American Journal of Epidemiology
Published by Oxford University Press on behalf of the Johns Hopkins Bloomberg School of Public Health 2015. This work is written by (a) US Government employee(s) and is in the public domain in the US.

Vol. 181, No. 12
DOI: 10.1093/aje/kwu461
Advance Access publication:
May 1, 2015

Practice of Epidemiology

Using Behavioral Risk Factor Surveillance System Data to Estimate the Percentage of the Population Meeting US Department of Agriculture Food Patterns Fruit and Vegetable Intake Recommendations

Latetia V. Moore*, Kevin W. Dodd, Frances E. Thompson, Kirsten A. Grimm, Sonia A. Kim, and Kelley S. Scanlon

* Correspondence to Dr. Latetia V. Moore, Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770 Buford Highway NE, Mailstop F77, Atlanta, GA 30341 (e-mail: lvmoore@cdc.gov).

Initially submitted June 17, 2014; accepted for publication December 15, 2014.

Most Americans do not eat enough fruits and vegetables with significant variation by state. State-level self-reported frequency of fruit and vegetable consumption is available from the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS). However, BRFSS cannot be used to directly compare states' progress toward national goals because of incongruence in units used to measure intake and because distributions from frequency data are not reflective of usual intake. To help states track progress, we developed scoring algorithms from external data and applied them to BRFSS 2011 data to estimate the percentage of each state's adult population meeting US Department of Agriculture Food Patterns fruit and vegetable intake recommendations. We used 24-hour dietary recall data from the National Health and Nutrition Examination Survey, 2007–2010, to fit sex- and age-specific models that estimate probabilities of meeting recommendations as functions of reported consumption frequency, race/ethnicity, and poverty-income ratio adjusting for intraindividual variation. Regression parameters derived from these models were applied to BRFSS to estimate the percentage meeting recommendations. We estimate that 7%–18% of state populations met fruit recommendations and 5%–12% met vegetable recommendations. Our method provides a new tool for states to track progress toward meeting dietary recommendations.

fruits; recommended intake; states; vegetables

Abbreviations: BRFSS, Behavioral Risk Factor Surveillance System; NHANES, National Health and Nutrition Examination Survey; PIR, poverty-income ratio.

Despite the numerous benefits of consuming adequate amounts of fruits and vegetables, most Americans do not eat nearly enough (1). Higher intakes of both contribute important nutrients frequently lacking from Americans' diets (2) and reduce the risk of heart disease (3), stroke (4), diabetes (5), and some cancers (6). Substituting fruits and vegetables for higher calorie foods may also aid in healthy weight management (2, 7, 8). Fruit and vegetable intake recommendations vary by sex, age, and physical activity level according to the US Department of Agriculture Food Patterns, one of the dietary patterns consistent with the Dietary Guidelines for Americans 2010 (2). American adults should be consuming from 1.5 to 2 cup equivalents of fruits and from 2 to 3 cup equivalents of vegetables daily depending on their age and sex (9, 10). Physically active adults should consume more. One cup is approximately equal to 1 small apple (149 g), 8 large strawberries (144 g), 12 baby carrots (120 g), or 1 large tomato (182 g) (9, 10).

Twenty-four-hour dietary recall data from the National Health and Nutrition Examination Survey (NHANES) are the source for monitoring national progress toward meeting US Department of Agriculture Food Patterns fruit and vegetable recommendations, hereafter referred to as "federal recommendations." Because significant state variation in consumption exists (11), there is also a need to monitor state-specific progress. However, NHANES does not have

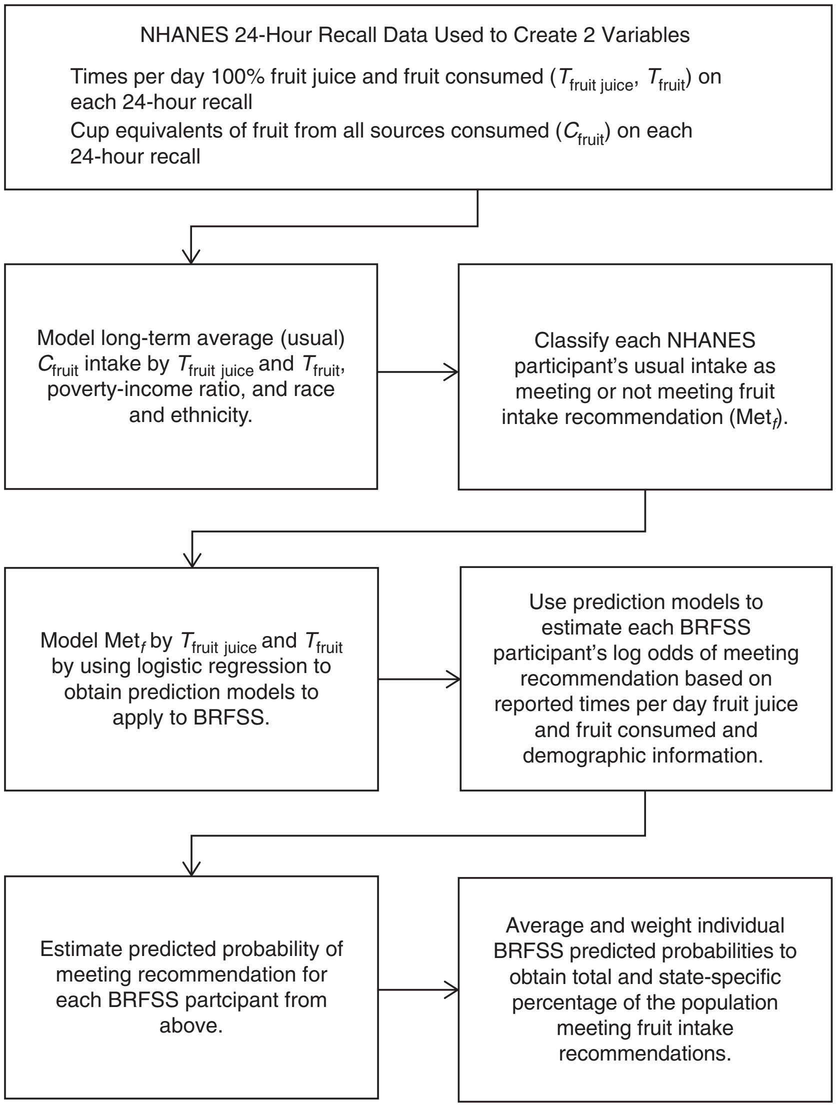

Figure 1. Overview of the method to estimate the percentage of the population meeting fruit intake recommendations, National Health and Nutrition Examination Survey (NHANES), United States, 2007–2010, and Behavioral Risk Factor Surveillance System (BRFSS), United States, 2011.

an adequate sample size to produce state-specific estimates. The sole surveillance system that tracks state-level adult fruit and vegetable intake is the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS).

