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Article

Breakfast in the United States: Food and Nutrient Intakes in Relation to Diet Quality in NHANES 2011-2014.

A Study from the International Breakfast Research Initiative (IBRI)

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Abstract: The contribution of breakfast to diet quality (DQ) can inform future dietary guidelines. This study examined breakfasts that were associated with highest-quality diets. Dietary data came from the first reported day of the National Health and Examination Survey (NHANES) 2011-2014 (n=14,488). DQ measures were the Nutrient Rich Foods Index (NRF9.3) and the USDA Healthy Eating Index 2015 (HEI 2015). Analyses of breakfast intakes were conducted by NRF9.3 tertiles and by age and socioeconomic groups. Four out of 5 NHANES participants ate breakfast. Breakfast provided 19-22% of dietary energy depending on age. Breakfast intakes of complex carbohydrates and total sugars were higher and intakes of protein and fats were lower relative to energy intakes. Breakfast provided more that 20% of daily intakes of B vitamins, vitamins A and D, folate, calcium, iron, potassium and magnesium. Eating breakfast was associated with higher NRF9.3d scores. Breakfasts associated with top tertile of NRF9.3d had more carbohydrates and less added sugars and fats. Such breakfasts had more fruit and juices, more whole grains, more milk and yogurt and less meat and eggs. Breakfast patterns that favored fruit, whole grains, and dairy were associated with healthiest diets.

Keywords: Breakfast; dietary intake; nutrition; dietary quality; NRF9.3 index; USDA HEI 2015 index

1. Introduction

Breakfasts that provide more nutrients than calories can be viewed as nutrient-rich meals [1-4]. Eating breakfast has been associated with higher-quality diets and with higher intakes of key nutrients and desirable food groups [5,6]. By contrast, skipping breakfast has been linked to lower-quality diets, lower cognitive performance, and a host of negative health outcomes [7-15]. The International Breakfast Research Initiative (IBRI) aimed to identify breakfast patterns associated with highest quality diets using nationally representative data from six countries: Canada, Denmark, France, Spain, UK and the US.

Analyses of NHANES 2001-2008 data showed that about 19% of the US population skipped breakfast altogether [4]. The rest exhibited as many as 12 breakfast "patterns" that typically included grain products, fruit juice, milk, whole fruit, sweets, meat and eggs, and coffee or tea [4]. In some studies, the consumption of selected breakfast components (e.g. RTE cereals) was associated with higher-quality diets [16-19]. What food groups make for a healthy breakfast pattern across countries and consumer subgroups continues to be a topic of research interest [1,5,20,21].

This study examined the notion that the US breakfast is a nutrient-rich meal by assessing the contribution of breakfast to daily energy and nutrient intakes among US children and adults. Breakfast patterns associated with different-quality diets were then examined in detail. The goal was to arrive at an optimal combination of breakfast foods that could be the basis of future dietary recommendations and guidelines.

2. Materials and Methods

2.1. Study Population & Dietary Data

Analyses were based on the first day of dietary intakes in the 2011-2012 and 2013-2014 cycles of the nationally representative National Health and Nutrition Examination Survey (NHANES)[22,23]. Data were available for 14,488 children, adolescents and adults aged ≥6y. The sample included 2,511 children (ages 6-12y); 1,546 adolescents (ages 13-17y); 6,594 adults (ages 18-54y), and 3,837 older adults (ages ≥55y).

The first 24-hour recall in the NHANES was completed in-person at the Mobile Examination Center with a trained interview. The 24-hour recall queries all foods/beverages consumed by participants from midnight-to-midnight on the previous day [22,23]. Dietary supplements were excluded. Breakfast was defined as the self-reported "breakfast/desayuno" and brunch. An energy threshold of 50 kcal was imposed. Breakfast skippers were defined as having no breakfast or an eating episode of <50 kcal.

The population sample was stratified by four age groups (6-12y, 13-17y, 18-54y, and ≥55y) and six race/ethnicity groups (non-Hispanic white, non-Hispanic black, Mexican-American, other Hispanic, Asian, and other/mixed race). Education was defined as: <High School (<12y), High School (12y); Some college (12-16y) and >College (>16y). Income to poverty ratio (IPR) cut-points were set at : <1.3; 1.3-1.849; 1.85-2.99; >3.

2.2. Measures of diet quality

The Nutrient Rich Foods (NRF) index was the principal measure of nutrient density of the total diet [19,24,25]. Its development and validation with respect to other measures of diet quality and long term health outcomes have been described in the literature [24-27] The present NRF9.3 variant applied to total diets was based on 9 qualifying nutrients (NR) and 3 disqualifying nutrients (LIM). Reference daily values (DVs) were based on the US Food and Drug Administration (FDA) and other standards [19,24]. The qualifying nutrients and standard reference amounts were as follows: protein (50g), fiber (28g), vitamin A (900 RAE), vitamin C (90 mg), vitamin D (20 mcg), calcium (1300 mg), iron (18 mg), potassium (4,700 mg) and magnesium (420 mg). The 3 disqualifying nutrients and maximum recommended values (MRVs) were: added sugar (50g), saturated fat (20g) and sodium (2,300 mg). The NRF9.3 was calculated as follows:

$$\text{NRF 9.3} = (\text{NR-LIM}) \times 100 \quad (1)$$

With

$$NR = \sum_{i=1}^{9} \frac{{Intake_i}/{Energy} \times 2000}{DV_i} \quad (2)$$

and

$$LIM = \sum_{i=1}^{3} \frac{{Intake_i}/{Energy} \times 2000}{MRV_i} - 1 \quad (3)$$

where $intake_i$ is the intake of each nutrient i, and DVi is the reference daily value for that nutrient.

In NR calculation, each daily nutrient intake i was adjusted for 2000 kcal and expressed in percentage of DV. Following past protocol, percent DVs for nutrients were truncated at 100, so that an excessively high intake of one nutrient could not compensate for the dietary inadequacy of another. In LIM, only the share in excess of the recommended amount was considered.

The development and validation of the NRF family of nutrient density scores are all well-documented in the literature [26,27]. In the present adaptation, vitamin D, a nutrient of public health concern [28-30], replaced vitamin E. Fiber, vitamin D, calcium, magnesium, and potassium were all identified in the 2010 Dietary Guidelines for Americans as nutrients of concern [29]. The NRF score was adjusted for energy intakes, analogous with the recent versions of the USDA Healthy Eating Index (HEI), a federal measure of diet quality [31].

