Association of Dietary Variety and Diversity With Body Mass Index in US Preschool Children

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abstract

BACKGROUND AND OBJECTIVES: Dietary variety and diversity are recommended in dietary guidelines, but their association with BMI in US preschool-aged children is unknown. This study examined predictors of dietary variety and diversity and their association with child BMI z score (BMIz).

METHODS: Primary caregivers responded to a food frequency questionnaire. Child anthropometry was obtained concurrently ($n = 340$) and prospectively ($n = 264$). Dietary variety scores and dietary diversity scores were computed. Multivariable linear regression was used to model predictors of these scores and their association with BMIz concurrently and BMIz change per year prospectively.

RESULTS: The sample was 49.4% boys; 69.4% of the primary caregivers were non-Hispanic white and 46.2% had a high school education or less. Girls and older children had greater Fruit and Vegetable Variety (gender: $P = .03$, age: $P < .001$), Healthy Foods Variety ($P = .02$, $P < .001$), and Dietary Diversity ($P = .04$, $P = .03$) scores. Older children also had greater scores for Overall Variety ($P < .001$) and Moderation Foods (eg, high-fat, high-sugar foods recommended to be consumed in moderation) ($P < .001$). Having a non-Hispanic white primary caregiver (versus not) was associated with lower Dietary Diversity ($P = .01$). Greater Healthy Variety, Overall Variety, and Dietary Diversity were associated with greater annual increases in BMIz prospectively (β [SE] = 0.009 [0.004], $P = .04$; β [SE] = 0.007 [0.003], $P = .02$; β [SE] = 0.003 [0.001], $P = .02$, respectively), adjusted for energy intake.

CONCLUSIONS: Greater dietary variety and diversity were prospectively associated with higher BMIz. Targeting dietary variety and diversity as an obesity prevention strategy in children requires careful consideration.

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Ms Fernandez carried out the analysis and drafted the initial manuscript; Dr Kasper designed the diet measurements and analysis plan and critically reviewed and revised the manuscript; Dr Miller designed the overall study, oversaw subject recruitment and data collection, and critically reviewed and revised the manuscript; Dr Lumeng designed the overall study, oversaw subject recruitment, data collection, and analysis, and critically reviewed and revised the manuscript; Dr Peterson designed the component of the study that involved diet assessment, oversaw the creation of diet measurements and the analysis plan, and critically reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

WHAT'S KNOWN ON THIS SUBJECT: Dietary variety and diversity from more healthful food categories are associated with a healthier weight status in US adults. Limited research examines this relationship in US children.

WHAT THIS STUDY ADDS: Dietary variety and diversity are either weakly associated or not associated with an increase in BMI z score in low-income US preschool-aged children. Child age and gender are common predictors of measures of dietary variety and diversity.

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Approximately 22.8% of preschoolers in the United States are overweight or obese,¹ and the prevalence in low-income families is even greater, at 30.4%.² Interventions are needed to prevent obesity in preschoolers, and dietary quality is a frequent focus for these interventions. Dietary quality is a broad term for several measures, including variety and diversity. Dietary variety measures the number of foods consumed from a predetermined list over a given time period. Dietary diversity captures not only the overall variety of foods consumed but also their relative distribution, and adherence to recommended dietary patterns for food groups. Dietary guidelines for Americans^{3–5} promote the consumption of a variety of fruits, vegetables, and proteins, and recommend the proportion of each food group to consume.^{3,4} However, the data supporting the link of either dietary variety or dietary diversity with weight status as a basis for informing obesity interventions are mixed.

A number of studies have examined the association of dietary variety and diversity^{6–12} with weight status in children, mostly outside of the United States, and their results have been conflicting, finding either no association^{6,8,9,12} or positive associations.^{9–11,13,14} The associations of dietary variety and dietary diversity with weight status have been studied more frequently in US adults^{15–17} than children. In adults, a greater variety of healthy foods is associated with a lower prevalence of overweight or obesity, whereas a greater variety of foods recommended to be consumed in moderation (eg, foods containing high levels of fats, added sugars, and sodium) is associated with a higher prevalence.^{15,18} We have been unable to identify any studies examining the association between dietary variety and dietary diversity with weight status in US preschoolers.¹⁹

The overall goal of this study was to examine the associations of dietary variety and dietary diversity with BMI z score (BMIz) in low-income US preschoolers. The first objective was to determine, within a low-income population of preschoolers, the socio-demographic correlates of dietary variety and dietary diversity. The second objective was to test the hypotheses that dietary fruit and vegetable variety, healthy dietary variety, moderation foods variety, and dietary diversity are each associated with BMIz concurrently and with BMIz change per year prospectively.

