Relationship between Snacking Patterns, Diet Quality and Risk of Overweight and Abdominal Obesity in Children

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Abstract: Snacking is very common among Americans; the impact of variety of snacking patterns on nutrient intake and weight status is unclear. This study examined the associations of snacking patterns on nutrient intake and weight in U.S. children 2-18 years (n=14,220) participating in the 2001-2008 National Health and Nutrition Examination Survey. Cluster analysis generated 12 distinct snacking patterns, explaining 57% of variance in total calories consumed. Only 8% of the children did not consume snacks on the day of the 24-hour recall. Cakes, cookies and pastries was the most common snacking pattern (16%) followed by miscellaneous snacks (e.g. whole milk, orange juice and meat/fish/poultry; 13%), and crackers and salty snacks (10%). Most snacking patterns resulted in higher total energy intake than the no snack pattern. After controlling for energy intake, most snacking patterns resulted in higher intakes of fiber; vitamins A, C, B_{12}, and K; riboflavin; folate; potassium; calcium; zinc; and magnesium than the no snack pattern. However, most of the snacking patterns resulted in higher total intake of saturated fatty acids, solid fats, added sugars, and sodium (nutrients to limit). Several of the snacking patterns (i.e. cakes/cookies/pastries, crackers/salty snacks, sweets, and other grains) were associated with a reduced risk of overweight and abdominal obesity. Overall, several snacking patterns compared with non-snackers had better diet quality and were less likely to be overweight or obese and less likely to have abdominal obesity. Education is needed to improve snacking patterns in terms of nutrients to limit in the diet.

Keywords: Children, Snacking Patterns, Overweight, Abdominal Obesity, Diet Quality.

INTRODUCTION

In 2009-2010 nearly 32% of children and adolescents aged 2-19 years were obese [1] and rates of childhood obesity have tripled in the last 25 years [2]. Childhood obesity tracks to adulthood [3] and can lead to increased chronic disease risk [4]. Thus, it is important to understand the factors associated with overweight in children.

Snacking is ubiquitous in America. The percentage of children consuming snacks increased from 74% in 1977-78 to 98% in 2003-2006 [5], with snacks accounting for more than 27% of children's daily energy intake [5]. Few studies have looked at broad eating patterns, including snacking, and their association with weight [6-10]. Snacking has been shown to be associated with increased energy intake [11]. Thus, snacking may be an important strategy for meeting energy needs for increased physical activity and for meeting recommended intakes that cannot be met with the consumption of only three meals per day [12, 13]. However, snacking could also provide a mechanism to overeat [14]. Snacking contributed significantly to nutrient intake [11, 12, 15], improvement of diet quality [16], and increased likelihood of meeting selected national food recommendations [11, 12]. The increased energy intake associated with snacking may reflect the energy density [5] and portion sizes of many foods and beverages consumed as snacks [14, 17, 18].

The relationship between snacking and childhood obesity is less clear. Nearly 15 years ago, the Booth hypothesis [19] stated that "grazing" or multiple eating episodes between meals, rather than the traditional pattern of three meals per day, was a major contributing factor to obesity. Conversely, few studies have actually shown that snacking was negatively associated with body fatness [20] and reduced risk of overweight and abdominal obesity [8, 21]. However, others have shown that snacking was not associated with weight [11, 22] and was not an independent predictor of weight gain [23].

There are several possible explanations for the inconsistent results on snacking and childhood obesity. Study results may be equivocal because snack definitions have not been clearly established or were inconsistent across studies [5, 24-26]. The snacking studies were also based on the assumption that "snacks" were not unique in their contribution to nutrient intake. Moreover, the effect of snacking on

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weight was consistent regardless of the types of foods and beverages consumed as snacks. Identification of different snacking patterns allows characterization of a variety of snacking behaviors and examination how they impact nutrient intake and weight. To our knowledge this is the first study to examine the various snacking patterns among children and their impact on nutrient intake, diet quality, and weight/adiposity.

SUBJECTS AND METHODS

Study Overview, Population, and Analytic Sample

The study design for NHANES has been previously described [27]. Data from children 2-18 years of age (y) (n = 14,220) participating in the NHANES 2001-2008 were combined for these analyses to increase the sample size. This was a secondary data analysis with a lack of personal identifiers; therefore, this study was exempted by the Baylor College of Medicine Institutional Review Board.

Snacks were self-defined by subjects as eating occasions with foods or beverages not consumed with meals. Snacks included eating occasions designated by the respondent as “snack,” “drink,” “extended consumption,” or the Spanish equivalents “merienda,” “entre conida,” “botana,” “bacadillo,” “tentempie,” and “bebida.” For NHANES 2001-2002, snacks and beverages not consumed at meals were a combined code. For NHANES 2003-2008, there were separate codes for snacks and beverages not consumed at meals. For consistency across years, food and beverages were included in our definition of snacking.

Dietary Assessment

Dietary intake data were obtained from in-person 24-hour dietary recall interviews (Day 1) using an Automated Multiple-Pass Method [28] in the Mobile Examination Center (MEC). For data collection years 2001-2002, a single 24-hour dietary recall was collected. Although two 24-hour dietary recalls were collected in 2003-2008, to ensure consistency in methodology, only data from the first recall were used. Caretakers of children 2 to 5 y provided the 24-hour dietary recalls for their children; children 6 to 11 y were assisted by an adult: older children provided their own recall. Twenty-four-hour recall data judged to be incomplete or unreliable by staff of the National Center for Health Statistics (Hyattsville, MD) were excluded from analyses. Pregnant/lactating females were also excluded. Descriptions of the dietary recalls and data collection are available in the NHANES Dietary Interviewer’s Training Manual [29].