The HEI-2015 is the latest iteration of the USDA diet quality measurement tool, specifically designed to monitor compliance with the 2015 Dietary Guidelines for Americans [31]. The HEI-2015 is a 100-point scale where the adequacy components are total fruits (5 points), whole fruits (5), total vegetables (5), greens and beans (5), whole grains (5), dairy (10), total protein (5), seafood and plant protein (5), and fatty acid ratio (10); the moderation components are refined grains (10), sodium (10) added sugars (10) and saturated fats (10). HEI 2015 values were calculated using the USDA Food Patterns Equivalents Database (FPED) [32]. Both NRF9.3d and HEI 2015 were corrected for dietary energy (1,000 kcal for HEI and 2000 kcal for NRF).

2.3. Analytical Strategy

Energy and nutrient intakes for NHANES participants were calculated using the Food and Nutrient Database for Dietary Studies 2011-2014. The primary nutrient outcome measures were selected based on their overall importance to current dietary recommendations [29]. Some of the nutrients were in the NRF model but some were not. For example, fiber, vitamin D, calcium, magnesium, and potassium (all in the NRF model) were identified in the 2010 Dietary Guidelines for Americans as nutrients of concern [29]. Iron (also in the model) was identified as a nutrient of concern for adolescent girls and women capable of becoming pregnant. By contrast, the NRF model did not include nutrients of concern such as folic acid (women capable of becoming pregnant) or vitamin B12 (older adults) [19,24]. Breakfast food groups of interest were based on reported consumption frequency by children and adults and included milk, whole fruit and fruit juices, whole grains and low-fat dairy, soy, nuts and legumes, as well as ready to eat cereals (RTEC).

All analyses were conducted using SAS software, Version 9.4 (SAS Institute Inc. Cary, NC, USA) and are representative of the US population. Differences between proportions were tested using X^2 tests. Differences in quantitative variables (such as intakes) were tested using Generalized Linear Models, adjusted as appropriate (without and with adjustment for energy at breakfast as well as energy at breakfast and socio-demographics characteristics). Pearson coefficient correlations between NRF9.3d and HEI score as well as between NRF9.3d and all HEI subscores were estimated. The statistical significance level was set at p-value < 0.05.

2.4. Data availability and ethical approval

The necessary IRB approval for NHANES had been obtained by the National Center for Health Statistics (NCHS) [33]. Adult participants provided written informed consent. Parental/ guardian written informed consent was obtained for children. Children/adolescents ≥ 12y provided additional written consent. All NHANES data are publicly available on the NCHS and USDA websites [22,23]. Per University of Washington (UW) policies, public data do not involve "human subjects" and their use requires neither IRB review nor an exempt determination. Such data may be used without any involvement of the Human Subjects Division or the UW Institutional Review Board.

3. Results

Table 1 shows that out of 4,057 children, 3,296 (82.0%) ate breakfast on the first day of the NHANES survey and 761 did not (18.0%). Out of 10,431 adults, 8,269 (80.3%) ate breakfast and 2,162

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(19.7%) did not. Those figures were based on the <50 kcal breakfast energy threshold. With the threshold removed, 17.4% of children and 15.2% of adults ate no breakfast at all.

Breakfast consumption patterns showed a bimodal distribution by age. Most likely to eat breakfast (87.5%) were young children and older adults. Only 3 out of 4 adolescents and young adults ate breakfast. Among children, most likely to eat breakfast were Asians, Whites, and other Hispanics. Least likely to eat breakfast were non-Hispanic Blacks. Among adults, most likely to eat breakfast were non-Hispanic Whites, other Hispanics and Asians. Least likely to eat breakfast were non-Hispanic Blacks. Breakfast consumption increased sharply with household incomes for children and adults and with education and incomes for adults. Higher-income groups and college graduates were most likely to eat breakfast.

Subsequent analyses were conducted among breakfast consumers only. **Figure 1** shows the percent contribution of breakfast to total daily energy and nutrient intakes by age group. For the whole NHANES sample, mean and median energy intakes at breakfast were 447 kcal/d and 366 kcal/d, respectively. Breakfast accounted for approximately 20% of daily energy intakes. The exact percentages were 19.2% of energy intakes for children, 21.7% for adolescents; 20.0% for adults, and 21.8% for older adults.

Breakfast supplied just <20% of daily protein and total fat, approximately 20% of fiber and saturated fatty acids (SFA), and around 25% of total sugars and between 20% and 22% of added sugar, depending on age. Older adults consumed more dietary fiber, carbohydrates, and total and added sugars at breakfast than did children and teenagers.

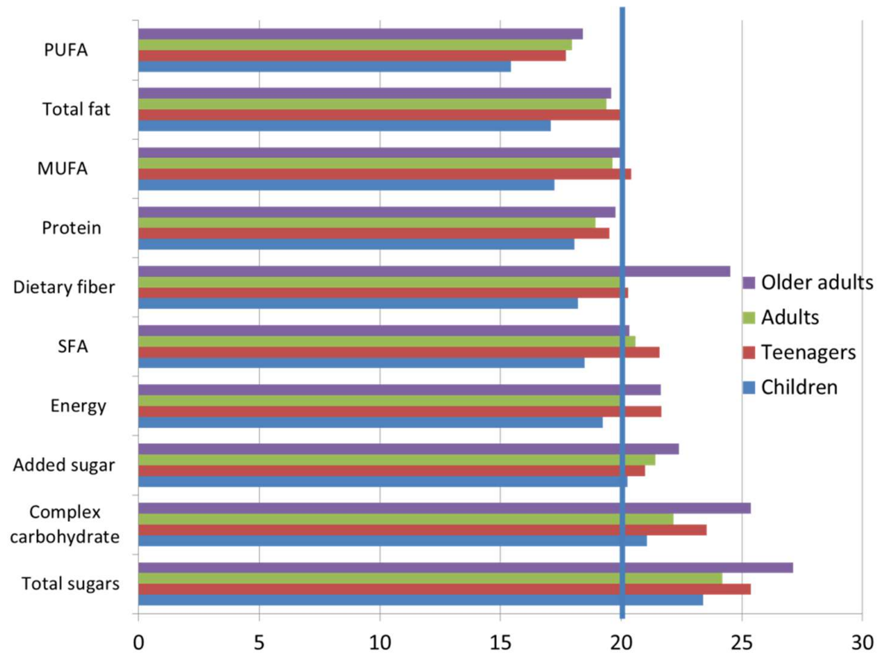

Figure 1: Percent contribution of breakfast to macronutrient intakes relative to energy intakes among breakfast consumers. PUFA stands for Polyunsaturated fatty acids, MUFA stands for Monounsaturated fatty acids, SFA stands for Saturated fatty acids. The 20% cutoiff is indicated by a vertical line

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Table 1. Frequency (%) and 95% confidence limits of breakfast consumption by age group and by key demographics

