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# Assessment of a modified household food weighing method in a study of bone health in China

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*Objective:* A 'modified' household dietary method to estimate individual intakes from total household intakes was evaluated in comparison to the individual food weighing method, i.e. direct weighing of foods consumed by individuals.
*Design:* Foods consumed by the household were weighed and recorded over a 3 day period and were proportionally allocated to a specific person in the household by using energy conversion factors based on age, gender and physical activity. The individual dietary intakes were standardized by body weight (ratio of individual body weight to reference body weight from Chinese Recommended Daily Allowances (*Acta Nutr. Sin.* **12**, 1–9), and were compared with the estimates from the individual food weighing method for both accuracy and associations with bone density.
*Setting:* The subjects were randomly selected from five rural countries in China, characterized by different dietary patterns.
*Subjects:* A total of 712 women aged 35–75 years participated in the dietary and bone measurements.
*Results:* Nutrient intakes estimated by the modified household method (adjusting for body weight were very similar to those obtained by the individual method ($r=0.53$–$0.78$, $P<0.001$), except for sodium which had the largest deviation from the individual methods ($r=0.23$, $P<0.001$). Calcium intakes were $405 \pm 271$ and $409 \pm 323$ mg/day, respectively, as estimated by the individual and modified household methods. A very similar degree of correlation with radial bone density also was obtained for both calcium estimates.
*Conclusion:* The results indicate that the modified household method is appropriate for assessing food intakes of individuals in large nutritional studies.
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*Descriptors:* calcium, bone density, dietary assessment, food intake, osteoporosis

## Introduction

There is growing interest in the potential role of nutritional factors in the aetiology and management of diseases, including the role of dietary calcium in osteoporosis (Matkovic *et al.* 1979; Wardlaw, 1988; Nordin *et al.* 1991). In order to study this relationship reliably, it is essential to estimate calcium intake accurately. Uncertainty in the estimation of dietary calcium intake is thought to be one of the factors accounting for the inconsistent results linking dietary calcium and bone mass (Heaney, 1986). There are several methods which can be used to estimate individual dietary intakes, including 24-h or 7-day dietary recall, food frequency questionnaires, food history, and food weighing methods. These standard methods of determin-

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ing food intakes have been discussed and reviewed extensively (Pekkarinen, 1970; Burke & Pao, 1976; Bingham, 1987; Gibson, 1990).

The food weighing method, though expensive and time-consuming, is often employed as the 'gold standard' to access actual dietary intakes of individuals (Barrett-Connor, 1991). An offspring of this method, the 3-day household food weighing method, has been successfully employed in two nationwide studies in China (Jin, 1986; Chen *et al*). In this method, a combination of household food weighing and disappearing techniques was used over a period of 3 days. Food intakes were calculated on the basis of the total person-days in the household and then were standardized by sex, age and physical activity of each member of the household to obtain intakes per 'reference man' (more accurately speaking, a standardized per person intake). The high efficiency, low cost, and relatively high accuracy have resulted in the extensive use of this method in nutritional studies in China. However, the use of this method to reliably estimate dietary intakes per individual (i.e. a specific person in the household surveyed), instead of per reference person, has not been previously considered. Under some circumstances, measurement of dietary intakes for a specific individual in the household is more relevant than estimation of the intakes for a standardized reference person, particularly when the outcome variables are measured at the individual level.

In 1989, in conjunction with the parent ecological survey at the county level (Chen *et al*., 1991), a more focused survey was conducted on 843 Chinese women to investigate the relationship between bone health and nutritional factors, especially calcium intakes, at the individual level (Hu *et al*., 1993). As part of this survey, the food intakes of each female were recorded quantitatively by direct weighing of foods consumed by each individual. At the same time, food intakes of each household, from which subjects were selected, also were estimated by a 3-day household food weighing method as in the parent survey (Chen *et al*., 1991). The primary objective of this communication is to assess the feasibility and validity of the household food weighing method as a means to estimate food intakes per individual. In addition to a comparative statistical evaluation with estimates obtained using the direct weighing method for each individual subject, the household method also was validated in terms of utility for biological analyses, by examining the relationship between radial bone density and dietary calcium intakes estimated on the basis of these dietary assessment methods. Furthermore, the body weight of survey subjects also was recorded, which allowed us to consider this factor in relation to energy partitioning in the household method as suggested by Geissler (1991).