Biennially since 1994, BRFSS has asked respondents to report their frequency of fruit and vegetable intake via a brief food frequency screener module. The module asks how many times per day, week, or month various fruit and vegetable groups are consumed. Although the BRFSS fruit and vegetable module can track national and state-specific changes in reported frequencies of consumption, the module cannot be used to directly compare the progress states are making toward meeting national goals or federal recommendations. Previously, BRFSS data were used to estimate the percentage of adults consuming fruits and vegetables 5 or more times daily and the percentage consuming fruit 2 or more times and vegetables 3 or more times daily (12) in line with the 5-A-Day for Better Health Program and Healthy People 2010 objectives (consume ≥2 fruit servings and ≥3 vegetable servings daily) (13, 14). However, times per day and servings per day are not equivalent (15), the 5-A-Day Program was discontinued in 2007, and Healthy People 2020 objectives are now measured in cup equivalents per 1,000 calories (16). Federal fruit and vegetable intake recommendations are also measured in cup equivalents that are not directly comparable to frequency data from BRFSS.

To address this gap in monitoring state-level progress toward meeting national goals, we developed a method to estimate the percentage of the population meeting federal fruit and vegetable intake recommendations for the 50 states and Washington, DC, using times per day data from BRFSS 2011.

METHODS

To estimate the percentage of each state's population meeting recommendations, we extended a scoring procedure (17) that used NHANES 2003–2006 twenty-four-hour dietary recall data and ordinary least-squares regression to estimate cup equivalents consumed from consumption frequency and median portion sizes for selected food groups. The prediction model is then applied to screener frequency data to predict the mean cup equivalents consumed. We built upon the original scoring procedure in 4 ways. First, we used data from a more recent source, NHANES 2007–2010 (17). All NHANES 2007–2010 participants 18 years of age or older with reliable 24-hour dietary recalls were included (n = 11,742 participants; 1,561 participants with 1 day of recall and 10,181 participants with 2 days of recall). Second, we accounted for intraindividual variation. Because individuals do not eat the same foods and amounts of food each day, intraindividual variation may lead to an overestimation of the percentage of persons with very low or very high usual intakes (18). The original procedure estimated only mean intake, which is not affected by this variation. Third, we revised the fruit and vegetable food groups to parallel the food groups currently asked about in BRFSS 2011 (100% fruit juice, fruit, dried beans, dark green vegetables, orange vegetables, and other vegetables). Fourth, we accounted for variation in portion sizes by using 8 sex- and age-specific models to be consistent with prior research assessing compliance with federal dietary recommendations (1). An overview of the method for estimating the percentage meeting fruit intake recommendations is presented in Figure 1.

NHANES times per day each fruit and vegetable group was consumed (independent variable)

The first variable calculated from NHANES 24-hour dietary recalls was the reported number of times per day fruits and vegetables were consumed. To calculate this, we sorted all foods and beverages on the basis of main ingredients into 1 of the 6 fruit and vegetable food groups in the BRFSS 2011 module or labeled as all other foods (Web Appendix 1 available at http://aje.oxfordjournals.org/) (19). We then summed the number of times each participant reported any food classified into 1 of the 6 fruit and vegetable groups for each day of report. The following foods were excluded to make calculated times per day from NHANES better reflect the types of foods that are typically reported when adults are asked food frequency screener questions like those in BRFSS: beverages other than 100% fruit juice, fried potatoes, baby foods, dried fruit, condiments including tomato sauces (salsa, ketchup, spaghetti sauce, etc.), olives, pickles, relishes, vinegars, and fruits and vegetables eaten in combination with sandwiches (i.e., lettuce and tomatoes on sandwiches). Fried potatoes and non-100% fruit juices were excluded because BRFSS explicitly instructs respondents not to include these items. Baby foods were excluded because these analyses are intended for use in adult populations. The other foods were excluded because cognitive testing indicates that, when adults are asked food frequency screener questions similar to the BRFSS questions, they do not report these types of foods without explicit prompting (20–22). We compared extracted frequencies for 100% fruit juice, fruit, and legumes using only 2009–2010 twenty-four-hour dietary recalls to reported frequencies from 3 similar items from the 26-item diet screener in NHANES 2009–2010 to test the validity of these assumptions. Frequencies extracted from NHANES were used as the independent variable in the scoring procedure models.

NHANES cup equivalents from all sources of fruits and vegetables (dependent variable)

The second variable calculated from the NHANES dietary recall data was reported cup equivalents of fruits and of vegetables consumed from all food sources in the 24-hour dietary recalls except fried potatoes and non-100% fruit juice beverages. This variable includes foods and beverages previously excluded when estimating the times per day variable (baby foods, dried fruit, condiments, olives, pickles, relishes, vinegars, and fruits and vegetables eaten in combination with sandwiches). US Department of Agriculture Food Patterns Equivalents Databases 2007–2008 and 2009–2010 were used to disaggregate all reported foods and beverages except fried potatoes and non-100% fruit juices into their ingredients and estimate cup equivalents of fruits and vegetables consumed by each respondent (23–26). For each individual, cup equivalents of fruits and vegetables from all relevant food sources were totaled for each day of report. Total cup equivalents of fruits and total cup equivalents of vegetables were used as the dependent variables in the scoring procedure models.

