

Inadequate nutrient intakes among homebound elderly and their correlation with individual characteristics and health-related factors¹⁻³

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ABSTRACT

Background: The prevalence of inadequate nutrient intakes among the homebound elderly and their correlation with individual characteristics and health-related factors remain poorly understood.

Objective: We assessed the extent of inadequate dietary intakes of key nutrients among the homebound elderly by using the newly released dietary reference intakes and examined the associations of individual characteristics and health-related factors with low nutrient intakes.

Design: This was a cross-sectional examination of data collected during the baseline assessment of a prospective study of nutrition and function among a randomly recruited sample of cognitively eligible recipients of home-delivered meals who completed a home visit and three 24-h dietary recalls ($n = 345$). Nutrient analysis was performed with the NUTRITION DATA SYSTEM software, and associations were identified through multiple regression models.

Results: In multiple regression models, lower intakes of specific nutrients were associated with subjects who were women, who were black, who reported a low income and limited education, and who did not usually eat breakfast. On the basis of the estimated average requirement standard for nutrient inadequacy, the intake of ≥ 6 nutrients was inadequate in 27% of subjects, of 3–5 nutrients in 40% of subjects, and of 1–2 nutrients in 29% of subjects. On the basis of the adequate intake standard, a less than adequate intake of calcium was reported by 96% of subjects and of vitamin D by 99% of subjects.

Conclusions: The findings suggest that home-delivered meals programs should target specific subgroups of participants with interventions, such as a breakfast meal or more-nutrient-dense meals, tailored to increase nutrient intakes and reduce the prevalence of nutrient inadequacy. *Am J Clin Nutr* 2002;76:1435–45.

KEY WORDS Homebound elderly, inadequate nutrient intakes, home-delivered meals, estimated average requirements, EAR, dietary reference intakes, DRI

INTRODUCTION

Although nutritional inadequacy represents a potential health threat to the entire elderly population (1), the risk of poor nutrition is greater among some subgroups of community-living older adults. These include women, minorities, those with limited income and education, and persons who are homebound (2–5). Previous studies showed an increased interest in the nutritional status of the elderly, but few researchers targeted the increasing

homebound elderly population for study (6–8). Therefore, the adequacy of nutrient intakes and the interplay of individual characteristics and health-related factors with nutrient intakes among the homebound elderly remain poorly understood.

For the rapidly growing elderly population, the achievement and maintenance of good nutritional status are critical to health, functioning, and quality of life (1). As embodied in the national goals of Healthy People 2010, these outcomes are a high public health priority (9). Conversely, an inadequate dietary intake, with associated imbalances of needed nutrients and energy from food, can increase the vulnerability of the elderly to adverse health outcomes. These include a diminished immune response (10), longer hospital stays and increased likelihood of hospital readmission (11, 12), impairment in physical and cognitive function (13, 14), premature institutionalization (15), and mortality (16, 17). Underpinning the adequacy of dietary intake are the availability, preparation, and consumption of an appropriate quality and quantity of food (1), which in turn, may be negatively influenced by many factors. These include multiple medications (18), burden of disease (7), social isolation (19, 20), oral health problems (21), difficulty shopping for food or preparing meals (22), inadequate financial resources (23), depression and life stresses (7, 24), and chemosensory dysfunction (25, 26).

Previous investigations of the elderly suggested that one or several individual characteristics (eg, sex, race, poverty, income, living arrangement, and education) and health-related factors (eg, medical conditions, depression, stress, and vision) were associated with nutrient adequacy and low nutrient intakes (5, 7, 19, 24, 27, 28). However, many of these studies were limited in evaluating the adequacy of nutrient intakes among the homebound elderly. Attention was not directed to the homebound elderly in some

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(5, 27, 28); confounders, such as socioeconomic and health-related variables were omitted from others (5, 7); and in others nutrient inadequacy was defined by arbitrary criteria now considered inappropriate (27) or was based on nutrient intakes from a single 24-h dietary recall (19, 24, 28).

To overcome these limitations, the goals of the present study were 1) to determine the extent of inadequate dietary intake of key nutrients among the homebound elderly by using the newly released dietary reference intakes (DRIs) and 2) to examine the associations of individual characteristics and health-related factors with low nutrient intakes.

SUBJECTS AND METHODS

The Nutrition and Function Study (NAFS) is a university-community collaborative project between the School of Public Health at the University of North Carolina at Chapel Hill and the home-delivered meals component of the older Americans Act Nutrition Programs in 4 North Carolina counties. The primary objective of the NAFS is to examine prospectively the influence of dietary intake on incident and prevalent functional limitations and disability among a probability sample of home-delivered meal recipients. Eligibility for inclusion in the NAFS was limited to current home-delivered meals participants aged ≥ 60 y with a telephone-administered Mini-Mental State Examination score ≥ 17 (of a maximum score of 22 points) and able to participate without a proxy (29, 30). Only 18 individuals were excluded from our sample cohort because they did not have a telephone. Of the 430 persons who were eligible, 348 (81%) were recruited for the study, 79 declined to participate, and 3 were hospitalized at the time home visits were scheduled.

Subjects

The analytic sample was composed of NAFS subjects who completed a baseline home visit (self-report questionnaires and physical performance-based measures) and three 24-h dietary recalls ($n = 345$; 99.1%). Informed consent was obtained from all subjects, and the study was approved by the University of North Carolina at Chapel Hill School of Public Health Institutional Review Board.

Individual characteristics

The self-report questionnaires administered during the home visit provided the data for individual characteristics. These included sex, age, race, education, income, marital status, living arrangement, and Food Stamp Program (FSP) participation. There were 3 categories for age (60–74, 75–84, and ≥ 85 y), 2 for race (white and black), 3 for completed education (grades 0–8, 9–11, and ≥ 12), 4 for personal income ($< \$500$ /mo, $\$500$ to $< \$750$ /mo, $\$750$ to $< \$1000$ /mo, and $\geq \$1000$ /mo), 2 for marital status (married and not married), 2 for living arrangement (lives with others and lives alone), and 2 for FSP participation (yes and no).

