lung and serum decreased in the S6 rats. The differences in the pattern of vitamin B_6 decline may be due to the fat content of each tissue. Nicotinamide concentrations in tissues and blood were unchanged by starvation, despite this vitamin being involved in energy metabolism. Since nicotinamide is biosynthesised from tryptophan[43], nicotinamide concentrations in organs and blood were maintained. Urinary excretion of the sum of nicotinamide and its catabolites was high after 1 d of starvation and subsequently decreased. These results are in agreement with those reported by a previous study[30]. The proportion of nicotinamide, MNA, 2-Py and 4-Py in urine is controlled by enzymes involved in the metabolism of tryptophan to niacin. Starvation or food restriction induces a decline in MNA oxidase activity[44] and an elevation in nicotinamide methyltransferase[44]. This may explain why levels of 2-Py and 4-Py in urine decreased while those of MNA increased. MNA is an inhibitor of nicotinamide methyltransferase[45]. Therefore, an accumulation of MNA inhibits the activity of nicotinamide methyltransferase and leads to an increase in free form of nicotinamide, which inhibits the activities of histone deacetylase[46] and poly(ADP-ribose) synthetase[47]. This control might be suitable for living long during starvation.

To our knowledge, the present study presents the first data on vitamin status during the three phases of starvation. The changes in B-group vitamin concentrations in tissues and blood did not always correspond to metabolic states. The changes in vitamin content can be divided into three groups. First, vitamin B_1, vitamin B_2, nicotinamide and biotin levels declined gradually. Second, vitamin B_6 and vitamin B_{12} levels rapidly decreased after 1 d of starvation and then remained at a steady level. Finally, pantothenic acid and folate initially decreased in the S1 rats, then returned to near basal levels in the next day of starvation, then subsequently decreased again. This might mean that pantothenic acid and folate were mobilised to other tissues. We are unsure why such complicated changes occur. It is clear that further investigation, such as separate measurement of the free forms of the vitamins and of coenzymes, into the changes in the vitamin requirements of starving rats would be useful for the prevention of vitamin deficiency during starvation or for consequent refeeding.

Acknowledgements

The present study was supported by a Research Grant for Comprehensive Research on Cardiovascular and Lifestyle Related Diseases from the Ministry of Health, Labour and Welfare of Japan. The title of the project was 'Studies on Construction of Evidence to revise the Dietary Reference Intakes for Japanese – Elucidation of balance between macronutrient and micronutrient' (Principal Investigator, K. S.). A. M. and T. F. were responsible for designing the study strategies, retrieving the references and writing the manuscript. M. S. participated in retrieving references and critical reading. K. S. directed and designed the study. The authors have no conflict of interests to report.

References

1. Robin J-P, Decrock F, Herzberg G, *et al.* (2008) Restoration of body energy reserves during refeeding in rats is dependent on both the intensity of energy restriction and the metabolic status at the onset of starvation. *J Nutr* **138**, 861–866.
2. Li R-Y, Zhang Q-H, Liu Z, *et al.* (2006) Effect of short-term and long-term fasting on transcriptional regulation of metabolic genes in rat tissues. *Biochem Biophys Res Commun* **344**, 562–570.
3. Cherel Y, Robin JP & Maho LY (1988) Physiology and biochemistry of long-term fasting in birds. *Can J Zool* **66**, 159–166.
4. Koubi HE, Robin JP, Gewasmes G, *et al.* (1991) Fasting-induced rise in locomotor activity in rats coincides with increased protein utilization. *Physiol Behav* **50**, 337–343.
5. Goodman MN, Larsen PR, Kaplan MN, *et al.* (1980) Starvation in the rat. II. Effect of age and obesity on protein sparing and fuel metabolism. *Am J Physiol* **239**, E277–E286.
6. Le Maho Y, Vu Van Kha H, Koubi H, *et al.* (1981) Body composition, energy expenditure, and plasma metabolites in long-term fasting geese. *Am J Physiol* **41**, E342–E354.
7. Cherel Y & Le Maho Y (1985) Five months of fasting in king penguin chicks, body mass loss and fuel metabolism. *Am J Physiol* **249**, R387–R392.
8. Le Maho Y, Vu Van Kha H, Koubi H, *et al.* (1976) Thermoregulation in fasting emperor penguins under natural conditions. *Am J Physiol* **231**, 913–922.
9. Robin J-P, Cherel Y, Girard H, *et al.* (1987) Uric acid and urea in relation to protein catabolism in long-term fasting geese. *J Comp Physiol B* **157**, 491–499.
10. Le Maho Y, Vu Van Kha H, Koubi H, *et al.* (1981) Body composition, energy expenditure, and plasma metabolites in long-term fasting geese. *Am J Physiol* **241**, E342–E354.
11. Kraft MD, Btaiche IF & Sacks GS (2005) Review of the refeeding syndrome. *Nutr Clin Pract* **20**, 625–633.
12. Dietary Reference Intakes for Japanese (2010) *Dietary Reference Intakes for Japanese*. Tokyo: Ministry of Health, Labour, and Welfare, Japan; 2009.
13. Reeves PG, Nielsen FH & Fahey GC Jr (1993) AIN-93 purified diets for laboratory rodents: final report of the American Institute of Nutrition *ad hoc* writing committee on the reformulation of AIN-76A rodent diet. *J Nutr* **123**, 1939–1951.
14. Habold C, Chevalier C, Dunel-Erb S, *et al.* (2004) Effects of fasting and refeeding on jejuna morphology and cellular activity in rats in relation to depletion of body stores. *Scand J Gastroenterol* **39**, 531–539.
15. Fukuwatari T, Suzuura C, Sasaki R, *et al.* (2004) Action site of bisphenol A as metabolic disruptor lies in the tryptophan–nicotinamide conversion pathway. *J Food Hyg Soc Japan* **45**, 231–238.
16. Ohkawa H, Ohishi N & Yagi K (1983) New metabolites of riboflavin appear in human urine. *J Biol Chem* **258**, 5623–5628.
17. Ohakawa H, Ohishi N & Yagi K (1982) A simple method for micro-determination of flavin in human serum and whole blood by high-performance liquid chromatography. *Biochem Int* **4**, 187–194.
18. Gregory JF 3rd & Kirk JR (1979) Determination of urinary 4-pyridoxic acid using high performance liquid chromatography. *Am J Clin Nutr* **32**, 879–883.
19. Rybak ME & Pfeiffer CM (2004) Clinical analysis of vitamin B_6: determination of pyridoxal 5′-phosphate and 4-pyridoxic acid in human serum by reversed-phase high-performance liquid chromatography with chlorite postcolumn derivatization. *Anal Biochem* **333**, 336–344.