Estimating percentage meeting recommendations

The 2 variables above were used to simulate samples of individual usual intake amounts fit via 1- or 2-part nonlinear mixed models using macros provided by the National Cancer

Table 1. Amounts of Fruits and Vegetables Needed Daily[a]

Sex and Age Range, years	Recommended Servings, cup equivalents/day[b]	
	Vegetables	Fruits
Women		
19–30	2½	2
31–50	2½	1½
≥51	2	1½
Men		
19–30	3	2
31–50	3	2
≥51	2½	2

[a] These amounts are appropriate for individuals who get less than 30 minutes per day of moderate physical activity, beyond normal daily activities (9, 10). Those who are more physically active may be able to consume more while staying within calorie needs (9, 10).

[b] One cup is approximately equal to 1 small apple (149 g), 8 large strawberries (144 g), 12 baby carrots (120 g), or 1 large tomato (182 g) (9, 10).

Institute (27). These simulated intakes reflect relationships among usual intake amounts, reported frequencies of the 6 fruit and vegetable groups per day, and demographic covariates, after adjustment for intraindividual variation and systematic differences between weekend (Friday–Sunday) and weekday (Monday–Thursday) intake and between the first and second 24-hour dietary recalls. Each simulated usual intake amount was classified as meeting or not meeting the recommendation. The resulting binary variables were modeled by using logistic regression with the reported frequencies of the 6 fruit and vegetable groups per day used in the usual intake model to obtain prediction equations for the log odds of meeting federal fruit and vegetable intake recommendations (9, 10). Equations were also developed that estimate the usual amounts of fruits and vegetables consumed.

For these analyses, recommended amounts of fruits and vegetables for sedentary individuals were used (Table 1). All modeling accounted for the NHANES survey design. Consistent with prior work, sex- and age-specific 1- or 2-part models were estimated for males and females separately for fruits and vegetables (18–30, 31–50, 51–70, and ≥71 years of age) (1, 28). A 2-part nonlinear mixed model was used to estimate the usual fruit intake distributions for all sex-age groups because fruit was consumed episodically (4%–44% of 24-hour dietary recall days had 0 intake) (1, 29). Part 1 models, represented below, model the probability of consuming fruit (cup equivalents of fruit consumed >0) by extracted times per day fruit juice and whole fruits were consumed for each NHANES participant's day of recall. Part 2 models for fruit model the amount of fruit consumed in cup equivalents by the frequencies of fruit juice and fruit intake for each reported recall day. Part 1 and part 2 models were fit simultaneously. Additional details regarding how models were fit are available from prior work (29). One-part models were used to estimate the usual vegetable intake distributions for all sex-age groups because they were consumed almost daily by everyone (i.e., days of 0 intake ranged from 5% to 8%) (1, 29). Models for vegetables modeled the amount of vegetables consumed in cup equivalents by the extracted times per day dried beans, dark green vegetables, orange vegetables, and other vegetables were consumed. Dummy variables were included in models to account for variation due to collecting 24-hour dietary recalls on weekends versus weekdays and first versus second 24-hour dietary recall, and also for demographic covariates, poverty-income ratio (PIR), and race/ethnicity. To be consistent with prior work estimating the percentage meeting recommendations and to fully account for each person's intake given all their own covariates, not just population averages, we account for race/ethnicity and PIR to explain some of the variation observable between usual intake and times per day fruits and vegetables are eaten. PIR was categorized as 2 dummy variables: <1.25 and 1.25–3.49 versus the referent group of >3.49. Race/ethnicity was categorized with 2 dummy variables: Hispanic and non-Hispanic black versus a referent group of all others.

Two-part model for fruit:

Part 1. Probability of consumption model with a person-specific random effect:

$$\begin{aligned}&\log(\text{probability of consuming fruit})/(1-\text{probability of consuming fruit})\\&\quad=\beta_0+\beta_1(T_{\text{fruit juice}})+\beta_2(T_{\text{fruit}})+\beta_3(\text{weekend effect})+\beta_4(\text{day of recall})\\&\qquad+\beta_5(\text{Hispanic})+\beta_6(\text{non-Hispanic black})+\beta_7(\text{PIR}<1.25)\\&\qquad+\beta_8(\text{PIR }1.25-3.49)+\text{person-specific effect},\end{aligned}$$

where $T_{\text{fruit juice}}$ and T_{fruit} = number of times that 100% fruit juice and fruit consumed on each 24-hour recall and the person-specific effect are normally distributed.

Part 2. Consumption amount model with a person-specific random effect:

$$\begin{aligned}&\text{Transformed cup equivalents of fruits consumed from all sources}\\&\quad=\beta_0+\beta_1(T_{\text{fruit juice}})+\beta_2(T_{\text{fruit}})+\beta_3(\text{weekend effect})+\beta_4(\text{day of recall})\\&\qquad+\beta_5(\text{Hispanic})+\beta_6(\text{non-Hispanic black})+\beta_7(\text{PIR}<1.25)\\&\qquad+\beta_8(\text{PIR }1.25-3.49)+\text{person-specific effect}+\text{within-person variability},\end{aligned}$$

where the person-specific effect and within-person random variability are normally distributed.

The logistic regression prediction equations from the NHANES models (Web Table 1) were then applied to BRFSS to obtain individual BRFSS participants' log odds of meeting recommendations. The times per day each BRFSS participant reported eating each fruit and vegetable group and each participant's PIR and race/ethnicity were substituted for the frequency and demographic covariates in the prediction equations, respectively. Data from BRFSS 2011 participants aged 18 years or older with complete data were analyzed (n = 393,169 of 506,467). Participants were excluded if they did not reside in the 50 states and Washington, DC (n = 8,500), their reported fruit or vegetable frequency exceeded upper limits of acceptable dietary data values (reported eating fruit >16 times per day or vegetables >23 times per day; n = 105) (15), or they were missing responses to 1 or more questions (n = 48,422). Reported frequencies of fruit and vegetable intakes were converted into daily frequencies (weekly frequencies were divided by 7; monthly by 30; and yearly by 365). Categories for PIR and race/ethnicity were identical to those described for NHANES. To calculate PIR in BRFSS, the midpoint of reported household income was used for those who reported their household income (n = 393,169). Household size was assumed to be 1 for the 55,875 participants who did not report the number of individuals residing in the household.