Dietary intake

Three 24-h dietary recalls occurring on randomly selected, non-consecutive days (one represented intake on the weekend and 2 for weekdays) were collected by trained interviewers to provide dietary intake information for the sample ($n = 345$). The first recall was obtained during the home visit, and the second and third recalls were collected by telephone within 2 wk of the home visit (97% within 2 wk and 100% within 4 wk). The combination of face-to-face and telephone-administered methods for collecting dietary recalls was chosen to maximize the quality of interaction

between the interviewer and subject and thereby minimize measurement error that may occur with food reporting, food identification, and food quantification (31). The face-to-face recall in the home was used to establish rapport with the subject and to provide appropriate training in dietary recall and portion-size estimation. Several strategies were used to aid in the estimation of portion size. First, bowls, glasses, and cups that were usually used were measured and the information was recorded (7). Second, portion sizes from home-delivered meals were used as a frame of reference (ie, comparing the amount consumed with the portion provided in the home-delivered meal). Third, a listing of common foods eaten, including brand and common names, specialty and cultural foods, and snacks (including portion sizes) was recorded. This also included a visual inspection and contemporaneous recording of food items present in the home. To minimize respondent burden and avoid disrupting daily routines, each subject was asked to indicate times of the day and days of the week when they would not be available for telephone recalls (eg, dialysis, meal-times, naps, bedtime, favorite television and radio programs, and religious observance), and this information was recorded. The subsequent telephone recalls built on the rapport established during the home visit and used the recorded information for the timing of the random telephone calls and to assist in the collection of dietary intake information in a manner that minimized the burden to the subject.

Detailed information on food and beverage consumption (including description, brand name, and method of preparation) for the previous 24 h was collected with the use of standardized protocols that followed the multiple-pass interview technique of the NUTRITION DATA SYSTEM FOR RESEARCH (32). In the multiple-pass procedure, subjects were first asked to provide a quick list of generic food items consumed; probes included food consumption occasions, based on smaller chunks of time (eg, before breakfast, breakfast, between breakfast and lunch and dinner). This was immediately followed by a review of the quick list (pass number 2). During this pass, probes for forgotten foods were used; home-delivered meal menus and prompts for snacks, dietary supplements, and the source of the food were asked. The third pass provided food details. This included time and place of the eating occasion, food descriptions, brand name, ingredients and preparation, condiments added, and portion size and quantity eaten. As described above, equating the amount consumed to measured containers (bowls, glasses, and cups) and home-delivered meal portions aided in estimating the amount consumed. In addition, home-delivered meal menus (including ingredients, methods of preparation, and portion size) were available as a prompt to limit the amount of underreporting from “forgotten food” (33). The fourth pass was a final and comprehensive review of the previous day’s intake. Researchers have found that elderly persons omit fewer items from recall if the interviewer reads the completed recall back to each subject, with as much as 28% of all recalled items added at this stage (34).

Health-related factors

Four concerns related to the preparation and consumption of food were measured at baseline: 1) physical characteristics, 2) psychosocial characteristics, 3) meal patterns (7, 35), and 4) current nutritional health status.

Physical characteristics

The 6 measures of physical characteristics quantified burden of disease, medication use, oral health status, chemosensory deficits,



physical limitations in meal preparation and consumption, and smoking status. Burden of disease allowed the self-assessment of disease in terms of level of effect. For example, one individual with the same disease or health condition as another (eg, diabetes or arthritis) could have different manifestations and symptoms of the disease (36). For burden of disease, the method devised by Payette et al (7) was used to calculate a score that summarized the presence of disease and its perceived effect on daily activities. From a list of 16 health conditions, subjects were first asked if a doctor had ever told them that they had a specific health condition and then asked the current effect of that specific health condition on their daily activities (no effect, a little effect, or a large effect). Each health condition was coded: 0 for not present, 1 for present and no effect, 2 for present and a little effect, or 3 for present and a large effect. Higher scores indicated an overall greater burden of disease on daily activities.

Actual prescription medication containers were visually inspected and listed. From a list of drug names for each subject, medication use was constructed as a continuous variable indicating the number of individual prescription medications currently taken. Oral health status was measured with a summary score of a 3-item survey adapted from the Nutrition Screening Initiative's Level II Screen and Oral Health Checklist (37). The 3 items asked about the amount of current difficulty with chewing and swallowing and the amount of mouth or tongue pain: 0 for none, 1 for a little, 2 for some, and 3 for a lot. Higher scores indicated a greater problem with oral status.

Two separate variables were used for chemosensory impairments: 1) diminished sense of taste and 2) diminished sense of smell. Each deficit was constructed as a dichotomous variable, with 0 = no and 1 = yes for self-report of deficit. For physical limitations in meal preparation and consumption, 9 questions were asked that measured difficulty performing tasks that were believed to be associated with the ability to prepare and consume food: 1) using a manual can opener, 2) lifting a cup or glass to drink, 3) opening a new milk or juice carton, 4) opening a frozen food package, 5) opening jars that have previously been opened, 6) reaching and getting down a 2.25-kg (5-lb) object from a shelf, 7) bending down to take something such as a pan from a lower cabinet, 8) opening a jar and removing a safety seal, and 9) opening a sealed plastic package. Difficulty with performing each task was rated along a 4-point Likert scale ranging from a 1 for no problem to a 4 for unable to do. Because this scale has not been previously tested in the literature, factor analysis was performed and revealed that one component explained 85.9% of the shared variance among the 9 items. Factor loadings ranged from a low of 0.58 (lifting a cup or glass to drink) to a high of 0.79 (opening a sealed plastic package). A summary scale was calculated with higher scores indicating greater difficulty with meal preparation and consumption tasks (Cronbach's $\alpha = 0.86$). Smoking status consisted of a dichotomous variable for current smoking (0 = no and 1 = yes).

Psychosocial characteristics

Five psychosocial measures assessed depressive symptoms, life stresses, and subjective health, function, and vision. Depressive symptoms were measured with the 15-item Geriatric Depression Scale (scores from 0 to 15), with higher scores indicating more depressive symptoms (Cronbach's $\alpha = 0.80$) (38, 39). The concept of life stresses was measured by the sum of 10 life events that occurred in the previous 12 mo: 1) death of spouse, child, parent, and brother or sister; 2) major illness that was new; 3) major financial

difficulty; 4) difficulty with a child or close relative; 5) someone new moving in; 6) car accident; and 7) forced discontinuance of an enjoyable hobby or activity. A higher score would suggest a greater amount of stress. Self-rated health, function, and vision were each measured along a 5-point Likert scale ranging from a 1 for excellent to a 5 for poor (5). A separate dichotomous variable was constructed for each measure (excellent, very good, or good = 0; fair or poor = 1).

