The 2005 USDA Food Guide Pyramid Is Associated with More Adequate Nutrient Intakes within Energy Constraints than the 1992 Pyramid

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ABSTRACT The USDA issued the *Food Guide Pyramid* (FGP) to help Americans choose healthy diets. We examined whether adherence to the 1992 and 2005 FGP was associated with moderate energy and adequate nutrient intakes. We used data for 2138 men and 2213 women > 18 y old, from the 2001–2002 U.S. National Health and Nutrition Examination Survey (NHANES). Quadratic programming was used to generate diets with minimal departure from intakes reported for the NHANES 2001–02. We examined the effect of the number of servings/d of *Food Pyramid* groups set at 1992 and at 2005 FGP recommendations for 1600, 2200, and 2800 kcal (1 kcal = 4.184 kJ) levels. We calculated energy and nutrients provided by different FGP dietary patterns. Within current U.S. dietary practices, following the 1992 FGP without sodium restriction may provide 200 more kcal than recommended for each energy level. Although it can meet most of old nutrient recommendations (1989), it fails to meet the latest dietary reference intakes, especially for the 1600 kcal level. The 2005 FGP appears to provide less energy and more adequate nutrient intakes, with the exception of vitamin E and potassium for some groups. However, without discretionary energy restriction, Americans are at risk of having excessive energy intake even if they follow the 2005 FGP food serving recommendations. Our analysis suggests that following the 2005 FGP may be associated with lower energy and optimal nutrient intake. Careful restriction of discretionary calories appears necessary for appropriate energy intakes to be maintained. J. Nutr. 136: 1341–1346, 2006.

KEY WORDS: • *USDA food guide pyramid* • *energy* • *optimization programming* • *dietary reference intake* • *dietary pattern*

The U.S. government issued the *Food Guide Pyramid* (FGP)[3] to help Americans choose healthy diets that meet nutritional standards but are moderate in energy and in food components often consumed in excess (1–3). The first edition was released in 1992 (4). However, the success of the 1992 FGP has been questioned (5,6), especially in relation to the current epidemic of obesity (7–9). On the other hand, some nutritionists argued that these accusations against the pyramid use it as a scapegoat when, in fact, there are many contributing factors to the prevalence of obesity (10). Moreover, new nutrient intake recommendations, the dietary reference intakes (DRI), have been in place since 1997. The most recent edition of the FGP was issued in 2005, and included greater emphasis on lower energy intake and more physical activity (11).

The *Food Guide Pyramids* were developed by using nutrient profiles for the 5 major nutrient-bearing food groups (fruit, vegetable, dairy, grain, and meat and bean) and their subgroups. Foods were included with their lowest fat content, and without added sugars (2,3). For example, the meat group included lean cuts of meat trimmed of all fat, and fruits and vegetables were without added fats or sugar (3). Therefore, it is important to evaluate the FGP against actual current American dietary patterns.

Mathematical optimization programming, such as linear programming and quadratic programming, is a mathematical approach that optimizes (minimizes or maximizes) a linear or nonlinear function of decision variables, while respecting multiple constraints (12). The USDA used quadratic programming to formulate nutritionally optimal dietary patterns with different cost levels (13). Linear programming is used to develop food-based dietary guidelines in a developing country (14), to examine how to meet recommended nutrient intake(15,16), and to examine the relation between diet cost and dietary quality (12,17).

We hypothesized that the 1992 food pyramid may be associated with higher energy intake, whereas the 2005 pyramid constrains food choices more tightly and requires a more moderate energy intake. Similarly, the 1992 food pyramid permits nutrient intake that is inadequate relative to the new (post-1992) recommendations, whereas the 2005 pyramid constrains nutrient intake more tightly to meet these new recommendations. We examined these hypotheses using a quadratic programming methodology to choose solution dietary patterns that adhere to the 1992 and 2005 pyramids. We compared the

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[3] Abbreviations used: AI, adequate intake; AT, α-tocopherol; ATE, α-tocopherol equivalents; CSFII, Continuing Survey of Food Intakes by Individuals; DRI, dietary reference intake; EAR, estimated average requirement; EER, estimated energy requirements; FGP, Food Guide Pyramid; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey; PAL, physical activity level; RAE, retinol activity equivalency; RDA, recommended daily allowance; RE, retinol equivalents.

