Consumption of Bone Mineral Density-Associated Nutrients, and Their Food Sources in Pre-school Japanese Children

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Abstract

In order to fortify bone mineral density (BMD), and to prevent osteoporosis in the future, we investigated consumption of BMD-associated nutrients, and their food sources of pre-school Japanese children. Intakes of minerals (calcium, magnesium, and phosphorus) and vitamins (vitamin D, vitamin K, and vitamin C) were studied based on two weekdays dietary record surveys together with photos taken by 84 parents/caregivers of 5-year-old children. Food sources of relevant nutrients were identified according to contribution analyses, and potential associations of consumption of food sources with selected nutrients were investigated. We further conducted a multiple regression analysis to clarify food groups providing calcium. Calcium consumption of approximately 40% of the subjects manifested an inadequacy, but intakes of other nutrients met the criteria of Dietary Reference Intakes (DRIs). Major food sources of calcium were milk and dairy products, green and yellow vegetables, soybeans, and other vegetables, and 50% of calcium was supplied by milk and dairy products. Other nutrients were provided by various food food items, including milk and dairy products, vegetables, soybeans, fruit, fish and shellfish, meat, eggs, potatoes, and algae. A multiple regression analysis also detected that milk and dairy products were top contributors of calcium intake. Because there was an obvious inadequate intake of calcium in Japanese children, they are advised to enhance consumption of calcium from milk and dairy products and BMD-related minerals and vitamins from green and yellow vegetables, and other vegetables at home. Pertinent nutrition education should be given to parents/caregivers for promotion of bone health.

Keywords: Bone mineral density; Food/food item; Japanese children; Mineral; Vitamin

Abbreviations: AI: Adequate intake; BMD: Bone mineral density; DRIs: Dietary reference intakes; EAR: Estimated average requirement; KNU: Kagawa Nutrition University; QOL: Quality of life; RDA: Recommended dietary allowance; STFC: Standard Tables of Food Composition

Introduction

In Japan, due to the growth of the elderly population, the number of osteoporosis patients has increased annually. Its prevalence was estimated to be 1.28 million (aged 40 years or over) as of 2005 [1]. Osteoporosis brings about health-care problems and social issues because it not only bone fracture, bedridden confinement, reduction of activities of daily living, shortening of life/healthy life expectancy, and degrading quality of life (QOL), but also an increase in medical/health-care expenditures.

Since the mid-90s, it has been well established that it is important to achieve as high bone mineral density (BMD) as possible prior to late adolescence when the peak BMD is attained [2-4]. Calcium and other BMD-associated nutrients are critical for fortifying BMD and for bone health [5-7], and it seems prerequisite to increase consumption of calcium-rich and other various food items, and weight-loaded physical exercise from childhood to adolescence [4-8].

Our lifestyle diet, sleep, defecation, tidiness, dressing etc. are developed and stabilized during childhood, and do not change much later in life [9-11]. Pre-school dietary preferences are important, but there are few relevant Japanese studies.

We studied Japanese children’s intake of BMD-associated minerals (Ca, Mg and P), vitamins D, K and C and food sources at home attending nurseries to establish a baseline for preventing later osteoporosis development, curricular changes, catering guide-lines and parental advice.

Materials and Methods

Subjects

We invited the Department of Health and Welfare, N City, Aichi Prefecture and guardians of 5-year-olds attending 7 nurseries to study their two weekday dietary surveys, and received data for 84 (34/50 boys/girls) of the 98 participants.

Dietary record surveys

Two weekday dietary records and pre- and post-meal photos were taken during the 1st fortnight in June 2011, including menus and portion sizes for all meals at home. We issued a 3 x 3 cm gridded mat, a 12 cm diameter bowl, and a photo manual, requesting pictures of all food at 45°. Two trained dieticians (SH, RS) estimated the constituents accordingly. School caterers provided menus; it was assumed that everything was consumed.