Meal patterns

Because of the increased interest in breakfast consumption among the elderly and the national pilot testing of a Morning Meals on Wheels program (40), the frequency of breakfast consumption was used to measure meal patterns on a 3-point scale (almost every day, sometimes or once in awhile and rarely or never). A dichotomous variable was constructed to indicate frequency of breakfast occasions (almost every day = 0; sometimes, rarely, or never = 1).

Current nutritional health status

The anthropometric measure of body mass index (BMI) was used to give a general picture of nutritional health status (41). Weight was measured with a portable, self-zeroing scale. Because knee height is considered an indicator of original height before possible vertebral collapse, an estimate of height for subjects unable to stand, highly correlated with stature, and more appropriate for use in determination of BMI in elderly persons (41–43), we measured knee height with knee and ankle bent at 90°, with the Mediform sliding caliper (Medical Express, Beaverton, OR). Stature was computed from knee height with the appropriate sex- and race-specific formulas (44), which adjust for ethnic differences in the ratio of knee height to height (45), and entered into the calculation of BMI, which is weight (kg)/height (m²). With the use of a modification of the guidelines from the National Institutes of Health (46) and the variable construction strategy of Peninx et al (47), a 5-category variable was constructed for BMI (1 = < 18.5, 2 = 18.5–24.9, 3 = 25–29.9, 4 = ≥ 30 , and 5 = unable to determine). The last category (unable to determine BMI) included 24 subjects for whom an actual weight could not be determined. Fourteen were nonambulatory, and 10 were unable to stand for weight measurement.

Statistical analysis

Data were analyzed with STATA statistical software release 6 (48). Differences between men and women in the prevalence (categorical variables) and distribution (continuous variables) of individual characteristics and health-related factors were assessed with contingency tables with the use of the chi-square statistic and comparison of means with the use of Student's *t* statistic. Dietary information was directly entered from hard copy into the computerized NUTRITION DATA SYSTEM FOR RESEARCH (32). Nutrient calculations were performed with NUTRITION DATA SYSTEM FOR RESEARCH software version 4.03 (49), developed by the Nutrition Coordinating Center, University of Minnesota, Minneapolis, Food and Nutrient Database 31, released November 2000. Three-day mean nutrient intakes, with equal weighting for each of the 3 d (2 weekdays and 1 weekend) of dietary recall, were calculated for each subject and used to determine the mean and median nutrient intakes for the entire sample and by sex. Nutrient estimates were based exclusively on the consumption of foods [including meal supplements such as Ensure



TABLE 1
Individual characteristics of the study subjects¹

Variable	Men (n = 66)	Women (n = 279)
	%	
Age (y) ²		
60–74	34.8	31.5
75–84	45.5	40.5
≥85	19.7	28.0
Race		
White	53.0	50.9
Black	47.0	49.1
Education (highest grade completed)		
0–8	37.9	30.1
9–11	25.8	30.1
≥12	36.4	39.8
Income (per person/mo) ³		
<\$500	10.6	24.4 ⁴
\$500 to <\$750	36.4	45.9
\$750 to <\$1000	25.7	16.8
≥\$1000	27.3	12.9 ⁴
Marital status		
Married	36.4	13.3 ⁵
Not married	63.6	86.3
Living arrangement		
Lives with others	42.4	41.6
Lives alone	57.6	58.4
Receiving food stamps	18.2	28.3

¹Tests for significant difference by sex: *t* test for age (continuous variable) and contingency tables with chi-square test (categorical variables). Because of rounding, group totals may not add to 100%.

² $\bar{x} \pm$ SD age of the men 78.2 ± 8.6 y, of the women 78.2 ± 8.3 y.

³Contingency table with chi-square test (<\$500 compared with others, \$500 to <\$750 compared with others, \$750 to <\$1000 compared with others, and ≥\$1000 compared with others).

^{4,5}Significantly different from men: ⁴ $P \leq 0.01$, ⁵ $P \leq 0.001$.

(Abbott Laboratories Inc, Columbus, OH); vitamin and mineral supplements did not contribute to the reported nutrient intakes (50). It has been generally accepted that for elderly subjects, 3 nonconsecutive days of intake are sufficient to describe the usual intakes of most nutrients (7, 50–52).

The proportion of recommended dietary allowance [RDA; adequate intake (AI) was used for calcium and vitamin D] from the newly released age- and sex-specific DRIs that was met by the entire sample and sex-specific subsamples was calculated by using both mean and median values for intakes of energy, protein, and 16 vitamins and minerals (53–56). Because the DRIs did not include a recommendation for energy and protein, amounts for men and women aged ≥51 y from the 1989 RDA were used for energy (2300 kcal for men and 1900 kcal for women) and for protein (63 g for men and 50 g for women) recommendations (57). Dietary intakes of energy, protein, and micronutrients were characterized in 3 ways. First, sample and sex-group mean and median nutrient intakes were calculated by using a 3-d average of dietary intakes for each subject. Then the percentage of the new RDA-AI met by the mean and median were compared between men and women by using the Student's *t* test. Finally, sex comparisons of the prevalence of nutrient inadequacy [intake less than the estimated average requirement (EAR)] were examined by using contingency tables and the chi-square statistic (58).

A 2-phase approach was used to examine the association of individual characteristics and health-related factors with nutrient

intakes. First, bivariate analyses identified health-related factors significantly associated with each dependent variable (individual nutrient). Only variables (health-related factors) significantly correlated to nutrient intake ($P \leq 0.05$) were included in the multiple regression models. Second, 2 separate multiple regression models, with robust (White-corrected) SEs, were individually fitted for energy, protein, and each of the 16 vitamins and minerals of interest. The *robust* command in STATA corrects the SEs for heteroscedasticity of unknown form. In model 1 each nutrient was regressed on all the individual characteristics (sex, race, education, income, age, marital status, living arrangement, and FSP participation) and significant health-related factors from the bivariate analyses. For model 2, energy was added as an explanatory term to model 1. Thus, model 2 identified significant correlates of nutrient intake, controlling for total energy intake. Because both models are basically the same, only the results of model 1 are shown. To determine whether multicollinearity was a problem, the variance inflation factor was computed for both models. According to these rules, collinearity is harmful if the largest variance inflation factor is > 10 or if the average of all variance inflation factors is much larger than 1 (48, 59). Collinearity was found not to be a problem in these analyses.

