin A (RAE)						
SBP, mm Hg	−0.19	0.04*	−0.34	0.02*	−0.12	0.33
DBP, mm Hg	−0.03	0.77	−0.02	0.88	−0.03	0.80

DBP indicates diastolic blood pressure; RAE, Retinol Activity Equivalents; SBP, systolic blood pressure.
*Correlation is significant at $P<0.05$.

Tables S1 through S6. Including sex and waist:hip ratio in the models did not strengthen either the overall effect of dairy servings on BP or the race–dairy interaction on BP.

Discussion

Our findings suggest a strong inverse relationship between average daily dairy servings reported and SBP in white children and adolescents ($r=-0.49$, $P=0.001$) but not in black children and adolescents enrolled in a weight management program. For each serving of dairy consumed by white children, we observed a decrease of 11.2±3.3 mm Hg in SBP, but there was no such decrease in SBP in black children.

Intake of dairy foods and their components have been shown to lower BP via a number of hypothesized mechanisms, including bioactive peptide action preventing blood vessel constriction, decreasing oxidative stress, increasing nitric oxide bioavailability, and decreasing inflammation.[9] Calcium and phosphorus intakes have been shown to decrease BP in various studies; however, handling of these minerals may be different in black and white persons. Gillman et al showed an inverse relationship between dietary calcium intake and SBP in a sample of white children[10]; however, in a study of teen girls, although dietary calcium intake was lower in black participants, BP was inversely related to calcium intake in both groups of girls.[11] Conversely, in a study of children with chronic renal insufficiency, dietary calcium intake was unrelated to BP in white children and directly related to SBP and DBP in black children, likely because of the alteration in renal handling of this divalent mineral.[12] In our study, black participants had significantly lower intake of calcium ($P=0.02$) and tended to have lower intake of phosphorus ($P=0.12$) compared with white participants, owing to much lower dairy intake. No significant relationships were noted between either SBP or DBP and phosphorus or calcium in the total sample or either racial subgroups; however, in the white children, SBP tended to be inversely related to phosphorus intake ($r=-0.27$, $P=0.07$).

We observed a weaker relationship between dairy servings and DBP in the total sample and none in the racial subgroups (Table 2). The regression models showed no significant effect of dairy servings on DBP and no significant race–dairy serving interaction on DBP. Vitamin D intake, however, yielded the strongest associations of all dietary variables with DBP in the total sample ($r=-0.20$, $P=0.03$) and in the subgroups, with the least difference in association between the 2 racial subgroups (white: $r=-0.23$, $P=0.13$; black: $r=-0.18$, $P=0.14$).

Dairy intake and BP were examined because hypertension during childhood is an important risk factor for cardiovascular disease in adulthood, and it is estimated that hypertension affects >6% of US children and adolescents.[1] In the current study of obese children and adolescents, 40.3% of the total sample was classified as either prehypertension or hypertension. Almost 3 times as many black as white children were classified as prehypertension; and twice as many black as white children were classified as hypertension. We know that the prevalence of adult hypertension is different by race in the United States, with non-Hispanic black persons having a higher prevalence than white persons, and this racial disparity also exists among US children and teens.[1] It has been