	Children (N=4,057)			Adults (N=10,431)		
	All (N=4,057)	Skippers N=761 (18%)	Consumers N=3,296 (82%)	All (N=10,431)	Skippers N=2,162 (19.7%)	Consumers N=8,269 (80.3%)
Age (y)						
6-13	2,511	12.53 (10.29-14.76)	87.47 (85.24-89.71)			
13-18	1,546	25.76 (21.71-29.81)	74.24 (70.19-78.29)			
18-55				6,594	23.51 (21.38-25.63)	76.49 (74.37-78.62)
>55				3,837	12.5 (10.89-14.11)	87.5 (85.89-89.11)
		<0.001			<0.001	
Gender						
Male	2,073	17.68 (15.18-20.18)	82.32 (79.82-84.82)	5,092	21.41 (19.78-23.05)	78.59 (76.95-80.22)
Female	1,984	18.36 (15.13-21.59)	81.64 (78.41-84.87)	5,339	18.04 (15.9-20.18)	81.96 (79.82-84.1)
		0.66			<0.005	
Race/ethnicity						
Non-Hispanic White	1,010	16.47 (12.87-20.07)	83.53 (79.93-87.13)	4,225	17.43 (15.5-19.35)	82.57 (80.65-84.5)
Non-Hispanic Black	1,119	26.21 (21.86-30.57)	73.79 (69.43-78.14)	2,443	27.09 (24.44-29.74)	72.91 (70.26-75.56)
Mexican American	854	20.35 (17.17-23.53)	79.65 (76.47-82.83)	1,252	24.28 (19.98-28.58)	75.72 (71.42-80.02)
Asian	415	12.87 (7.64-18.11)	87.13 (81.89-92.36)	1,199	20.56 (17.18-23.94)	79.44 (76.06-82.82)
Other Hispanic	424	16.46 (13.00-19.92)	83.54 (80.08-87.00)	984	19.61 (15.52-23.7)	80.39 (76.3-84.48)
Other/mixed race	235	10.38 (4.30-16.47)	89.62 (83.53-95.7)	328	26.15 (20.72-31.58)	73.85 (68.42-79.28)
		<0.001			<0.001	
Family IPR[1,2]						
<1.3	1,739	22.97 (19.92-26.01)	77.03 (73.99-80.08)	3,445	26.66 (23.83-29.5)	73.34 (70.5-76.17)
1.3-1.849	498	20.92 (15.81-26.03)	79.08 (73.97-84.19)	1,176	20.29 (16.71-23.87)	79.71 (76.13-83.29)
1.85-2.99	561	22.79 (15.75-29.84)	77.21 (70.16-84.25)	1,515	19.88 (16.74-23.02)	80.12 (76.98-83.26)
≥3.0	996	9.93 (6.70-13.17)	90.07 (86.83-93.3)	3,511	15.46 (13.42-17.5)	84.54 (82.5-86.58)
		<0.001			<0.001	
Education[3]						
<High school				2,130	24.58 (21.49-27.67)	75.42 (72.33-78.51)
High school				2,149	20.3 (17.59-23.01)	79.7 (76.99-82.41)
Some college				3,040	22.08 (19.77-24.39)	77.92 (75.61-80.23)
≥College graduate				2,522	12.98 (10.73-15.23)	87.02 (84.77-89.27)
					<0.001	

[1]IPR stands for Income to poverty ratio
[2]In children (resp in adults), 263 (resp. 784) missing IPR were removed from the analysis
[3]In adults, 590 missing education information were removed from the analysis

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Figure 2 shows percent contribution of breakfast to total dietary energy and micronutrient intakes by age group. Although the energy contribution was about 20%, breakfast provided substantially more than 20% of daily magnesium, potassium, phosphorus, niacin, vitamin C, zinc, calcium, thiamin, vitamin B6, iron, folate, riboflavin, vitamin A, folate, vitamin B12, vitamin D and retinol. For all age groups, breakfast provided >40% of daily vitamin D. While the percentage of sodium was <20%, the percentage of cholesterol from breakfast was in the order of 30%.

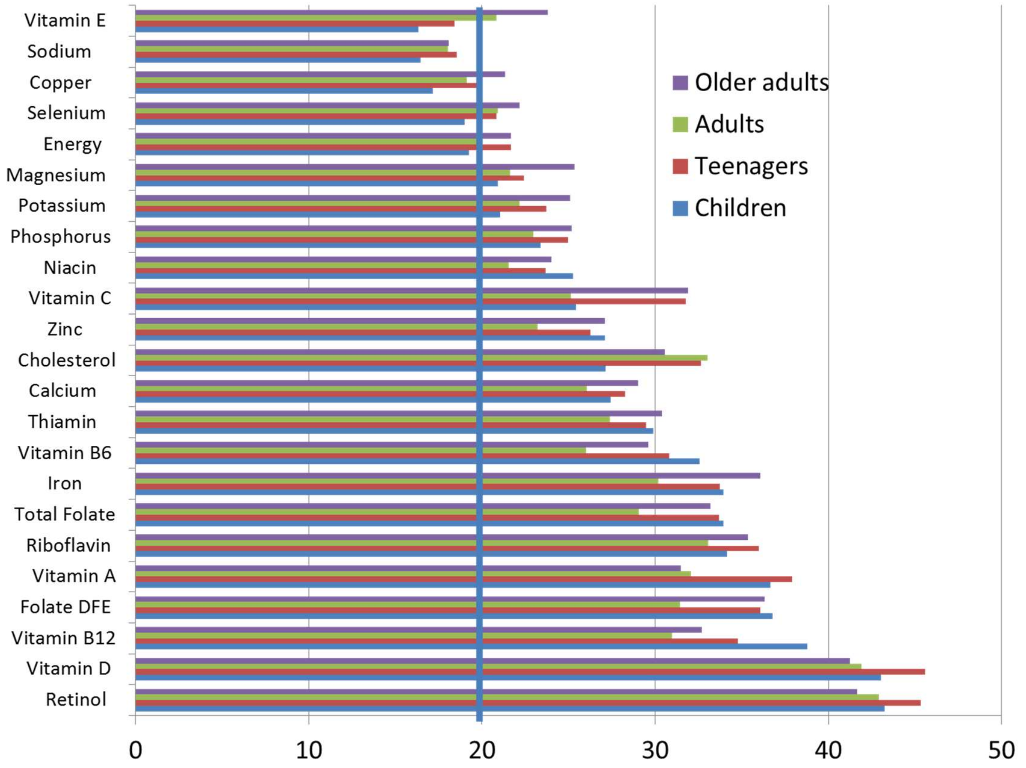

Figure 2. Percent contribution of breakfast to micronutrient intakes relative to energy intakes among breakfast consumers. The 20% cutpoint ins indicated by the vertical line.