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values of total energy and a set of nutrient intakes provided by the solution dietary patterns with recommended intake levels.

SUBJECTS AND METHODS

Subjects. Subjects were 4994 men and women >18 y old from the 2001–2002 National Health and Nutrition Examination Survey (NHANES). We excluded subjects who were pregnant ($n = 309$), and who reported energy intake <600 kcal/d or >4000 kcal/d (1 kcal = 4.184 kJ) ($n = 334$), leaving 4351 subjects (2138 men and 2213 women) in the analysis. Estimated energy requirements (EER) were calculated on the basis of sex, age, weight, height, and physical activity level (PAL) (18). Given the sedentary lifestyles of many Americans, we assumed PAL <1.4. We collapsed all subjects to 3 EER categories, with mean EER of 1727, 2120, and 2677 kcal (7.22, 8.86, and 11.2 MJ). Reported dietary intakes of subjects in these 3 categories were used to simulate diets that follow the Food Pyramid recommendations for 1600, 2200, and 2800 kcal (6.69, 9.20, and 11.7 MJ) energy intake levels, respectively.

Input data for quadratic programming models. We used a quadratic programming model to simulate dietary patterns. For each EER category, the model selected the dietary pattern that met the FGP recommended food intakes, and did so with as little change as possible from reported food consumption.

Dietary data from the NHANES 2001–2002 were available from 2 datasets: Individual Food files (19), which provided nutrient data, and Pyramid servings intake data for NHANES (20), which provided information on standard serving size and added sugar and discretionary fat. For modeling purposes, we collapsed foods to 61 subgroups based on similarity of nutrient composition (21). Nutrients from each subgroup were calculated on the basis of the food items in the subgroup and the mean consumption of each item. For example, the citrus fruit category included oranges, grapefruit, and other citrus fruits. Mean nutrient intakes for this category were calculated by weighting the average reported consumption of these 3 food items by the population. The nutrient profile for each food subgroup was then used in the definition of the constraints, which were introduced in the quadratic programming models. We calculated nutrient profiles for each EER category separately.

These food subgroups were further collapsed into 6 major food groups (grain, dairy, fruit, vegetable, meat and bean, and oil groups). The oil group included vegetable oils and soft margarine. According to 2005 FGP definitions, we also counted fat from oil-rich foods, such as nuts, olives, and fish, in the oil group. Discretionary calories were calculated by summing energy from added sugar, solid fats, and alcohol. Solid fats are fats that are solid at room temperature, such as butter, beef fat, or shortening (11). Solid fats can be visible, such as butter, or invisible, such as excess fats from whole milk relative to 1% low-fat milk. The pyramid servings intake data for NHANES (20) provided discretionary fat information. Discretionary fat was defined as fat in excess of the small amounts of fat that people would consume if their food choices were among the lowest in fat in each food group (22). We treated discretionary fats from non-oil foods as solid fats based on the 2005 FGP. Details about calculation of the excess fats for 5 major food groups were given elsewhere (22).

We used SAS (Release Version 8.02, SAS Institute) to merge and arrange the data, which were then transferred to EXCEL files. Microsoft EXCEL SOLVER (Frontline Systems) was used for quadratic programming.

Objective function. Quadratic programming is designed to find the optimal solution to minimize or maximize the objective function (or goal), which is dependent on a set of decision variables restricted by various linear constraints (17,23). In this case, the objective function (goal of the model) was to minimize departure (Y) from the current dietary pattern observed in the NHANES 2001–2002. The rationale for using this objective function is that one of the goals of the USDA FGP is to be based on foods commonly consumed by Americans, as determined from national food consumption surveys, thus making the recommendations realistic and practical (2,3). The current dietary pattern observed was defined by the mean daily intakes (servings/d) for each food subgroup in the NHANES 2001–2002. We minimized the sum of square of differences (Y) between each food subgroup servings X_n, selected by quadratic programming, and the mean servings A_n of each food subgroup intake, observed in the NHANES 2001–2002. A_n was used as a weight to ensure that frequently consumed foods had more chance to be selected by the models. The formula is as follows:

$$Y = [(X_1 - A_1)/A_1]^2 + [(X_2 - A_2)/A_2]^2 + \ldots [(X_{61} - A_{61})/A_{61}]^2.$$