Energy and nutrient intakes were calculated using the Food and Nutrient Database for Dietary Studies (versions 1.0 – 4.0) [30], for NHANES 2001-2002, 2003-2004, 2005-2006, and 2007-2008, respectively. The nutrients studied reflect the nutrients to limit, nutrients of public health concern, and nutrients under-consumed, as defined by the 2010 Dietary Guidelines for Americans [31]. The MyPyramid Equivalents Database (MPED), versions 1.0 [32] and 2.0 [33], was used to examine consumption in terms of MyPyramid [33] food group equivalents. The MPED translates dietary recall data into equivalent servings of the seven MyPyramid major food groups and corresponding subgroups. The number of MyPyramid food group equivalent servings was based on the 24-hr food dietary recall data. Foods were hand matched to the same/similar foods for NHANES 2003-2008 since these data were released without an update to the MPED.

Diet quality was calculated using the Healthy Eating Index-2005 (HEI-2005) [34, 35]. Development and evaluation of the HEI-2005 have been previously described [36, 37]. The SAS code used to calculate HEI-2005 scores was downloaded from the Center for Nutrition Policy and Promotion website [38].

Physiologic Measures

Height and weight were obtained according to NHANES Anthropometry Procedures Manual [39].. The manual provides information about equipment, calibration, methods, quality control, and survey procedures. Body mass index was calculated as body weight (in kilograms) divided by height (in meters) squared [40]. The Centers for Disease Control and Prevention’s growth chart programs were used to determine BMI z-score; children with a BMI z-score greater than or equal to the 85^{th} and less than 95^{th}, and greater than or equal to the 95^{th} percentile were considered overweight or obese, respectively [41]. Waist circumference (WC) was obtained using NHANES protocols [39]. Reference percentiles of waist circumference for the children’s year of age and gender were obtained [42], and abdominal obesity was defined as a waist circumference ≥90th percentile.

Statistical Analyses

Snacking intake patterns were identified using SAS 9.2 (SAS Institute, Cary, NC 2009) PROC CLUSTER using NHANES 2001-2008 dietary day 1 data. For these analyses, the USDA food groups were collapsed into 20 snacking food groupings (Supplemental Table **1**). All food codes fit into only one of the snacking food groupings. For each participant the percent of snacking kilojoules (kJ) from each of these snacking food groupings was determined. The patterns identified by the cluster analysis were then identified by percent kJ within each snacking food grouping at the centroid of each cluster. This method resulted in 12 readily identifiable snacking patterns, including crackers/salty snacks, sweets, fruit; no snacks was one of the twelve patterns identified. Dietary day 1 weights were used for all analyses.

There were 12 snacking patterns defined by the percent of snacking kJ (only foods that contributed 5% or more of kJ were included) at the centroid of each snacking cluster (Figure **1**). With snacking patterns identified, each participant was placed into one snacking pattern. Least-square means ± SE were calculated using PROC REGRESS of SUDAAN for dietary intake, diet quality (HEI-2005), and physiologic measures were determined for participants consuming each snacking pattern. Covariates were: age, gender, race/ethnicity, poverty income ratio (PIR) grouped into three categories (<1.25, 1.25–3.49, and >3.49), physical activity level (sedentary, moderate and vigorous), alcohol intake (g/d), and energy intake for nutrient related variables (not for energy intake itself, HEI-2005, or physiological measures). The HEI-2005 was not controlled for energy intake, since it is already controlled for energy [43]. Statistical differences for variables of interest were determined *via* t-test comparing to the no snacking group. A probability of $p \leq 0.05$ was considered significant; however, a Bonferroni correction was applied for multiple comparisons (0.05/12), so the effective p value was $p \leq 0.0042$.

Odds ratios for overweight or obesity were evaluated with the PROC LOGISTIC procedure of SUDAAN software controlling for above-mentioned covariates. The statistical significance of risks associated with each snacking pattern was measured by testing whether the 95% CI around the odds ratio overlapped with the value of 1.0 (the odds ratio given to the reference group of no snacks).