20. Association of Official Analytical Chemists (2000) *Official Methods of Analysis*, 17th ed. Arlington, VA: AOAC, Inc.
21. Watanabe F, Katsura H, Takenaka S, *et al.* (1999) Pseudovitamin B_{12} is the predominant cobamide of an algal health food, spirulina tablets. *J Agric Food Chem* **47**, 4736–4741.
22. Shibata K, Kawada T & Iwai K (1988) Simultaneous microdetermination of nicotinamide and its major metabolites, N^1-methyl-2-pyridone-5-carboxamide and N^1-methyl-3-pyridone-4-carboxamide, by high-performance liquid chromatography. *J Chromatogr* **424**, 23–28.
23. Shibata K (1987) Ultramicro-determination of N^1-methylnicotinamide in urine by high-performance liquid chromatography. *Vitamins (Japan)* **61**, 599–604.
24. Shibata K (1987) High-performance liquid chromatographic determination of nicotinamide in rat tissue samples and blood after extraction with diethyl ether. *J Chromatogr* **422**, 257–262.
25. Takahashi K, Fukuwatari T & Shibata K (2009) Fluorometric determination of pantothenic acid in human urine by isocratic reversed-phase ion-pair high-performance liquid chromatography with post-column derivatization. *J Chromatogr B* **877**, 2168–2172.
26. Skeggs HR & Wright LD (1944) The use of *Lactobacillus arabinosus* in the microbiological determination of pantothenic acid. *J Biol Chem* **156**, 21–26.
27. Aiso K & Tamura T (1998) Trienzyme treatment for food folate analysis. Optimal pH and incubation time for α-amylase and protease treatment. *J Nutr Sci Vitaminol* **44**, 361–370.
28. Fukui T, Iinuma K, Oizumi J, *et al.* (1994) Agar plate method using *Lactobacillus plantarum* for biotin determination in serum and urine. *J Nutr Sci Vitaminol* **40**, 491–498.
29. Cherel Y, Burnol A-F, Leturque A, *et al.* (1988) *In vivo* glucose utilization in rat tissues during the three phases of starvation. *Metabolism* **37**, 1033–1039.
30. Fukuwatari T, Yoshida E, Takahashi K, *et al.* (2010) Effect of fasting on the urinary excretion of water-soluble vitamins in humans and rats. *J Nutr Sci Vitaminol* **56**, 19–26.
31. Wittwer CT, Beck S, Peterson M, *et al.* (1990) Mild pantothenate deficiency in rats elevates serum triglyceride and free fatty acid levels. *J Nutr* **120**, 719–725.
32. Bannister DW (1976) The biochemistry of fatty liver and kidney syndrome. Biotin-mediated restoration of hepatic gluconeogenesis in vitro and its relationship to pyruvate carboxylase activity. *Biochemistry J* **156**, 167–173.
33. Fukuwatari T & Shibata K (2008) Urinary water-soluble vitamin and their metabolites contents as nutritional markers for evaluating vitamin intakes in young Japanese women. *J Nutr Sci Vitaminol* **54**, 223–229.
34. Shibata K, Fukuwatari T, Watanabe T, *et al.* (2009) Intra- and inter-individual variations of blood and urinary water-soluble vitamins in Japanese young adults consuming a semi-purified diet for 7 days. *J Nutr Sci Vitaminol* **55**, 459–470.
35. Fukuwatari T, Sugimoto E, Tsuji T, *et al.* (2009) Urinary excretion of vitamin B_{12} depends on urine volume in female university students and elderly subjects in Japan. *Nutr Res* **29**, 839–845.
36. Tsuji T, Fukuwatari T, Sasaki S, *et al.* (2010) Urinary excretion of vitamin B_1, B_2, B_6, niacin, pantothenic acid, folate, and vitamin C correlates with dietary intakes of free-living elderly, female Japanese. *Nutr Res* **30**, 171–178.
37. Tsuji T, Fukuwatari T, Sasaki S, *et al.* (2010) Twenty-four-hour urinary water-soluble vitamins correlate to vitamin intakes in free-living Japanese university students. *Eu J Clin Nutr* **64**, 800–807.
38. Tsuji T, Fukuwatari T, Sasaki S, *et al.* (2011) Twenty-four-hour urinary water-soluble vitamin levels correlate with their intakes in free-living Japanese school children. *Public Health Nutr* **14**, 27–33.
39. Alcarraz-Vizán G, Boren J, Lee W-NP, *et al.* (2010) Histone deacetylase inhibition results in a common metabolic profile associated with HT29 differentiation. *Metabolomics* **6**, 229–237.
40. Zhao S, Xu W, Jiang W, *et al.* (2010) Regulation of cellular metabolism by protein lysine acetylation. *Science* **327**, 1000–1004.
41. Samols D, Thornton CG, Murtif VL, *et al.* (1988) Evolutionary conservation among biotin enzymes. *J Biol Chem* **263**, 6461–6464.
42. Knowles JR (1989) The mechanism of biotin-dependent enzymes. *Annu Rev Biochem* **58**, 195–221.
43. Gholson RK, Ueda I, Ogasawara N, *et al.* (1963) The enzymatic conversion of quinolinate to nicotinic acid mononucleotide in mammalian liver. *J Biol Chem* **239**, 1208–1214.
44. Shibata K, Kondo T & Miki A (1998) Increased conversion ratio of tryptophan to niacin in severe food restriction. *Biosci Biotech Biochem* **62**, 580–583.
45. Aksoy S, Szumlanski CL & Weinshilboum RM (1994) Human liver nicotinamide N-methyltransferase. cDNA cloning, expression, and biochemical characterization. *J Biol Chem* **269**, 14835–14840.
46. Gallo CM, Smith DL & Smith JS (2004) Nicotinamide clearance bu Pnc1 directly regulates Sir2-mediated silencing and longevity. *Mol Cell Biol* **24**, 1301–1312.
47. Banasik M, Komura H, Shimoyama M, *et al.* (1992) Specific inhibitors of poly(ADP-ribose) synthetase and mono(ADP-ribosyl)transferase. *J Biol Chem* **267**, 1569–1575.