Logistic regression prediction equation for fruit:

$$\frac{\log(\text{probability of meeting recommendation})}{(1-\text{probability of meeting recommendation})_{\text{sex-age group } i}}$$
$$= \beta_0 + \beta_1(T_{\text{fruit juice}}) + \beta_2(T_{\text{fruit}}) + \beta_3(\text{Hispanic}) + \beta_4(\text{non-Hispanic black}) + \beta_5(\text{PIR} < 1.25) + \beta_6(\text{PIR } 1.25\text{–}3.49),$$

where p(meeting recommendation) = probability of meeting the fruit intake recommendation for sex-age group i and $T_{\text{fruit juice}}$ and T_{fruit} = number of times 100% fruit juice and fruit consumed on each 24-hour recall.

To obtain the total and state-specific estimates of percentage of the population meeting recommendations, we first calculated individual BRFSS participants' predicted probabilities of meeting recommendations from their log odds of meeting recommendations from the prediction equations.

$$p(\text{meeting recommendation}) = e^{\log\left[\frac{p(\text{meeting recommendation})}{1-p(\text{meeting recommendation})}\right]} \Big/ \left\{1 + e^{\log\left[\frac{p(\text{meeting recommendation})}{1-p(\text{meeting recommendation})}\right]}\right\}.$$

Table 2. Fruit and Vegetable Intake According to Selected Demographic Characteristics, National Health and Nutrition Examination Survey, United States, 2007–2010, and the Behavioral Risk Factor Surveillance System, United States, 2011[a]

Characteristic	National Health and Nutrition Examination Survey							Behavioral Risk Factor Surveillance System		
	Unweighted No. of Participants	Unweighted % With 0 Intake[b]		Median Times per Day[c]		Median Cup Equivalents[d]		Unweighted No. of Participants	Median Times per Day	
		Fruits	Vegetables	Fruits	Vegetables	Fruits	Vegetables		Fruits	Vegetables
Total	11,742	19.0	2.0	0.53	1.11	0.69	1.28	393,169	1.10	1.63
Females										
18–30	1,289	23.7	2.1	0.31	0.70	0.49	0.99	20,700	1.10	1.57
31–50	1,994	18.5	1.9	0.46	1.15	0.52	1.16	69,217	1.14	1.78
51–70	1,740	12.4	1.6	0.88	1.72	0.95	1.42	100,512	1.16	1.86
≥71	964	7.0	1.6	1.18	1.76	0.99	1.25	43,304	1.43	1.76
Males										
18–30	1,245	30.0	2.7	0.24	0.49	0.49	1.19	16,886	1.00	1.43
31–50	1,825	27.3	2.0	0.27	0.85	0.50	1.42	47,350	1.00	1.53
51–70	1,773	17.3	2.0	0.64	1.36	0.81	1.53	69,373	1.00	1.56
≥71	912	10.9	2.1	1.01	1.54	0.99	1.39	25,827	1.17	1.57
Race/ethnicity										
Hispanic	3,381	16.7	1.3	0.58	1.06	0.78	1.33	24,868	1.14	1.63
Non-Hispanic black	2,298	23.4	2.7	0.36	0.68	0.62	0.90	31,136	1.06	1.30
Other	6,063	18.6	2.1	0.55	1.20	0.69	1.32	337,165	1.07	1.67
Poverty-income ratio										
<1.25	4,389	23.2	2.7	0.39	0.87	0.63	1.13	73,588	1.00	1.43
1.25–3.49	4,232	18.8	1.8	0.51	1.04	0.66	1.22	159,790	1.06	1.57
>3.49	3,121	13.4	1.2	0.66	1.36	0.79	1.44	159,791	1.14	1.77

[a] Estimates are weighted to account for complex sampling by using SUDAAN software except where noted. Fruits consist of 100% fruit juice and whole fruit. Vegetables include legumes, dark green and orange vegetables, and other vegetables.

[b] Percentage of people with 0 intake over 1 or 2 twenty-four-hour dietary recall days; 1,561 have 1 recall day, and 10,181 have 2 recall days. Estimates are unweighted.

[c] Only foods that parallel Behavioral Risk Factor Surveillance System questions were counted in times per day. Estimates were averaged over number of recall days.

[d] Total cup equivalents per day of fruits and vegetables from all sources except fried potatoes and beverages other than 100% fruit juice. One cup is approximately equal to 1 small apple (149 g), 8 large strawberries (144 g), 12 baby carrots (120 g), or 1 large tomato (182 g) (9, 10). Estimates were averaged over number of recall days.

Table 3. Fruit and Vegetable Intake, Behavioral Risk Factor Surveillance System, United States, 2011[a,b]