## Methods

### *Subjects*

Characteristics of survey subjects have been reported in a previous publication analysing the relationship between dietary calcium and bone density (Hu *et al*., 1993). Briefly, a total of 843 women, aged 35–75 years, were selected from five rural countries in China, including two pastoral counties (Tuoli County in Xinjiang Autonomous region and Xianghuangqi County in Neimongol Autonomous Region) and three non-pastoral countries (Jiexiu County in Shanzi Province, Cangxi County in Sichuan Province, and Changle County in Fujian Province). These female subjects were selected to obtain an equal distribution among four 10-year age groups (35–, 45–, 55– and 65–75 years) and among four villages in each county. A complete set of food survey data for both methods were available for a total of 712 women, of which 472 were postmenopausal women.

### *Household food weighing method*

Food weighing and recording was conducted in each household by members of the county health survey teams, who had received a 1-week training course prior to the survey. In this method, all raw and cooked foods available at the beginning and leftover foods at the end of the survey were weighed and recorded. During the survey period, the team members also visited each household once or twice per day to weigh and record any foods brought into the household either from the market or from the family garden. Foods consumed by the whole household were estimated on the basis of the disappearance of each food during the survey period. Plate wastes and discarded foods also were estimated and subtracted from the total household food disappearance.

In addition, the number of persons present for each meal was recorded by team members during daily visits to the household in order to calculate the total number of person-days for the household. Other important information, including age, sex, occupation, lactation, pregnancy, and physical activity, was also recorded for each person. A conversion factor (or conversion ratio) was estimated for each individual based on recommended energy intakes by age, sex and physical activity level from the Chinese RDA (Chinese Nutrition Society, 1990). These conversion factors were subsequently used to standardize food intakes for differences in age, sex and physical activity of each person in the household, to obtain a reference person intake (standardized per person intake). This method has been described and discussed in detail by Chen *et al.* (1991), Jin (1986) and Geisslerf (1991).

The calculation procedure is illustrated in Tables 1, 2 and 3 for an actual household with four members. First, information was recorded for each person as shown in Table 1. The number of person-days and reference-person-days were calculated as follows. The absence of any household member at each meal was recorded and subtracted from his/her total number of person-days, assuming proportions of 20%, 40% and 40% as the energy consumed during breakfast, lunch and dinner, respectively, for this household. (The actual proportions for three meals were obtained on the basis of the response of either the subject or other members in the same family to questions on the usual distribution of food intakes across the three meals.) The conversion factor for each person was calculated as the proportion of his/her energy RDA to the energy value recommended for a 'reference person' (or reference man), defined as a male, aged 18–45 years, weighing 63kg and undertaking very light physical work. These conversion factors based on the RDA values for energy intake for each age and sex group are listed in Table 2. The quantity of a specific food consumed by the household during the 3-day survey period (Table 3) was then divided by the total reference-person-days for the household (Table 1) in order to express intake per reference person (Jin, 1986; Chen *et al.*, 1991; Geissler, 1991), i.e. a per person intake standardized for differences in age, sex and physical activity.

The above procedure was modified in this analysis to estimate food intakes per individual. To estimate food intakes for a specific person in the household, the proportion of reference-person-days for the subject to the total reference-person-days for the household was calculated, and then applied to the total household intakes to obtain total food intake for the individual, which then was divided by the number of person-days for this individual to yield individual food intake per day (Table 3).

This procedure, however, does not take into account the often sizeable differences in body weight between the reference person and the specific individual for whom the intakes are to be estimated. Since body size is related closely to energy intake (on the basis of which conversion factors were calculated), an adjust-

**Table 1.** Household food weighing method: example of the estimation of reference-person-days in a household with four members

| | | | | | |
|---|---|---|---|---|---|
| *Recorded information* | | | | | |
| Subject no. | 1 | 2 | 3 | 4 | |
| Sex | F | M | F | F | |
| Age (years) | 65 | 30 | 28 | 2 | |
| Occupation | Housewife | Farmer | Farmer | None | |
| Physical activity | 2 | 4 | 3 | – | |
| *Calculation procedure* | | | | | *Total* |
| Person-day | 3.0 | 2.4 | 2.6 | 3.0 | 11.0 |
| Conversion factor[a] | 0.792 | 1.417 | 1.125 | 0.479 | |
| Reference man-day[b] | 2.376 | 3.401 | 2.925 | 1.437 | 10.14 |

[a] Obtained from 1989 Chinese RDAs for total energy intake (see Table 2).
[b] Reference-man-day = person-day × conversion factor.

ment factor for this body weight difference then was applied to the final individual estimate to yield an adjusted estimate of individual intake (see the last row in Table 3). Reference body weights used in the Chinese RDA are 63 kg for male and 53 kg for female, respectively. Thus, a ratio of body weight of the individual to that of the reference person (53 kg for women) was used here to adjust the final estimated dietary intakes.