NS British Journal of Nutrition

Journal of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
doi:10.1093/gerona/glr174

A Significant Relationship between Plasma Vitamin C Concentration and Physical Performance among Japanese Elderly Women

Kyoko Saito,[1,2] Tetsuji Yokoyama,[2] Hideyo Yoshida,[1] Hunkyung Kim,[1] Hiroyuki Shimada,[3] Yuko Yoshida,[1] Hajime Iwasa,[4] Yoko Shimizu,[1] Kondo Yoshitaka,[5] Setsuko Handa,[5] Naoki Maruyama,[5] Akihito Ishigami,[5] and Takao Suzuki[6]

[1]Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan.
[2]Department of Human Resources Development, National Institute of Public Health, Saitama, Japan.
[3]Section for Health promotion, Department of Health and Medical Care, Center for Development of Advanced Medicine for Dementia, National Center for Geriatrics and Gerontology, Aichi, Japan.
[4]Department of Social Gerontology, School of Public Health, Tokyo University, Tokyo, Japan.
[5]Molecular Regulation of Aging, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan.
[6]Research Institute, National Center for Geriatrics and Gerontology, Aichi, Japan.

Address correspondence to Kyoko Saito, PhD, Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, 35-2, Sakaecho, Itabashi, Tokyo, 173-0015, Japan. Email:kyon@tmig.or.jp

Background. Maintenance of physical performance could improve the quality of life in old age. Recent studies suggested a beneficial relationship between antioxidant vitamin (eg, vitamin C) intake and physical performance in elderly people. The purpose of this study was to examine the relationship between plasma vitamin C concentration and physical performance among Japanese community-dwelling elderly women.

Methods. This is a cross-sectional study involving elderly females residing in an urban area in Tokyo, Japan, in October 2006. We examined anthropometric measurements, physical performance, lifestyles, and plasma vitamin C concentration of participants.

Results. A total of 655 subjects who did not take supplements were analyzed. The mean age (±standard deviation) of participants was 75.7 ± 4.1 years in this study. The geometric mean (geometric standard deviation) of plasma vitamin C concentration was 8.9 (1.5) μg/mL. The plasma vitamin C concentration was positively correlated with handgrip strength, length of time standing on one leg with eyes open and walking speed, and inversely correlated with body mass index. After adjusting for the confounding factors, the quartile plasma vitamin C level was significantly correlated with the subject's handgrip strength (p for trend = .0004) and ability to stand on one leg with eyes open (p for trend = .049).

Conclusions. In community-dwelling elderly women, the concentration of plasma vitamin C related well to their muscle strength and physical performance.

Key Words: Plasma vitamin C—Physical performance—Elderly women—Japanese.

Received January 26, 2011; Accepted August 30, 2011

Decision Editor: Luigi Ferrucci, MD, PhD

PHYSICAL performance and physical ability are the most important indicators of health status in elderly people and are also closely related to the quality of life. Declines in physical performance and physical activity, whether from specific disease, fall, fracture, poor nutrition, or aging itself, are associated with future disability, morbidity, and death (1,2).

In recent years, many studies have examined the roles of diet, protein, and vitamins in physical performance and physical activity(3–5). Several studies have associated low serum albumin concentration with deteriorated muscle strength and function (6,7). Some other studies have examined the relationship between serum vitamin D level and physical performance such as muscle mass, muscle strength, handgrip, walking speed, and functional capacity (8,9). Cesari et al. (3) examined the relationship between antioxidant vitamin intake (vitamin C, vitamin E, β-carotene, and retinol) and physical performance in elderly people and showed significant positive correlations between most antioxidants, especially vitamin C, and higher skeletal muscular strength in this group of people.

There are a number of mechanistic hypotheses about the potential beneficial effects of antioxidant vitamins(10–12). Vitamin C, vitamin E, β-carotene, and retinol are important antioxidants that are not synthesized by humans and, therefore, are mainly supplied via dietary intake. Vitamin C (ascorbic acid) is a water-soluble antioxidant present in the cytosol and extracellular fluid and can directly react with free radicals such as superoxide ($O_2\cdot^-$) and hydroxyl radicals (·OH) (13,14). Each one of these oxygen-derived intermediates is considered highly reactive because of their unstable electron configurations, which could attract electrons from other molecules, resulting in another free radical that is capable of reacting with yet another molecule. This chain reaction is thought to contribute to lipid peroxidation, DNA damage, and protein degradation during oxidative stress. Oxidative damage is thought to play an important role in the age-related decline of functional activity in human skeletal muscle (15). Concentration of plasma vitamin C, which has potent antioxidant activity, is known to increase after exercise (4).

An increase in the amount of blood vitamin C content has been used as an indicator of increased oxidative reaction (11). Previous studies have examined the effects of vitamin C supplementation on physical performance and exercise (4,11). Although findings from some of the previous studies do not support any beneficial effect of increased antioxidant intake on physical performance, other studies have shown improved recovery from exercise with antioxidant intake and have also shown a preventive role of antioxidant supplementation against oxidative damage. These studies were carried out on athletes after heavy exercise. So far, however, there has been no study examining the relationship between physical performance and blood levels of vitamin C, which may be a more direct marker of the antioxidative ability of the human body.

The present study, to the best of our knowledge, is the first report that examines the relationship between plasma vitamin C concentration and physical performance in Japanese community-dwelling elderly women.

Subjects and Methods

Study Subjects

The present cross-sectional study was carried out as part of a project involving mass health examination of community-dwelling people ("Otasha-kenshin" in Japanese) aged 70 years and older living in Itabashi-ku, Tokyo. "Otasha-kenshin," which literally means "health examination for successful aging," is a comprehensive health examination program for community-dwelling older adults aimed at preventing geriatric syndromes including falls and fractures, incontinence, mild cognitive impairment, depression, and undernutrition (16).