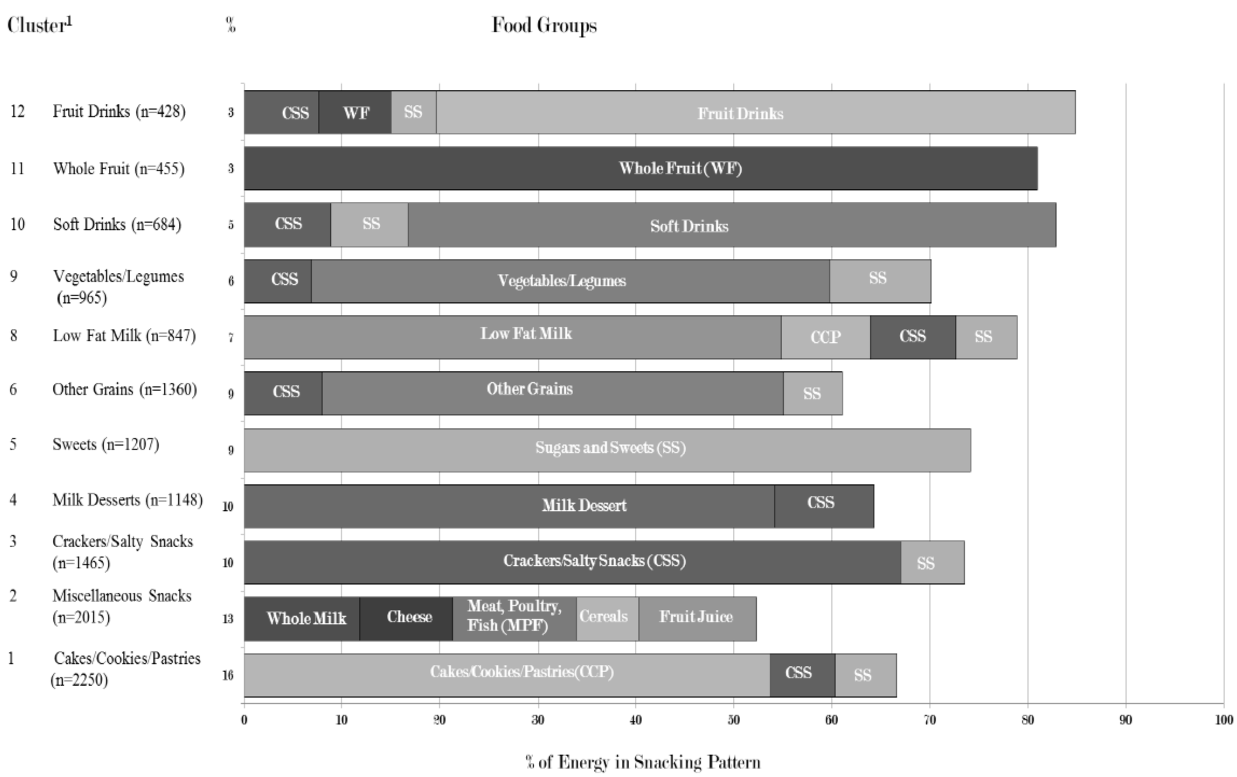

Figure 1: Description of the Twelve Snacking Pattern Clusters.

A food group needed to comprise at least 5% of the energy in the cluster to be included in the above figure.

CCP = Cakes/Cookies/Pastries; CSS = Crackers/Salty Snacks; SS = Sugars & Sweets; WF = Whole Fruit; MPF = Meat, Poultry, Fish.

[1]No Snacks (n = 1396, 8.4%).

RESULTS

Description of Snacking Patterns

The 12 snacking patterns (n, % of population) were: cakes/cookies/pastries (n=2250, 16.2%); miscellaneous snacks (n=2015, 13.3%); crackers/salty snacks (n=1465, 10.4%); milk desserts (n=1148, 9.8%); sweets (n=1207, 8.9%); other grains (n=1360, 8.8%); no snacks (n=1396, 8.4%); low fat milk (n=847, 7.1%); vegetables/legumes (n=965, 6.3%); soft drinks (n=684, 5.2%); whole fruit (n=455, 3.1%); and fruit drinks (n=428, 2.5%).

Demographics of the Snacking Patterns

The total sample (n=14,221) consisted of 2-18 year olds (51% males; 15% African-American; 61% whites; 18% Mexican-American and 6% other) with a mean poverty ratio of 2.51**,** and 66% of the population reported doing moderate-vigorous physical activity (Table **1**). There were several notable differences in the snacking patterns by gender, ethnicity, and physical activity. There were more females in the cakes/cookies/pastries and vegetable/legumes snacking patterns and more males in the soft drink snacking pattern or reported no snacks. There were fewer African-Americans in the milk desserts and low fat milk snacking patterns. The percentage reporting moderate-vigorous physical activity was lowest in those who reported no snacking.

Energy and Nutrients to Limit

Table **2** shows energy intake and intake of nutrients to limit, including saturated fatty acids (SFA), solid fat, added sugars, and sodium by snacking patterns for the entire day. Majority of the snacking patterns resulted in a higher total energy intake (with the exception of the whole fruit pattern) compared to no snacks. Total energy intake of the snacking patterns ranged from 6995 kJ (no snacks) to 9324 kJ (other grains). Total SFA intake of the snacking patterns ranged from 9.95 g (fruit drinks) to 12.74 g (milk desserts). Total SFA

Table 1: Demographics of the Sample by Snacking Patterns in Children Participating in the 2001-2008 NHANES

Snacking Pattern	Total %	Gender		Ethnicity				Physical Activity			PIR %
		Male %	Female %	White %	African-American %	Mexican-American %	Other %	Sed. %	Light %	Mod-Vig %	
Total Sample (n=14,221)	100.0	50.80	49.20	61.15	14.60	17.94	6.30	14.03	20.06	65.91	2.51
No Snacks (n=1397)	8.41	52.92	47.08	54.40	20.15	20.71	4.75	15.21	21.90	62.89	2.29
Cakes/Cookies/ Pastries (n=2250)	16.15	47.08	52.92	63.16	15.21	14.85	6.78	14.64	21.39	63.97	2.59
Misc. Snacks (n=2015)	13.26	51.93	48.07	54.80	15.86	22.16	7.18	13.92	19.14	66.94	2.40
Crackers/Salty Snacks (n=1465)	10.41	48.77	51.23	60.97	16.18	16.71	6.15	13.81	20.81	65.38	2.59
Milk Desserts (n=1148)	9.83	49.46	50.54	70.88	9.64	13.73	5.75	12.85	22.01	65.15	2.68
Sweets (n=1207)	8.87	51.89	48.11	64.87	14.25	14.13	6.75	12.62	19.82	67.56	2.61
Other Grains (n=1360)	8.76	51.58	48.42	53.19	16.01	24.71	6.08	11.47	21.23	67.31	2.29
Low Fat Milk (n=847)	7.09	54.69	45.31	69.56	5.21	20.49	4.75	15.76	17.93	66.31	2.78
Vegetables/Legumes (n=965)	6.32	46.91	53.09	57.51	19.56	17.14	5.80	15.36	18.44	66.20	2.36
Soft Drinks (n=684)	5.24	60.15	39.85	71.80	10.45	12.87	4.88	14.56	17.53	67.91	2.52
Whole Fruit (n=455)	3.13	49.79	50.21	58.13	10.55	21.91	9.41	16.03	14.86	69.12	2.37
Fruit Drinks (n=428)	2.53	49.19	50.81	48.73	22.55	18.35	10.37	14.61	17.70	67.69	2.56