Classification/categorization of food/food groups

Using the Standard Tables of Food Composition in Japan 2010 (STFC-J 2010) [12], we classified rice, bread, noodles and other cereals, Japanese and Western confectioneries, soy and other beans, green, yellow and other vegetables into 24 groups. Food consumption was assessed using the Kagawa Nutrition University Diet (KNU-Diet) food
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Table 2: Daily consumption of food/food items according to the classification adopted in the present study (n=84).

| Classification in the STFC-J2010* (18 groups) | Categorization adopted in the present study (24 groups) | KNU-Dietb food consumption | Total intakec Mean | Total intakec SD | Intake at home Mean | Intake at home SD | Proportion consumed at home (%)d |
|----------------------------------------------|--------------------------------------------------------|----------------------------|--------------------|------------------|---------------------|------------------|---------------------------------|
| Cereals                                      | #1 Rice #2 Breads #3 Noodles #4 Other cereals           |                            | 350                | 220.3 (60.2)     | 127.3 (49.4)       | 57.8             | 80.1, 44.3, 27.4                |
| Potatoes and starches                        | #5 Potatoes and starches                                |                            | 60                 | 41.3 (27.4)      | 18.6 (17.4)        | 45.1             |                                 |
| Sugars and sweeteners                        | #6 Sugars and sweeteners                                |                            | 5                  | 5.8 (3.3)        | 2.6 (2.4)          | 44.9             |                                 |
| Pulses                                       | #7 Soybeans #8 Other beans                              |                            | 60                 | 28.7 (20.0)      | 16.5 (16.6)        | 57.6             | 5.7                             |
| Nuts and seeds                               | #9 Nuts and seeds                                       |                            | 0.6                | 0.6 (0.9)        | 0.4 (0.9)          | 66.0             |                                 |
| Vegetables                                   | #10 Green and yellow vegetables #11 Other vegetables     |                            | 80                 | 76.0 (31.9)      | 58.0 (30.8)        | 76.4             | 53.0                            |
| Fruit                                        | #12 Fruit                                               |                            | 150                | 96.7 (49.8)      | 57.1 (43.6)        | 59.0             |                                 |
| Mushrooms                                    | #13 Mushrooms                                           |                            | 5.8                | 5.8 (6.0)        | 4.1 (5.8)          | 71.4             |                                 |
| Algae                                        | #14 Algae                                               |                            | 8.6                | 8.6 (7.5)        | 4.9 (7.0)          | 56.6             |                                 |
| Fish and shellfish                           | #15 Fish and shellfish                                   |                            | 24.9               | 24.9 (17.8)      | 19.7 (16.9)        | 79.1             |                                 |
| Meat                                         | #16 Meat                                                |                            | 60                 | 55.0 (20.5)      | 36.2 (19.2)        | 65.8             |                                 |
| Eggs                                         | #17 Eggs                                                |                            | 30                 | 27.3 (19.5)      | 24.4 (19.6)        | 89.3             |                                 |
| Milk and dairy products                      | #18 Milk and dairy products                             |                            | 250                | 219.6 (89.6)     | 116.9 (84.3)       | 53.2             |                                 |
| Fats and oils                                | #19 Fats and oils                                       |                            | 10                 | 6.9 (2.8)        | 3.6 (2.5)          | 52.3             |                                 |
| Confectioneries                              | #20 Japanese confectioneries                            |                            | 4.1                | 4.1 (7.5)        | 2.7 (7.0)          | 66.0             |                                 |
| Beverages                                    | #22 Beverages                                           |                            | 294.3              | 294.3 (112.8)    | 114.3 (112.8)      | 38.8             |                                 |
| Seasonings and spices                        | #23 Seasonings and spices                               |                            | 87.3              | 87.3 (72.3)      | 78.7 (71.6)        | 90.2             |                                 |
| Prepared foods                               | #24 Prepared foods                                      |                            | 2.3                | 2.3 (4.9)        | 1.2 (4.6)          | 50.1             |                                 |

*Standard Tables of Food Composition in Japan 2010
*Kagawa Nutrition University Diet
*Intake at home + intake at nurseries
*(Intake at home/Total intake) × 100
*Weight of dried food/food items eaten after cooking was measured after soaking them in water

Table 3: Daily consumption of energy, three major nutrients, and BMD-related nutrients (n=84).