The eligible subjects were all female residents, aged between 70 and 84 years, living in the Itabashi area, an urban part of Itabashi-ku, Tokyo, Japan in October 2006. The population of women belonging to this age range and residing in the Itabashi area was 5937, and they were recruited by invitation through postal mail. Of them, 1,112 women applied for admission and 957 women ultimately participated in this study. The participants who were taking vitamin C supplements (n = 238) were excluded from the primary analyses for examination of the relationship between plasma vitamin C and physical performance because intake of supplements could strongly influence the plasma vitamin C level. Thus, data from 655 subjects were ultimately used for the primary analysis. However, data from the 238 supplement users were also used for subanalysis to determine whether any relationship exists between vitamin C supplementation and physical performance.

All participants were examined at the Tokyo Metropolitan Institute of Gerontology's hall. Physical performance, blood examinations, lifestyle assessments, and anthropometric measurements were performed as described below (9).

The present study was approved by the ethics review committee of the Tokyo Metropolitan Institute of Gerontology. All subjects gave written informed consent.

Anthropometric Measurements

Height and weight of each participant were measured, and body mass index was defined as weight/height^2 (kg/m^2). Body composition measurements (percent body fat) were obtained by segmental bioelectrical impedance using eight tactile electrodes according to the manufacturer's instructions (In Body 3.0; Biospace, Seoul, Korea). Measurements for the triceps surae muscles were taken between the knee and the ankle, at the level of maximum circumference of the medial and anterior calf of the left leg of each participant at sitting position.

Physical Performance

Physical performance was assessed by muscle strength (handgrip strength), balance capability, and usual and maximal walking speeds, without prior practice before the actual measurements. These assessments are routinely conducted for the elderly community as described previously (9). Handgrip strength (kg) was measured once for the dominant hand with the subjects in a standing position using a Smedley's Hand Dynamometer (Yagami, Tokyo, Japan). Grip devices were calibrated with known weights. Subjects held the dynamometer at thigh level and were encouraged to exert the strongest possible force. Balance capability was measured in terms of the length of time standing on one leg, that is, we asked the subjects to look straight ahead at a dot 1 m in front of them and to stand on the preferred leg with their eyes open and hands down alongside the trunk. The time until balance was lost (or maximum 60 seconds) was recorded. We used the better of two trials in the analysis. To determine the walking speed, participants were asked to walk on a flat surface at their "usual and maximum walking speeds." Two marks were used to delineate the start and end of a 5-m path. The start mark was preceded by a 3-m approach to ensure that the participants achieved their pace of usual or maximum before entering the test path. The participants were also instructed to continue walking past the end of the 5-m path for a further 3 m to ensure that their walking pace was maintained throughout the test path. The time taken to complete the 5-m walk was measured by an investigator and used for analysis. Walking test at maximum speed was repeated twice, and the faster speed was recorded for the test.

All physical performance tests were performed between 9 AM and 4 PM during the day. We have no data on the reproducibility of the measurements. To reduce interexaminer variation, each test was conducted by the same staff member specifically trained for this study.

Blood Examinations

Blood samples (nonfasting) were collected from the subjects between 9 am and 4 pm during the day. There was no difference in mean plasma vitamin C concentration with regard to the time of collection (data not shown). Venous blood samples were drawn into Ethylene diamine tetraacetic acid tubes. Plasma was then obtained by centrifugation at 3,000 rpm for 15 min at 4°C and subsequently used for biochemical assays. Plasma was treated with Ethylene diamine tetraacetic acid to prevent the spontaneous vitamin C degradation. Next, 100 μl of the plasma was dispensed into storage tubes, to which 450 μl of 3% metaphosphoric acid solution was added, and the mixture was stored at –80°C until further use. Vitamin C concentration was determined by an High performance liquid chromatography-electrochemical detection–based method (17). The analysis was carried out centrally in our laboratory. Serum albumin concentration was measured by the Bromocresol Green method (Special Reference Laboratories Inc., Tokyo, Japan). The coefficient of variation for serum albumin found using this method was less than 1% (9).

Lifestyle Assessment

Information regarding the participants' general health (such as medical history, smoking habits, alcohol drinking habits, regular exercise habits, vegetable intake, fruit intake and use of vitamin C supplement) was collected by interview, and history of medical conditions including hypertension, stroke, heart attack, diabetes mellitus, and hyperlipidemia was self-reported.

Alcohol drinking habits of the subjects were classified as nondrinker, current drinker, or ex-drinker. Smoking habits of the subjects were classified using three categories: never smokers, current smokers, and ex-smokers. The frequency of vegetable and fruit intake was asked using four categories: almost every day, once every two days, once or twice per week, and almost never. Subsequently, for analysis, the categories were summarized as almost every day and others.

Statistical Analysis

Data were summarized as mean and standard deviation or percentage values. The data of plasma vitamin C concentration was logarithmically transformed to approximate a normal distribution and was summarized as the geometric mean and geometric standard deviation.

Table 1. Characteristics of Study Subjects ($N = 655$)

Characteristic	Mean (*SD*)
Age (y)	75.7 (4.1)
Height (cm)	149.1 (5.7)
Weight (kg)	51.0 (8.3)
Body mass index (kg/m^2)	22.9 (3.4)
Triceps surae muscle (cm)	33.1 (2.8)
Plasma vitamin C (μg/ml)*	8.9 (1.5)
Serum albumin (mg/dL)	4.3 (0.2)
Body composition	
Percent body fat (%)	32.2 (7.0)
Physical performance tests	
Handgrip strength (kg)	18.7 (4.4)
One leg standing with eyes open (s)	35.2 (23.5)
Usual walking speed (m/s)	1.2 (0.3)
Maximal walking speed (m/s)	1.8 (0.4)
	%
Medical history	
Hypertension	50.7
Stroke	6.6
Heart attack	21.2
Diabetes mellitus	9.0
Hyperlipidemia	34.7
Alcohol drinking habit	
Current	25.3
Former	5.0
Never	69.6
Smoking habit	
Current	3.7
Former	5.7
Never	90.7
Regular exercise habit	
Yes	69.2
No	30.8
Vegetable intake	
Everyday	84.2
Others†	15.8
Fruit intake	
Everyday	81.8
Others†	18.2

Notes: Data of vitamin C supplement users were excluded.
*The geometric mean and geometric *SD*.
† Including participants taking vegetables/fruits not everyday or almost never.