State	Unweighted No. of Participants	Median Times per Day		% of the Recommended Amount Consumed[c]		% Meeting or Exceeding Recommendations[c,d]	
		Fruits	Vegetables	Fruits	Vegetables	Fruits	Vegetables
All states	393,169	1.1	1.6	59.4	63.1	13.8	8.2
Alabama	5,773	1.0	1.6	52.1	60.5	10.4	6.5
Alaska	2,744	1.1	1.7	59.2	66.5	13.8	9.8
Arizona	5,139	1.1	1.7	60.5	66.2	14.5	10.3
Arkansas	3,666	1.0	1.5	53.0	59.7	11.7	6.8
California	15,189	1.3	1.9	67.4	68.2	17.7	11.4
Colorado	10,691	1.1	1.7	61.2	66.0	14.5	9.6
Connecticut	5,448	1.3	1.7	65.4	65.1	17.0	9.1
Delaware	3,810	1.0	1.6	55.1	60.6	11.5	6.3
Florida	9,512	1.1	1.6	61.4	63.0	15.0	8.4
Georgia	7,748	1.0	1.6	55.7	61.3	12.3	7.2
Hawaii	6,520	1.0	1.7	57.1	65.9	12.9	10.4
Idaho	4,934	1.1	1.6	57.9	64.0	13.0	8.4
Illinois	4,985	1.1	1.6	60.6	61.5	14.0	7.5
Indiana	6,577	1.0	1.5	56.7	61.1	12.7	7.3
Iowa	5,823	1.0	1.4	56.0	59.9	11.9	6.4
Kansas	16,717	1.0	1.6	52.4	63.0	10.2	7.6
Kentucky	6,886	1.0	1.5	49.1	59.6	9.1	6.0
Louisiana	8,160	1.0	1.4	48.4	55.4	8.7	4.7
Maine	11,079	1.2	1.7	62.2	64.9	14.9	8.8
Maryland	7,825	1.1	1.6	60.3	62.0	14.3	7.3
Massachusetts	16,820	1.2	1.7	63.1	64.4	15.4	8.5
Michigan	9,041	1.1	1.6	60.1	62.3	13.9	7.9
Minnesota	12,413	1.1	1.6	58.5	61.3	12.7	6.6
Mississippi	6,913	0.9	1.4	48.5	56.1	9.4	5.5
Missouri	4,960	1.0	1.5	52.6	60.8	10.5	7.1
Montana	8,549	1.0	1.6	55.9	63.3	11.9	7.9
Nebraska	21,043	1.0	1.5	56.2	60.9	12.2	7.2
Nevada	4,272	1.1	1.6	61.6	64.2	15.1	9.3
New Hampshire	5,130	1.3	1.8	65.6	67.8	16.7	10.4

Table continues

The amounts of fruits and vegetables consumed by each BRFSS participant were also estimated (Web Table 2). The predicted amounts participants consumed were divided by their recommended intake and averaged to obtain the percentages of the recommended amounts of fruits and vegetables consumed. Weighted averages of the predicted probabilities and percentages of the recommendations met were computed by using SAS, version 9.3.2 (SAS Institute, Inc., Cary, North Carolina), and SAS Callable SUDAAN, version 10.1 (RTI International, Research Triangle Park, North Carolina), to account for BRFSS's complex, multistage, probability survey design. The methodology permits estimation of distributions not only for individual sex-age groups but also for collapsed groups, such as all adult females and for other demographic characteristics, such as race/ethnicity and PIR for comparison purposes. (Refer to Web Appendix 2 for the SAS Callable SUDAAN code.) Variation in the prediction equations was accounted for by using the balanced repeated replication technique and replicate weights designed for use with NHANES. Variation due to the BRFSS sampling design was accounted for by using Taylor linearization. Confidence intervals were calculated by using standard errors that reflect variation from the combination of both survey sources.

RESULTS

Extracted times per day and cup equivalents from all sources averaged over the number of reported days from the NHANES 24-hour dietary recalls are shown in Table 2 by selected demographics. Overall, 19% of the sample (unweighted) reported 0

Table 3. Continued

State	Unweighted No. of Participants	Median Times per Day		% of the Recommended Amount Consumed[c]		% Meeting or Exceeding Recommendations[c,d]	
		Fruits	Vegetables	Fruits	Vegetables	Fruits	Vegetables
New Jersey	11,454	1.1	1.6	60.9	62.9	14.0	7.5
New Mexico	7,503	1.1	1.7	61.6	65.1	15.3	9.3
New York	6,002	1.2	1.6	63.6	63.0	16.1	8.2
North Carolina	8,644	1.0	1.7	54.2	63.3	10.8	7.8
North Dakota	4,213	1.1	1.4	56.8	59.7	12.4	6.2
Ohio	7,659	1.0	1.5	55.7	60.4	11.8	6.8
Oklahoma	7,021	0.9	1.5	48.0	59.6	8.8	5.8
Oregon	4,926	1.1	1.9	63.3	69.4	15.5	11.5
Pennsylvania	8,918	1.1	1.6	60.0	61.7	13.9	7.4
Rhode Island	5,144	1.2	1.7	63.3	64.5	15.5	8.8
South Carolina	9,938	1.0	1.5	53.9	59.0	11.5	6.3
South Dakota	6,606	1.0	1.4	53.1	58.8	10.5	5.5
Tennessee	3,949	1.0	1.6	47.5	59.3	8.4	6.0
Texas	11,830	1.0	1.7	58.8	64.2	13.6	8.8
Utah	10,183	1.1	1.7	61.1	64.3	14.2	8.2
Vermont	5,822	1.3	1.8	64.8	67.5	16.5	10.6
Virginia	5,147	1.1	1.7	58.4	62.4	13.2	7.5
Washington	12,106	1.1	1.7	59.5	65.7	13.4	9.2
Washington, DC[e]	3,682	1.3	1.9	66.8	65.8	18.1	11.2
West Virginia	4,161	1.0	1.5	46.1	58.5	7.0	5.3
Wisconsin	4,280	1.1	1.5	61.1	60.0	14.5	6.4
Wyoming	5,614	1.1	1.6	58.2	63.7	13.5	8.1

[a] Estimates are weighted to account for complex sampling by using SUDAAN software except where noted. Fruits consist of 100% fruit juice and whole fruit. Vegetables include legumes, dark green vegetables, orange vegetables, and other vegetables.

[b] Recommendations are age- and sex-specific and appropriate for individuals who get less than 30 minutes per day of moderate physical activity, beyond normal daily activities.

[c] Derived from age- and sex-specific models that account for the usual intake of foods and race/ethnicity, poverty-income ratio, and variation due to collecting 24-hour recall data on weekends versus weekdays and first versus second recalls.

[d] Standard errors for percentages of the population meeting recommendations were 1% for fruits and 3%–4% for vegetables.