**Table 2.** Conversion factors (CF) based on the RDA for total energy intake by age, sex and physical activity level[a]

| | | *Males* | | | *Females* | | |
|---|---|---|---|---|---|---|---|
| | *Physical activity*[b] | *Weight (kg)* | *Energy (kJ)* | *CF* | *Weight (kg)* | *Energy (kJ)* | *CF* |
| Infants (months) | | | | | | | |
| Newborn– | – | 6.7 | 3364 | 0.335 | 6.2 | 3113 | 0.310 |
| 6– | – | 9.0 | 3766 | 0.375 | 8.4 | 3515 | 0.350 |
| Children (years) | | | | | | | |
| 1– | – | 9.9 | 4602 | 0.479 | 9.2 | 4393 | 0.438 |
| 2– | – | 12.2 | 5021 | 0.500 | 11.7 | 4812 | 0.479 |
| 3– | – | 14.0 | 5648 | 0.563 | 13.4 | 5439 | 0.542 |
| 4– | – | 15.6 | 6067 | 0.604 | 15.2 | 5858 | 0.583 |
| 5– | – | 17.4 | 6694 | 0.667 | 16.8 | 6276 | 0.625 |
| 6– | – | 19.8 | 7113 | 0.708 | 19.1 | 6694 | 0.667 |
| 7– | – | 22.0 | 7531 | 0.750 | 21.0 | 7113 | 0.708 |
| 8– | – | 23.8 | 7950 | 0.792 | 23.2 | 7531 | 0.750 |
| 9– | – | 26.4 | 8368 | 0.833 | 25.8 | 7950 | 0.792 |
| 10– | – | 28.8 | 8786 | 0.875 | 28.8 | 8368 | 0.833 |
| 11– | – | 32.1 | 9205 | 0.917 | 32.7 | 8786 | 0.875 |
| 12– | – | 35.5 | 9623 | 0.958 | 37.2 | 9205 | 0.917 |
| Adolescents (years) | | | | | | | |
| 13– | – | 42.0 | 10042 | 1.000 | 42.4 | 9623 | 0.958 |
| 16– | – | 54.2 | 11715 | 1.167 | 48.3 | 10042 | 1.000 |
| Adults (years) | | | | | | | |
| 18–[c] | 1 | 63.0 | 10042 | 1.000 | 53.0 | 8786 | 0.875 |
| | 2 | | 100878 | 1.083 | | 9623 | 0.958 |
| | 3 | | 12552 | 1.250 | | 11297 | 1.125 |
| | 4 | | 14226 | 1.417 | | 12552 | 1.250 |
| | 5 | | 16736 | 1.667 | | 15062 | 1.500 |
| 45– | 1 | 63.0 | 9205 | 0.917 | 53.0 | 7950 | 0.792 |
| | 2 | | 10042 | 1.000 | | 8786 | 0.875 |
| | 3 | | 11297 | 1.125 | | 10042 | 1.000 |
| | 4 | | 12552 | 1.250 | | 11297 | 1.125 |
| | 5 | | 13807 | 1.375 | | 12552 | 1.250 |
| 60– | 1 | 63.0 | 8368 | 0.833 | 53.0 | 7113 | 0.708 |
| | 2 | | 9205 | 0.917 | | 7950 | 0.792 |
| | 3 | | 10460 | 1.042 | | 8786 | 0.875 |
| | 4 | | 11715 | 1.167 | | 10042 | 1.000 |
| | 5 | | 12970 | 1.292 | | 11297 | 1.125 |
| 70– | 1 | 63.0 | 7531 | 0.750 | 53.0 | 6694 | 0.667 |
| | 2 | | 8368 | 0.833 | | 7531 | 0.750 |
| 80– | – | 63.0 | 6694 | 0.667 | 53.0 | 5858 | 0.583 |

[a] Adapted from the 1989 Chinese RDA (Chinese Nutrition Society, 1990).
[b] Activity level: 1 = very light, 2 = light, 3 = medium, 4 = heavy, and 5 = very heavy.
[c] 837 kJ for pregnant women and 3347 kJ for lactating women were added to the RDA values for these groups, and conversion factors for the two groups were estimated accordingly.