The age-adjusted Pearson's correlation coefficient between the plasma vitamin C concentration and other factors were calculated. The least square means and SEs adjusted for potential confounders were calculated and compared between categories by analysis of covariance. To examine the relationship between plasma vitamin C concentration and physical performance, statistical adjustment was done by analysis of covariance for variables (except for other physical performance variables) that were correlated to plasma vitamin C concentration with $p < .20$. The same analyses were repeated for the 238 users of vitamin C supplement. All statistical analyses were performed using the SAS (version 9.0; SAS Institute Inc., NC).

RESULTS

Table 1 summarizes the basic characteristics of the subjects. As shown, the mean age (±standard deviation) of the

Table 2. Correlation between Plasma Vitamin C Concentration and Selected Factors ($N = 655$)

Factor	Correlation* r	p
Age	−0.004	.91
Height	0.04	.27
Weight	−0.05	.19
Body mass index	−0.08	.054
Triceps surae muscle	0.001	.98
Serum albumin	−0.04	.33
Percent body fat	−0.12	.002
Handgrip strength	0.16	<.001
One leg standing with eyes open	0.15	<.001
Usual walking speed	0.14	<.001
Maximal walking speed	0.09	.036

Notes: Number of subjects is slightly different for the selected factors because of missing values.

*Age-adjusted Pearson's correlation coefficient between logarithm of vitamin C concentration and each factor.

subjects was 75.7 ± 4.1 years. The geometric mean (geometric standard deviation) of plasma vitamin C concentration was 8.9 (1.5) μg/mL. The prevalence of women eating vegetables everyday was 84.2% and those eating fruits everyday was 81.8%.

The age-adjusted geometric mean of plasma vitamin C concentration was significantly lower in subjects who had a medical history of hypertension (8.53 vs 9.22, $p = .0015$) and diabetes mellitus (7.59 vs 9.00, $p = .002$) as compared with those who did not. A history of stroke, heart attack, or hyperlipidemia was not associated with plasma vitamin C concentration. Subjects who took fruits every day had a significantly higher concentration of vitamin C than those who did not (9.14 vs 7.78, $p < .0001$). Vegetable intake, alcohol drinking habit and smoking habit were not related to plasma vitamin C concentration (not shown in table).

Table 2 shows the age-adjusted correlations between the plasma vitamin C concentration and selected factors. As shown, the plasma vitamin C concentration was positively but modestly correlated with handgrip strength, length of time standing on one leg with eyes open, as well as usual walking speed and maximal walking speed, and modestly inversely correlated with body mass index and percent body fat of the subjects.

Table 3 shows the relationship between plasma vitamin C concentration and each physical performance after adjusting for confounding factors. Results obtained after the adjustment for potential confounders confirmed that the plasma vitamin C concentration was correlated with the handgrip strength independently from the other factors (eg, p for trend = .0004 after adjusting for age, body mass index, percent body fat, hypertension, diabetes mellitus, and fruit intake; Table 3). There was also a significant relationship between the plasma vitamin C level and the subject's length of time standing on one leg with eyes open after adjustments for age, body mass index, percent body fat, hypertension, diabetes mellitus, and fruit intake (Table 3; p for trend = .049). We did not observe any significant association between the plasma vitamin C level and the usual or the maximal walking speed of the subjects.

A subanalysis using data from the 238 vitamin C supplement users showed almost null relationship between handgrip strength and plasma vitamin C concentration (data not shown).

Discussion

A previous study has shown an association between higher daily dietary intake of vitamin C and skeletal muscle strength in elderly people (3). Results described in the present study indicated that plasma vitamin C concentration was positively related with muscle and physical performance in community-dwelling elderly women. To the best of our knowledge, this is the first study showing a significant

Table 3. Relationship between Plasma Vitamin C Concentration and Physical Performance Adjusted for Potential Confounder

	Quartile of plasma vitamin C level				
	Q1	Q2	Q3	Q4	
Physical performance	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	p for trend
Handgrip strength (kg), N	154	159	154	152	
Age adjusted	17.70 ± 0.34	18.75 ± 0.33	18.75 ± 0.34	19.60 ± 0.34	.0001
Multivariate adjusted*	17.83 ± 0.34	18.83 ± 0.32	18.89 ± 0.33	19.60 ± 0.33	.0004
One leg standing with eyes open† (s), N	162	163	164	161	
Age adjusted	31.44 ± 1.71	33.98 ± 1.70	37.70 ± 1.70	37.83 ± 1.71	.003
Multivariate adjusted*	33.39 ± 1.74	34.08 ± 1.67	37.63 ± 1.67	37.50 ± 1.70	.049
Usual walking speed (m/s), N	146	154	145	147	
Age adjusted	1.13 ± 0.02	1.19 ± 0.02	1.23 ± 0.02	1.21 ± 0.02	.008
Multivariate adjusted*	1.18 ± 0.02	1.19 ± 0.02	1.22 ± 0.02	1.21 ± 0.02	.23
Maximal walking speed (m/s), N	146	154	154	147	
Age adjusted	1.70 ± 0.03	1.76 ± 0.03	1.82 ± 0.03	1.76 ± 0.03	.15
Multivariate adjusted*	1.76 ± 0.03	1.77 ± 0.03	1.80 ± 0.03	1.75 ± 0.03	.94

Notes: Values are least squares mean and SE adjusted for the factors by analysis of covariance. Q1–Q4: first to fourth quartile groups of plasma vitamin C concentration, respectively.

*Adjusted for age, body mass index, percent body fat, hypertension, diabetes mellitus and **fruit intake**.