X_n: Servings of each food subgroup intake selected by Quadratic Programming

A_n: Mean servings of each food subgroup intake observed in the NHANES 2001–2002.

Model constraints. FGP serving constraints (**Table 1**) were introduced to ensure that the dietary patterns simulated by quadratic programming had intakes for the 5 major food groups that were identical to the FGP recommended intake servings for energy levels of 1600, 2200, and 2800 kcal/d. For example, the dietary pattern with 1992 FGP constraints for the 2200 kcal level was forced to have

TABLE 1

Pyramid food group serving constraints for 3 energy levels, according to the 1992 and 2005 food guide pyramids

	1600 kcal[1]		2200 kcal		2800 kcal	
	1992	2005	1992	2005	1992	2005
Fruit, *servings*	2	3	3	4	4	5
Vegetables, *servings*	3	4	4	6	5	7
Dark green	—	≥0.4	—	≥0.9	—	≥1.0
Orange	—	≥0.6	—	≥0.6	—	≥0.9
Legumes	—	≥0.7	—	≥1.7	—	≥2.0
Starchy	—	≥0.7	—	≥0.9	—	≥1.0
Other	—	≥1.6	—	≥2.0	—	≥2.4
Grains, *oz*	6	5	9	7	11	10
Whole grains	—	≥2.5	—	≥3.5	—	≥5
Meat and beans, *oz-eq*	5	5	6	6	7	7
Milk, *servings*	2.5	3[2]	2.5	3[2]	2.5	3[2]
Oils, *g*	—	22	—	29	—	36
Discretionary calories, *kcal*	—	132	—	290	—	426
Added-sugar, *tsp*	≤6	—	≤12	—	≤18	—

[1] 1 kcal = 4.184 kJ.

[2] Low-fat or fat-free milk and dairy products.

3 servings of fruit, 4 servings of vegetables, 9 oz of grains, 6 oz-eq of meat or beans, and 2.5 servings of milk. Added sugars were ≤12 teaspoons. Although the 2005 FGP presents 12 dietary patterns for various energy intake levels, we used only 3 in the current study, to be consistent with the 1992 FGP.

The diets were set to meet the recommended dietary allowances (RDA) or adequate intakes (AI) for the following 16 essential nutrients, as available in the NHANES dataset: fiber, vitamin A, vitamin E, vitamin C, thiamine, riboflavin, niacin, folate, vitamin B-6, vitamin B-12, calcium, iron, zinc, phosphorus, potassium, and magnesium (Table 1). We used the highest level of RDA/AI from each of the energy level's target age-sex groups. For the 1600 kcal pattern, RDA/AI for women 51+ y were used. For 2200 and 2800 kcal patterns, RDA/AI for men aged 19–50 y were used, except for iron and calcium. We used the iron RDA for women 19–50 y for 2200 kcal patterns and calcium AI for men 50+ y for both patterns.

Because the AI for fiber is set for total fiber rather than the dietary fiber that is available in the dataset, we calculated total fiber by adding 2.5 g/1000 kcal to the amount of dietary fiber (2). In the NHANES 2001–2002 dataset, the unit for vitamin A is μg retinol activity equivalency (RAE) and for vitamin E is mg α-tocopherol (AT). For the 1992 FGP, to compare the vitamin A and vitamin E intake levels with the 1989 RDA (24), we converted them to the previously used units, retinol equivalents (RE) for vitamin A and α-tocopherol equivalents (ATE) for vitamin E. Vitamin E expressed in mg AT was divided by 0.8 to obtain an estimate of vitamin E in mg ATE (25). Vitamin A from carotenoid sources (fruit and vegetables) expressed in μg RAE was multiplied by 2 to obtain an estimate of vitamin A in μg RE (26).