METHODS

Participants

Participants ($n = 380$) were recruited from Head Start, a federally funded preschool program for low-income children, at sites in Southeast Michigan through an invitation to primary caregivers to participate in a study about children's eating behavior.²⁰ Exclusion criteria were parent with ≥ 4 -year college degree; parent or child not English speaking; child in foster care, with food

allergies, with significant medical problems or perinatal complications, or born at gestational age < 35 weeks. Participants returned for follow-up measurements at an average of 20.6 months (range 7.6–39.2 months). The study was approved by the University of Michigan Institutional Review Board. Written informed consent was provided by parents; families were compensated for their time.

Data Collection and Measures

Most (95%) participating primary caregivers were the child's mother. Questionnaires were administered verbally by research staff. Primary caregivers reported children's gender and age, as well as their own education (categorized as high school education or less versus more than high school education) and race/ethnicity (categorized for this report as non-Hispanic white versus not). Primary caregivers completed the US Department of Agriculture 18-item Household Food Security Survey that categorizes households as food secure or insecure.²¹

Children and their primary caregiver were weighed and measured without shoes or heavy clothing by

TABLE 1 Sample Characteristics ($n = 340$)

	<i>n</i> (%)
Child gender	
Boys	168 (49.4)
Girls	172 (50.6)
Primary caregiver education	
HS graduate/GED or less	157 (46.2)
> HS graduate	183 (53.8)
Race/ethnicity	
White (non-Hispanic)	236 (69.4)
Hispanic or not white	104 (30.6)
Household food security	
Food secure	260 (76.5)
Food insecure	80 (23.5)
	Mean (SD)
Child age, y, at baseline	4.2 (0.5)
Child age, y, at follow-up, $n = 264$	6.0 (0.7)
Primary caregiver BMI	32.4 (8.9)
Fruit and Vegetable Variety	10.1 (4.2)
Healthy Foods Variety	21.7 (6.1)
Moderation Foods Variety	14.1 (4.8)
Overall Variety	35.8 (9.4)
Dietary Diversity	0.5 (0.2)

HS, high school.

TABLE 2 Associations Between Dietary Variety and Dietary Diversity Scores With Sociodemographic Correlates

	Fruit and Vegetable Variety			Healthy Foods Variety			Moderation Foods Variety			Overall Variety			Dietary Diversity		
	Mean (SD)	P		Mean (SD)	P		Mean (SD)	P		Mean (SD)	P		Mean (SD)	P	
Child gender		.16			.21			.52			.63			.14	
Boys	9.8 (4.2)			21.2 (6.0)			14.3 (4.7)			35.5 (9.3)			45.3 (16.2)		
Girls	10.5 (4.3)			22.1 (6.2)			13.9 (5.0)			36.0 (9.6)			47.9 (15.3)		
Primary caregiver education		.84			.61			.28			.82			.21	
HS graduate/GED or less	10.2 (4.2)			21.5 (6.2)			14.4 (5.2)			35.9 (10.1)			45.4 (15.6)		
> HS graduate	10.1 (4.3)			21.8 (6.1)			13.8 (4.5)			35.7 (8.8)			47.6 (15.9)		
Primary caregiver race/ethnicity		.57			.22			.10			.10			.005	
White (non-Hispanic)	10.1 (4.2)			21.4 (6.1)			13.8 (4.6)			35.2 (9.0)			45.0 (15.3)		
Hispanic or not white	10.3 (4.3)			22.3 (6.2)			14.8 (5.3)			37.0 (10.3)			50.2 (16.3)		
Household food security		.41			.39			.01			.05			.50	
Food secure	10.0 (4.3)			21.5 (6.1)			13.7 (4.9)			35.2 (9.4)			46.3 (15.4)		
Food insecure	10.5 (4.0)			22.2 (6.0)			15.4 (4.5)			37.5 (9.6)			47.6 (16.9)		
Child age, y		<.001			<.001			.02			<.001			.07	
Primary caregiver BMI	0.21			0.29			0.12			0.25			0.10		
	0.04			0.03			0.06			0.05			0.09		