†Length of time standing on one leg with eyes open.

correlation between plasma vitamin C concentration and handgrip strength and ability to stand on one leg with eyes open. We, however, were unable to find any relationship between skeletal muscle mass and plasma vitamin C concentration. Handgrip strength has been found to correlate well with the strength of other muscle groups and is thus a good indicator of overall strength (18). Consistent with this idea, handgrip strength was found to be a strong and consistent predictor of all-cause mortality and morbidity of Activities of Daily Living in middle-aged people (19). The handgrip test is considered an easy and inexpensive screening tool to identify elderly people at risk of disability. Handgrip strength, an indicator of overall muscle strength, is thought to predict mortality through mechanisms other than underlying disease that could cause muscle impairment (18,19). The one leg standing test is one of the balance tests (20). The test is a clinical tool to assess postural steadiness in a static position by quantitative measurement. Many studies have shown that the decreased one leg standing time is associated with declines in Activities of Daily Living and increases in other morbidities including osteoporosis and fall (20).

Our findings suggest that vitamin C may play an important role in maintaining physical performance and thereby may help to improve healthy life expectancy in the elderly. However, the usual and maximal walking speeds did not relate to plasma vitamin C concentration. Walking speed test may be an efficient tool in screening older persons with higher risk of mortality and may easily identify high-risk groups in the community (21). Walking is a rhythmic, dynamic, and aerobic activity of the large skeletal muscles that confers multifarious benefits with minimal adverse effects. Muscles of the legs, limbs, and lower trunk are strengthened, and the flexibility of their joints are preserved (22). One of the reasons why walking speed was not related to vitamin C concentration may be because walking requires coordinated movements of arms, legs, and many parts of the body rather than a simple muscle and balance function. Previous reports showed that walking balance function did not correlate with standing balance function (23). Although we did not find any clear association between walking and plasma vitamin C concentration in this study, vitamin C may still have effects on relatively simple strength and balance functions.

One of the possible explanations for the observed relationship between vitamin C and physical performance, especially handgrip strength and the ability to stand on one leg with eyes open, may be the potential protective effects of the antioxidant vitamins against muscle damage (4,11). Vitamin C is a six-carbon lactone that is synthesized from glucose in the liver of most mammalian species, but not in humans (12). Vitamin C is an antioxidant because, by donating its electrons, it prevents other compounds from being oxidized (12). Thus, vitamin C readily scavenges reactive oxygen and nitrogen species, thereby effectively protects other substrates from oxidative damage (10,24). Although habitual exercise reduces systemic inflammation and oxidative stress as the production of endogenous antioxidants are enhanced, acute exercise increases the generation of oxygen-free radicals and lipid peroxidation (4,25). Strenuous physical performance can increase oxygen consumption by 10- to 15-folds over the resting state to meet the energy demands and results in muscle injury (26). Prolonged submaximal exercise was shown to increase the amount of both whole-body and skeletal muscle lipid peroxidation by-products; in the case of the former, the increase was indicated by greater exhalation of pentane but not of ethane (4,27,28). Supplementation with vitamin C was shown to decrease the exercise-induced increase in the rate of lipid peroxidation (27,28). Several studies suggested that oxidative damage may play a crucial role in the decline of functional activity in human skeletal muscle with normal aging (15). Consistent with this idea, several studies showed significantly lower plasma vitamin C level in the elderly population than in the younger adult population (29–31). Because the plasma vitamin C levels in these apparently healthy elderly persons rose markedly after an oral dose of vitamin C, their initially low plasma levels can be attributed to the low intake rather than to an age-related physiological defect.

In fact, the relationship between handgrip strength and plasma vitamin C concentration was significantly different between supplement users and nonusers, that is, an almost null relationship in the former and a positive relationship in the latter (data not shown). This finding suggested that vitamin C supplementation did not have any beneficial effect on the physical performance and muscle strength despite the increased plasma level of vitamin C. A number of studies reported that vitamin C supplement users had significantly higher blood vitamin C concentration than non-users (29, 32, 33). Several studies have examined the effects of exercise on changes in the serum vitamin C concentration (34–36). Some other experimental studies have shown that vitamin C supplementation can reduce symptoms or indicators of exercise-induced oxidative stress (37–40). However, the results regarding vitamin C supplementation are equivocal, and most well-controlled intervention studies report no beneficial effect of vitamin C supplementation on either endurance or strength performance (41,42). Likewise, vitamin C restriction studies showed that a marginal vitamin C deficiency did not affect the physical performance (43). Although evidence from a number of studies show that vitamin C is a powerful antioxidant in biological systems in vitro, its antioxidant role in humans has not been supported by currently available clinical studies.

Vitamin C is especially plentiful in fresh fruits and vegetables. Plasma vitamin C concentration may be merely a marker for intake of other nutrients that are abundant in fruits and vegetables. However, the statistical adjustment for fruit intake did not attenuate the relationship between plasma vitamin C and physical performance (Table 3), suggesting that vitamin C did have some beneficial effects independently of other nutrients. A number of biochemical, clinical, and observational epidemiologic studies have indicated that diets rich in fruits, vegetables, and vitamin C may be of benefit for the prevention of chronic diseases such as cardiovascular disease and cancer (44,45). Several cohort studies have examined associations between plasma vitamin C concentration and mortality from stroke or coronary heart disease (30,46,47). The effects of vitamin C supplementation are, however, still unclear. A pooled study suggested reduced incidences of coronary heart disease events with higher intake of vitamin C supplement (48), while another study showed that a high intake of vitamin C supplement is associated with an increased risk of mortality due to cardiovascular diseases in postmenopausal women with diabetes (49). A randomized placebo controlled 5-year trial, however, did not show any significant reduction in the mortality from, or incidence of, any type of vascular disease or cancer (50). These studies, in fact, have failed to demonstrate any benefit from such supplementation.

There are a number of potential weaknesses in our study that should be mentioned here. The subjects used in this study were not selected randomly from the study population, and they may be relatively healthy elderly women who were able to come to the health examination hall from their homes. A previous study assessed the correlation of antioxidants with physical performance and muscular strength (3) and demonstrated that a higher daily intake of vitamin C and carotene associated with skeletal muscle strength. However, we have no data regarding the presence of other dietary antioxidants in blood such as vitamin E, retinol, and carotene. In our questionnaire, participants were asked to respond "Yes" or "No" to whether they took supplements, and not about the frequency and quantity of intake of the supplements. Thus, we were unable to examine the reason why plasma vitamin C was not related to the handgrip strength in the supplement users by considering the dose of vitamin C they took.