3.1. Measures of Diet Quality – NRF9.3

Figure 3 summarizes the construction of the NRF9.3 score, used here as a measure of nutrient density of the total diet. The NRF9.3 was adjusted per 2000 kcal, as detailed above. Separate panels show the NR subscore, composed of nutrients to encourage and the LIM subscore, composed of nutrients to limit. Figure 3 shows that percent daily values for index nutrients rose with tertiles of the NRF9.3 score, whereas the LIM subscores, to the contrary, decreased. As expected, going from the lowest (T1) to the highest tertile of diet quality (T3) was associated with an increase in percent DVs of nutrients to encourage and a corresponding decrease in percent MRVs of nutrient to limit.

The corelation between NRF9.3 scores and HEI 2015 scores based on the entire population aged >2 was statistically significant, r=0.43. The correlation between NRF9.3 scores and HEI subscores held for most HEI components (r=0.2 to r=0.34) and was strongest for added sugars, dairy, whole fruit and total fruit. Previous studies have shown that HEI scores were sensitive to age, gender and sociodemographic characteristics of NHANES study participants

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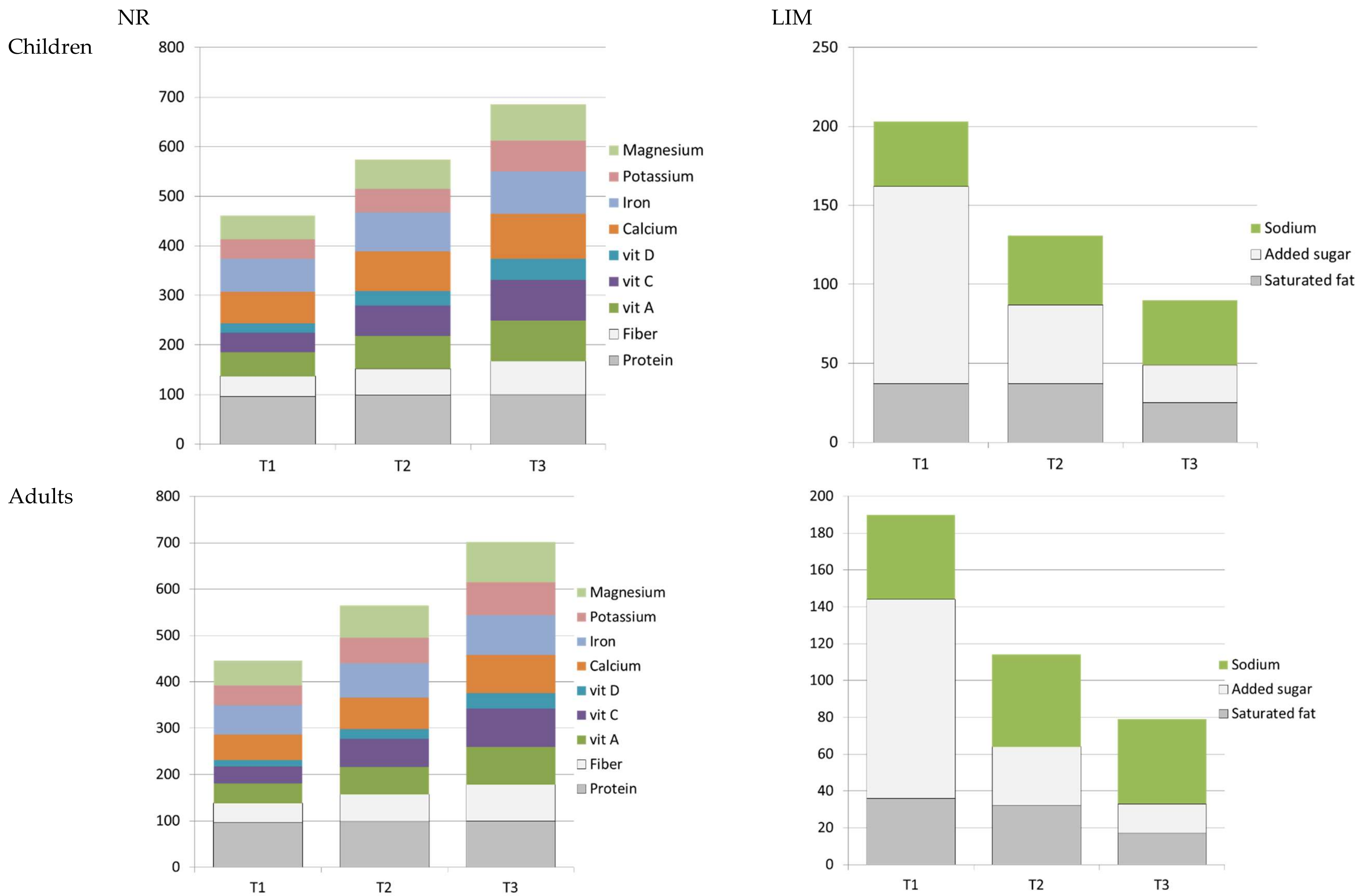

Figure 3 Nutrient subscores of the Nutrient Rich Index adapted to total diets (NRF9.3d) index by tertiles of total NRF9.3 scores for diets of children and adults.

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Table 2 shows mean NRF9.3 scores for total diets of breakfast consumers by age, gender and sociodemographic characteristics of NHANES 2009-2014 participants. First, there was a bimodal effect of age – highest quality diets were consumed by children and by older adults; by contrast, teenagers had lowest-quality diets, consistent with many other reports [34,35]. Gender effects depended on age; whereas no gender differences were observed for children or teenagers, adult women had more nutrient-dense diets than did men.

The most nutrient-dense diets were consumed by Asians and other Hispanics. Non-Hispanic Blacks had lowest quality diets at every age. Diet quality of adults greatly improved with education and with household incomes. An income gradient for children was not observed. Differences in NRF scores by education and incomes were far greater than those observed by race/ethnicity.

Skipping breakfast had profound effects on NRF9.3 scores in univariate analyses. For children the difference was 107 points (Consumers=449; skippers=342); for teenagers the difference was 80 points (Consumers=407; skippers=327); for young adults it was 110 points (Consumers=420; skippers=310) and for older adults the difference was 95 points (Consumers=483; skippers=388).