RESULTS

Individual characteristics, nutrient intakes, and health-related factors

Cross-tabular analysis indicated that NAFS subjects were not significantly different in age, sex, and race from the home-delivered meal participants not included in the study (data not shown). The characteristics of the 345 subjects are shown in **Table 1**, where the sex-specific distributions of age (61–98 y), race, education, income, marital status, living arrangement, and FSP participation are described. Significant sex differences were observed for income and marital status. Unmarried women were more likely than unmarried men to report the lowest levels of income (<\$500/mo, 19% compared with 4.8%, $P = 0.02$; <\$750/mo, 68% compared with 47%, $P = 0.01$; data not shown). FSP participation was low (<38%) among those with the lowest incomes (monthly income <\$750); almost 96% of FSP participants received \$10, and the trend for FSP participation among all subjects decreased with increasing age ($P < 0.01$).

Because asymmetric distributions were observed for energy and 16 micronutrients (skewness > 1.0), the sample median intake for each of the nutrients is presented in **Table 2**, along with the median intake as a percentage of the RDA-AI by sex. NAFS subjects did not meet the RDA (or AI) for energy and 7 micronutrients (vitamins D, E, and B-6, folate, calcium, magnesium, and zinc). A comparison of median intakes by sex indicated that the diets of women (compared with men) met a significantly lower percentage of the RDA-AI for vitamins D, E, and B-12, folate, calcium, iron, phosphorus, riboflavin, and selenium.

The sample and sex-specific means and prevalence of health-related factors are shown in **Table 3**. The most commonly reported diseases and health conditions were arthritis (78% for the sample; 83% of women compared with 62% of men, $P \leq 0.001$), high blood pressure (71%), diabetes (36%), various lung diseases (27% with asthma, emphysema, chronic obstructive pulmonary disease, or chronic bronchitis, or more than one of these), history of heart attacks (26% for the sample; 36% of men compared with

TABLE 2
Nutrient intakes as a percentage of recommended dietary allowances (RDAs)¹

Nutrient	Total (n = 345)	Men (n = 66)	Women (n = 279)
Energy (kJ)	5839.2 (69.5)	6583.4 (68.4)	5548.6 (69.8)
Protein (g)	56.99 (109.6)	67.56 (107.2)	55.08 (110.2)
Vitamin D (µg) ²	4.26 (31.3)	5.65 (41.4)	4.06 (29.8) ³
Vitamin E (mg) ⁴	5.77 (38.4)	6.83 (45.5)	5.57 (37.1) ⁵
Vitamin C (mg)	82.73 (106.8)	92.89 (103.2)	80.61 (107.5)
Vitamin A (µg) ⁶	906.96 (124.1)	1069.21 (118.8)	851.13 (121.6)
Vitamin B-6 (mg)	1.44 (94.1)	1.78 (104.7)	1.39 (92.7)
Folate (µg) ⁷	362.68 (90.7)	408.45 (102.1)	345.88 (86.5) ³
Vitamin B-12 (µg)	2.81 (116.9)	3.56 (148.3)	2.65 (110.4) ³
Calcium (mg) ²	625.77 (52.1)	773.18 (64.4)	602.08 (50.2) ³
Magnesium (mg)	209.00 (62.3)	254.88 (60.7)	200.05 (62.5) ⁵
Iron (mg)	10.53 (131.7)	12.68 (158.5)	9.96 (124.5) ³
Zinc (mg)	7.08 (83.9)	8.72 (79.3)	6.85 (85.6)
Thiamine (mg)	1.28 (114.2)	1.58 (131.7)	1.23 (111.8)
Niacin (mg)	15.86 (110.6)	18.24 (114.0)	15.16 (108.3)
Phosphorus (mg)	884.02 (126.3)	1096.11 (156.6)	853.26 (121.9) ³
Riboflavin (mg)	1.52 (134.1)	1.94 (149.2)	1.45 (131.8) ⁵
Selenium (µg)	80.21 (145.8)	94.02 (170.9)	76.79 (139.6) ³

¹Median; percentage of RDA in parentheses. Intakes were calculated from 3-d averages of individual dietary recalls. RDAs from the 1997, 1998, 2000, and 2001 dietary reference intakes are age-group and sex specific for men and women aged 51–70 y and >70 y. 1989 RDAs (adults aged ≥51 y) are used for energy and protein.

²Vitamin D and calcium recommended amounts are based on adequate intakes from the 1997 dietary reference intakes.

^{3,5}Significantly different from men (*t* test): ³ $P \leq 0.001$, ⁵ $P \leq 0.05$.

⁴α-Tocopherol.

⁶Total vitamin A.

⁷Dietary folate equivalents.

24% of women, $P = 0.041$), having suffered at least one stroke (23%), osteoporosis (20% of women and 0% of men), and congestive heart failure (16%). Most subjects (54%) reported some difficulty with chewing, swallowing, or mouth pain (data not shown). Although there were no observed differences (data not shown) between men and women in the prevalence of chewing difficulty or mouth pain, women were more likely to report difficulty swallowing (30% of women compared with 11% of men, $P = 0.009$). Of the 219 subjects who reported no difficulty with chewing, 59% reported having dentures that did not fit properly and 94% were missing teeth (data not shown). In an analysis of the total number of physical limitations in meal preparation and consumption (data not shown), women were more likely than men to report a larger number of tasks that were either very difficult or impossible to accomplish (2.3 compared with 0.76 for men, $P < 0.001$). In particular, women were more likely to report 1–2 tasks (40% of women compared with 30% of men), 3–4 tasks (24% compared with 8%), and 5–9 tasks (14% compared with 2%) as being very difficult or impossible to accomplish. The most frequently reported limitations included reaching for a 2.25-kg (5-lb) object on a shelf (59%), bending to get a pan from a lower shelf (41%), using a manual can opener (34%), opening a new milk or juice carton (15%), and opening a jar that had been opened previously (15%).