This study was a cross-sectional study and, therefore, does not provide cause/effect relationships, although we demonstrated a significant correlation between physical performance and concentration of plasma vitamin C. Therefore, longitudinal follow-up studies and controlled clinical trials are necessary to confirm the role of plasma vitamin C and physical performance of the elderly women. These limitations should be considered in future studies.

In conclusion, we found a strong correlation of a higher plasma vitamin C concentration with handgrip strength and one leg standing time in community-dwelling elderly women. Although the elderly are prone to vitamin C deficiency, and they appear to have a higher dietary requirement for vitamin C, the beneficial effects of vitamin C supplementation to maintain physical performance in elderly people are equivocal and thus, need further in-depth studies.

Funding

Ministry of Education, Culture, Sports, Science and Technology, Japan (grant-in-aid 16390187 for Scientific Research [B] and grant-in-aid [21790591] for Young Scientists [B]).

Acknowledgment

We offer special thanks to Dr. Satoshi Sasaki for his suggestions and useful comments to this paper; we are indebted to Dr. Shoji Sinkai, Dr. Yoshinori Fujiwara, Mr Toshiro Tango, Mrs Sachiko Imai, Mrs Turuko Maekawa, Miss Erika Hosoi and the staff of the Otasha-kenshin who participated in this study.

References

1. Fried LP. Epidemiology of aging. *Epidemiol Rev.* 2000;22:95–106.
2. Bartali B, Salvini S, Turrini A, et al. Age and disability affect dietary intake. *J Nutr.* 2003;133:2868–2873.
3. Cesari M, Pahor M, Bartali B, et al. Antioxidants and physical performance in elderly persons: the Invecchiare in Chianti (InCHIANTI) study. *Am J Clin Nutr.* 2004;79:289–294.
4. Evans WJ. Vitamin E, vitamin C, and exercise. *Am J Clin Nutr.* 2000;72:647S–652S.
5. Houston DK, Cesari M, Ferrucci L, et al. Association between vitamin D status and physical performance: the InCHIANTI study. *J Gerontol A Biol Sci Med Sci.* 2007;62:440–446.
6. Corti MC, Guralnik JM, Salive ME, Sorkin JD. Serum albumin level and physical disability as predictors of mortality in older persons. *JAMA.* 1994;272:1036–1042.
7. Baumgartner RN, Koehler KM, Romero L, Garry PJ. Serum albumin is associated with skeletal muscle in elderly men and women. *Am J Clin Nutr.* 1996;64:552–558.
8. Howard C, Ferrucci L, Sun K, et al. Oxidative protein damage is associated with poor grip strength among older women living in the community. *J Appl Physiol.* 2007;103:17–20.
9. Kwon J, Suzuki T, Yoshida H, Kim H, Yoshida Y, Iwasa H. Concomitant lower serum albumin and vitamin D levels are associated with decreased objective physical performance among Japanese community-dwelling elderly. *Gerontology.* 2007;53:322–328.
10. Carr AC, Frei B. Toward a new recommended dietary allowance for vitamin C based on antioxidant and health effects in humans. *Am J Clin Nutr.* 1999;69:1086–1107.
11. Clarkson PM, Thompson HS. Antioxidants: what role do they play in physical activity and health? *Am J Clin Nutr.* 2000;72:637S–646S.
12. Padayatty SJ, Katz A, Wang Y, et al. Vitamin C as an antioxidant: evaluation of its role in disease prevention. *J Am Coll Nutr.* 2003; 22:18–35.
13. Nishikimi M. Oxidation of ascorbic acid with superoxide anion generated by the xanthine-xanthine oxidase system. *Biochem Biophys Res Commun.* 1975;63:463–468.
14. Bielski BH, Richter HW, Chan PC. Some properties of the ascorbate free radical. *Ann N Y Acad Sci.* 1975;258:231–237.
15. Pansarasa O, Castagna L, Colombi B, Vecchiet J, Felzani G, Marzatico F. Age and sex differences in human skeletal muscle: role of reactive oxygen species. *Free Radic Res.* 2000;33:287–293.
16. Suzuki T, Iwasa H, Yoshida H, et al. [Comprehensive health examination ("Otasha-Kenshin") for the prevention of geriatric syndromes and a bed-ridden state in the community elderly. 1. Differences in characteristics between participants and non-participants]. *Nippon Koshu Eisei Zasshi.* 2003;50:39–48.
17. Sato Y, Uchiki T, Iwama M, Kishimoto Y, Takahashi R, Ishigami A. Determination of dehydroascorbic acid in mouse tissues and plasma by using Tris(2-carboxyethyl)phosphine hydrochloride as reductant in metaphosphoric acid/ethylenediaminetetraacetic acid solution. *Biol Pharm Bull.* 2010;33:364–369.
18. Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. *JAMA.* 1999;281:558–560.