Food use constraints (**Table 2**) set upper limits on the amount of each food included, so that the program model did not select food quantities exceeding amounts commonly consumed in the population. These limits were derived from actual intake distributions. Specifically, dietary intake from each food subgroup was set to not exceed the 90th percentile of the population intake.

We used 3 fat constraints (Table 2), based on the 1992 and 2005 FGP. We limited the saturated fat intake to <10% of total energy, and cholesterol to 300 mg. We limited total fat to ≤30% of total energy for the 1992 FGP and to ≤35% for the 2005 FGP. We also limited sodium intake to ≤2400 mg/d for the 1992 FGP and ≤2300 mg/d for the 2005 FGP.

We employed FGP serving constraints for 3 energy levels (1600, 2200, and 2800 kcal) to simulate dietary patterns that resembled the FGP. We gradually introduced added sugar/discretionary calories, fat, sodium and DRI constraints into models and calculated total energy provided by the different patterns. We then compared these energy intakes with their standard levels, 1600, 2200, and 2800 kcal. To assess whether the FGP provides adequate nutrient intakes, we employed food use, FGP servings, and added sugar/discretionary energy constraints, i.e., the constraints appearing on the FGP graphic. Nutrient intakes from different patterns were compared with nutrient standards based on the DRI for the 2 FGP and the 1989 RDA for the 1992 FGP.

Sensitivity analysis. We did sensitivity analysis to assess the stability of results to the objective function selected. We repeated all analyses by minimizing departure from the average percentage of energy contributed by food subgroups.

RESULTS

With food use and FGP constraints in the models (model 1, **Table 3**), dietary patterns formulated by quadratic programming provided higher energy than standard levels for both the 1992 and 2005 FGP. Restrictions for added sugar or discretionary calories resulted in a lower energy intake (model 2, Table 3). Quadratic programming dietary patterns provided 1818 and 1506 kcal of energy for the 1992 and 2005 FGP, respectively, in the 1600 kcal patterns; 2450 and 1996 kcal in the 2200 kcal patterns; and 3047 and 2676 kcal in the 2800 kcal patterns. These energy intakes decreased by ~50 kcal with the addition of the fat limits for the 1992 FGP, but remained the same for the 2005 FGP (model 3, Table 3). When we conducted sensitivity analyses to minimize energy percentage contributions by each food subgroup, the results were similar. Dietary patterns following the 1992 FGP recommendations of food group servings and added sugar provided 1708, 2342, and 2909 kcal for the 1600, 2200, and 2800 kcal patterns, and for the 2005 FGP, 1380, 1997, and 2594 kcal, respectively.

Sodium restriction caused further decreases in energy intakes (model 4, Table 3) for the 1600 and 2200 kcal patterns. However, for the 2800 kcal patterns, models became unsolvable, suggesting that sodium intakes exceeded recommended levels when the FGP recommended food servings for this energy level were consumed, within the constraints of current food choices in the U.S. diets.

Adding DRI constraints for all essential nutrients except potassium and vitamin E further decreased energy intake (from 1668 to 1565 kcal) for the 1992 FGP 1,600 kcal patterns but did not affect results for the 2005 FGP. Adding the potassium AI constraint (≥ 4700 mg/d) caused energy intake to increase to 2208 and 2237 kcal from 1565 and 1506 kcal for the 1992 and 2005 FGP, respectively. Further adding the vitamin E RDA constraint (≥ 15 mg/d) increased energy intake to 2450 for the 1992 FGP, but the 2005 FGP model became unsolvable. This suggests that the 1600 kcal pattern of the 2005 FGP cannot

TABLE 2

List of constraints to be employed

Food amount constraints	
Consumption of food subgroup, servings/d.	Number of servings does not exceed 90th percentile of the population.
DRI constraints	
Fiber, vitamin A, vitamin C, thiamin, riboflavin, niacin, folate, vitamin B-6, vitamin B-12, vitamin E, calcium, iron, zinc, phosphorus, potassium, and magnesium.	Intakes are not less than recommended dietary allowances or AI. Intakes do not exceed Upper Limits.
Sodium constraints	Intakes do not exceed 2400 mg/d for 1992 food pyramid, and 2300 mg/d for 2005 pyramid.
Fat constraints	
Saturated fat	Intakes <10% of total energy.
Cholesterol	Intakes do not exceed 300 mg.
Total fat	Between 20 and 35% of total energy for 2005 food pyramid, and ≤30% for 1992 pyramid.