| DRIs-J 2015* | Total intakeb Mean | Intake at home Mean/Median | Proportion of intake at home (%) | Proportion of inadequacy in reference to DRIs-J 2015 (%) |
|--------------|--------------------|---------------------------|---------------------------------|-------------------------------------------------------|
| (Boys, Girls)|--------------------|---------------------------|---------------------------------|-------------------------------------------------------|
| Energy (kcal)| (1,300, 1,250)     | 1,348 (151)               | 812 (146)                       | 60.3                                                  |
| Protein (g)  | (20, 20)           | 49.8 (6.4)                | 31.2 (6.3)                      | 62.6                                                  | 0*          |
| Fat (g)      | NA                 | 40.5 (7.7)                | 25.6 (7.1)                      | 63.2                                                  |
| Carbohydrate (g)| NA               | 189.9 (24.1)              | 112.7 (21.4)                    | 59.3                                                  |
| Calcium (mg) | (500, 450)         | 516 (118)                 | 278 (120)                       | 53.9                                                  | 42.9*       |
| Magnesium (mg)| (80, 80)          | 182 (30)                  | 110 (28)                        | 60.5                                                  | 0*          |
| Phosphorus (mg)| (800, 600)      | 757 [670, 845]            | 477 [425, 562]                 | 65.5                                                  | low risk    |
| Vitamin D (µg)| (2.5, 2.0)        | 2.7 [1.8, 4.3]            | 1.9 [1.1, 3.4]                 | 78.0                                                  | low risk    |
| Vitamin K (µg)| (70, 70)          | 136 [99,167]              | 85 [57,129]                     | 71.8                                                  | low risk    |
| Vitamin C (mg)| (35, 35)          | 89 (27)                   | 54 (24)                         | 60.5                                                  | 0*          |

* Dietary Reference Intakes for Japanese 2015.
* Intake at home + intake at nurseries.
* Estimated Average Requirement (EAR).
* Proportion of children having nutrient consumption below EAR.
* Not available.
* Adequate Intake (AI).
* Median [25th percentile, 75th percentile].
Because the weighted average intake exceeded AI, the risk was judged as low.
### Food/food groups

| Calcium        | Magnesium      | Phosphorus     | Vitamin D    | Vitamin K    | Vitamin C   |
|----------------|----------------|----------------|--------------|--------------|-------------|
| % contribution | % Cumulative   | Frequency/day  | Portion size (g) | % contribution | % Cumulative | Frequency/day  | Portion size (g) | % contribution | % Cumulative | Frequency/day  | Portion size (g) | % contribution | % Cumulative | Frequency/day  | Portion size (g) |
| Milk and dairy products | 1 | 50.0 | 50.0 | 1.6 | 78 |
| Green and yellow vegetables | 2 | 7.0 | 57.0 | 3.7 | 11 |
| Soy beans | 3 | 5.7 | 62.8 | 0.9 | 12 |
| Other vegetables | 4 | 5.7 | 68.5 | 4.1 | 10 |
| Western confectioneries | 5 | 5.4 | 73.9 | 0.7 | 30 |
| Milk and dairy products | 1 | 12.3 | 12.3 | 1.6 | 78 |
| Green and yellow vegetables | 2 | 10.0 | 22.3 | 3.7 | 11 |
| Seasonings and spices | 3 | 9.8 | 32.1 | 8.4 | 2 |
| Other vegetables | 4 | 9.1 | 41.2 | 4.1 | 10 |
| Rice | 5 | 8.8 | 50.1 | 1.3 | 99 |
| Milk and dairy products | 1 | 24.2 | 24.2 | 1.6 | 78 |
| Green and yellow vegetables | 2 | 13.5 | 37.8 | 1.7 | 18 |
| Rice | 3 | 9.1 | 46.9 | 1.3 | 99 |
| Fish and shellfish | 4 | 9.1 | 56.0 | 1.1 | 11 |
| Eggs | 5 | 8.4 | 64.4 | 1.0 | 20 |
| Fish and shellfish | 1 | 69.3 | 69.3 | 1.1 | 11 |
| Eggs | 2 | 14.5 | 83.8 | 1.0 | 20 |
| Milk and dairy products | 3 | 7.4 | 91.2 | 1.6 | 78 |
| Meat | 4 | 3.3 | 94.5 | 1.7 | 18 |
| Mushrooms | 5 | 3.2 | 97.6 | 0.6 | 5 |
| Green and yellow vegetables | 1 | 40.5 | 40.5 | 3.7 | 11 |
| Soy beans | 2 | 23.0 | 63.5 | 0.9 | 12 |
| Other vegetables | 3 | 12.1 | 75.6 | 4.1 | 10 |
| Algae | 4 | 5.7 | 81.3 | 0.8 | 1 |
| Meat | 5 | 5.0 | 86.3 | 1.7 | 18 |
| Fruit | 1 | 34.3 | 34.3 | 1.4 | 31 |
| Green and yellow vegetables | 2 | 33.0 | 67.3 | 3.7 | 11 |
| Other vegetables | 3 | 14.1 | 81.4 | 4.1 | 10 |
| Potatoes | 4 | 9.6 | 91.0 | 0.9 | 16 |
| Meat | 5 | 5.1 | 96.1 | 1.7 | 18 |