Table 2 Mean (±SE) NRF 9.3 scores for breakfast consumers by age and socio-demographics

	All	Children (n=2,152)	Teenagers (n=1,144)	Younger adults (n=4,955)	Older adults (n=3,314)
Total	**N=11,565**	449.1 (5.82)	407.11 (7.15)	420.28 (4.97)	483.07 (6.12)
			<0.0001		
Gender					
Male	5,663	446.67 (6.67)	420.39 (8.66)	403.42 (5.75)	465.62(6.94)
Female	5,902	451.78 (8.38)	394.09 (9.69)	436.43 (6.14)	497.92 (6.89)
		0.5997	0.0362	<0.001	<0.001
Race/ethnicity					
Non-Hispanic White	4,346	435.52 (11.15)	390.95 (13.5)	419.53 (7.48)	487.61 (6.79)
Non-Hispanic Black	2,664	432.50 (8.57)	380.27 (11.29)	371.94 (5.79)	428.25 (8.89)
Mexican American	1,647	486.34 (9.53)	458.23 (8.46)	437.89 (8.33)	477.55 (11.36)
Asian	1,303	500.59 (17.69)	469.59 (23.45)	482.85 (7.17)	520.76 (10.7)
Other Hispanic	1,164	470.64 (16.56)	413.57 (21.68)	430.59 (7.78)	508.27 (10.67)
Other/mixed race	441	447.68 (26.88)	403.08 (15)	411.78 (20.73)	436.06 (39.03)
		0.0080	<0.001	<0.001	<0.001
Family income-to-poverty ratio[1]					
<1.3	3,912	448.64 (8.98)	403.2 (12.27)	381.05 (8.26)	459.09 (7.56)
1.3-1.849	1,310	459.92 (14.72)	416.6 (22.4)	403.76 (14.6)	462.46 (10.98)
1.85-2.99	1,683	433.01 (16.92)	365.12 (19.64)	405.24 (10.84)	464.92 (11.12)
≥3.0	3,835	448.81 (12.17)	425.61 (11.66)	451.36 (5.96)	500.84 (7.79)
		0.4986	0.0676	<0.001	0.0014
Education[1]					
<High School	1,625			383.05 (9.01)	457.81 (10.14)
High school	1,707			367.08 (9.88)	453.53 (11.2)
Some college	2,362			407.77 (6.63)	482.68 (9.27)
≥College graduate	2,181			482.18 (7.56)	517.95 (9.23)
				<0.001	<0.001
Breakfast consumption	N=14,488				
Eat	11,565	449.10 (5.81)	407.10 (7.15)	420.28 (4.97)	483.07 (6.12)
Skip	2,923	341.70 (14.67)	327.18 (12.53)	310.55 (7.63)	388.21 (9.70)
		<0.001	<0.001	<0.001	<0.001

[1]Missing values were removed from the analysis

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3.2. Breakfast Patterns by Tertiles of NRF9.3 Diet Quality Scores

Figure 4 shows the macronutrient composition of breakfasts associated with tertiles of NRF9.3d scores. Breakfasts associated with better diets had much less added sugar and less fat but more carbohydrate and slightly more protein.

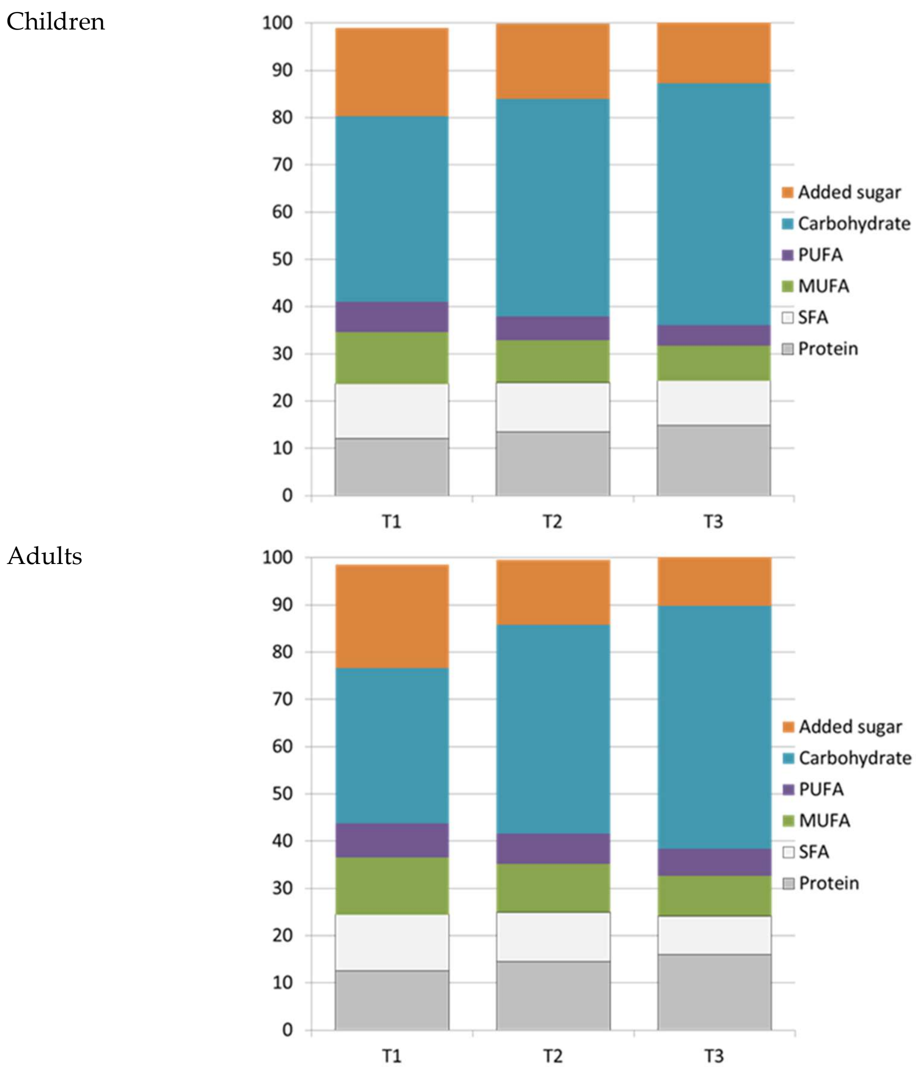

Figure 4. Distribution of breakfast macronutrients by tertiles of NRF9.3d diet quality score. PUFA stands for Polyunsaturated fatty acids, MUFA stands for Monounsaturated fatty acids, SFA stands for Saturated fatty acids,

The amounts of specific food groups consumed by diet quality tertiles are shown in **Table 3**, separately for children and for adults. First, higher-quality diets were associated with higher consumption of citrus fruit, juice and other fruits, whole grains, and milk and yogurt. The consumption of citrus fruit, juice and other fruits doubled or tripled. The consumption of refined grains was cut in half but the consumption of whole grains almost tripled. Higher-quality diets were associated with lower consumption of refined grains, breakfast meats, eggs, and cheese. Meat, poultry and seafood were substantially reduced; there was an increase in consumption of soy, nuts and legumes. The consumption of milk and yogurt increased, cheese dropped slightly. Solid fats were sharply reduced. Among adults, higher quality diets were associated with higher breakfast consumption of soy, nuts and legumes.