**Table 3.** Household food weighing method: estimation of intakes per reference person and per individual (subject 1 in Table 1)

| | Potato | Rice | Salt | Plant oil | Cabbage | Pork |
|---|---|---|---|---|---|---|
| *Food record for household* | | | | | | |
| Food name | Potato | Rice | Salt | Plant oil | Cabbage | Pork |
| Amount at the beginning of the survey (g): | 1500 | 8000 | 120 | 500 | 0 | 0 |
| Amount entering the household (g): | | | | | | |
| Day 1 | 0 | 0 | 0 | 0 | 600 | 0 |
| Day 2 | 2050 | 0 | 0 | 0 | 0 | 0 |
| Day 3 | 0 | 0 | 0 | 0 | 400 | 480 |
| Amount left at the end of the survey (g): | 850 | 2800 | 36 | 289 | 0 | 0 |
| *Calculation procedure* | | | | | | |
| Food consumed (g/day)[a] | 2700 | 5200 | 84 | 211 | 1000 | 480 |
| Reference person intake (g/day)[b] | 266.3 | 512.9 | 8.3 | 20.8 | 98.6 | 47.3 |
| Individual intake for subject 1 (g/day)[c] | 210.9 | 406.2 | 6.6 | 16.5 | 78.1 | 37.5 |
| Adjusted individual intake for subject 1 (g/day)[d] | 204.9 | 394.7 | 6.4 | 16.0 | 75.9 | 36.4 |

[a] Sum of amount at the beginning of the survey and entering the household during the survey period minus amount left at the end of the survey.
[b] Food consumed divided by the total reference-person-days for the household obtained from Table 1 (10.14 in this example).
[c] Food consumed by the entire household multiplied by proportion of reference-person-days attributed to subject 1 (2.376/10.14 × 100 = 23.43% in this example) and averaged by person-days for subject 1 (3 days), e.g. potato intake by subject 1 = 2700 g × 23.43%/3 days = 210.9 g.
[d] Intake for subject 1 adjusted for body weight, i.e. by applying the ratio of the specific individual's body weight to the reference RDA body weight for women (51.5 kg/53 kg).

*Individual food weighing method*

In this method, actual food consumption of the individual subject was measured daily during the 3-day period of the household food survey to estimate food intakes for each individual as follows.

During the survey period, all foods eaten by each female subject were weighed directly and recorded by trained members of the county health team. In order to estimate individual food consumption more accurately, foods were divided into two groups: 'simple foods' and 'mixed dishes'. The amounts of the simple foods, like cheese, cake, bread and pickled vegetables, were weighed and recorded by differences in food weight before and after each meal, or weighed according to the portion size described by the subject to the investigators who visited their home after a particular meal ('image' food weighing) if interviews had not had a chance to weigh foods before that meal. In order to enhance accuracy in the estimation of

**Table 4.** Direct individual food weighing method: estimation of food intakes per individual (subject 1) from a mixed dish (pork-cabbage)

| | Cabbage | Salt | Plant oil | Pork |
|---|---|---|---|---|
| *Components of the mixed dish* | | | | |
| Food name | Cabbage | Salt | Plant oil | Pork |
| Amount used (g) | 600 | 12 | 18 | 120 |
| *Calculation procedure* | | | | |
| Total amount of the dish[a] | 16 (scoops) | | | |
| Amount consumed by subject 1[b] | 2 (scoops) | | | |
| Food intakes from the dish (g)[c] | 75.0 | 1.5 | 2.3 | 15.0 |

[a] The total volume of the ready-to-eat dish was measured quantitatively with a scoop as the measuring unit.
[b] The amount consumed by the subject was measured using the same scoop.
[c] Estimated by applying the proportion of the dish taken by the subject (12.5% = 2 scoops/16 scoops in this case) to the amount of the food in the prepared dish. Thus the intake of raw cabbage for subject 1 = 600 × 12.5% = 75.0 g.

individual intakes, team members first separated and weighed selected foods for each subject prior to the meal. After the meal, the remaining foods were weighed and recorded again to calculate the disappearance of foods during the meal. This strategy minimized the possible effects of the presence of the investigators on the food consumption patterns of the individual.

To estimate the components of more complex mixed dishes, all raw ingredients used in the dish were weighed before cooking to obtain the 'recipe' for that dish. After cooking, the whole ready-to-eat dish was measured quantitatively by either the team members or subjects themselves using a scoop or other small utensil as the measuring unit, which was subsequently used to measure the amount of the dish eaten by the subject at the meal. Intakes (for the subject) of each food item in the dish then were calculated proportionally.

An illustration of this estimation procedure is provided in Table 4 for a mixed dish (pork-cabbage) consumed by a female subject (subject 1). The entire cooked dish was measured as 16 scoops, of which two scoops were consumed by subject 1. Therefore, 12.5% of the total dish was consumed by the subject at that meal. The amounts of each food item in the dish consumed by the subject then were calculated proportionally.