HS, high school.

trained staff according to standard protocols on a ± 0.1 kg calibrated scale (Detecto Physician's Scale Model DR550; Webb City, MO) and a ± 0.1 cm calibrated stadiometer (Seca 217/213; Birmingham, United Kingdom). Child BMI z scores were calculated based on the US Centers for Disease Control and Prevention growth references.²²

Data on children's dietary intake were obtained via the Harvard Service Food Frequency Questionnaire (HSFFQ) at baseline.²³ For this study, the times the mother reported the child consumed foods over the past 4 weeks were converted to serving sizes, based on updated information from two 24-hour recalls of foods listed on the HSFFQ in low-income 2- to 3- and 4- to 5-year-olds (Laura Sampson, RD, e-mail communication, October 19, 2012). Mixed dishes were broken down into their constituent foods, based on the standard ingredient assumptions made in the HSFFQ (Laura Sampson, RD, e-mail communication, June 10, 2014).

Each food was assigned into ≥ 1 of the following categories: grain, protein, vegetable, fruit, dairy, combined fruit and vegetable, healthy foods, and moderation foods based on the 2010 Dietary Guidelines for Americans.³ Healthy foods included those for which increases in consumption are recommended (eg, fruits, vegetables, grains, dairy, lean protein). These are foods that, when consumed as part of a balanced diet, are associated with health benefits or with achieving a healthy nutritional status.³ Moderation foods included those for which decreases in consumption are recommended (eg, sweets, salty snacks, high-fat meats, fried foods) to manage body weight and to decrease the risk of certain chronic diseases.³

Creation of Dietary Variety and Diversity Scores

We created an Overall Variety score and variety scores for foods

TABLE 3 Correlates of Dietary Diversity and Dietary Variety Scores

	Fruit and Vegetable Variety		Healthy Foods Variety		Moderation Foods Variety		Overall Variety		Dietary Diversity	
	β (SE)	P	β (SE)	P	β (SE)	P	β (SE)	P	β (SE)	P
Child gender; girls versus boys	0.91 (0.41)	.03	1.29 (0.56)	.02	0.003 (0.42)	.99	1.30 (0.79)	.10	3.30 (1.62)	.04
Child age, y	1.94 (0.39)	<.001	3.68 (0.53)	<.001	1.55 (0.40)	<.001	5.23 (0.75)	<.001	3.26 (1.53)	.03
Primary caregiver education > HS	−0.08 (0.42)	.84	0.28 (0.57)	.63	−0.34 (0.43)	.43	−0.06 (0.80)	.94	2.51 (1.65)	.13
graduate versus not										
Primary caregiver race/ethnicity non-Hispanic white versus not	−0.04 (0.45)	.93	−0.50 (0.61)	.42	−0.57 (0.46)	.22	−1.07 (0.86)	.22	−4.57 (1.77)	.01
Primary caregiver BMI	0.02 (0.02)	.43	0.02 (0.03)	.54	0.03 (0.02)	.18	0.05 (0.04)	.25	0.11 (0.09)	.21
Food secure versus not	0.08 (0.49)	.87	0.05 (0.67)	.94	−0.72 (0.50)	.15	−0.67 (0.95)	.48	−0.48 (1.94)	.81
Adjusted for daily energy intake. HS, high school.										

consumed within the following groups: Fruits and Vegetables, Healthy Foods, and Moderation Foods. Scores were assigned based on the number of foods within each group of which a child consumed ≥ 1 serving per week. One point was awarded to the Variety score for each food that met the criterion of ≥ 1 serving per week. The range of potential scores for Fruit and Vegetable Variety was 0 to 30, for Healthy Variety was 0 to 49, and Moderation Foods Variety was 0 to 31, and Overall Variety was 0 to 80.