intake was significantly higher in the milk desserts snacking pattern, compared to no snacks. Total intake of SFA was significantly lower for the majority of the snacking patterns, with the exception of the snacking patterns, miscellaneous snacks and low fat milk, compared to no snacks. Total intake of solid fat was similar to SFA intake. Total intake of solid fat of the snacking patterns ranged from 39.8 g (vegetables/legumes) to 49.6 g (cakes/cookies/pastries and no snacks). Total intake of added sugars ranged from 17.7 tsp (other grains) to 30.2 tsp (soft drinks). Total intake of added sugars was significantly higher in the snacking patterns, cakes/cookies/pastries, milk desserts, soft drinks, and fruit drinks, compared to no snacks. Total intake of sodium ranged from 2914 mg (soft drinks) to 3275 mg (no snacks). Total intake of sodium was significantly lower in the snacking patterns, cakes/cookies/pastries, milk desserts, sweets, low fat milk, vegetables/legumes, and soft drinks, compared to no snacks.

Nutrients of Public Health Concern and Nutrients Under-Consumed

Table **3** shows the mean intake of nutrients of public health concern and nutrients that are of potential concern for under-consumption for sub-populations for the entire day. Potassium intake ranged from 1925 mg (soft drinks) to 2569 mg (low fat milk). Potassium intake was significantly higher in the snacking patterns, miscellaneous snacks, milk desserts, low fat milk, vegetables/legumes, and whole fruit, compared to no snacks. Calcium intake ranged from 887 mg (soft drinks) to 1327 mg (low fat milk). Compared to no snacks, calcium intake was higher for the snacking patterns, miscellaneous snacks and low fat milk, and lower for the snacking patterns, cakes/cookies/pastries, crackers/salty snacks, sweets, other grains, vegetables/legumes, and soft drinks. Intake of vitamin D ranged from 4.87 mcg (other grains) to 8.88 mcg (low fat milk). When vitamin D intake among the patterns was compared to no snacks, vitamin D intake was higher for the miscellaneous snacks and low fat milk but lower for the other grains. Total dietary fiber intake ranged from 10.53 g (soft drinks) to 15.38 g (whole fruit). When total mean intake of dietary fiber was considered, those consuming crackers/salty snacks, other grains, vegetables/legumes, and whole fruit consumed more dietary fiber than those consuming no snacks. For those in the soft drink pattern, total dietary fiber was lower than no snacks. Intake of vitamin A was significantly higher in the

Table 2: Consumption of Energy and Nutrients to Limit by Snacking Patterns[1] in Children Participating in the 2001-2008 NHANES

Snacking Pattern	Total Energy (kj) LSM (SE)	Saturated Fatty Acid (g) LSM (SE)	Solid Fat (g) LSM (SE)	Added Sugars (tsp) LSM (SE)	Sodium (mg) LSM (SE)
No Snacks (n=1396)**	6995.47 (146.87)	27.53 (0.35)	49.61 (0.82)	20.20 (0.55)	3274.64 (39.79)
Cakes/Cookies/Pastries (n=2250)	8909.88 (104.71)*	25.71 (0.28)*	49.56 (0.55)	23.76 (0.40)*	2999.42 (30.42)*
Miscellaneous Snacks (n=2015)	8758.28 (186.94)*	28.08 (0.42)	49.26 (0.85)	18.33 (0.45)	3180.71 (31.37)
Crackers/Salty Snacks (n=1465)	8378.50 (147.54)*	25.47 (0.32)*	45.74 (0.76)*	18.54 (0.43)	3254.57 (40.22)
Milk Desserts (n=1148)	8756.52 (141.43)*	29.25 (0.41)*	49.42 (0.88)	22.52 (0.54)*	2980.43 (47.47)*
Sweets (n=1207)	8445.82 (124.60)*	25.48 (0.43)*	42.30 (0.87)*	27.66 (0.59)	2862.50 (39.05)*
Other Grains (n=1360)	9323.84 (155.46)*	25.18 (0.30)*	46.71 (0.90)	17.66 (0.66)	3413.57 (75.14)
Low Fat Milk (n=847)	8195.24 (163.24)*	26.16 (0.39)	45.03 (0.75)*	21.00 (0.62)	2960.20 (42.82)*
Vegetables/Legumes (n=965)	8824.06 (258.70)*	25.47 (0.37)*	39.79 (1.14)*	20.23 (0.67)	2957.24 (56.04)*
Soft Drinks (n=684)	7792.72 (186.40)*	25.19 (0.55)*	44.58 (1.07)*	30.28 (0.77)*	2914.16 (49.17)*
Whole Fruit (n=455)	7514.38 (332.18)	24.80 (0.82)*	45.09 (1.47)	19.03 (1.54)	3153.01 (72.31)
Fruit Drinks (n=428)	7835.17 (209.55)*	23.96 (0.62)*	43.04 (1.14)*	27.65 (0.88)*	3050.84 (76.68)

[1]Covariates: Age, gender, race/ethnicity, poverty income ratio grouped into three categories as (<1.25, 1.25–3.49, and >3.49), current smoking status (yes/no) (adults only), physical activity level (sedentary, moderate and vigorous), alcohol intake (g/d), energy intake for nutrient related variables.
**Reference group is No Snacks.
*Statistically different from No Snacks with the Bonferroni correction effective p ≤ 0.0042.