Two of the psychosocial characteristics (depressive symptoms and stress events), meal patterns, and nutritional health status warrant additional comment. Almost 20% of the entire sample reported ≥ 7 (of 15) depressive symptoms and 8% (23 women and 3 men) identified the presence of ≥ 10 depressive symptoms. With

respect to experiencing life stress events in the previous year, one-fourth of the subjects reported the death of a spouse, parent, child, or sibling. Almost 37% reported major financial difficulty, 45% reported they had to give up a hobby or activity they enjoyed, and 40% ($n = 137$) experienced a new illness in the past year. For breakfast consumption, a nonparametric test for trend across age groups (60–74, 75–84, and ≥ 85 y) indicated that the frequency of breakfast consumption increased with age ($P < 0.01$; data not shown). In addition to sex differences in BMI, we found significant associations between race and categories of BMI. White subjects were more likely than blacks to have a BMI of 18.5–24.9 (30% compared with 17%, $P < 0.01$). Conversely, black subjects were more likely to have a BMI of ≥ 30 (40% compared with 29%, $P < 0.05$). In addition, we were unable to determine BMI for a greater proportion of black subjects, compared with whites (12% compared with 2%, $P < 0.001$).

Low nutrient intakes

For both men and women, as shown in **Table 4**, the nutrients for which the largest proportion of subjects had inadequate intakes (less than the EAR) were magnesium (81%), vitamin E (94%), and zinc (51%). Although there are not recommended EARs for calcium and vitamin D, almost all subjects failed to consume AIs. With respect to calcium intake, 95.6% and significantly more women than men failed to consume AIs. All but one subject ($n = 344$; 99.7%) reported dietary intakes of vitamin D below the recommended AI. The results also suggested that the nutrient intakes of a sizable proportion of subjects were inadequate (based on the EARs) for multiple nutrients: 27% for ≥ 6 nutrients, another 40% for 3–5 nutrients, and 29% for 1 or 2 nutrients (data not shown). Although nonparametric tests for trend (data not shown) indicated that sex and race proportions across the categories of increasing multiple inadequate nutrients were not different ($P = 0.91$ and $P = 0.16$, respectively), the proportion of subjects who reported regularly consuming breakfast diminished as the number of inadequate nutrients increased ($P < 0.01$).

Multiple regression models

Bivariate analyses indicated that 3 of the health-related factors were significantly correlated with nutrient intakes and hence included in the regression models: diminished sense of taste, physical limitations in meal preparation and consumption, and breakfast consumption. As a continuous variable, BMI was not significantly associated with nutrient intakes. However, when dummy variables were used for BMI categories (eg, BMI ≥ 30 compared with others), only a BMI ≥ 30 was significantly associated with nutrient intakes ($P < 0.05$). As a result, BMI was included in multiple regression models as dummy variables for BMI categories. The multiple regression results of model 1 (energy not included as an independent variable), presented in **Table 5**, show the association of individual characteristics and health-related factors to nutrient-specific intakes of energy, protein, calcium, vitamin D, and nutrients in which ≥ 20% of the sample reported an intake less than the EAR. Regression diagnostics indicated that multicollinearity was not a problem in either model (eg, model 1 with energy not included and model 2 with energy included as an independent variable).

Sex

In multiple regression models that controlled for covariates (race, education, income, age, marital status, living arrangement,

TABLE 3

Health-related factors in the study subjects¹

	Total	Men	Women	Range
Physical characteristics				
Burden of diagnosed diseases	8.5 ± 5.0 ²	7.3 ± 5.4	8.7 ± 4.9 ³	0–26
Medications ⁴	6.3 ± 4.5	5.7 ± 4.9	6.5 ± 4.3	0–31
Oral status	1.4 ± 1.8	1.2 ± 1.8	1.5 ± 1.8	0–9
Diminished sense of taste (%)	33.0 [114] ⁵	28.8 [19]	34.0 [95]	
Diminished sense of smell (%)	23.5 [81]	28.8 [19]	22.2 [62]	
Physical limitations in meal preparation and consumption	16.4 ± 5.6	12.4 ± 3.6	17.4 ± 5.6 ⁶	9–36
Current smoker (%)	17.1 [59]	27.3 [18]	14.7 [41] ²	
Psychosocial characteristics				
Depressive symptoms	4.2 ± 3.0	3.5 ± 2.9	4.4 ± 3.0 ³	0–15
Stress events in past year	1.7 ± 1.3	1.6 ± 1.4	1.7 ± 1.2	0–6
Self-rated fair or poor health (%)	66.4 [229]	56.1 [37]	68.8 [192] ³	
Self-rated fair or poor function (%)	65.2 [225]	56.1 [37]	67.4 [188]	
Self-rated fair or poor vision (%)	56.2 [194]	57.6 [38]	55.9 [156]	
Meal patterns				
Eat breakfast almost every day (%)	82.0 [283]	77.3 [51]	83.1 [232]	
Current nutritional status				
BMI (kg/m ²) ⁷	28.7 ± 6.6	26.9 ± 4.7	29.2 ± 6.9 ⁸	14–61
BMI categories (kg/m ²) ⁹				
< 18.5 (%)	3.8 [13]	1.5 [1]	4.3 [12]	
18.5–24.9 (%)	24.8 [82]	36.4 [24]	20.8 [58] ⁸	
25–29.9 (%)	31.0 [107]	42.4 [28]	28.3 [79] ³	
≥ 30 (%)	34.5 [119]	16.7 [11]	38.7 [108] ⁶	
Unable to determine (%) ¹⁰	7.0 [24]	3.0 [2]	7.9 [22]	

¹n = 345.² $\bar{x} \pm$ SD.^{3,6,8}Significantly different from men [*t* test (continuous variables) and contingency tables with chi-square test (dichotomous variables, all others as reference category)]: ³*P* ≤ 0.05, ⁶*P* ≤ 0.001, ⁸*P* ≤ 0.01.⁴n = 342 (medication information unavailable for 3 subjects).⁵n in brackets.⁷n = 321 (unable to determine knee height or weight or both for 24 subjects).⁹Totals may exceed 100% because of rounding.¹⁰Unable to measure weight or knee height or both (n = 14 nonambulatory subjects, 10 subjects unable to stand on a scale).

and FSP participation) and health-related factors (diminished sense of taste, physical limitations in meal preparation and consumption, breakfast consumption, and BMI), women had significantly lower intakes of total energy, protein, and 8 of 9 specific vitamins and minerals. Although this is not shown in Table 5, women also had significantly lower intakes of phosphorus, thiamine, niacin, riboflavin, selenium, vitamin A, and iron. After energy intake was controlled for in model 2 (data not shown), the lower intakes remained significant (although attenuated in the size and significance of the coefficient) for protein and were nearly significant for vitamin D and phosphorus (*P* < 0.08).