*Bone mass measurement*

Bone mass was measured at both the distal and mid radius of the non-dominant arm using a single-photon absorptiometer (SPA) with $^{125}I$ source (Model 2780, Norland Co., Wisconsin). The results were recorded as bone mineral content (BMC, g/cm) and bone mineral density (BMD, g/cm$^2$, the ratio of BMC and bone width). At the beginning and end of each working day, SPA measurements of the radius were calibrated by using a standard bone phantom provided by the manufacturer.

*Statistical methods*

Average food intakes for each subject were calculated by dividing the total food intake by the total person-days, and daily nutrient intakes were estimated using the recently revised Chinese Food Composition Table (Institute of Nutrition and Food Hygiene, 1991). A total of 712 women had a complete set of data for both the individual and household food weighing methods. Only these subjects were used in the statistical analysis reported here.

Data were analysed with the Statistical Analysis System (SAS Institute Inc., Cary, NC) software package. Average daily nutrient intakes estimated by the two methods were compared to determine any significant differences. The statistical significance of differences in means of nutrient intakes were assessed by the paired $t$-test. The average values obtained on the basis of the two methods also were compared to assess the accuracy of the household method in terms of the absolute values obtained. Pearson product-moment coefficients were used to determine the association of the household method in estimating individual food intakes.

The feasibility of the modified household method in estimating individual food intakes was also examined to see whether the same degree of correlation with bone density would be obtained for both estimates of calcium. For this purpose, partial regression coefficients from a multivariate analysis of the effects of dietary calcium on bone density adjusting for age and body weight were estimated and compared. Similar correlation coefficients obtained from both methods would provide additional evidence to support estimation of individual intakes from the household food weighing method in large studies examining the relationship between nutrition and disease.

## Results

Table 5 presents the mean individual nutrient intakes estimated by the direct individual food weighing and the individual estimates from the household weighing method with and without adjusting for body weight. The unadjusted individual intakes estimated from the household food weighing method generally yielded higher values than those obtained from direct individual food weighing, except for vitamin C, which showed no statistically significant difference in values between the two methods. Percentage differences in nutrient intakes varied from 3.2% (vitamin C) to 28.9% (sodium) between the two methods. The estimate of vitamin $B_2$ was slightly lower in the household method than in the individual method (−5.7%).

However, almost identical nutrient intakes for individuals were obtained from the house-

**Table 5.** Average daily nutrient intakes and correlation coefficients ($r$) for three methods estimating individual nutrient intakes: direct individual food weighing versus individual estimates from household food weighing, unadjusted and adjusted for body weight[a]

| | | *Household (adjusted)* | | | *Household (unadjusted)* | | |
|---|---|---|---|---|---|---|---|
| | *Individual (direct)* | *Mean ± SD* | *Difference (%)* | $r^{a}$ | *Mean ± SD* | *Difference (%)* | $r^{a}$ |
| Macronutrients | | | | | | | |
| Energy (kJ) | 7778 ± 2845 | 7937 ± 3343 | 2.0 | 0.62 | 8393 ± 3389[b] | 7.9 | 0.69 |
| Protein (g) | 59.4 ± 23.4 | 59.2 ± 28.9 | –0.3 | 0.74 | 62.0 ± 26.6[b] | 4.4 | 0.78 |
| Fat (g) | 31.6 ± 20.4 | 34.4 ± 29.0[c] | 8.9 | 0.53 | 36.0 ± 32.4[b] | 13.9 | 0.46 |
| Carbohydrate (g) | 335 ± 153 | 338 ± 158 | 0.9 | 0.69 | 359 ± 165[b] | 7.2 | 0.77 |
| Fibre (g) | 12.2 ± 7.4 | 12.2 ± 8.5 | 0.0 | 0.69 | 12.9 ± 8.5[b] | 5.7 | 0.71 |
| Vitamins (mg) | | | | | | | |
| $B_1$ | 0.97 ± 0.45 | 1.06 ± 0.54[b] | 9.3 | 0.63 | 1.10 ± 0.49[b] | 13.4 | 0.69 |
| $B_2$ | 0.70 ± 0.36 | 0.63 ± 0.33[b] | –7.2 | 0.67 | 0.66 ± 0.31[b] | –5.7 | 0.69 |
| Niacin | 11.7 ± 5.2 | 12.1 ± 5.3[d] | 3.4 | 0.58 | 12.8 ± 5.2[b] | 9.4 | 0.65 |
| C | 83.2 ± 86.5 | 81.1 ± 83.8 | –2.5 | 0.75 | 85.9 ± 88.0 | 3.2 | 0.74 |
| A (μg) | 397 ± 594 | 430 ± 580 | 8.3 | 0.54 | 453 ± 588[c] | 14.1 | 0.46 |
| Minerals (mg) | | | | | | | |
| Calcium | 405 ± 271 | 409 ± 323 | 1.0 | 0.78 | 426 ± 309[c] | 5.2 | 0.80 |
| Phosphorous | 972 ± 355 | 985 ± 466 | 1.3 | 0.69 | 1030 ± 421[b] | 6.0 | 0.74 |
| Iron | 21.9 ± 8.3 | 23.3 ± 12.3[b] | 6.4 | 0.65 | 24.3 ± 11.2[b] | 11.0 | 0.68 |
| Magnesium | 281 ± 105 | 284 ± 126 | 1.1 | 0.67 | 298 ± 117[b] | 6.0 | 0.72 |
| Potassium | 1394 ± 540 | 1402 ± 641 | 0.6 | 0.67 | 1470 ± 593[b] | 5.5 | 0.71 |
| Sodium | 3426 ± 2059 | 4195 ± 2536[b] | 22.4 | 0.23 | 4417 ± 2543[b] | 28.9 | 0.24 |
| Zinc | 9.21 ± 3.63 | 9.10 ± 4.2 | –1.2 | 0.71 | 9.60 ± 4.05[b] | 4.2 | 0.77 |