The Dietary Diversity score was created to account for (1) the variety of foods served within each food group (more points awarded for more variety); (2) the distribution of consumption of different foods (more points awarded for more even distribution of foods consumed within a group); and (3) the distribution of food groups in the diet, in comparison with the recommended distribution based on the Dietary Guidelines for Americans.³ First, the Berry Index (BI) score²⁴ for vegetables, grains, protein, dairy, and fruit was calculated. The BI score represents the proportion of different types of foods consumed within each of these food groups, and is calculated as $BI = 1 - \sum s_i^2$, where s_i is equal to the number of servings consumed within the food group divided by the number of all foods on the HSFFQ within that group.²⁴ To standardize the BI scores across different food groups, a BI percentile was created comparing the child's BI for each food group with the distribution of BI scores in the analytic sample for that food group.

Next, the total percent concordance of a child's diet with the recommended food group proportions according to the Dietary Guidelines for Americans³ was calculated. The percentage of servings from the 5 major food groups (vegetables, grains, protein,

dairy, and fruit) for each age group was compared with the age-specific recommended proportion of servings to obtain a percentage concordance with dietary guidelines for each food group for that child, from 0% to 100%. This value was multiplied by the BI percentile and then all of the food groups were summed to attain the Dietary Diversity score. The range of potential scores for Dietary Diversity was 0 to 100 with higher scores reflecting a more diverse diet.

Statistical Analysis

The analytic sample was limited to children with complete data for baseline BMIz, dietary data, and sociodemographic information ($n = 340$). The sample with complete data ($n = 340$) did not differ from the sample without complete data ($n = 40$) with regard to child gender, child age, and child BMIz. The analytic sample did differ with regard to the primary caregiver's level of education ($P = .02$), such that primary caregivers of those included in the study had a higher level of education. The participants with follow-up measurements ($n = 264$) did not differ from those with baseline data but without follow-up measurements ($n = 76$) with regard to child gender, child age, primary caregiver's education level, or child BMIz at baseline.

Univariate statistics were used to describe the sample. Bivariate associations between the sociodemographic characteristics and the dietary variety and Dietary Diversity scores were estimated. Multivariable linear regression models were used to test the association of sociodemographic characteristics with the dietary variety and Dietary Diversity scores, adjusting for estimated energy intake. Linear regression models were used to assess the association of the dietary variety and Dietary Diversity scores with the children's BMIz concurrently

TABLE 4 Association of Dietary Variety and Dietary Diversity Scores with BMIZ

	Baseline BMIZ ^a		BMIZ Change Per Year ^b	
	β (SE)	<i>P</i>	β (SE)	<i>P</i>
Fruit and Vegetable Variety	0.013 (0.015)	.37	0.011 (0.006)	.06
Healthy Foods Variety	0.006 (0.011)	.55	0.009 (0.004)	.04
Moderation Foods Variety	0.014 (0.014)	.32	0.008 (0.005)	.13
Overall Variety	0.007 (0.008)	.33	0.007 (0.003)	.02
Dietary Diversity	−0.001 (0.004)	.86	0.003 (0.001)	.02

^a Adjusted for child: gender, age, daily energy intake; primary caregiver: education, race/ethnicity, BMI; household food security.

^b Adjusted for all the same variables as the Baseline BMIZ model and for baseline BMIZ. Average follow-up time was 20.6 months.

($n = 340$) and rate of change per year in BMIZ from baseline to the follow-up time ($n = 264$), controlling for child gender, age, energy intake; primary caregiver education, race/ethnicity, and BMI; and household food security. The models evaluating change in BMIZ as outcomes also controlled for the child's baseline BMIZ. We also computed models to examine whether the association of dietary variety and dietary diversity scores with prospective change in child BMIZ differed by the child's baseline weight status, adjusting for covariates.

RESULTS

Characteristics of the sample at baseline ($n = 340$) are shown in Table 1. The unadjusted bivariate associations are shown in Table 2. Non-Hispanic whites had a lower mean Dietary Diversity score (mean [SD] = 45.0 [15.3]) than other race/ethnicities (mean [SD] = 50.2 [16.3]) ($P = .005$). Those in food insecure households had a higher mean Moderation Foods Variety score (mean [SD] = 15.4 [4.5]) than those in food secure households (mean [SD] = 13.7 [4.9]) ($P = .01$). None of the mean scores for any of the measures differed by child gender or primary caregiver education. Age was positively correlated with each of the measures of dietary variety, but not with the Dietary Diversity score ($P = .07$). Primary caregiver BMI was not significantly correlated with any of the 5 scores.