Race

As shown in Table 5, blacks consumed significantly more protein, significantly less calcium and folate, and less magnesium, but this was not significant (*P* = 0.08). Blacks consumed significantly less thiamine and riboflavin and more selenium (data not shown). Although correlations with significant nutrients were not altered with the additional control for energy intake in model 2, lower intakes of magnesium and iron were now significant for black subjects (*P* < 0.05).

Education

Lower intakes of particular nutrients were associated with less education. Subjects with <9 y of education had significantly lower

intakes of calcium, magnesium, and vitamin E and had lower intakes of vitamin D and phosphorus that were nearly significant (*P* = 0.07). Independent of energy intake (model 2), lower levels of education were associated with lower intakes of calcium and magnesium.

Income and Food Stamp Program participation

The lowest level of income (<\$500/mo) was directly associated with lower intakes of energy, magnesium, vitamin B-6, and niacin (data not shown). After energy intake was controlled for, vitamin B-6 was the only nutrient whose intake was nearly significant (*P* = 0.06). FSP participants had significantly lower intakes of energy, calcium, magnesium, zinc, and 3 nutrients not shown in Table 5 (phosphorus, riboflavin, and iron), and lower intakes of protein and vitamin C were nearly significant (*P* = 0.06 and *P* = 0.09, respectively). Although none of the significant relations remained for FSP participation after energy intake was controlled for, calcium intake was nearly significant (*P* = 0.06).

Health-related factors

A diminished sense of taste was significantly associated with lower intakes of energy and protein and, in data not shown, phosphorus, thiamine, and riboflavin. Significant associations disappeared after energy intake was controlled for. In both models,

TABLE 4
Proportion of study subjects with nutrient intakes below dietary reference intakes¹

Nutrient	Less than 100% RDA or AI		Less than EAR	
	Men	Women	Men	Women
Energy	89.4	92.8	None	None
Protein	34.8	34.8	None	None
Calcium	89.4	97.1 ²	None	None
Vitamin E	93.9	97.8	89.4	94.3
Vitamin B-12	16.7	42.3 ³	9.1	26.5 ²
Folate (DFE)	48.5	64.9 ⁴	31.8	40.1
Iron	12.1	25.8 ⁴	0.0	2.5
Vitamin D	100.0	99.6	None	None
Vitamin A	33.3	36.9	13.6	16.8
Vitamin C	47.0	45.2	33.3	29.4
Magnesium	97.0	94.3	87.9	79.2
Vitamin B-6	43.9	55.6	30.3	41.9
Zinc	75.8	68.8	60.6	48.4 ⁴
Niacin	25.8	41.9 ⁴	9.1	16.1
Thiamine	21.2	36.6 ⁴	10.6	16.1
Phosphorus	6.1	24.7 ³	3.0	10.4
Selenium	6.1	14.0	1.5	5.7
Riboflavin	10.6	18.3	6.1	6.8
Total low nutrients ⁵	—	—	3.86 ± 0.32	4.25 ± 0.17

¹*n* = 345. RDA, AI for calcium and vitamin D, and EAR from the 1997, 1998, 2000, and 2001 dietary reference intakes. RDA for energy and protein from the 1989 RDA. RDA, recommended dietary allowance; AI, adequate intake; EAR, estimated average requirement; DFE, dietary folate equivalents.

²⁻⁴Significantly different from men: ²*P* ≤ 0.01, ³*P* ≤ 0.001, ⁴*P* ≤ 0.05.

⁵Range of total low nutrients $\bar{x} \pm \text{SEM}$: less than EAR (0–14).

physical limitations in meal preparation and consumption were significantly associated with lower calcium intake. Independent of individual characteristics and health-related factors (diminished taste, physical limitations in meal preparation and consumption, and BMI), not regularly eating breakfast was significantly associated with decreased intakes of energy, protein, and 12 of the 16 vitamins and minerals. Only vitamins D, B-12, and A and zinc were not significantly associated with breakfast consumption. After energy intake was further controlled for, all nutrients retained their significant association with breakfast consumption, except for protein and magnesium. In multiple regression models, BMI was not significantly associated with nutrient intakes.

DISCUSSION

Research on the adequacy of nutrient intakes has started to recognize the greater vulnerability of certain groups of the elderly, including women, blacks, and those who are homebound (5, 7, 28). However, little attention has been paid to the specific factors that may predispose these groups to such vulnerability. The present study attempted to highlight the prevalence of inadequate nutrient intakes by using three 24-h dietary recalls, the newly released DRIs, and the correlates of low nutrient intakes among a probability sample of 345 homebound elderly persons. Several findings warrant closer examination.

First, although home-delivered meals were regularly provided to all men and women in this study, their dietary intake suggested inadequacies in key nutrients that have previously been associated

with physical and cognitive function, immune response, bone health, and vision (14, 60, 61). This was apparently the first report to use the EAR as the appropriate criterion for nutrient inadequacy among the homebound elderly, and we found a large number of subjects with inadequate intakes in individual and multiple nutrients. Of particular interest was the inverse association between the frequency of breakfast consumption and the number of inadequate intakes of specific nutrients.

Second, we are especially concerned about our inability to determine the extent of inadequate intakes of either calcium or vitamin D in this sample (58), for several reasons. Both calcium and vitamin D are key to bone health (60), and dietary intake is especially critical for in the elderly (62–64). Previous studies that used arbitrary criteria of inadequacy found high proportions of the elderly to be deficient in one or both of them (27, 28, 51). Furthermore, the Food and Nutrition Board indicated that recommended intakes of calcium and vitamin D are based on an AI, which is an inappropriate measure of nutrient inadequacy (58). Therefore, we are unable to ascribe a quantitative estimate of inadequacy for either nutrient. We must point out, however, that DRI criteria of an AI allows us to characterize calcium and vitamin D intakes as adequate for only 4.3% and 0.3% of the sample, respectively.