[a] All correlation coefficients are significant at $P < 0.001$.
[b,c,d] Significant different from the direct individual food weighing: [b] $P < 0.001$, [c] $P < 0.01$, [d] $P < 0.05$.

hold method after adjusting for body weight in the estimation. There were no significant differences in means for most nutrients between the adjusted estimates and those from the direct individual weighing, suggesting that estimates of individual intakes based on the household food weighing method adjusted for body weight provided relatively valid estimates of nutrient intakes for individuals. Mean daily intakes of calcium were not significantly different between the household and individual methods (405 and 409 mg/d, respectively), whereas sodium intake was still much higher in the household method than in the individual method (22.4%). As compared with the unadjusted estimates, percentage differences of most nutrients decreased dramatically (0.000–9.3%), but the percentage difference for sodium remained high (22.4%).

The correlation coefficients between nutrient intakes determined by the individual and household food weighing also are listed in Table 5. For most nutrients, values estimated by the household method adjusting for body weight were highly correlated with the direct individual method ($r = 0.58$–$0.78$), particularly for energy, protein, and calcium. Estimates of fat and vitamin A from the household method were not as strongly correlated with the individual method ($r = 0.53$ and $0.54$, respectively), and values for dietary sodium showed the weakest association between methods ($r = 0.23$). Interestingly, estimates derived from the households weighing method standardized for body weight resulted in most nutrient values being closer to those estimated from the direct individual food weighing than the unadjusted estimates, but the correlation coefficients remained the same for nutrients from both estimation procedures (Table 5). The results suggest that adjusting for body weight only has an effect on the absolute values of dietary intakes estimated (i.e. increasing accuracy), and may not necessarily effect the overall trend of values for this sample of female subjects as seen in the similar correlations obtained.

**Table 6.** Partial regression coefficients of bone mineral content (BMC) and bone mineral density (BMD) in 712 Chinese women: comparison between calcium estimates from the individual, adjusted and unadjusted household methods[a,b]

| | *Dietary calcium (mg/d)* | | |
|---|---|---|---|
| | *Individual (direct)* | *Household (adjusted)* | *Household (unadjusted)* |
| Distal radius | | | |
| BMC (mg/cm) | 0.246 | 0.224 | 0.230 |
| BMD (mg/cm$^2$) | 0.068 | 0.062 | 0.064 |
| Mid radius | | | |
| BMC (mg/cm) | 0.146 | 0.126 | 0.127 |
| BMD (mg/cm$^2$) | 0.054 | 0.047 | 0.050 |

[a] All correlation coefficients are significant at $P < 0.0001$.
[b] The model included dietary calcium, age and body weight.