The associations of sociodemographic characteristics in multivariable

models with each dietary variety score and the Dietary Diversity score, adjusted for energy intake, are shown in Table 3. Girls had higher Fruit and Vegetable Variety (β [SE] = 0.91 [0.41]; $P = .03$), Healthy Foods Variety (β [SE] = 1.29 [0.56]; $P = .02$), and Dietary Diversity (β [SE] = 3.30 [1.62]; $P = .04$) scores than boys. Older child age was associated with higher scores in all measures of dietary variety and Dietary Diversity. The child's primary caregiver being non-Hispanic white was associated with a lower Dietary Diversity score than if the primary caregiver was any other race/ethnicity (β [SE] = −4.57 [1.77]; $P = .01$). Primary caregiver education, primary caregiver BMI, and household food security were not associated with any of the scores.

The associations of the dietary variety scores and the Dietary Diversity score with BMIZ are shown in Table 4. There were no significant associations between any of the 5 scores and concurrent BMIZ. Greater Healthy Variety, Overall Variety, and Dietary Diversity each were associated with greater annual increases in BMIZ from baseline to follow-up, but the effect sizes were small. There was suggestive evidence of an association of greater Fruit and Vegetable Variety with a greater annual increase in BMIZ ($P = .06$) though the effect size also was small.

The association of the dietary variety scores and the Dietary Diversity score with the rate of change in BMIZ per year, stratified by child baseline weight status is shown in Table 5. Among children who were

obese at baseline, greater Healthy Foods Variety was associated with greater annual increases in BMIZ. In this same subset of children, there was suggestive evidence of a positive association between greater Fruit and Vegetable Variety, Overall Variety, and Dietary Diversity and annual increases in BMIZ ($P = .08$, $P = .06$, and $P = .05$, respectively). For children with a baseline BMI under the 50th percentile, there was suggestive evidence of an association between Overall Variety and greater annual increases in BMIZ ($P = .08$).

DISCUSSION

This study had several key findings. First, girls had higher measures of healthier dietary quality. Older children had more variety in all measures and also had greater diversity. Children of Hispanic or nonwhite primary caregivers had more diverse diets. The primary caregiver's level of education, primary caregiver's BMI, and the household's food security status were not associated with the child's dietary variety or diversity. The second key finding was that there was no detectable association of dietary variety or diversity with the child's BMIZ concurrently. Furthermore, greater dietary variety and diversity were associated with significantly greater prospective annual increases in the child's BMIZ over a follow-up period averaging 20.6 months in models adjusting for energy intake and potential confounders. Although these effect sizes were small, they are notable in

TABLE 5 Association of Dietary Variety and Dietary Diversity Scores With BMIz Change per Year, Stratified by Baseline BMI

	BMIz Change Per Year ^a					
	BMI Percentile <50, n = 49		50 ≤ BMI percentile <85, n = 116		Overweight, n = 47	
	β (SE)	P	β (SE)	P	β (SE)	P
Fruit and Vegetable Variety	0.016 (0.031)	.60	0.009 (0.008)	.25	0.007 (0.013)	.58
Healthy Foods Variety	0.016 (0.022)	.47	0.005 (0.006)	.41	0.008 (0.009)	.37
Moderation Foods Variety	0.036 (0.021)	.09	0.003 (0.007)	.73	−0.006 (0.012)	.61
Overall Variety	0.026 (0.015)	.08	0.003 (0.004)	.44	0.003 (0.007)	.71
Dietary Diversity	0.004 (0.007)	.56	0.003 (0.002)	.13	0.003 (0.003)	.34

^a Adjusted for child: gender, age, daily energy intake; primary caregiver: education, race/ethnicity, BMI; household food security; baseline BMIz. Average follow-up time was 20.6 months.

that the direction of effect was the opposite of that which is generally motivating efforts to improve the quality of children's diets. The effects on greater prospective annual change in BMIz were most notable for Healthy Variety, Overall Variety, and Dietary Diversity. We sought to determine whether these positive associations could be explained by healthy weight gain in lower-weight children. Stratified analyses indicate that this is the not the case, because statistically significant and suggestive associations primarily were observed in children who were obese at baseline.