### Intake of BMD-related-nutrients

| Calcium | Magnesium | Phosphorus | Vitamin D | Vitamin K | Vitamin C |
|---------|-----------|------------|-----------|-----------|-----------|
| Rice | 0.057 | 0.268 | 0.168 | -0.096 | 0.298 | -0.117 |
| Breads | 0.051 | -0.069 | -0.030 | -0.050 | -0.276 | 0.177 |
| Potatoes | 0.026 | 0.067 | 0.085 | -0.084 | -0.012 | 0.263 |
| Soybeans | 0.279 | 0.397 | 0.310 | -0.152 | 0.376 | -0.050 |
| Nuts and seeds | 0.205 | 0.315 | 0.258 | -0.096 | -0.015 | 0.053 |
| Green and yellow vegetables | 0.192 | 0.345 | 0.242 | 0.028 | 0.403 | 0.318 |
| Other vegetables | -0.023 | 0.390 | 0.168 | -0.100 | 0.092 | 0.333 |
| Fruit | 0.008 | 0.170 | 0.045 | -0.071 | -0.172 | 0.480 |
| Algae | 0.221 | 0.247 | 0.154 | 0.091 | 0.061 | 0.032 |

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**Table 4:** Percent contribution and percent cumulative contribution of food/food groups consumed at home for BMD-related nutrients (n=84).

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**Note:**

- **% contribution** = (Amount of a nutrient provided by each food/food item/day ÷ total amount of the nutrient provided by all food/food items/day) × 100
- **% Cumulative contribution** = Sum of % contributions
taken by 84 guardians of 5-year-old pre-school Japanese children. >40% manifested inadequate Ca consumption, but intakes of Mg and P, vitamins D, K and C were satisfactory. Contribution analyses demonstrated milk and dairy products, green and yellow vegetables, and soybeans were major sources for Ca. >50% Ca was supplied by milk and dairy products. Various foods, including milk and dairy products, vegetables, soybeans, fruit, and fish and shellfish provided other minerals and vitamins. A multiple regression analysis also detected that milk and dairy products mainly contributed Ca. The present study appears to show inadequate Ca consumption compared with the DRIs-J 2015 values, but not for other BMD-related nutrients.

Strategies and education to increase Ca intake seem essential. Kubota et al. [20] reviewing articles of meta-analyses, intervention and cohort studies recruiting children and adolescents [17] suggested dietary Ca of 900 mg/day was required for fortifying BMD and bone health. For American children (both sexes) aged 4-8 years, RDA value was set at 1,000 mg/day [18] and Population Reference Intake (RDA equivalent) at 800 mg for European children aged 4-10 years [19]. These values exceeded Japanese RDA figures (600/550 mg for boys/girls), indicating greater disparities even when differences in anthropometric values exceeded Japanese RDA figures (600/550 mg for boys/girls), indicating greater disparities even when differences in anthropometric sizes are taken into account. These reports suggest it may be necessary to review Japanese Ca DRI values.

~50% of Ca was provided by milk and dairy products, fish and shellfish provided ~ 69% and eggs ~ 15% vitamin D, various vegetables (green and yellow vegetables, and soybeans) ~ 76% vitamin K, and fruit and vegetables ~ 81% vitamin C. A variety of foods including milk and dairy products, green, yellow and other vegetables, rice, seasonings and spices contributed Mg. Food/food items such as milk and dairy products, meat, rice, fish and shellfish and eggs determined P intake. Our observations are compatible with those of Imai et al. who recruited elementary 5th and 6th graders, university students, and elderly people [20], noting that milk and dairy products and vegetables provided Ca, and many foods supplied Mg and P for fortifying BMD. It may be recommended that one should consume various foods, primarily milk and dairy products, vegetables, soybeans, fish and shellfish, eggs, and meat.