Table 3: Consumption of Nutrients of Public Health Concern and Nutrients Under-Consumed by Snacking Patterns[1] in Children Participating in the 2001-2008 NHANES

Snacking Pattern	Nutrients of Public Health Concern				Nutrients Under-Consumed				
	Potassium (mg) LSM (SE)	Calcium (mg) LSM (SE)	Vitamin D (mcg) LSM (SE)	Fiber (gm) LSM (SE)	Vitamin A (mcg) LSM (SE)	Vitamin C (mg) LSM (SE)	Vitamin K (mcg) LSM (SE)	Folate (mcg) LSM (SE)	Magnesium (mg) LSM (SE)
No Snacks** (n=1396)	2168.21 (27.67)	1021.18 (16.99)	5.58 (0.16)	12.15 (0.26)	546.01 (12.47)	70.00 (3.17)	52.25 (2.60)	542.61 (14.33)	220.35 (2.76)
Cakes/Cookies/ Pastries (n=2250)	2078.07 (23.37)	910.97 (11.91)*	5.27 (0.14)	12.37 (0.17)	575.40 (14.61)	76.58 (2.06)	55.65 (2.96)	519.83 (8.57)	216.93 (2.03)
Miscellaneous Snacks (n=2015)	2423.25 (37.10)*	1132.74 (17.22)*	6.81 (0.22)*	12.21 (0.25)	624.59 (19.99)*	105.77 (3.65)*	56.58 (2.91)	602.72 (18.86)	236.44 (3.15)*
Crackers/Salty Snacks (n=1465)	2050.18 (32.08)	913.95 (18.24)*	4.94 (0.19)	13.35 (0.19)*	522.93 (16.65)	81.85 (3.04)	50.34 (1.80)	530.34 (13.22)	227.51 (2.22)
Milk Desserts (n=1148)	2363.46 (35.60)*	1043.03 (21.04)	5.77 (0.21)	12.96 (0.39)	676.37 (19.00)*	77.93 (3.14)	60.21 (5.10)	528.79 (15.49)	230.83 (3.38)
Sweets (n=1207)	2036.40 (29.56)*	903.21 (17.97)*	4.91 (0.17)	11.79 (0.21)	524.98 (19.56)	88.55 (4.20)*	50.50 (3.29)	481.23 (13.13)*	213.96 (3.04)
Other Grains (n=1360)	2184.59 (48.26)	948.92 (16.98)*	4.87 (0.15)*	13.79 (0.32)*	554.42 (21.45)	80.19 (4.53)	53.49 (3.19)	589.55 (14.47)	232.44 (3.69)
Low Fat Milk (n=847)	2569.23 (43.88)*	1326.62 (32.35)*	8.88 (0.30)*	12.23 (0.26)	732.34 (22.78)*	84.32 (3.82)*	48.71 (1.82)	548.92 (20.03)	250.87 (2.90)*
Vegetables/Legumes (n=965)	2454.31 (39.39)*	919.00 (23.31)*	5.18 (0.25)	13.86 (0.32)*	516.28 (20.70)	85.83 (4.43)	53.51 (3.45)	568.43 (26.87)	253.93 (5.84)*
Soft Drinks (n=684)	1924.80 (46.31)*	887.23 (25.31)*	5.12 (0.32)	10.53 (0.27)*	478.52 (22.03)	57.83 (3.60)	38.16 (1.72)*	436.44 (19.43)*	197.03 (3.88)*
Whole Fruit (n=455)	2433.55 (71.73)*	1011.48 (40.92)	5.77 (0.51)	15.38 (0.49)*	632.09 (28.47)	104.30 (7.96)*	61.13 (4.80)	561.35 (21.84)	233.25 (6.44)
Fruit Drinks (n=428)	2152.39 (65.43)	968.40 (28.78)	5.01 (0.25)	13.15 (0.71)	580.13 (28.85)	123.95 (8.62)*	46.97 (4.26)	490.19 (15.66)	219.87 (5.08)

[1]Covariates: Age, gender, race/ethnicity, poverty income ratio grouped into three categories as (<1.25, 1.25–3.49, and >3.49), current smoking status (yes/no) (adults only), physical activity level (sedentary, moderate and vigorous), alcohol intake (g/d), energy intake for nutrient related variables.
*Statistically different from No Snacks with the Bonferroni correction effective p ≤ 0.0042.
**Reference group is No Snacks.

snacking patterns, miscellaneous snacks, milk desserts, and low fat milk compared to no snacks. Intake of vitamin C was higher in the snacking patterns, miscellaneous snacks, sweets, low fat milk, whole fruit, and fruit drinks, compared to no snacks. Intake of vitamin K and folate were lower in the soft drink pattern compared to no snacks. Intake of magnesium was higher in the snacking patterns, miscellaneous snacks, low fat milk, and vegetables/legumes but lower in the soft drink pattern, compared to no snacks.

Overall Diet Quality

Figure **2** shows the Healthy Eating Index-2005 (HEI-2005) by snacking patterns. On average the HEI-2005 scores were higher for six of the snacking patterns (*i.e.* miscellaneous snacks, crackers/salty snacks, other grain**s**, low fat milk, vegetables/legumes, and whole fruit) compared to no snacks. The HEI-2005 score for the soft drink pattern was lower than no snacks. Half of the snacking patterns had a total HEI-2005 score of less than 50.

Snacking Patterns and Weight/Adiposity Status

Table **4** shows the relationship between the snacking patterns and weight/adiposity. BMI z-score was significantly lower for the snacking patterns, cakes/cookies/pastries, crackers/salty snacks, sweets, other grains, and vegetables/legumes, compared to no snacks. WC was significantly lower for four snacking patterns, cakes/cookies/pastries, crackers/salty snacks, sweets, and other grains, than no snacks.