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Table 3 Amounts*** *of selected food groups consumed at breakfast across tertiles of NRF 9.3 score by age group in breakfast consumers only

	Children (N=3296)						Adults (N=8269)					
	T1	T2	T3	P*	P**	P***	T1	T2	T3	P*	P**	P***
Citrus fruits	0.02(0)	0.04(0.01)	0.07(0.02)	0.0104	0.015	0.0058	0.02(0)	0.06(0.01)	0.1(0.01)	<0.001	<0.001	<0.001
Juice (cup)	0.09(0.01)	0.19(0.02)	0.21(0.02)	<0.001	<0.001	<0.001	0.07(0.01)	0.16(0.02)	0.17(0.01)	<0.001	<0.001	<0.001
Other fruits	0.06(0.02)	0.09(0.01)	0.12(0.01)	0.0325	0.033	0.0343	0.06(0)	0.13(0.01)	0.24(0.01)	<0.001	<0.001	<0.001
Whole grains	0.18(0.02)	0.3(0.03)	0.47(0.03)	<0.001	0.000	<0.001	0.22(0.02)	0.47(0.03)	0.7(0.03)	<0.001	<0.001	<0.001
Refined grains	1.63(0.06)	1.24(0.07)	0.81(0.04)	<0.001	0.000	<0.001	1.54(0.04)	1.28(0.04)	0.79(0.03)	<0.001	<0.001	<0.001
Meat/poultry/fish	0.41(0.05)	0.29(0.03)	0.1(0.01)	<0.001	0.000	<0.001	0.61(0.03)	0.38(0.03)	0.16(0.01)	<0.001	<0.001	<0.001
Eggs	0.30 (0.03)	0.29(0.03)	0.2(0.03)	0.0457	0.545	0.5191	0.44(0.03)	0.44(0.02)	0.31(0.03)	0.0023	<0.001	0.0098
Soy,Nuts,legumes	0.06(0.01)	0.05(0.01)	0.09(0.02)	0.1455	0.047	0.0738	0.13(0.02)	0.19(0.02)	0.31(0.02)	<0.001	<0.001	<0.001
Milk	0.41(0.03)	0.6(0.03)	0.74(0.03)	<0.001	0.000	<0.001	0.23(0.01)	0.35(0.02)	0.52(0.01)	<0.001	<0.001	<0.001
Yogurt	0.01(0)	0.01(0)	0.03(0.01)	0.0312	0.038	0.0439	0.02(0)	0.03(0)	0.04(0.01)	<0.001	<0.001	0.0027
Cheese	0.07(0.01)	0.08(0.01)	0.05(0.01)	0.0217	0.393	0.3791	0.13(0.01)	0.1(0.01)	0.05(0)	<0.001	<0.001	<0.001

*Unadjusted p-value

**P value adjusted for total energy at breakfast

***P value adjusted for energy at breakfast, ethnicity, income to poverty ratio, education (adults only) and gender

**** Units for citrus fruits, juice, other fruits, milk, yogurt and cheese are cup-equivalents; the units for whole grains, refined grains, MPF, eggs, soy, nuts and legumes are ounce-equivalents.

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Percentages of consumers of specific food groups by diet quality tertiles are shown in Figure 5. First, higher quality diets were associated with more children and adults consuming citrus fruit, juice and other fruits, whole grains and milk and yogurt. Higher quality diets were associated with fewer people consuming refined grains, breakfast meats, eggs, and cheese. Higher quality diets were associated with more adults consuming soy, nuts and legumes.

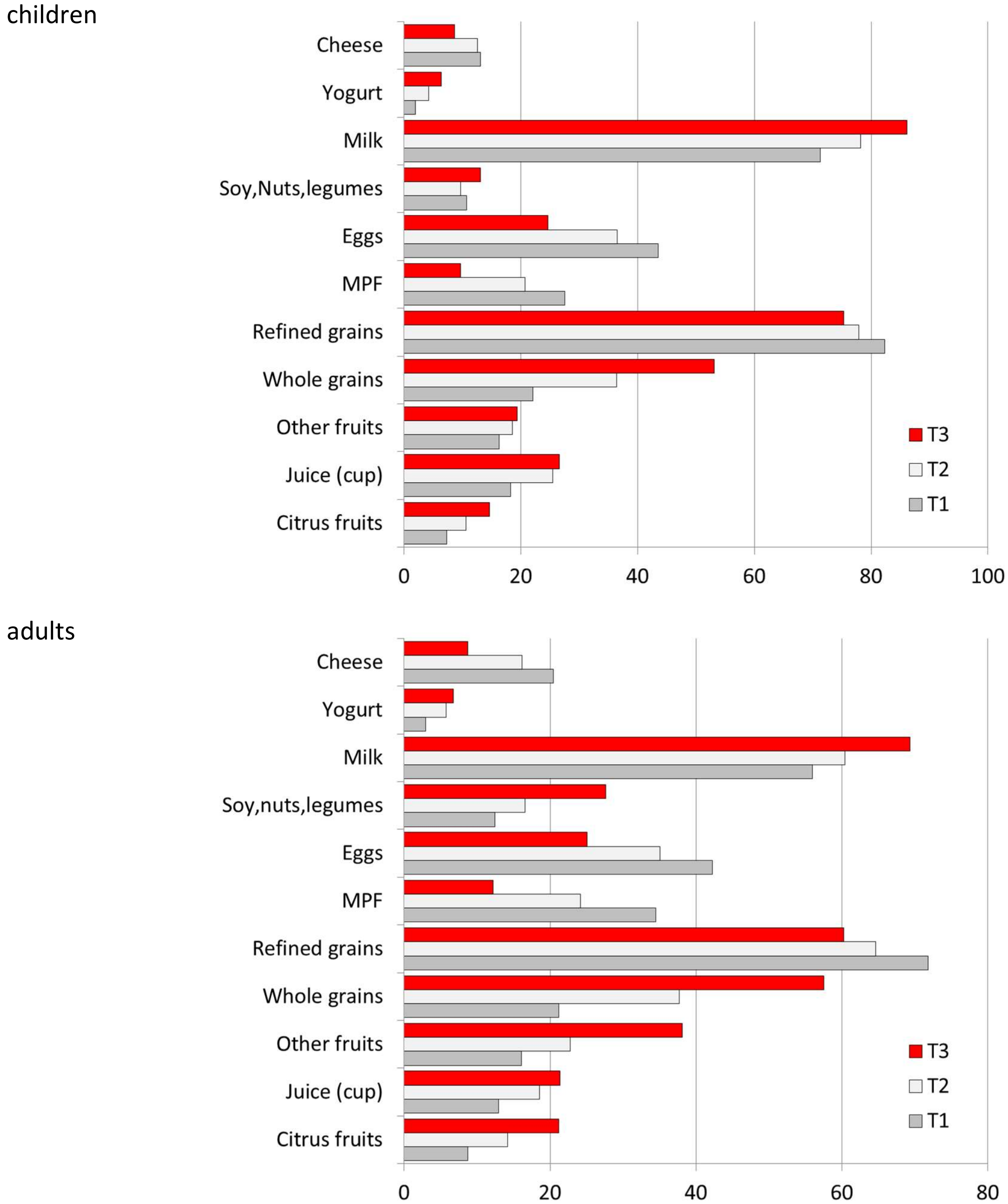

Figure 5: Percent consumers at breakfast for selected food groups by NRF9.3d tertiles. MPF stands for Meat, Poultry, Fish