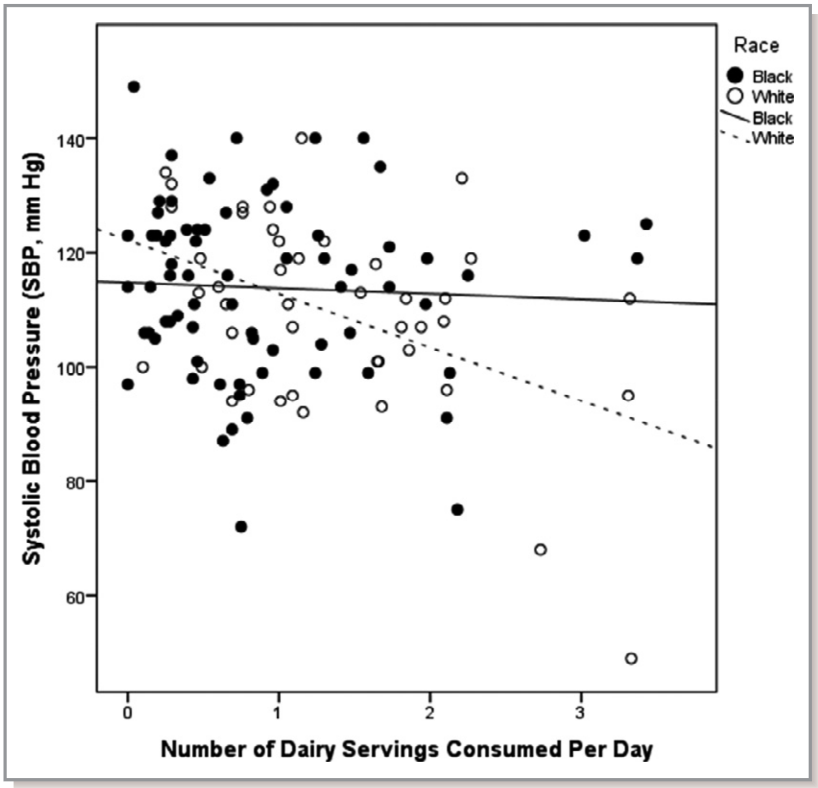

Figure. Relationship between number of dairy servings consumed per day and SBP in a cohort of 117 black and white children and adolescents enrolled in a weight management program. Model 1: main effects of SBP (mm Hg)=constant (β=92.12, P<0.001)+BMI (β=0.52, P=0.04)−race (β=2.26×white, P=0.44)+age (β=0.70, P=0.26)−dairy servings per day (β=4.30, P=0.01), R^2=0.15. Model 2: effects of SBP (mm Hg) with interaction, as shown in this figure, equal constant (β=85.83, P<0.001)+BMI (β=0.50, P=0.04)+race (β=10.30×white, P=0.03)+age (β=0.89, P=0.13)+dairy servings per day (β=0.43, P=0.84)−race-by-dairy interaction (β=11.20, P=0.001), R^2=0.22. BMI indicates body mass index; SBP, systolic blood pressure.

reported that lower urinary potassium excretion in black girls is partly responsible for the greater renal retention of potassium in black children and teens, leading to greater susceptibility to hypertension compared with white peers, regardless of sodium intake.[13]

NHANES (National Health and Nutrition Examination Survey) analyses have shown that black children also have lower intake of dairy foods compared with white children, as shown in the current study.[14] Many minority groups in the United States tend to avoid dairy products because of a higher prevalence of lactose intolerance compared with white persons.[15] The current study agrees with those findings, as white children and adolescents in our study reported 31% higher intake of dairy servings per day compared with black children. Consequently, white children reported higher intake of calcium (+18%), vitamin D (+18%), and saturated fat (+11%) compared with black children, as has been shown in NHANES analyses.[16] Intake of calcium in white children, however, was still only 50% of the Dietary Reference Intake (DRI; 1300 mg/day), and intake of vitamin D was also far below the DRI (600 IU/day).[17]

The current study showed no difference in reported intake of fruits (1.0±0.7 servings per day) and vegetables (1.1±0.8 servings per day) between black and white children, and no differences in intake of sodium or potassium were reported. Most children and adolescents reported consuming <50% of the recommended fruit and vegetable servings per day, according to the Dietary Guidelines for Americans.[18] Although reported sodium intake of all children and adolescents in the current study (≈2.2 g/day) exceeded the DRI (1.5 g/day) by 47%, potassium intake (≈1.5 g/day) was only 30% of the DRI (4.5 g/day).[19]

The effect of the DASH dietary pattern and its components (eg, fruits, vegetables, and dairy) on the BP of children and adolescents has been examined in several studies with different designs; however, none have examined racial differences. In a cross-sectional study of white Canadian children, for example, high dairy intake (≥2 servings per day, assessed from 3 consecutive 24-hours recalls) was associated with 1.7 mm Hg lower SBP and 0.9 mm Hg DBP compared with lower dairy intakes, but no association of calcium, magnesium, or potassium intake on BP was observed.[20] In another cross-sectional study of Portuguese adolescents, researchers observed that although total dairy intake (assessed via FFQ) was not associated with a cardiometabolic risk score, teens with higher milk intake (704 g/day) had lower risk scores than those with lower milk intake (258 g/day).[21] In a longitudinal study, young children who followed a DASH dietary pattern (≥2 servings of dairy plus ≥3 servings of fruits and vegetables) during their preschool years had smaller increases in SBP over time, and by their early teenage years, the SBP of those DASH children was about 7 mm Hg lower than those with lower fruit, vegetable, and dairy intake (106 versus 113 mm Hg, respectively).[22] When examining dairy alone in that study, participants who increased either fruits and vegetables or dairy alone had intermediate levels of SBP in adolescence, highlighting the synergistic effects of the DASH dietary pattern. In the current study, only 15 participants reported consuming higher dairy intake (≥2 servings of dairy per day), and only 3 participants reported consuming ≥3 servings of fruits and vegetables per day. Two participants reported both higher dairy plus fruit and vegetable intake that would meet the definitions of a DASH dietary pattern, so no direct conclusions can be made about the DASH dietary pattern and BP in this study.