In addition to the above comparison of absolute values of nutrient intakes and correlation analysis of values obtained from the various methods considered here, dietary calcium intakes obtained from the household method also were evaluated by comparing associations with radial bone density in a linear regression model adjusting for the effects of age and body weight (Table 6). Similar partial regression coefficients were obtained between bone density and dietary calcium intakes derived from both methods, indicating that the modified household method provided a reliable estimation of trend in individual calcium intakes to assess the relationship between nutritional factors and biological outcomes. Similarly, in models adjusting for the effect of age and body, the unadjusted individual intakes from the household method also yielded very similar partial regression coefficients as the adjusted intakes (Table 6). However, in the univariate analysis, the correlation between calcium and bone density was slightly lower for the unadjusted than for the adjusted estimation of calcium intake (the differences in correlation coefficients were between 0.04 and 0.1 across the bone density measures included here, data not shown).

## Discussion

Random and systematic measurement errors in dietary data, particularly calcium intake, have often been implicated as one of the problems in assessing the effects of nutritional factors on bone mass. While some methods, like the 24-h dietary recall (Garn, Soloman & Friedl, 1981; Freudenheim, Johnson & Smith, 1986; Holbrook, Barret-Connor & Wingard, 1988) and food frequency (Sandler *et al.*, 1985; Picard *et al.*, 1988 van Beresteijn *et al.*, 1990), have been used to estimate calcium intakes in bone studies, directly weighing individual foods consumed over a period of time appears to be the best and most precise method for estimating calcium intakes of individuals. Not only is such a method practical in rural China because dietary practices are quite simple, but also the data are reasonably representative of long-term intake due to stable agricultural and food consumption patterns. However, this method is time-consuming and expensive, especially when the meal contains many food items and the sample size is large. Thus, an alternative method (modified household food weighing) was evaluated in this cross-sectional survey to obtain estimates of individual nutrient intakes for Chinese women aged 35–75 years. Using dietary intakes obtained by direct individual food weighing as the standard, the reliability of these estimates (both unadjusted and adjusted for body weight) was asssessed for survey subjects residing in different rural areas of China characterized by dramatically different dietary patterns.

### *Estimation of reference person intakes*

A procedure to estimate intakes per reference person within each household was utilized in two nationwide nutrition studies (Jin, 1986; Chen *et al.*, 1991) to avoid the potential pitfalls and errors associated with a crude calculation of dietary intakes per person, i.e. simply dividing the quantity of foods by the number of people in the household. In this approach, a conversion factor is used to standardize intakes for the household, not only by the number of household members but also on the basis of age, sex and physical activity of each household member. This household weighing method also provides additional advantages over other dietary estimation methods, such as more accurate estimation of dietary intakes, reduced bias resulting from interviewers and subjects, and less sensitive to education and literacy level of subjects.

However, a major limitation of the household method is that it does not directly provide food intakes for a specific person in the household, which then must be estimated indirectly in a variety of ways as in the case of a reference person (Jin, 1986; Chen *et al.*, 1991). The reference person adjustment, however, does not accurately reflect the intakes of women, the elderly and the very young, whose energy intakes and food selection patterns are often distinct. For example, the reference person intakes estimated from the results obtained for the female subjects in the present study were about 20–25% higher than those estimated by the direct individual weighing method (data not shown). Correlation of these reference person intakes with outcome variables measured at the individual level, such as bone density, are clearly more error-prone due to differences in dietary intakes between individuals and the hypothetical 'reference person'.

*Estimation of intakes by modified household method*

In this communication, a modification of the household method was developed and assessed in comparison to individual intakes obtained by directly weighing the foods consumed by each individual subject for 712 middle-aged and elderly women in rural China. The results of the analysis demonstrate the feasibility and reliability of assessing individual food intakes by a simple modification of the previously used procedures in the household food weighing method discussed above. Nutrient intakes adjusting for body weight were very similar to the values obtained from direct weighing of individual foods (Table 5). Calcium intakes estimated by the two methods were significantly correlated ($r=0.78$, $P<0.001$). There were no significant differences in average calcium intakes obtained from the two sets of data, although the variability was marginally greater in the household method ($405 \pm 271$ and $409 \pm 323$ mg/d for the individual and household food weighing methods, respectively). The modified household method also was validated in terms of the relationship between dietary intakes and biological outcome on the basis of results of multiple linear regression analysis of radial bone density and dietary calcium intakes in the pre- and postmenopausal female subjects (Table 6). The household method yielded almost identical partial regression coefficients as compared with the individual method, underscoring the utility of the method for estimating individual intakes (Table 6). This consistency also was observed when data were analyzed within each of the five counties of residence (data not shown), suggesting that the dramatically different diets in these areas did not affect the generally high degree of correspondence between intakes obtained by these two methods.