Third, we found that regardless of health-related factors, women, blacks, and those with low income and limited education were the most vulnerable for low nutrient intakes. It is quite striking that, after covariates and health-related factors were controlled for (diminished taste, physical limitations in meal preparation and consumption, breakfast consumption, and BMI), women had significantly lower intakes of total energy, protein, and 15 of 16 vitamins and minerals. There are several possible explanations, such as burden of disease, oral status, and depressive symptoms, that merit further investigation. Burden of disease, which reflected the presence and perceived effect of individual diseases or health conditions on daily activities, was not directly associated with nutrient intake. However, the observed greater prevalence of individual health conditions (eg, arthritis and osteoporosis) that may affect dietary intake (eg, food preparation and consumption) and a greater summary score of disease burden among women suggest the possibility for unobserved indirect effect of disease burden on nutrient intakes. As a summary measure, oral status was not directly linked with nutrient intakes. However, the significantly greater difficulty that women reported with swallowing also suggests a conceivable indirect association with nutrient intakes. We suspect that the type of compensatory strategies made for swallowing difficulties may include alteration of food choices, amounts, and frequency of eating occasions. Depressive symptoms, which were more prevalent among women in this study, have been linked with social interaction and mobility (65). Thus, we expect that increased depressive symptoms among women affect nutrient intake through loss of appetite, loss of enjoyment of food and food preparation, and consumption of a less varied diet.

Finally, we observed a significant link between those who reported that they did not regularly eat breakfast and low dietary intake. As observed, this relation was independent of individual characteristics, health-related factors, and current nutritional health status. Others have pointed out the importance of a breakfast meal for the elderly, because it is nutrient dense and increases the intake of critical food groups, such as cereal and grain products, fiber, fruit, and calcium-rich foods (40). As the Morning Meals on Wheels Pilot Program showed, there

TABLE 5
Demographic and health-related correlates of nutrient intakes from multiple regression¹

	Energy (kJ)	Protein (g)	Calcium (mg)	Vitamin D (µg)	Magnesium (mg)	Vitamin B-12 (µg)	Folate (µg DFE)	Vitamin B-6 (mg)	Zinc (mg)	Vitamin C (mg)	Vitamin E (mg)
Demographic variables											
Female	-1266.74 ² (280.64)	-13.34 ² (2.88)	-163.29 ² (44.09)	-1.33 ² (0.37)	-36.51 ² (11.36)	-1.01 ² (0.42)	-69.72 ² (28.45)	-0.28 ² (0.092)	-1.84 ² (0.62)	-10.26 (9.21)	-1.26 ² (0.61)
Black	-67.20 (204.31)	4.08 ⁴ (2.13)	-107.43 ² (29.27)	-0.42 (0.28)	-13.83 ² (7.96)	-0.27 (0.32)	-46.12 ² (18.74)	-0.014 (0.067)	-0.18 (0.43)	7.94 (6.83)	-0.50 (0.38)
Education <9 y	-311.37 (230.81)	-2.99 (2.48)	-85.69 ⁴ (36.54)	-0.59 ² (0.33)	-23.30 ² (9.73)	0.22 (0.41)	-11.69 (22.72)	-0.059 (0.077)	-0.79 (0.48)	-14.12 (8.75)	-0.96 ² (0.47)
Education 9-11 y	-225.67 (238.62)	-0.97 (2.48)	-48.89 (44.01)	-0.58 ² (0.34)	-13.66 (9.83)	-0.07 (0.34)	-11.08 (23.95)	0.015 (0.080)	-0.05 (0.58)	-19.08 ² (7.88)	-0.07 (0.68)
Income <\$500	-722.06 ⁴ (344.13)	-5.42 ² (3.24)	-55.62 (63.14)	-0.18 (0.53)	-30.43 ⁴ (14.78)	-0.52 (0.54)	-26.55 (37.50)	-0.35 ² (0.12)	-0.91 (0.77)	-25.93 ² (15.60)	-0.76 (1.00)
Income \$500 to <\$750	-239.56 (338.34)	-1.45 (3.21)	4.15 (55.86)	0.32 (0.46)	-3.74 (14.76)	-0.34 (0.44)	4.59 (36.80)	-0.16 (0.11)	-0.16 (0.72)	-9.35 (15.83)	-0.95 (0.82)
Income \$750-\$1,000	-348.85 (314.67)	-1.71 (2.88)	-91.60 ² (53.37)	-0.43 (0.46)	-19.98 (14.07)	0.16 (0.58)	-20.66 (33.12)	-0.28 ² (0.11)	0.16 (0.89)	-16.44 (15.99)	-0.77 (0.88)
Age 60-74 y	690.91 ⁴ (302.63)	4.56 (2.86)	27.32 (53.79)	0.20 (0.39)	7.77 (11.58)	0.21 (0.36)	63.82 ⁴ (31.44)	0.047 (0.093)	0.33 (0.59)	-1.99 (7.94)	0.29 (0.77)
Age 75-84 y	263.25 (211.13)	2.62 (2.31)	-32.35 (47.58)	0.24 (0.37)	5.69 (10.78)	0.31 (0.38)	29.06 (23.47)	0.030 (0.079)	0.15 (0.56)	6.31 (8.35)	-0.20 (0.69)
Married	105.90 (296.15)	0.31 (2.97)	-41.29 (46.36)	-0.08 (0.36)	1.93 (10.66)	-0.44 (0.41)	-6.68 (25.18)	-0.047 (0.093)	0.09 (0.58)	1.65 (10.00)	-0.02 (0.65)
Lives alone	-304.64 (209.20)	-0.92 (2.25)	-23.81 (35.87)	0.08 (0.31)	5.62 (8.60)	-0.20 (0.37)	-13.47 (20.71)	-0.004 (0.080)	-0.05 (0.52)	4.29 (7.98)	-0.55 (0.51)
Receiving food stamps	-445.56 ⁴ (229.11)	-4.52 ⁶ (2.46)	-90.22 ² (35.56)	-0.42 (0.30)	-22.09 ² (8.80)	-0.28 (0.33)	-30.82 (22.84)	-0.11 (0.07)	-0.92 ² (0.41)	-11.35 ² (6.71)	-0.45 (0.44)
Health-related variables											
Diminished taste	-448.27 ² (186.06)	-4.50 ² (1.91)	-41.09 (35.23)	-0.16 (0.29)	-8.74 (8.66)	-0.15 (0.31)	-23.42 (19.86)	-0.045 (0.071)	-0.58 (0.41)	3.85 (9.07)	0.13 (0.54)
Physical limitations in meal preparation and consumption	-6.22 (16.00)	-0.15 (0.17)	-5.71 ⁴ (2.82)	-0.04 (0.02)	-0.73 (0.70)	-0.014 (0.026)	-0.49 (1.68)	-0.005 (0.006)	-0.014 (0.033)	-0.09 (0.60)	0.003 (0.043)
Not eating breakfast	-665.50 ² (227.35)	-7.42 ² (2.47)	-126.39 ² (39.30)	-0.51 (0.37)	-29.70 ² (9.48)	-0.31 (0.38)	-106.50 ² (21.44)	-0.31 ² (0.08)	-1.07 (0.66)	-29.09 ² (6.86)	-1.51 ² (0.43)
BMI < 18.5	-88.94 (559.48)	-2.78 (4.39)	-73.30 (66.20)	-0.69 (0.56)	-15.79 (21.33)	-0.87 (0.57)	-48.58 (49.29)	0.007 (0.20)	-0.98 (0.80)	5.01 (13.88)	-0.53 (0.43)
BMI 18.5-29.9	-43.67 (283.34)	-2.06 (2.76)	-36.88 (47.16)	-0.31 (0.37)	-6.95 (11.18)	-0.56 (0.37)	-32.00 (30.04)	-0.046 (0.086)	-0.48 (0.56)	0.42 (7.46)	-0.17 (0.66)
BMI ≥ 30	-158.50 (268.07)	0.76 (2.69)	-31.30 (43.75)	-0.40 (0.36)	4.93 (10.61)	-0.47 (0.38)	-34.71 (28.92)	0.021 (0.088)	-0.30 (0.58)	10.40 (10.56)	-0.53 (0.65)
Unable to determine BMI	408.33 (473.77)	5.13 (4.15)	69.23 (99.70)	0.37 (0.66)	9.14 (20.12)	-0.13 (0.57)	-21.67 (40.03)	0.12 (0.14)	1.47 (1.40)	9.32 (15.25)	1.48 (1.60)
R ²	0.205	0.196	0.203	0.132	0.188	0.071	0.141	0.153	0.127	0.099	0.089