The strengths of our study include a sample size that was racially diverse and anthropometrically and metabolically representative of children and teens being treated for overweight and obesity in the United States and worldwide. Limitations of the current study include its cross-sectional design and self-reported dietary data. Dietary assessment is a complex, time-consuming process subject to many biases, including recall and social desirability biases. We attempted to minimize these biases by using an FFQ that was developed for and validated in the population of interest. Although the Block Kids 2004 FFQ was validated in a sample of children and teens aged 10 to 17 years, we found the same results when we excluded those children and teens outside of this age range from all analyses (n=47). FFQs are less time-consuming and are easy and inexpensive to administer compared with other methods. Although not all biases can be eliminated using this method, we accounted for them as best as possible. FFQs are designed to assess food-intake patterns and may not capture quantitative relationships between all individual nutrients and health outcomes; this may be the reason why only dairy was related to SBP and not the other micronutrients. In addition, this assessment might not capture all sources of dairy (eg, yogurt, Greek yogurt, and yogurt-based beverages, which are popular among this demographic) because it was not designed specifically for dairy foods and/or calcium and vitamin D.

Conclusions

Our study showed racial differences in the positive effects of dairy intake on SBP in a cohort of children and teens enrolled in a weight management program. Higher dairy intake was related to lower SBP in white, but not black children and adolescents. Future studies would benefit from a more sensitive dietary assessment tool to quantify dairy intake and the nutrients in dairy to complement this dietary pattern assessment. Based on the current research, RDNs should assess the quality of the overall dietary pattern as opposed to single nutrients when providing recommendations to lower BP in the overweight and obese childhood and adolescent population. Previous studies have indicated that the DASH dietary pattern has a synergistic effect, and this study also suggests that an increase in dairy intake alone is not beneficial for all races. In addition, nonnutrition factors contributing to childhood hypertension and other cardiovascular disease risk factors must be considered because current dietary recommendations appear to have differential outcomes across race.

Author Contributions

DellaValle designed the study, analyzed the data and was responsible for the manuscript. Henshaw, Carter, and Jones collected the data. All authors reviewed the final manuscript prior to submission.

Sources of Funding

This research was funded by grants from the South Carolina Clinical and Translational Research Institute (SCTR) at the Medical University of South Carolina through grant UL1 TR000062 from the National Center for Advancing Translational Sciences. SCTR had no role in the design, analysis or writing of this article.

Disclosures

Over the past 2 years, DellaValle has received funding from the Medical University of South Carolina, Marywood University, USDA-ARS, Global Institute for Food Security, University of Saskatchewan, and the Saskatchewan Pulse Growers. Henshaw has received funding from South Carolina Clinical and Translational Research Institute (SCTR) at the Medical

University of South Carolina through grant UL1 TR000062 from the National Center for Advancing Translational Sciences. The remaining authors have no disclosures to report.