[e] Washington, DC, is not a state; it is a federal district.

fruit intake compared with 2% for vegetables. Vegetable intake was twice the reported intake for fruits (1.11 times per day for vegetables and 0.53 times per day for fruit). Median cup equivalents of fruits and vegetables consumed from all sources were 0.69 cup equivalents for fruits and 1.28 cup equivalents for vegetables. Zero fruit intake was more common among males, younger age groups, non-Hispanic blacks, and those with a PIR of <1.25. Older age groups and those with a PIR of >3.49 reported the highest intake of fruits and vegetables, and non-Hispanic blacks had the lowest intake as measured by reported times per day and cup equivalents. Extracted frequencies were similar to reported frequencies in the NHANES diet screener (data not shown). Median times per day from BRFSS were typically higher than those reported in NHANES.

Regression parameters for the prediction equations are shown in Web Tables 1 and 2, respectively. National and state-specific median fruit and vegetable intakes in cup equivalents, percentages of the recommended amount consumed, and percentages of the population meeting or exceeding fruit and vegetable intake recommendations generated from applying these equations to BRFSS data are shown in Table 3. Median times per day of fruits and vegetables reported consumed in BRFSS are shown as well. Total median daily intake of fruit reported from BRFSS was 1.1 times per day, ranging from 0.9 to 1.3 times per day. Total median intake of vegetables was higher than fruit intake at 1.6 times per day, ranging from 1.4 to 1.9 times per day. On the basis of estimates from the prediction equations, on average, BRFSS participants consumed approximately 60% of the recommended amount of fruit per day and

63% of the recommended amount of vegetables per day. Approximately 14% of the total population met fruit recommendations (95% confidence interval: 12.9, 15.0), and 8.2% met vegetable recommendations (95% confidence interval: 4.7, 12.0). The percentage of state populations meeting recommendations ranged from 7.0% in West Virginia to 18.1% in Washington, DC, a federal district, for fruits and from 4.7% in Louisiana to 11.5% in Oregon for vegetables. Among those who consumed fruits and vegetables, on average, 63% of the variation in the amounts of fruits and vegetables they consumed is explained by their reported frequency of fruit and vegetable intake rather than demographic information (range by sex-age group, 54%–73%).

DISCUSSION

The analytical method we used is a novel application of an existing method that provides a way to estimate the distribution of dietary data from a short frequency screener. It uses the National Cancer Institute method to estimate distributional tail probabilities from screeners and provides a tool for states to gauge progress toward federal recommendations by using the BRFSS dietary screener (9, 10). We found that only 14% of BRFSS participants met or exceeded fruit intake recommendations, and 8% met or exceeded vegetable recommendations. The prevalence of meeting recommendations varied by state; however, in no state did more than 19% of the population meet fruit recommendations or more than 12% meet vegetable recommendations.

BRFSS is the only source of dietary surveillance data for most states. Although some states including California, Arkansas, and Wisconsin have independent surveillance systems that measure adult intakes of fruits and vegetables, published metrics derived from those systems are not directly comparable to those developed here (30, 31). However, it is possible to compare our estimates with national estimates. Using NHANES 2007–2010 twenty-four-hour dietary recalls, the National Cancer Institute reported that 14% of American adult males and 24% of adult females met or exceeded fruit recommendations, and that 13% and 16% of males and females met or exceeded vegetable recommendations (32). We estimated that 14% of adults met or exceeded fruit recommendations (10.5% for males and 17.5% for females; data not shown) and 8% met or exceeded vegetable recommendations (6.8% for males and 9.8% for females; data not shown). At least 2 methodological differences might explain the differences in estimates.

First, our estimates of the percentage meeting recommendations do not include non-100% fruit juice contributions or fried potatoes, while National Cancer Institute estimates include both of these sources. We excluded these sources because BRFSS specifically instructs respondents not to include these items. Including these food sources increases the estimated percentage meeting recommendations using BRFSS data for fruit from 10.5% and 17.5% to 11.1% and 18.2% for males and females, respectively, and from 6.8% and 9.8% to 9.8% and 12.7% for vegetables (data not shown). Second, BRFSS and NHANES are designed and administered differently, which may contribute to differences in estimates of both times per day variables and percentages meeting recommendations. BRFSS is administered via a telephone survey, refers to intake over the past month, and provides only usual frequencies consumed of 6 fruit and vegetable food groups. NHANES frequencies are derived from what people reported eating or drinking over the past 24 hours on at least 1 day collected via an in-person interview during a comprehensive health examination. A second recall is administered via the telephone 3–10 days later but accompanied by materials obtained during the in-person examination.

There are at least 2 strengths to this analysis. First, this is the first proposed method to estimate distributions and thus percentages reaching some threshold from frequency screeners. The original method we adapted to accomplish this was developed to convert an individual respondent's screener responses to estimates of mean intake and may underestimate median cup equivalents consumed by about 0.5 cup equivalents (33). We extended this method by using previously validated National Cancer Institute usual intake methods (34) to estimate the distribution of usual intake. Although applied to BRFSS data to allow tracking of state-level progress toward a federal recommendation, the methodology could also be used with other screeners. Second, when calculating the total cup equivalents of fruits and vegetables from NHANES (the dependent variable), we included foods often not considered by participants when they respond to brief screeners like BRFSS, such as mixtures and condiments. By including intake of these foods as background intake via the intercept, our prediction equation may give us a better estimate of fruit and vegetable intake.