¹ Includes energy, protein, vitamin D, calcium, and individual nutrients that ≥20% of the sample reported intakes less than the EAR. Robust SEs are in parentheses and are corrected with the White-Huber correction. There were 345 observations. Reference categories (variables) omitted to prevent perfect collinearity: education (≥12 y), income (>\$1000/mo), age (≥85 y), BMI (18.5-24.9), EAR, estimated average requirement; DFE, dietary folate equivalents.

² P ≤ 0.001.

³ P ≤ 0.01.

⁴ P ≤ 0.05.

⁵ P ≤ 0.09.


⁶ P ≤ 0.06.

may be benefits of providing a breakfast meal as a second meal to the more vulnerable homebound elderly, such as improved nutrient intakes and improved appetite and perceived health status (40).

There are several particular strengths to the present study. First, compared with previous research (6, 7), we completed more in-home assessments ($n = 345$) and obtained dietary information from a greater proportion of homebound elderly men and women (99%) who completed three 24-h dietary recalls. Second, the comprehensive information collected during the in-home visit allowed us to examine many health-related factors with multiple regression analysis. Third, current nutritional health status was determined through objective measurement of knee height and weight. Fourth, the protocol used for training subjects in portion-size estimation and dietary recall minimized respondent burden and enhanced our completion rate. Finally, nutrient inadequacy was based on a more appropriate criterion of inadequacy, the EAR.

There are several limitations to this study. Although the cross-sectional design allowed us to examine the relation of individual characteristics and health-related factors to reported nutrient intakes, we were unable to make causal inferences. The study sample was representative (eg, sex, age, and race) of all home-delivered meal participants in the counties of interest. However, the exclusion criteria may have resulted in a study sample with a nutrient intake profile different from that of nonparticipants. We also recognize limitations in our use of self-reporting rather than objective measurement of oral health status and physical limitations. An additional limitation is that the new DRIs recommend intakes for healthy individuals but have not been modified for the vulnerable, frail, or homebound elderly. Although the racial groups in this sample reflect the predominant racial groups historically served by the Elderly Nutrition Program (66), confirmation of these findings in other homebound elderly populations, such as Hispanics and Asians, are needed.

Notwithstanding its limitations, the present study extends our knowledge on the extent of nutrient inadequacy among elderly men and women who are homebound. The findings also identify individual characteristics and health-related factors that are related to nutrient intakes. The data suggest that home-delivered meals programs should target specific subgroups of participants with interventions tailored to increase nutrient intakes and reduce the prevalence of nutrient inadequacy. Considering that the DRIs refer to the "nutrient intake of apparently healthy individuals over time" (58) and that the burden of certain disorders may lead to increased energy requirements (1), the high prevalence of observed nutrient inadequacies may understate the proportion of home-delivered meal participants who are vulnerable to nutrient deficiencies.

The findings suggest specific areas for intervention. First, nutrient intakes could be increased with the availability of a breakfast meal. The results of the Morning Meals on Wheels Pilot Program confirm the effects of a morning home-delivered meal on the improvement in dietary intake, food security, and health status (40). Second, current Older Americans Act Nutrition Program requirements that the home-delivered meal achieve a minimum of one-third of the RDA may be inadequate. Previous research indicated that although the home-delivered meal met this requirement, the reliance on this meal as the main source of daily food intake resulted in an overall daily intake below recommended amounts (31–33, 66). Finally, programs should recognize the importance of individual food preferences, palatability, and taste, and any intervention targeted to improve nutrient intakes must include tailored nutrition education for the participant and any caregiver. 

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