Keast et al. [21], using NHANES 2003-2006 data, reported American children aged 2-18 years consumed on average 1,101 mg/day of Ca from milk and dairy products (61%), yeast breads and rolls (6%), biscuits, corn bread, pancakes and tortillas (3%), fruit juice (3%) and mixtures, mostly grain (3%). Studies conducted in 10 European countries [22] demonstrated mean adult Ca intakes ranged from 620 mg/day (in women, Ragusa in Italy) to 1,190 mg (in men, Greece). Main sources were dairy products (33-62%), cereals and products (5-37%), and beverages, non-alcoholic (2-34%). The European Food Safety Authority recommended consuming milk and milk products, dark green vegetables, small canned fish with bone, and dried pulses as Ca sources [23]. Despite differences in culture and dietary habits across countries, milk and dairy products are major Ca sources, and consumption was greater than in Japan. All these findings seem to support childhood milk and dairy consumption.

Many articles suggested the importance of food/food items other than milk and dairy products for enhancing BMD. Subjects in early puberty demonstrated relations between fruit and vegetable consumption and bone formation [24-26] studies investigating associations between dietary patterns and BMD observed that adult Japanese women eating more fruit and vegetables, mushrooms, fish and shellfish manifested significantly higher BMD values than those consuming meat, fat and oil [27].

For enhancing BMD and bone health, vegetables, milk and dairy products seem of the essence; the % contribution of green, yellow and other vegetables, and soybeans to Ca were unexpectedly less than KNU-Diet values [13,14]. In the present study, frequencies of green and yellow vegetables were low: mini-tomatoes 0.5 times/day, tomatoes 0.4/day, spinach 0.2/day, leek 0.1/day and komatsuna (cruciferous vegetable) 0.1/day; median green and yellow vegetable portion size was only 11 g. For soybeans, frequency and portion size were 0.9/day and 12 g, those for other vegetables were 4.1/day and 10 g. Elevated frequency and increased portion size for vegetable intake are recommended to increase Ca and other BDM-related nutrient intake. Introducing ways to serve more palatable vegetable foods seems crucial, children often dislike eating vegetables.

In a meta-analysis of randomized controlled trials of Ca supplementation for children, Winzenberg et al. [28] concluded that the effect of Ca supplementation on upper limb BMD was small, it is unlikely to reduce the risk of fracture, either in childhood or later life. It is important to increase Ca intake from food because it may be safe. However, we should not ignore the adverse effects of excessive Ca intake from fortified supplements/medicines. They include such high-Ca intake syndromes as hypercalcaemia, urinary tract stones and vascular calcification.

Table 5: Pearson correlation coefficients across consumption of 14 food/groups at home and intake of BMD-related nutrients (n=84).

| Table 6: Multiple regression analysis assuming consumption of calcium as a dependent parameter and intake of food/groups as independent variables (n=84). |
|----------------|----------------|----------------|----------------|----------------|
| Crude coefficient | Standard error | Standard coefficient | Significance level |
| β               |             | t-value          |                  |
| Constant        | 169.753     | 40.789           | 4.162            | 0.000          |
| Milk and dairy products | 0.949 | 0.080 | 0.765 | 11.818 | 0.000 |
| Green and yellow vegetables | 0.886 | 0.234 | 0.249 | 3.705 | 0.000 |
| Soybeans        | 1.070       | 0.361            | 0.192            | 2.965          | 0.004 |
| Western confectioneries | 0.462 | 0.245 | 0.127 | 1.887 | 0.063 |
| Algae           | 1.355       | 0.955            | 0.092            | 1.419          | 0.160 |
| Other vegetables | 0.131      | 0.230            | 0.036            | 0.569          | 0.571 |

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The limitations of the present study include: first, our surveys were based on dietary records with portion size (albeit confirmed by photos) but no weighing, introducing some uncertainty in estimating intakes of foods and BMD-related nutrients. The two weekday surveys were inadequate to analyze food/food items consumed or enable in-depth discussion. Analyses of variations in weekend diets and seasonal variations could not be made; the number of study subjects may be insufficient and we only obtained data for 5-year-olds attending municipal nurseries. There is nutritional guidance for food services, but no apparent difference in dietary consumption of relevant nutrients across institutions/facilities. The observations could be applied to Japanese children residing elsewhere.

In conclusion, our two weekday dietary record surveys demonstrated that ~ 40% of subjects had inadequate Ca consumption, but intake of other BMD-related minerals and vitamins was satisfactory in 5-year-old pre-school Japanese children. Contribution and multiple regression analyses noted that milk and dairy products were the main food sources for Ca. A variety of food/food items provided other BMD-associated nutrients. We advise increasing consumption of a variety of food/food items, including milk and dairy products at home, for Ca and BMD-related nutrients for fortifying BMD and bone health.

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Conflict of Interest

The authors declare no conflict of interests.

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