Our finding that girls consume diets higher in healthy dietary variety and diversity measures (indicators of high dietary quality) but not in Moderation Foods Variety (an indicator of lower dietary quality) is consistent with previous studies that have found that girls tend to have higher-quality diets than boys.^{25–28} Also, several studies have demonstrated that girls tend to consume greater quantities of fruits and vegetables and that they consume them more frequently.²⁶ Our finding that older children consumed diets higher in variety and diversity is consistent with previous work documenting that children accept a wider variety of foods as they grow older.²⁹ Our finding that having a parent who is Hispanic or nonwhite is associated with the child consuming a diet with greater diversity, and that race/ethnicity was not associated with variety measures, contributes to a mixed literature with regard to the association between diet quality and race/ethnicity.^{28,30–33}

The emphasis on variety and diversity in dietary guidelines may not be compatible with efforts to decrease the risk of obesity in low-income children. Our results showed either no association or a positive association between variety and diversity with BMIz.

Our cross-sectional results, which indicated no association between any of the variety or diversity measures with BMIz, were consistent with several other cross-sectional studies^{6,8,9} in children of similar age ranges but they were also inconsistent with some that show significant positive associations.^{7,9–11} However, the vast majority of these cross-sectional studies were conducted in developing countries.^{7–11} In a cross-sectional study⁶ conducted in a population more likely to be similar to US children (Spain), the results were consistent with those in the current study: there was no significant association between obese or overweight with dietary variety. The results of our prospective analyses, which showed a positive association between most measures of dietary variety and diversity with annual change in BMIz, are consistent with the other prospective studies^{12–14} in US children who we were able to identify. In contrast, other measures of overall dietary quality have been shown in some studies to be negatively associated with BMI in children.^{34,35} It is important to note that, although we saw some positive associations between variety and diversity with BMIz, the effect sizes were small and are not indicative of an increased risk of attaining an unhealthy BMIz. Furthermore, previous literature shows that greater dietary variety and diversity are associated with a decreased risk for nutritional inadequacy.^{36–39}

The inconsistent findings in the literature of dietary variety or diversity may be due, in part, to different serving cutoff points to determine if the consumption of a particular food will count toward the variety or diversity score. For example, in the study by Mirmiran et al,¹⁰ at least half a serving of a food must be consumed for it to count toward the diversity score; in the Diet Diversity 10-g score created by

Kennedy et al,⁹ at least 10 g of a food needs to be consumed for it to count toward the variety score (except fats and oils); and in the study by Chua et al,¹¹ a point was awarded toward the variety score for any food item consumed daily or in the past 7 days. Additionally, other aspects in the measurement of variety and diversity differ. In some studies (as in the current study), a simple count of foods consumed within food groups is used as a measure of variety.^{6,7,11} In other studies, additional steps are taken when creating a measure, such as truncating scores so that the consumption of more than the recommended serving of a single food or food group does not inflate the variety score.^{8,13}

Strengths of this study include the longitudinal sample with a high prevalence of overweight and obesity. This population is unique in that no previous studies of dietary variety

and diversity have the combined characteristics of this sample: a US population that is low-income, of mixed race/ethnicity, and of preschool age. We constructed indices of dietary variety that differentiate between foods for which an increase in consumption is recommended and foods for which a decrease in consumption is recommended. Furthermore, we created a novel measure of dietary diversity that accounted not only for the variety of intake but also for proportions and adherence with the 2010 Dietary Guidelines for Americans. Another strength is that we adjusted for energy intake and for several other confounders. There are limitations that should be noted. The dietary data were obtained by food frequency questionnaire, which relies on estimated portions and preparation methods and does not differentiate between different types or brands of food items. Also, the results may not

be generalizable to populations unlike this cohort (low-income Midwestern preschool-aged children).

CONCLUSIONS

The current study, as well as previous literature, finds that dietary variety and diversity are either not associated, or are weakly associated with an increase (not decrease) in BMIz. Despite the importance of dietary quality for a healthy nutritional profile and for healthy growth, increasing the variety of healthy foods in children's diets for the purpose of obesity control or prevention requires careful consideration.

ABBREVIATIONS

BI: Berry Index
 BMIz: BMI z score
 HSFFQ: Harvard Service Food Frequency Questionnaire

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