*Body weight adjustment*

Conversion factors, used to proportionately allocate total household consumption to individuals within the household, were derived as proportional ratios of the energy intakes recommended for the specific age, sex and physical activity levels of the individual to the reference person of a 63 kg adult male as shown in Table 2. This reference person intake can only be assumed to be roughly equivalent to an individual intake if the average body size in the household is the same as that of the reference person. However, if the body weight of the individual differs from the body weight of the respective reference group, then the conversion factor may not be an appropriate ratio for estimating individual food consumption. Thus, the household method must be refined further to take individual body weights into account. One method for doing this is to assume that energy intake is roughly proportional to body weight, or some derivative thereof. For the purpose of the analyses presented here, a simple linear relationship was assumed.

Individual nutrient intakes estimated by the household food weighing method (unadjusted) were somewhat higher than those obtained from the direct weighting method as seen in the Table 5. The discrepancy could be due to differences in body weight, which were not taken into account in the unadjusted estimation procedure used in the household weighing method. The average body weight of subjects selected in the present study was $50.3 \pm 9.0$ kg, which was much lower than the reference person body weights used in the Chinese RDA tables (53 kg for women). Thus, the actual energy requirements for subjects in this survey may be slightly lower than those recommended. Consequently, the nutrient intakes derived from the household survey using the RDAs as the basis to allocate food intakes will be overestimated. Indeed, adjusting these values for body weight yields virtually identical values of most nutrients for both methods (Table 5). Comparison of partial regression coefficients between unadjusted and adjusted estimates of calcium (Table 6) is also informative. When body weight was included as a covariate in the regression analysis, no apparent differences in the partial regression coefficients using the unadjusted and adjusted individual calcium intakes were observed. However, in the univariate correlation analysis, the unadjusted calcium intakes yielded a lower correlation coefficient with bone density than the adjusted calcium intakes (data not shown). Again, the lower partial repression coefficients in the univariate analysis may be accounted for, at least partially, by differences in body weight between the female subjects and the reference person.

The results obtained in this study also suggests that body weight should be taken into account under any circumstance, even in the estimation of intakes per reference person (Jin, 1986; Chen *et al.*, 1991). For example, mean body weights estimated in a survey sample of Chinese adults in 65 rural counties (Chen *et al.*, 1991) were 54.9 kg for males and 48.7 kg for females, which were much lower than the reference body weights used in the Chinese RDA (63 kg for males and 53 kg for females). These differences are quite substantial, thus suggesting that in ecological studies comparing areas where body weights are significantly different, more precise intake data would be obtained by adjusting for body weight. As a matter of fact, there is a significant gradient in adult weights in China, with larger individuals predominating in north China and smaller individuals in the south (Chen *et al.*, 1991). It should be emphasized that significantly improved individual estimates may be obtained if body weight is used in the calculation of conversion factors for each member of the household in addition to age, sex and physical activity to calculate conversion factors for each member of the household. Alternatively, in addition to the specific person interested, body weight of other members of the household may also be standardized to yield individual intakes. However, data of body weight for other members of the household are not available for inclusion in this communication.

*Estimates of sodium intake*

Another finding that warrants further comment and discussion is the relatively weak and insignificant correlation between the two methods for dietary sodium intakes (Table 5). There are two possible explanations for this discrepancy. First, some pickled vegetables, spices and salted sea foods consumed in these survey areas contain very high concentrations of sodium, up to 9686 mg/100 g food for pickled cucumber, 7700 mg/100 g in soy sauce and 8992 mg/100 g in pork bacon (Institute of Nutrition and Food Hygiene, 1991). Consequently, a small difference in the intakes of these foods will contribute to a large variation in the estimated sodium intakes. Second, there is a possibility that investigators may have overlooked how the salt, which disappeared over the 3-day survey period, was actually used, i.e. it may not have been consumed by the household. In these survey counties, salt is used in large quantities to preserve vegetables, meat and other kinds of foods for future consumption. As a result, sodium intakes may be overestimated in the household method. However, the possible errors inherent in the second scenario were overcome easily when investigators were alerted to estimate the amount of salt used in the preservation process (and not consumed) and subtract them from the final consumption estimate.

## Conclusion

In summary, the results obtained from this cross-sectional study indicate that the modified household method is as reliable as the direct individual food weighing method in estimating food intakes per individual. In the context of the study on osteoporosis, calcium intakes obtained from both data sources were very close in average values and were correlated significantly with radial bone density to the same degree. Thus, this modified household method may be useful for assessing individual food intake in large nutritional studies in developing countries. However, in this modified household method, food intakes were derived from the proportional allocation of total foods consumed by age, sex and physical activity. Other factors, such as body weight and individual preference of specific foods, also may be related to energy partitioning and should be considered in this approach.

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