References

1. Chen L, Simonsen N, Liu L. Racial differences of pediatric hypertension in relation to birth weight and body size in the United States. *PLoS One*. 2015;10:e0132606.
2. Lohman TG, Roche AF, Martorell R. *Anthropometric Standardization Reference Manual*. Champaign, IL: Human Kinetics; 1988.
3. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. CDC growth charts: United States. National Health Statistics Reports; no 314. Hyattsville, MD: National Center for Health Statistics. 2000.
4. DellaValle DM, Carter J, Beischel A, Jones M, Henshaw MH. How are family-centered behaviors related to children's severity of obesity? *Digest*. 2016;51:1–5.
5. Gulati AK, Kaplan DW, Daniels SR. Clinical tracking of severely obese children: a new growth chart. *Pediatrics*. 2012;130:1136–1140.
6. Flegal KM, Wei R, Ogden CL, Freedman DS, Johnson CL, Curtin LR. Characterizing extreme values of body mass index-for-age by using the 2000 Centers for Disease Control and Prevention growth charts. *Am J Clin Nutr*. 2009;90:1314–1320.
7. American Academy of Pediatrics. National high blood pressure education program working group on high blood pressure in children and adolescents. *Pediatrics*. 2004;114;Supp 2:555–576.
8. Cullen KW, Watson K, Zakeri I. Relative reliability and validity of the Block Kids Questionnaire among youth aged 10 to 17 years. *J Am Diet Assoc*. 2008;108:862–866.
9. Ballard KD, Bruno RS. Protective role of dairy and its constituents on vascular function independent of blood pressure-lowering activities. *Nutr Rev*. 2015;73:36–50.
10. Gillman MW, Oliveria SA, Moore LL, Ellison RC. Inverse association of dietary calcium with systolic blood pressure in young children. *JAMA*. 1992;267:2340–2343.
11. Liebman M, Chopin LF, Carter E, Clark AJ, Disney GW, Hegsted M, Kenney MA, Kirmani ZA, Koonce KL, Korslund MK. Factors related to blood pressure in a biracial adolescent female population. *Hypertension*. 1986;8:843–850.
12. Trachtman H, Chan JC, Boyle R, Farina D, Baluarte HJ, Chinchilli VM, Dresner IG, Feld LG. The relationship between calcium, phosphorus, and sodium intake, race, and blood pressure in children with renal insufficiency: a report of the Growth Failure in Children with Renal Diseases (GFRD) Study. *J Am Soc Nephrol*. 1995;6:126–131.
13. Palacios C, Wigertz K, Martin BR, Braun M, Pratt JH, Peacock M, Weaver CM. Racial differences in potassium homeostasis in response to differences in dietary sodium in girls. *Am J Clin Nutr*. 2010;91:597–603.
14. Moore LL, Singer MR, Qureshi MM, Bradlee ML. Dairy intake and anthropometric measures of body fat among children and adolescents in NHANES. *J Am Coll Nutr*. 2008;27:702–710.
15. Heyman MB; Committee on Nutrition. Lactose intolerance in infants, children, and adolescents. *Pediatrics*. 2006;118:1279–1286.
16. Papanikolaou Y, Brooks J, Reider C, Fulgoni IVL. Comparison of inadequate nutrient intakes in non-Hispanic Blacks vs. non-Hispanic Whites: an analysis of NHANES 2007–2010 in US children and adults. *J Health Care Poor Underserved*. 2015;26:726–736.
17. Ross AC, Manson JE, Abrams SA, Aloia JF, Brannon PM, Clinton SK, Durazo-Arvizu RA, Gallagher JC, Gallo RL, Jones G. The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know. *J Clin Endocrinol Metab*. 2011;96:53–58.
18. DeSalvo KB, Olson R, Casavale KO. Dietary guidelines for Americans. *JAMA*. 2016;315:457–458.
19. Institute of Medicine (US). *Panel on Dietary Reference Intake for Electrolytes, Water, Potassium, Sodium, Chloride, Sulfate*. Washington, DC: National Academy Press; 2005.
20. Yuan WL, Kakinami L, Gray-Donald K, Czernichow S, Lambert M, Paradis G. Influence of dairy product consumption on children's blood pressure: results from the QUALITY cohort. *J Acad Nutr Diet*. 2013;113:936–941.
21. Abreu S, Moreira P, Moreira C, Mota J, Moreira-Silva I, Santos P, Santos R. Intake of milk, but not total dairy, yogurt, or cheese, is negatively associated with the clustering of cardiometabolic risk factors in adolescents. *Nutr Res*. 2014;34:48–57.
22. Moore LL, Singer MR, Bradlee ML, Djoussé L, Proctor MH, Cupples LA, Ellison RC. Intake of fruits, vegetables, and dairy products in early childhood and subsequent blood pressure change. *Epidemiology*. 2005;16:4–11.