TABLE 3

Energy intakes following the 1992 and 2005 food pyramid patterns

	1600 kcal pattern		2200 kcal pattern		2800 kcal pattern	
	1992	2005	1992	2005	1992	2005
			kcal			
Model 1	2075	1828	2641	2403	3250	3159
Model 2	1818	1506	2450	1996	3047	2676
Model 3	1762	1506	2395	1996	3081	2676
Model 4	1668	1506	1767	1962	3081[1]	2676[1]
Model 5	2450	2237[2]	2486	2118[2]	2666[1]	2676[1]

Model 1: food amount constraints and pyramid food group serving constraints.

Model 2: added sugar and discretionary calorie constraints were added for 1992 and 2005 food pyramids, respectively.

Model 3: constraints of model 2 plus fat (total fat, saturated fat, and cholesterol).

Model 4: constraints of model 3 plus sodium constraint.

Model 5: constraints of model 4 plus DRI constraints.

1 Sodium constraint was not used because the model cannot meet sodium and other constraints simultaneously.

2 Vitamin E recommendation (15 mg/d) was not included because it cannot be met.

meet the RDA for vitamin E with current U.S. diets. The maximal vitamin E intake is 10.3 mg in this pattern. We were able to increase this to 15.3 mg, if we used almonds, a nut with high vitamin E, to replace other nuts, and used green vegetables to replace starchy vegetables. However, this pattern provided 2223 kcal for the 1600 kcal pattern. For the 2200 kcal patterns, adding DRI constraints for all essential nutrients except vitamin E increased energy from 1767 to 1816 kcal for the 1992 FGP and from 1962 to 2118 kcal for the 2005 FGP. Further adding the vitamin E RDA constraint increased energy to 2486 for the 1992 FGP, but again, the 2005 FGP model became unsolvable. When other nuts were replaced by almonds, the vitamin E RDA with the same energy intake (2118 kcal) was met. Adding DRI constraints decreased energy intake for the 2800 kcal pattern of the 1992 FGP but did not change total energy intake for the 2005 FGP.

When we employed food use, FGP servings, and added sugar/discretionary fat constraints, dietary patterns following the 1992 FGP provided adequate intake for most of nutrients relative to the 1989 RDA (**Table 4**) (24). However, when the DRI standards for nutrient intakes were used, solutions did not meet recommended levels for fiber, vitamin E, vitamin A, and potassium. In the 1600 kcal pattern, recommendations for vitamin C, calcium, and magnesium were also not met. For the 2005 FGP, the DRI for most nutrients were met with the exceptions of vitamin E and potassium in the 1600 and 2200 kcal patterns.

DISCUSSION

Using quadratic programming methodology, we showed that with the current U.S. dietary practices, the 1992 FGP without

TABLE 4

Nutrient intake status for objective function solutions, following the 1992 and 2005 FGP, with selected constraints[1]

	1600 kcal pattern			2200 kcal pattern			2800 kcal pattern		
	1992		2005	1992		2005	1992		2005
	Old RDA/AI	New RDA/AI	New RDA/AI	Old RDA/AI	New RDA/AI	New RDA/AI	Old RDA/AI	New RDA/AI	New RDA/AI
					% RDA/AI				
Fiber[2]	—	77.4*	96.7*	—	80.4*	130	—	76.2*	122
Vitamin E[3]	97.1*	41.4*	44.9*	99.9*	53.3*	76.6*	118	62.7*	119
Vitamin A[4]	148	78.0*	346	93.5*	82.1*	190	105	91.2*	255
Vitamin C	141	93.8*	312	204	136	310	265	177	308
Calcium	135	90.2*	105	99.1*	99.1*	123	109	109	135
Magnesium	94.4*	82.6*	99.1*	96.5*	106	153	113	124	189
Potassium	—	59.1*	77.9*	—	74.2*	94.8*	—	88.3*	114

1 Nutrient intakes from different energy level patterns were compared with nutrient standards, with added constraints for food amount, pyramid food group serving, and added sugar (for the 1992 FGP) or discretionary calories (for the 2005 FGP).