Table 4 shows the association between breakfast micronutrients and tertiles of the NRF9.3d score. As expected, there was an increase in the intake of nutrients that were in the model (protein, fiber etc). There was also an increase in the intake of qualifying and shortfall nutrients that were not in the model. The latter include B vitamins, B12, folate and others.

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Table 4. Mean (standard error) intake of nutrients at breakfast (among consumers of breakfast only) across tertiles of NRF 9.3 score by age group

	Children						Adults					
	T1	T2	T3	P*	P**	P***	T1	T2	T3	P*	P**	P***
Ranges of NRF	[-568;378]	[378;506]	[506;866]				[-822;376]	[376;521]	[521;878]			
NRF9.3	258(5)	443(2)	595(3)	<0.001	<0.001	<0.001	255(2)	450(1)	622(2)	0.0000	<0.001	<0.001
Vitamins/ minerals in NRF9.3d model												
Vitamin A, RAE (mcg)	184(9)	242(9)	294(8)	<0.001	<0.001	<0.001	158(8)	212(7)	306(15)	<0.001	<0.001	<0.001
Vitamin C (mg)	13(1)	24(2)	28(2)	<0.001	<0.001	<0.001	13(1)	24(2)	35 (2)	<0.001	<0.001	<0.001
Vitamin D (mcg)	2(0.1)	3(0.1)	3(0.1)	<0.001	<0.001	<0.001	2 (0.1)	2(0.1)	3(0.1)	<0.001	<0.001	<0.001
Calcium (mg)	242(10)	312(12)	372(9)	<0.001	<0.001	<0.001	212(5)	268(7)	348(6)	<0.001	<0.001	<0.001
Iron (mg)	4(0.2)	5(0.2)	6.3(0.3)	<0.001	<0.001	<0.001	4(0.2)	5(0.1)	7(0.2)	<0.001	<0.001	<0.001
Potassium (mg)	415(14)	529(18)	581(12)	<0.001	<0.001	<0.001	540(10)	640(13)	789(15)	<0.001	<0.001	<0.001
Magnesium (mg)	44(1)	53(1)	64(2)	<0.001	<0.001	<0.001	57(1)	70(1)	95(2)	<0.001	<0.001	<0.001
Sodium (mg)	656(24)	572(23)	455(15)	<0.001	<0.001	<0.001	784(20)	677(22)	507(10)	<0.001	<0.001	<0.001
Vitamins/ minerals not in the NRF9.3d model												
Retinol (mcg)	180(10)	235(9)	281(7)	<0.001	<0.001	<0.001	150(8)	196(7)	264(6)	<0.001	<0.001	<0.001
Thiamin (mg)	0.4(0.01)	0.5(0.02)	0.6(0.02)	<0.001	<0.001	<0.001	0.4(0.01)	0.5(0.01)	0.6(0.01)	<0.001	<0.001	<0.001
Riboflavin (mg)	0.6(0.02)	0.7(0.02)	0.9(0.02)	<0.001	<0.001	<0.001	0.7(0.02)	0.8(0.01)	0.9(0.01)	<0.001	<0.001	<0.001
Niacin (mg)	5(0.2)	6(0.2)	6(0.2)	<0.001	<0.001	<0.001	6(0.2)	6(0.1)	7(0.2)	0,0010	<0.001	<0.001
Vitamin B6 (mg)	0.4(0.02)	0.6(0.03)	0.7(0.03)	<0.001	<0.001	<0.001	0.5(0.02)	0.6(0.02)	0.8(0.02)	<0.001	<0.001	<0.001
Vitamin B12 (mcg)	1(0.1)	2(0.1)	2(0.1)	<0.001	<0.001	<0.001	1(0.1)	2(0.1)	2(0.1)	<0.001	<0.001	<0.001
Vitamin E (mg)	1(0.1)	1(0.1)	1(0.1)	0.4962	0.139	0.1650	2(0.1)	2(0.1)	3(0.2)	<0.001	<0.001	<0.001
Folate, DFE (mcg)	159(9)	195(10)	258(12)	<0.001	<0.001	<0.001	135(6)	181(5)	265(10)	<0.001	<0.001	<0.001
Total folates (mcg)	107(6)	130(6)	167(7)	<0.001	<0.001	<0.001	96(4)	128(3)	180(6)	<0.001	<0.001	<0.001
Phosphorus (mg)	301(11)	329(12)	352(6)	0.0005	<0.001	<0.001	318(7)	339(7)	381(8)	<0.001	<0.001	<0.001
Zinc (mg)	2(0.1)	3(0.1)	4(0.1)	<0.001	<0.001	<0.001	2(0.1)	3(0.07)	4(0.1)	<0.001	<0.001	<0.001
Copper (mg)	0.2(0)	0.2(0.01)	0.2(0.01)	<0.001	<0.001	<0.001	0.2(0.01)	0.3(0.01)	0.3(0.01)	<0.001	<0.001	<0.001
Selenium (mcg)	22(0.8)	21(0.94)	18(0.7)	<0.001	0.573	0.8552	27(0.6)	26(0.8)	24(0.9)	0,0316	<0.001	<0.001

*p-value unadjusted

** p value adjusted for energy at breakfast

*** P value adjusted for energy at breakfast, ethnicity, income to poverty ratio, education (adults only) and gender

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Lastly, Figure 6 shows the most common food eaten at breakfast by US children and adults. For children, the most frequently consumed foods were milk, baked goods, sweets, whole grain RTEC, juice and whole fruit. For adults, the most frequently consumed items were coffee or tea, sweets (including sugar), baked goods, fats, white bread, and whole fruit. The consumption of low fat dairy and whole grain bread was low.