Snacking Patterns and the Likelihood of Being Overweight or Obese or having Abdominal Obesity

Figure **3** shows the likelihood of being overweight or obese by the snacking patterns. Compared to no

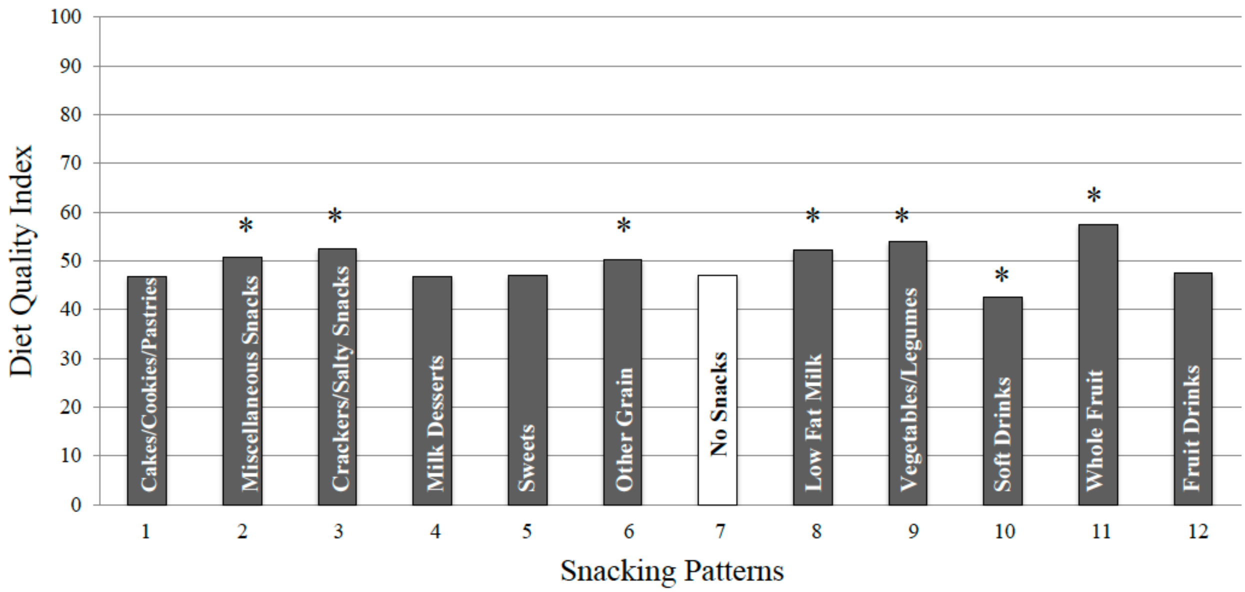

Figure 2: Snacking Patterns and Overall Diet Quality (HEI-2005) for children 2-18 years of age participating in the 2001-2008 NHANES.

Covariates: Age, gender, race/ethnicity, poverty income ratio grouped into three categories as (<1.25, 1.25-3.49, and >3.49), current smoking status *yes/no) (adults only), physical activity level (sedentary, moderate and vigorous), alcohol intake (g/d). Note that energy was not used as a covariate since the HEI score itself is controlled for energy.

*Significantly different from no snacking (pattern 7); Bonferroni correction p ≤ 0.0042.

Table 4: Relationship Between Snacking Patterns and Weight in Children Participating in the 2001-2008 NHANES

Snacking Pattern	Weight Status*	
	BMI z-score LSM (SE)	Waist Circumference (cm) LSM (SE)
Cakes/Cookies/Pastries (n=2250)	0.36 (0.04)*	67.64 (0.36)*
Miscellaneous Snacks (n=2015)	0.48 (0.05)	68.88 (0.49)
Crackers/Salty Snacks (n=1465)	0.39 (0.05)*	68.26 (0.51)*
Milk Desserts (n=1148)	0.49 (0.06)	69.35 (0.61)
Sweets (n=1207)	0.41 (0.05)*	67.94 (0.47)*
Other Grains (n=1360)	0.33 (0.05)*	67.26 (0.50)*
Low Fat Milk (n=847)	0.48 (0.04)	68.86 (0.46)
Vegetables/Legumes (n=965)	0.40 (0.05)*	68.54 (0.53)
Soft Drinks (n=684)	0.61 (0.07)	70.82 (0.73)
Whole Fruit (n=455)	0.61 (0.09)	71.04 (1.15)
Fruit Drinks (n=428)	0.62 (0.09)	70.66 (1.04)

[1]Covariates included age, gender, race/ethnicity, poverty income ratio, current smoking status, alcohol intake, and physical activity.
*Statistically different from No Snacks with the Bonferroni correction effective p ≤ 0.0042.
Reference group is No Snacks (BMI z-score: 0.62 (0.05); waist circumference: 70.8 (0.51) cm).

snacks, the odds of being overweight or obese were significantly lower for several of the snacking patterns, with the exception of the snacking patterns, soft drinks, whole fruit, and fruit drinks. The odds of having abdominal obesity (elevated WC) were significantly lower for several of the snacking patterns, with the exception of the snacking patterns, soft drinks, whole fruit, and fruit drinks.