2 For fiber, an AI of 14 g/1000 kcal was set based on total fiber. Total fiber was calculated by adding 2.5 g/1000 kcal to the amount of dietary fiber.

3 Old RDA for vitamin E was based on old mg ATE. Vitamin E expressed in mg AT was divided by 0.8 to obtain an estimate of vitamin E in mg ATE.

4 Old RDA for vitamin A was based on old μg RE. Vitamin A from carotenoid sources (fruit and vegetables) expressed in μg RAE was multiplied by 2 to obtain an estimate of vitamin A in μg RE.

* Intake below RDA or AI.

sodium restriction may be associated with ~200 more kcal than recommended for all 3 energy level patterns. Although it can meet most of the old nutrient recommendations (1989), it does not meet the latest DRI, especially for the 1600 kcal level. Within U.S. dietary practice, following the 2005 FGP appears to provide less energy as well as more adequate nutrient intakes than the 1992 FGP. However, it remains unable to meet vitamin E and potassium recommendations for some groups.

Although similar methods were used to design the FGP (2,3), this is the first time to our knowledge that a mathematic optimization programming methodology has been used to evaluate the FGP. The Healthy Eating Index (HEI) (27) was developed to measure how well American diets adhere to the *Dietary Guidelines* and the 1992 *Food Guide Pyramid.* However, the HEI has been criticized for reflecting only a few aspects of diet and for treating each component of the diet as independent and equally important, without consideration of correlations among score components (28–30). Krebs-Smith et al. (31) characterized dietary patterns by comparing each individual's intake servings with the recommended number of each of the 5 food groups. This method produced 32 combinations of dietary practices and was criticized for not including fat and added sugar recommendations (30). However, adding these would increase the possible number of patterns to 128, which seems infeasible. Recently, nutritionists used data-driven methods such as cluster analysis or factor analysis to identify comprehensive dietary patterns and to relate these to health outcomes (32–34). Although these are useful descriptions of current intake patterns, they do not necessarily define optimal patterns. Compared with these methods, optimization programming is appealing in several aspects. Dietary patterns are simulated a priori on the basis of the FGP recommendations. Several aspects of diets, such as food and nutrient intakes, can be considered simultaneously. Optimization programming also allows us to examine the effect of a single component on a specific outcome, for instance, discretionary calorie restrictions on total energy intake, and to model the effects of specific changes.

The 2005 FGP can be met with less energy than the 1992 FGP, while meeting most nutrient intake recommendations. This finding was consistent in low (1600 kcal), moderate (2200 kcal), and high (2800 kcal) energy patterns. Restricting discretionary calories was associated with ~300 kcal less daily energy intake. Without this restriction, Americans are at risk of having excessive energy intake even if they follow the 2005 FGP food serving recommendations. This is consistent with current high intakes of added fats and sugars, which increase food energy density, likely contributing to the current epidemic of obesity (35–37). Mean solid fat intakes were 46 and 33 g for men and women, aged 31–50 y, respectively, in the NHANES 2001–2002, relative to the recommended ≤19 and 15 g, respectively (11). Added sugar intakes were also >2 times the recommended allowance in the Continuing Survey of Food Intakes by Individuals (CSFII) 1994–1996 and the NHANES 1999–2002 (22,31). These suggest the importance of emphasizing the limitation of discretionary calorie intakes when the FGP is promoted.