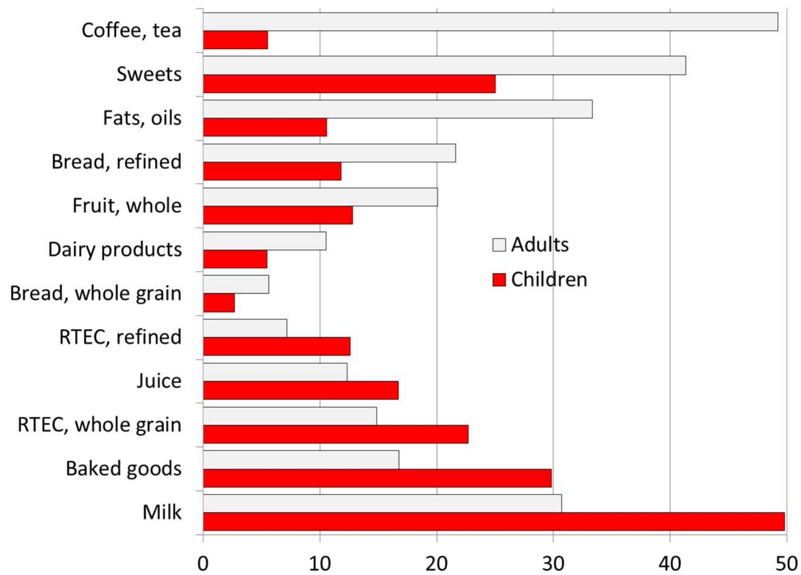

Figure 6. Percent consumers of specific food groups at breakfast by age group (data for breakfast consumers only). RTEC stands for Ready to eat cereals

4. Discussion

The present analyses of 2011-2014 NHANES data asked: what breakfast patterns were associated with highest quality diets for children and adults [1,4,6,19,36]. The answer could shape future dietary guidelines that are increasingly concerned with foods and food groups as well as with nutrients of concern. The 2015 Dietary Guidelines Advisory Committee has delineated the relation between food patterns and health outcomes [29]; the emphasis on healthy food choices and food patterns is likely to continue.

First, four out of 5 of the 2009-2014 NHANES participants ate breakfast on the first day of dietary data collection. Breakfast consumption was associated with higher socioeconomic status and also with higher-quality diets. NRF9.3 scores were higher for breakfast consumers than for non-consumers for every age group. Breakfast skipping was associated with lower education and incomes, themselves predictors of lower quality diets and impaired health [37]. Many previous studies have pointed to associations between breakfast skipping and unfavorable health outcomes [13,14,38-42].

Among breakfast consumers, breakfast provided about 20% of daily energy, depending on age. Breakfast provided >20% of daily carbohydrate and total sugar and <20% of protein and fats. By contrast many micronutrients, vitamins and minerals were provided in amounts exceeding 20% of daily intakes. The definition of nutrient density in the 2005 Dietary Guidelines [43] specified foods that contained "more nutrients than calories". Based on a simple nutrients-to-energy ratio, breakfast can be considered a nutrient rich meal.

Two measures of diet quality were used: the USDA HEI 2015 and the Nutrient Rich Foods Index, adapted for use with total diets (NRF9.3d). Diet quality improved with age. Consistent with past studies, NRF9.3 scores were associated with higher education and incomes. Asians had the highest NRF9.3 scores; non-Hispanic Blacks had the lowest.

As expected, NRF9.3d tertiles were associated with higher intakes of some key nutrients, including those that were in the model and those that were not. Diet quality tertiles are also

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associated with higher consumption of some food groups of interest and with and increasing prevalence of their consumption. The present conclusion is that the NRF9.3 nutrient density score, initially developed to capture nutrient density of individual foods, also captured nutrient density of the total diet. As expected, higher NRF scores were associated with higher SES>. The SES gradient in diet quality was significant for adults, but not for children and teenagers.

There was room for improvement in breakfast quality. For children, the typical breakfast foods were milk, baked goods and sweets, with whole grain RTEC and whole fruit further down on the list. Adult breakfast foods included coffee/tea, sweets, fats and white bread. The present analyses also allowed us to identify those food choices and breakfast patterns that were associated with highest quality diets. Among adults, those optimal patterns were characterized by higher intakes of citrus fruit, whole fruit and juice, soy, nuts, and legumes. Among children, those breakfast patterns were characterized by higher intakes of whole grain cereals, more milk and yogurt and lower intakes of animal protein, less meat, eggs, and saturated fats.

The present results have implications for future public policy, notably the 2020 Dietary Guidelines for Americans. The notion of what constitutes a healthy food is being revisited by the US Food and Drug Administration. Whereas most existing nutrient density scores are based on nutrients alone, there may be room for hybrid scores that include selected foods or food groups alongside nutrients to encourage and nutrients of concern. Such food groups may include fruits, nuts, seeds, whole grains and low-fat dairy.

The IBRI took a unique approach by defining nutrient quality of breakfast in relation to diet quality among breakfast consumers in 6 countries. Whereas nutrient profiles generally deal with individual foods, measures of diet quality assess the total diet. By contrast, federal guidelines for nutrition standards in the national school lunch and school breakfast program are both food and nutrient based. Their goal was to provide nutrient rich meals (high in nutrients and low in calories) to meet the dietary needs of schoolchildren. Rules to reduce sodium, saturated fat and trans fat were accompanied by rules to increase the availability of fruits, vegetables, whole grains and skim and low fat milk on the school menus [44].

The limitations of this study are worth noting. First, all population based dietary data in the US and the 5 other countries were based on self-report. While self-reports may not reflect true dietary intakes, the fact is that most representative population based dietary intake data globally are based on self-report. Second, data analyses were based on the first day of the 2-day NHANES survey. One day recalls are a reliable way to assess nutrient intakes of populations but do not capture the habitual dietary patterns of the individual. Better able to address habitual dietary patterns are the national dietary surveys in France, based on 7-day diaries, and those in the UK, based on 4 days. Third, the breakfast meal was defined by self-report (breakfast or brunch) as opposed to the time of day. In some past studies, the timing of the meal served to define breakfast. Fourth, the food groups of interest were based on a limited number of MyPlate food categories. Finally, the modeling of an optimum breakfast would benefit from formal diet optimization methods such as linear programming

5. Conclusions

The present analyses showed that the American breakfast was already a nutrient dense meal; however, there is room for improvement. While providing 20% of daily energy, breakfast provided higher amounts of key micronutrients. Diet quality of breakfast consumers, assessed using the NRF9.3d score for diets showed that higher diet quality NRF9.3 tertiles were associated with greater consumption of nutrients and food groups of interest.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure S1: title, Table S1: title, Video S1: title.

Author Contributions: CR, FV and AD conceptualized and designed the study. CR developed the databases. FV carried out the analyses and produced summary tables. All authors reviewed and revised the manuscript, and approved the final manuscript as submitted. AD drafted the initial manuscript, and approved the final manuscript as submitted

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