DISCUSSION

The dietary influences of childhood obesity are complex and poorly understood [6]. While individual nutrients and foods have been implicated in obesity, few attempts have been made to identify eating patterns associated with weight status. Since foods are generally not eaten in isolation, eating patterns may

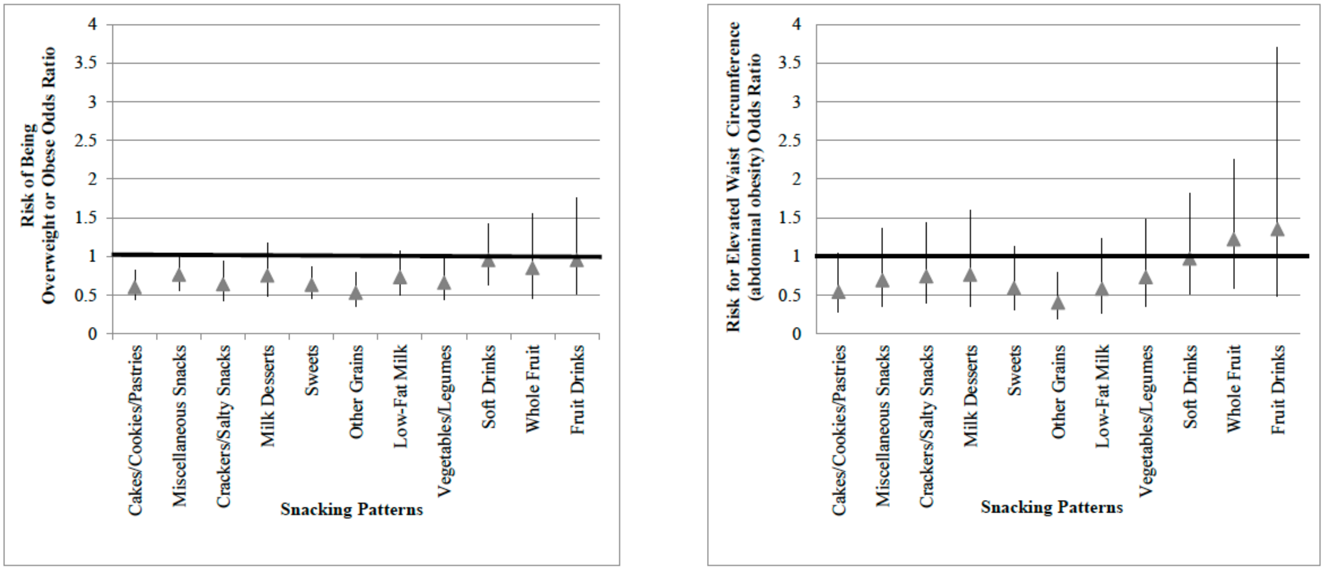

Figure 3: Likelihood of Being Overweight or Obese or having Abdominal Obesity by Snacking Pattern for Children 2-18 years of age participating in the 2001-2008 NHANES.

[1]All values are odds ratios (95% CIs) estimated with the PROC LOGISTIC procedure of SUDAAN software (release 10.0.1; Research Triangle Institute, Research Triangle Park, NC).

[2]BMI ≥ 85 percentile of BMI-for-age.

[3]Covariates included age, gender, race/ethnicity, poverty income ratio, current smoking status, alcohol intake, and physical activity.

have a greater influence on obesity than any single food or nutrient. Snacking is one such eating pattern; and it has been understudied. The findings that relate snacking to dietary intakes and weight are inconsistent, which makes them difficult to interpret. Currently, there are several commonly used definitions of snacks in studies exploring the relationship among snacking, diet, and obesity [44]. These include: 1) food categories consisting in taxonomy of food based on quality and composition; 2) using time as a criterion for defining snacks; and 3) a hybrid definition such as food-based classifications of eating episodes. Clearly, the study of snacking and its association with diet and weight is a quagmire that will continue to provide inconsistent findings until a consensus definition is reached. Moreover, the majority of studies have looked simply at snacking versus non-snacking which may have been an over-simplification of this eating pattern. A major assumption of these studies was that snacking patterns were homogeneous within the population studied. This study showed that, using cluster analysis, 12 specific snacking patterns, including no snacks, could be identified in a nationally representative sample of US children. The snacking patterns varied widely by foods consumed, nutrient contribution, and overall diet quality.

In this study, more males consumed no snacks or the soft drink snacking pattern compared to more females who consumed the cakes/cookies/pastries and vegetables/legumes snacking patterns. To our knowledge, no other studies have confirmed these gender differences in specific snacking patterns. There were fewer African-Americans who consumed milk desserts and low fat milk snacking patterns; this can be explained partially by the higher prevalence of perceived lactose intolerance among African-Americans [45]. The percentage reporting moderate-to-vigorous physical activity was lowest in those who reported no snacks. This finding was surprising in light of the studies showing that television viewing was positively associated with both an increased frequency of snacking [46] and the percent energy from snacks [47, 48]. Clearly more research is needed to confirm our findings and to identify several possible mechanisms for explaining an association among snacking patterns and physical activity.

In our study, total energy intake varied by pattern and resulted in a higher total energy intake compared to the no snack pattern. These data are consistent with other studies showing that snacking was associated with increased energy intake [11, 12, 49]. With the exception of no snacks, the whole fruit pattern had the lowest daily energy intake of all of the snacking patterns. The majority of the snacking patterns (including no snacks) showed a mean daily intake of SFA that exceeded the recommendation of less than

10% of total energy [31, 50]; three of the snacking patterns (i.e. sweets, soft drinks, and fruit drinks) showed a mean daily intake of added sugars that exceeded the Institute of Medicine's threshold of 25% of energy [50]. The data suggest that even those children consuming snacks with nutrient-dense foods or beverages, such as vegetables/legumes, low fat milk, and whole fruit, may need to improve aspects of their overall diet.