However, there are several limitations that should be noted. First, the 2 sources of data used in generating the percentage meeting fruit and vegetable recommendations had different recall timeframes (24 hours vs. 30 days). We applied statistical methods to estimate usual intake from the 24-hour dietary recalls when generating the prediction equations, but information elicited from a screener like BRFSS is inherently different from those generated from 24-hour dietary recalls. Second, we could not assess how internally valid the methodology is overall or by subgroup by comparing predicted intake with intake from 24-hour dietary recalls using the BRFSS population. Our estimates including fried potatoes and non-100% fruit juice were 3–6 percentage points lower than the National Cancer Institute estimates. In the absence of a true "gold standard" to measure predictions against, comparability of our estimates to national estimates from 24-hour dietary recalls establishes the consistency of our methodology with other more established methods for estimating percentage meeting recommendations. In the absence of an unbiased biomarker for fruits and vegetables, estimates from carefully done, multiple 24-hour recalls are considered the next best reference instrument. We compared 3 items from the NHANES 2009–2010 screener with our extracted times per day from the 24-hour recalls to compare how well our extracted times per day imitated actual screener responses, as well as comparing our overall estimates with national estimates. Further research is needed in an external population to compare estimates of the percentage meeting the population generated from 24-hour dietary recalls with estimates generated from items similar to the BRFSS screener to test the validity of the method. Work is underway currently to calibrate the NHANES screener directly to the multiple 24-hour recalls administered to the same respondents and to test the robustness of the resulting calibration scoring algorithms. Future application of this analytical approach to the 3 items common to both screeners will enhance our understanding of the method's validity. Third, our method assumes that the prediction equations are time invariant. Examining change over time in predicted estimates alongside changes in median intake may help to establish how reasonable this assumption is. Fourth, even though the data are weighted to account for nonresponse and to reflect the national population, both NHANES and BRFSS may be subject to selection bias. The median BRFSS survey response rate was 50% for all states and Washington, DC, in 2011, ranging from 34% to 64% (35). In NHANES 2007–2010, we had an interviewed response rate of 78%–79% and an examined response rate of 75%–77% (36). Fifth, almost 10% of BRFSS participants had missing fruit and vegetable data ($n = 48{,}422$). These individuals were significantly ($P < 0.0001$) more likely to be older (60 vs. 55 years) and to have a poverty-income ratio of <1.3 (29% vs. 19%) than were those who were not missing frequency data and were non-Hispanic black or Hispanic (20% vs. 14%) (data not shown). Including individuals who had complete data for fruit intake but were missing information on vegetable intake did not significantly affect the percentage meeting fruit recommendation estimates. Including individuals who had complete information on vegetable but not fruit intake similarly did not affect vegetable estimates. Finally, of the 449,440 BRFSS participants who had complete information for fruit and vegetable intakes and resided in the study area, 13% ($n = 56{,}271$) were excluded because they did not report household income. Household size was assumed to be 1 for the 55,875 participants who did not report the number of individuals residing in the household but otherwise had complete information. Estimated percentages meeting recommendations were similar when PIR and median household size was imputed for these individuals on the basis of age, sex, and race/ethnicity.

Identification of public health nutrition problems and effective management of nutrition intervention programs require an ongoing collection of relevant nutritional status and program data (37). Although there is regular national fruit and vegetable intake monitoring via NHANES, national data have limited value in tracking state and local health objectives and the effects of state and local nutrition programs because the data are not representative of states and localities (38). State- and local-level data are important for catalyzing local interest in nutrition programs and designing and evaluating programs (38). Our analysis enhances current surveillance efforts by enabling the comparison of intakes of fruits and vegetables generated through the widely used BRFSS dietary screener with federal recommendations. Notably, because BRFSS yields state and some local data and the fruit and vegetable questions are asked every 2 years, our method provides a unique tool for tracking changes in the percentage of state residents meeting fruit and vegetable intake recommendations over time.

ACKNOWLEDGMENTS

Author affiliations: Nutrition Branch, Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia (Latetia V. Moore, Kirsten A. Grimm, Sonia A. Kim, Kelley S. Scanlon); Biometry Research Group, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, Maryland (Kevin W. Dodd); and Applied Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, Maryland (Frances E. Thompson).

All authors contributed equally to this work.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of interest: none declared.

REFERENCES

1. Krebs-Smith SM, Guenther PM, Subar AF, et al. Americans do not meet federal dietary recommendations. *J Nutr*. 2010; 140(10):1832–1838.
2. US Department of Agriculture, US Department of Health and Human Services. *Dietary Guidelines for Americans, 2010*. 7th ed. Washington, DC: US Government Printing Office; 2010.
3. He FJ, Nowson CA, Lucas M, et al. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens*. 2007;21(9):717–728.
4. He FJ, Nowson CA, MacGregor GA. Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *Lancet*. 2006;367(9507):320–326.
5. Montonen J, Knekt P, Järvinen R, et al. Dietary antioxidant intake and risk of type 2 diabetes. *Diabetes Care*. 2004;27(2): 362–366.
6. World Cancer Research Fund. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a Global Perspective*. Washington, DC: American Institute for Cancer Research; 2007.
7. Rolls BJ, Ello-Martin JA, Tohill BC. What can intervention studies tell us about the relationship between fruit and vegetable consumption and weight management? *Nutr Rev*. 2004;62(1): 1–17.
8. Tohill BC, Seymour J, Serdula M, et al. What epidemiologic studies tell us about the relationship between fruit and vegetable consumption and body weight. *Nutr Rev*. 2004;62(10): 365–374.
9. US Department of Agriculture, US Department of Health and Human Services. Choose my plate: How much fruit is needed daily? http://www.choosemyplate.gov/food-groups/fruits-amount.html. Published June 2, 2011. Accessed June 17, 2014.
10. US Department of Agriculture, US Department of Health and Human Services. Choose my plate: How many vegetables are needed daily or weekly? http://www.choosemyplate.gov/food-groups/vegetables-amount.html. Published June 2, 2011. Accessed June 17, 2014.
11. Grimm KA, Blanck H, Scanlon KS, et al. State-specific trends in fruit and vegetable consumption among adults—United States, 2000–2009. *MMWR Morb Mortal Wkly Rep*. 2010; 59(35):1125–1130.
12. Centers for Disease Control and Prevention. *State Indicator Report on Fruits and Vegetables, 2009*. Atlanta, GA: US Department of Health and Human Services; 2009. http://www.cdc.gov/nutrition/downloads/stateindicatorreport2009.pdf. Accessed June 17, 2014.
13. Office of Disease Prevention and Health Promotion, US Department of Health and Human Services. Healthy People