SUPPLEMENTAL MATERIAL

Table S1. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	*Systolic Blood Pressure (SBP)			
	Model 1		Model 2 (**W/Interaction: Fig 1**)	
Independent variables	β	P	β	P
Constant	92.12	<0.001	85.83	<0.001
Body Mass Index, kg/m^2	0.52	0.04	0.50	0.04
Race (0=Black, 1=White)	-2.26	0.44	10.30	0.03
Child Age, years	0.70	0.26	0.89	0.13
Dairy Servings per day	-4.30	0.01	0.43	0.84
Race-by-Dairy Servings Interaction	---	---	**-11.20**	**0.001**
R^2	0.15		0.22	

Table S2. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	Systolic Blood Pressure (SBP)			
	Model 3		Model 4 (W/Interaction)	
Independent variables	β	P	β	P
Constant	91.82	<0.001	86.47	<0.001
Body Mass Index, kg/m^2	0.52	0.05	0.51	0.04
Race (0=Black, 1=White)	-2.25	0.44	10.41	0.03
Child Age, years	0.69	0.26	0.86	0.14
Dairy Servings per day	-4.26	0.02	0.40	0.86
Sex (0=Male, 1=Female)	***0.37***	***0.90***	***-0.88***	***0.76***
Race-by-Dairy Servings Interaction	---	---	**-11.33**	**0.001**
R^2	0.18		0.25	

Table S3. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	Systolic Blood Pressure (SBP)			
	Model 5		Model 6 (W/Interaction)	
Independent variables	β	P	β	P
Constant	106.23	<0.001	92.40	<0.001
Body Mass Index, kg/m^2	0.55	0.03	0.52	0.04
Race (0=Black, 1=White)	-1.35	0.65	10.23	0.03
Child Age, years	0.60	0.32	0.84	0.15
Dairy Servings per day	-4.31	0.01	0.25	0.91
Waist-to-hip ratio	***-16.55***	***0.29***	***-7.45***	***0.58***
Race-by-Dairy Servings Interaction	---	---	**-10.79**	**0.002**
R^2	0.19		0.25	

Table S4. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	Systolic Blood Pressure (SBP)			
	Model 7		Model 8 (W/Interaction)	
Independent variables	β	P	β	P
Constant	108.0	<0.001	95.35	<0.001
Body Mass Index, kg/m^2	0.56	0.03	0.53	0.03
Race (0=Black, 1=White)	-1.31	0.67	10.44	0.03
Child Age, years	0.57	0.35	0.80	0.18
Dairy Servings per day	-4.39	0.01	0.15	0.95
Waist-to-hip ratio	***-17.80***	***0.22***	***-9.55***	***0.50***
Sex (0=Male, 1=Female)	***-0.84***	***0.79***	***-1.48***	***0.62***
Race-by-Dairy Servings Interaction	---	---	**-10.90**	**0.002**
R^2	0.19		0.26	

Table S5. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	Systolic Blood Pressure (SBP)			
	Model 9		Model 10 (W/Interaction)	
Independent variables	β	P	β	P
Constant	111.86	<0.001	98.81	<0.001
~~Body Mass Index, kg/m²~~	---	---	---	---
Race (0=Black, 1=White)	-2.16	0.48	9.86	0.04
Child Age, years	1.47	0.002	1.66	<0.001
Dairy Servings per day	-3.86	0.03	0.76	0.74
Waist-to-hip ratio	***-13.94***	***0.34***	***-5.70***	***0.69***
Sex (0=Male, 1=Female)	***-0.004***	***1.00***	***-0.70***	***0.82***
Race-by-Dairy Servings Interaction	---	---	**-11.12**	**0.002**
R^2	0.15		0.22	

Table S6. Regression Models: Effect of Demographic, Anthropometric and Dietary Intake Variables on Systolic Blood Pressure (SBP)

	Systolic Blood Pressure (SBP)			
	Model 11		Model 12 (W/Interaction)	
Independent variables	β	P	β	P
Constant	111.85	<0.001	97.36	<0.001
~~Body Mass Index, kg/m²~~	---	---	---	---
Race (0=Black, 1=White)	-2.16	0.48	9.77	0.04
Child Age, years	1.47	0.001	1.67	<0.001
Dairy Servings per day	-3.86	0.03	0.80	0.72
Waist-to-hip ratio	***-13.94***	***0.32***	***-4.74***	***0.73***
~~Sex (0=Male, 1=Female)~~	---	---	---	---
Race-by-Dairy Servings Interaction	---	---	**-11.06**	**0.002**
R^2	0.15		0.22	