Following the 1992 FGP recommendations of food servings appears to provide higher energy than recommended, even after introducing restrictions for added sugar and fat. This is consistent with observations from Krebs-Smith et al. (31). They found that subjects who met recommended intake servings for all 5 major food groups had a higher energy intake (8.8 vs. 7.5 MJ/d) relative to the total population in the CSFII 1989–1991. Kennedy et al. (38) found that subjects who had fat intakes of ≤30% of energy and also had at least 1 serving from each of the 5 major food groups of the FGP, called the Pyramid diet, had significantly higher reported energy intake than other subjects (2184 vs. 1847 kcal/d) in the CSFII 1994–1996. A high HEI score, suggesting better adherence to the FGP, was also reported to be associated with higher energy intake (27,39,40).

Sodium appears to be a marker of energy intake in the U.S. diet. Limiting sodium intake to 2300–2400 mg/d results in clear reductions in energy intake, even when the 5 major food group intake servings are controlled for, especially in the 1992 FGP. This is consistent with our observation that sodium was significantly and positively associated with total energy intake ($r = 0.67$, $P < 0.001$). This correlation decreased to 0.26 after adjustment for intake of the 5 food groups and added sugar, but remained significant ($P < 0.001$). Relative to the 1992 FGP, a smaller effect of sodium restriction on total energy was seen in the 2005 edition. This may be due to additional recommendations in the 2005 FGP, including limitation of discretionary calories, more detailed vegetable subgroups, and greater whole grain intakes. However, at the 2800 kcal level, the upper limits of sodium were exceeded in both FGP. This is consistent with the 2005 FGP report (11), which acknowledges that the sodium limit cannot be met with an energy intake >2400 kcal. It suggests that selection of lower salt foods cannot ensure that people with high energy requirements will have low sodium intake. Reducing the sodium intake in the U.S. population appears to depend primarily on reducing the salt used during food processing because processed foods provide ~77% of total sodium (41). These data also suggest that even within the context of a reduced sodium diet, total intake limits should be expressed per 1000 kcal, rather than an upper limit independent of total energy needs for weight maintenance.

Although the 2005 FGP can meet most recommended nutrient intake levels, it does not achieve the intake goals for potassium (4700 mg/d) and vitamin E (15 mg/d) at the energy intake levels of 1600 and 2200 kcal. These findings are consistent with the USDA dietary guidelines report (42). They estimated that potassium intakes were 76, 96, and 112% of the AI, for 1600, 2200 and 2800 kcal patterns, respectively, similar to our estimates of 78, 95, and 114%. Similar estimates were also seen for vitamin E. These failures were consistent with the observations that >90% of Americans do not meet the AI for potassium (44) and RDA for vitamin E (21,43), suggesting a lack of good sources for those nutrients in current U.S. dietary practices. For example, when we used almonds, a nut high in vitamin E, to replace other nuts, the vitamin E RDA can be met at the 2200 kcal energy level. However, this use of almonds exceeds the 95th percentile of current practice. Alternatively, it is possible that these recommendations are currently set too high for those with low energy requirements.

This analysis does have some limitations. Because the NHANES datasets do not have vitamin D values, we were not able to examine whether adequate vitamin D can be provided by the FGP. However, the AI for vitamin D appears to be met by the FGP because the recommended 2.5–3 servings of fluid milk alone can provide ~6–8 μg of vitamin D, relative to the recommendation of 5 μg for men and women aged 19–50 y (45). A single 24-h recall was used in NHANES to assess dietary intake. This method cannot capture long-term dietary intake patterns for each subject because of high intraindividual variation. However, our study focuses on overall dietary patterns for whole populations rather than for each individual. Additional studies are required to include consideration of vitamin D and to confirm these findings.

In conclusion, the 2005 FGP performed better at meeting nutrient needs while staying within energy constraints compared with the earlier FGP. However, it remains difficult to meet some nutrient intake recommendations at the lowest (vitamin E and potassium) and highest (sodium) energy intake levels. It may be useful for health professionals to suggest specific foods with high nutrient density as choices when promoting the USDA FGP and to emphasize careful restriction of discretionary calories to maintain appropriate energy intakes.

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