2010: nutrition and overweight. http://www.healthypeople.gov/2010/Document/HTML/Volume2/19Nutrition.htm#_Toc490383124. Published January 2010. Accessed June 17, 2014.
14. Centers for Disease Control and Prevention. *5 A Day Works!* Atlanta, GA: US Department of Health and Human Services; 2005. http://www.cdc.gov/nccdphp/dnpa/nutrition/health_professionals/programs/5aday_works.pdf. Accessed June 17, 2014.
15. Applied Research, Cancer Control and Population Sciences, National Cancer Institute. Diet screener in the 2005 CHIS: scoring procedures. http://appliedresearch.cancer.gov/chis/dietscreener/scoring.html. Updated April 11, 2014. Accessed June 17, 2014.
16. Office of Disease Prevention and Health Promotion, US Department of Health and Human Services. Healthy People 2020: nutrition and weight status objectives. https://www.healthypeople.gov/2020/topics-objectives/topic/nutrition-and-weight-status/objectives. Updated December 10, 2014. Accessed December 11, 2014.
17. Applied Research, Cancer Control and Population Sciences, National Cancer Institute. Dietary screener in the 2009 CHIS: scoring procedures. http://appliedresearch.cancer.gov/chis/dietscreener/2009/. Updated April 11, 2014. Accessed June 17, 2014.
18. Freedman LS, Midthune D, Carroll RJ, et al. Adjustments to improve the estimation of usual dietary intake distributions in the population. *J Nutr*. 2004;134(7):1836–1843.
19. Food Survey Research Group, Agricultural Research Service, US Department of Agriculture. *USDA Food and Nutrient Database for Dietary 2010. Studies, 4.1 and 5.0*. Beltsville, MD: US Department of Agriculture; 2010. Updated December 4, 2014. Accessed June 17, 2014.
20. Thompson FE, Subar AF, Smith AF, et al. Fruit and vegetable assessment: performance of 2 new short instruments and a food frequency questionnaire. *J Am Diet Assoc*. 2002;102(12):1764–1772.
21. Thompson FE, Willis GB, Thompson OM, et al. The meaning of 'fruits' and 'vegetables'. *Public Health Nutr*. 2011;14(7):1222–1228.
22. Wolfe WS, Frongillo EA, Cassano PA. Evaluating brief measures of fruit and vegetable consumption frequency and variety: cognition, interpretation, and other measurement issues. *J Am Diet Assoc*. 2001;101(3):311–318.
23. Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, US Department of Agriculture. Food patterns equivalents database 2009–2010. http://www.ars.usda.gov/Services/docs.htm?docid=23869. Updated March 27, 2014. Accessed April 1, 2013.
24. Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, US Department of Agriculture. Food patterns equivalents database 2007–08. http://www.ars.usda.gov/Services/docs.htm?docid=23869. Updated March 27, 2014. Accessed April 1, 2013.
25. Bowman SA, Clemens JC, Thoerig RC, et al. Food patterns equivalents database 2009–10: methodology and user guide. http://www.ars.usda.gov/Services/docs.htm?docid=23870. Updated March 27, 2014. Accessed March 6, 2014.
26. Bowman SA, Clemens JC, Friday JE, et al. Food patterns equivalents database 2007–2008: methodology and user guide. http://www.ars.usda.gov/Services/docs.htm?docid=23870. Updated March 27, 2014. Accessed March 6, 2014.
27. National Cancer Institute. Usual dietary intakes: SAS macros for the NCI method. http://riskfactor.cancer.gov/diet/usualintakes/macros.html. Updated November 5, 2013. Accessed November 28, 2012.
28. Food and Nutrition Board, Institute of Medicine. *DRI Dietary Reference Intakes: Applications in Dietary Assessment. A report of the Subcommittee on Interpretation and Uses of Dietary Reference Intakes and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes.* Washington, DC: National Academy Press; 2000.
29. Tooze JA, Midthune D, Dodd KW, et al. A new statistical method for estimating the usual intake of episodically consumed foods with application to their distribution. *J Am Diet Assoc*. 2006;106(10):1575–1587.
30. Sugerman S, Foerster SB, Gregson J, et al. California adults increase fruit and vegetable consumption from 1997–2007. *J Nutr Educ Behav*. 2011;43(4 suppl 2):S96–S103.
31. Zohoori N, Pulley L, Jones C, et al. Conducting a statewide health examination survey: the Arkansas Cardiovascular Health Examination Survey (ARCHES) [abstract]. *Prev Chronic Dis*. 2011;8(3):A67.
32. Applied Research Program, National Cancer Institute. Usual dietary intakes: food intakes, US population, 2007–10. http://appliedresearch.cancer.gov/diet/usualintakes/pop/2007-10/. Updated May 22, 2014. Accessed May 6, 2014.
33. Applied Research Program, National Cancer Institute. Dietary screener in the 2009 CHIS: validation. http://appliedresearch.cancer.gov/chis/dietscreener/2009/validation.html. Updated April 11, 2014. Accessed August 21, 2014.
34. Applied Research Program, National Cancer Institute. Usual dietary intakes: the NCI method. http://appliedresearch.cancer.gov/diet/usualintakes/method.html. Updated October 18, 2013. Accessed August 21, 2014.
35. Centers for Disease Control and Prevention. *Behavioral Risk Factor Surveillance System (BRFSS) 2011 Summary Data Quality Report*. Atlanta, GA: Department of Health and Human Services; 2011. http://www.cdc.gov/brfss/pdf/2011_summary_data_quality_report.pdf. Updated February 4, 2013. Accessed March 3, 2014.
36. National Center for Health Statistics, Centers for Disease Control and Prevention. NHANES response rates and population totals. http://www.cdc.gov/nchs/nhanes/response_rates_CPS.htm. Updated September 23, 2013. Accessed March 27, 2014.
37. Trowbridge FL, Wong FL, Byers TE, et al. Methodological issues in nutrition surveillance: the CDC experience. *J Nutr*. 1990;120(suppl 11):1512–1518.
38. Byers T, Serdula M, Kuester S, et al. Dietary surveillance for states and communities. *Am J Clin Nutr*. 1997;65(4 suppl):1210S–1214S.