Snacking has been shown to contribute significantly to nutrient intake [11], and diet quality [16], and to an increased likelihood of meeting selected national food recommendations [13]. As shown in this study, total intake of selected nutrients varied across the snacking patterns. Several of the snacking patterns had higher intakes of nutrients of public health concern, and nutrients under-consumed as defined by the 2010 Dietary Guidelines for Americans [31], when compared with no snacks. Four of the snacking patterns (i.e. cakes/cookies/ pastries, milk desserts, sweets, or fruit drinks) did not show higher consumption of at least two of the nutrients of public health concern (when compared to no snacks). This finding was not surprising since the foods contributing the highest levels of energy in the cakes/cookies/pastries, milk desserts, and fruit drink patterns were foods and beverages that can be considered nutrient-poor and energy-dense compared to the other patterns that showed higher consumption of nutrients (Supplemental Table **2**).

Zizza *et al*. [16] showed, using data from the 1999-2004 NHANES, that snacking was positively associated with overall diet quality. Consumers of several of the snacking patterns in our study had significantly higher HEI-2005 scores (when compared to no snacks). This could be a reflection that some of the foods in those snacking patterns were nutrient-dense or that poor snacking choices were compensated with healthier food/beverage choices made at the other meals. Despite the higher HEI-2005 scores found with some of the snacking patterns, the mean HEI-2005 scores for all of the snacking patterns (including no snacks) were low, suggesting that overall diet quality in children was poor and needs improvement. These data also suggest that simply consuming a snack may not be associated with a higher diet quality, but the specific foods consumed as a snack and throughout the day are equally important. Consumers may need additional educational tools on how to incorporate healthier food and beverage choices into their routine snacking behaviors. One study found that women need information concerning snacks high in fiber and low in trans fat [51]. Given that mothers are the primary food shoppers in the family, their lack of knowledge in selecting healthier snacks may translate into less healthier snacks being available and accessible in the homes for their children. Family-based interventions are needed for enhancing self-confidence for healthful snack selection and for overcoming barriers [51] among mothers and their children.

An important finding from this study was the inverse association of several snacking patterns with overweight and abdominal obesity. Compared to no snacks, the odds of being overweight or obese or having abdominal obesity were significantly lower for all of the snacking patterns, except soft drinks, whole fruit, and fruit drinks. These results are consistent with other studies [8, 11, 13, 16, 52] showing that snacking was consistently inversely associated with overweight and abdominal obesity. However there are studies that have not shown a relationship between snacking and weight [11, 51]. The lack of association between the soft drink and fruit drink patterns has also been shown in other studies [53-57]; but the data on the association between whole fruit and weight are inconsistent [6, 58].

There are several possible explanations for the inverse association between several of the snacking patterns and weight, despite the increased energy intake associated with the snacking patterns. Snacking was shown to be associated with improved diet quality [11, 18, 59] and increased intakes of fruit, whole grains, and fiber [11, 18], which could promote satiety and reduce risks for obesity. Snacking was also associated with increased vigorous physical activity [12, 49]; thus, the increased energy intake associated with snacking may have been compensated for by increased energy expenditure during physical activity. An inverse association between snacking and weight is also possible if snackers exercise more than non-snackers because exercise can promote weight loss. An inverse association of snacking with weight could also be explained if overweight individuals who try to lose weight avoid eating snacks. More studies are needed to examine whether the increased energy intake reported for those who snack is an artifact of underreporting or is due to increased compensation for physical activity or a lack of compensation at subsequent meals.

LIMITATIONS

NHANES is a cross-sectional study; thus, cause and effect associations cannot be inferred. Twenty-four hour dietary recalls have several inherent limitations, including that they may not reflect usual intake and are memory dependent, which may lead to under- or over-reporting; however, a single 24-hour recall is sufficient to report mean group intake [60]. Proxies reported or assisted with the 24-hour recalls of children 2-11 y; whereas parents often report accurately what children eat at home [61], but may not know what their children consume outside the home [62], which could result in reporting errors [63]. Energy-dense, nutrient-poor foods and beverages, particularly when consumed as snacks, tend to be under-reported [21, 64, 65]; however, reported energy intakes in this population were plausible for children across the snacking patterns. Data from this study showed that the normal distributions of percent energy from snacks were similar across the weight categories (i.e. normal weight, overweight, obese) (Supplemental Figure **1**). The percent energy from snacks was both low and high, regardless of weight status, with majority of the children reporting 10% to 30% of energy from snacks. If there was under-reporting of energy-dense snacks among the overweight and obese children the distribution would have been skewed towards the left with a higher percentage of children reporting a lower percentage of energy from snacks compared to normal weight children.

CONCLUSIONS

Previous studies looking at the relationship between snacking patterns, diet quality, and risk of overweight and abdominal obesity in children were based on the major assumption that snacking patterns were homogeneous. The important contribution of this study is that this is not the case when trying to understand the complex nature of snacking patterns. Twelve snacking patterns (including no snacks) were identified in a nationally representative population of children 2-18 years. The patterns varied in food and beverage selections and their contribution to daily intake of nutrients and diet quality. More studies are needed to confirm these findings to better understand how specific snacking patterns fit within an overall healthier eating lifestyle. Some snacking patterns may also be inversely associated with weight and abdominal obesity. Because of inconsistent evidence in the literature, there are several noteworthy findings from this study that should generate future hypotheses for further testing. Moreover, longitudinal studies are needed to further evaluate whether snacking prevents weight gain in children.

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AUTHOR DISCLOSURE STATEMENT

There are no conflicts of interest for any of the authors. All authors have fully read and approved this manuscript. They have all contributed to the conception, design, analysis, and interpretation of data as well as the drafting and revising of the manuscript. No portion of this manuscript is currently under consideration for publication elsewhere and no portion of this manuscript, other than the abstract, has been published or posted on the internet.

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SUPPLEMENTAL MATERIALS

The supplemental materials can be downloaded from the journal website along with the article.

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