19. Rantanen T, Volpato S, Ferrucci L, Heikkinen E, Fried LP, Guralnik JM. Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. *J Am Geriatr Soc.* 2003;51:636–641.
20. Michikawa T, Nishiwaki Y, Takebayashi T, Toyama Y. One-leg standing test for elderly populations. *J Orthop Sci.* 2009;14:675–685.
21. Rolland Y, Lauwers-Cances V, Cesari M, Vellas B, Pahor M, Grandjean H. Physical performance measures as predictors of mortality in a cohort of community-dwelling older French women. *Eur J Epidemiol.* 2006;21:113–122.
22. Morris JN, Hardman AE. Walking to health. *Sports Med.* 1997;23: 306–332.
23. Shimada H, Obuchi S, Kamide N, Shiba Y, Okamoto M, Kakurai S. Relationship with dynamic balance function during standing and walking. *Am J Phys Med Rehabil.* 2003;82:511–516.
24. Halliwell B. Vitamin C: antioxidant or pro-oxidant in vivo? *Free Radic Res.* 1996;25:439–454.
25. Petersen AM, Pedersen BK. The anti-inflammatory effect of exercise. *J Appl Physiol.* 2005;98:1154–1162.
26. Clarkson PM. Antioxidants and physical performance. *Crit Rev Food Sci Nutr.* 1995;35:131–141.
27. Gee DL, Tappel AL. The effect of exhaustive exercise on expired pentane as a measure of in vivo lipid peroxidation in the rat. *Life Sci.* 1981;28:2425–2429.
28. Davies KJ, Quintanilha AT, Brooks GA, Packer L. Free radicals and tissue damage produced by exercise. *Biochem Biophys Res Commun.* 1982;107:1198–1205.
29. Blanchard J, Conrad KA, Mead RA, Garry PJ. Vitamin C disposition in young and elderly men. *Am J Clin Nutr.* 1990;51:837–845.
30. Fletcher AE, Breeze E, Shetty PS. Antioxidant vitamins and mortality in older persons: findings from the nutrition add-on study to the Medical Research Council Trial of Assessment and Management of Older People in the Community. *Am J Clin Nutr.* 2003;78:999–1010.
31. Jacob RA, Otradovec CL, Russell RM, et al. Vitamin C status and nutrient interactions in a healthy elderly population. *Am J Clin Nutr.* 1988;48:1436–1442.
32. Sinha R, Block G, Taylor PR. Determinants of plasma ascorbic acid in a healthy male population. *Cancer Epidemiol Biomarkers Prev.* 1992;1:297–302.
33. Newton HM, Schorah CJ, Habibzadeh N, Morgan DB, Hullin RP. The cause and correction of low blood vitamin C concentrations in the elderly. *Am J Clin Nutr.* 1985;42:656–659.
34. Gleeson M, Robertson JD, Maughan RJ. Influence of exercise on ascorbic acid status in man. *Clin Sci (Lond).* 1987;73:501–505.
35. Camus G, Felekidis A, Pincemail J, et al. Blood levels of reduced/oxidized glutathione and plasma concentration of ascorbic acid during eccentric and concentric exercises of similar energy cost. *Arch Int Physiol Biochim Biophys.* 1994;102:67–70.
36. Duthie GG, Robertson JD, Maughan RJ, Morrice PC. Blood antioxidant status and erythrocyte lipid peroxidation following distance running. *Arch Biochem Biophys.* 1990;282:78–83.
37. Maxwell SR, Jakeman P, Thomason H, Leguen C, Thorpe GH. Changes in plasma antioxidant status during eccentric exercise and the effect of vitamin supplementation. *Free Radic Res Commun.* 1993;19: 191–202.
38. Jakeman P, Maxwell S. Effect of antioxidant vitamin supplementation on muscle function after eccentric exercise. *Eur J Appl Physiol Occup Physiol.* 1993;67:426–430.
39. Kaminski M, Boal R. An effect of ascorbic acid on delayed-onset muscle soreness. *Pain.* 1992;50:317–321.
40. Bryer SC, Goldfarb AH. Effect of high dose vitamin C supplementation on muscle soreness, damage, function, and oxidative stress to eccentric exercise. *Int J Sport Nutr Exerc Metab.* 2006;16: 270–280.
41. Thompson D, Williams C, Kingsley M, et al. Muscle soreness and damage parameters after prolonged intermittent shuttle-running following acute vitamin C supplementation. *Int J Sports Med.* 2001; 22:68–75.
42. Gey GO, Cooper KH, Bottenberg RA. Effect of ascorbic acid on endurance performance and athletic injury. *Jama.* 1970;211:105.
43. van der Beek EJ, van Dokkum W, Schrijver J, Wesstra A, Kistemaker C, Hermus RJ. Controlled vitamin C restriction and physical performance in volunteers. *J Am Coll Nutr.* 1990;9:332–339.
44. Ness AR, Powles JW. Fruit and vegetables, and cardiovascular disease: a review. *Int J Epidemiol.* 1997;26:1–13.
45. Genkinger JM, Platz EA, Hoffman SC, Comstock GW, Helzlsouer KJ. Fruit, vegetable, and antioxidant intake and all-cause, cancer, and cardiovascular disease mortality in a community-dwelling population in Washington County, Maryland. *Am J Epidemiol.* 2004;160:1223–1233.
46. Yokoyama T, Date C, Kokubo Y, Yoshiike N, Matsumura Y, Tanaka H. Serum vitamin C concentration was inversely associated with subsequent 20-year incidence of stroke in a Japanese rural community. The Shibata study. *Stroke.* 2000;31:2287–2294.
47. Gale CR, Martyn CN, Winter PD, Cooper C. Vitamin C and risk of death from stroke and coronary heart disease in cohort of elderly people. *BMJ.* 1995;310:1563–1566.
48. Knekt P, Ritz J, Pereira MA, et al. Antioxidant vitamins and coronary heart disease risk: a pooled analysis of 9 cohorts. *Am J Clin Nutr.* 2004;80:1508–1520.
49. Lee DH, Folsom AR, Harnack L, Halliwell B, Jacobs DR Jr. Does supplemental vitamin C increase cardiovascular disease risk in women with diabetes? *Am J Clin Nutr.* 2004;80:1194–1200.
50. Heart Protection Study Collaborative Group. MRC/BHF Heart Protection Study of antioxidant vitamin supplementation in 20,536 high-risk individuals: a randomised placebo-controlled trial. *Lancet.* 2002;360:23–33.

J Nutr Sci Vitaminol, **58**, 253–262, 2012

Characteristics of Under- and Over-Reporters of Energy Intake among Young Japanese Women

Kentaro MURAKAMI[1], Satoshi SASAKI[1,2], Hitomi OKUBO[2,*] and the Freshmen in Dietetic Courses Study II Group[†]

[1] *Department of Social and Preventive Epidemiology, School of Public Health, University of Tokyo, Hongo 7–3–1, Bunkyo-ku, Tokyo 113–0033, Japan*
[2] *Department of Social and Preventive Epidemiology, Graduate School of Medicine, University of Tokyo, Tokyo 113–0033, Japan*

(Received February 13, 2011)

Summary Evidence on factors associated with misreporting of energy intake is limited, particularly in non-Western populations. We examined the characteristics of under- and over-reporters of energy intake in young Japanese women. Subjects were 3,956 female Japanese dietetic students aged 18–20 y (mean body mass index: 20.9 kg/m^2). Energy intake was assessed using a comprehensive self-administered diet history questionnaire. Estimated energy requirement was calculated based on self-reported information on age, body height and weight, and physical activity with the use of an equation from the US Dietary Reference Intakes. Under-, acceptable, and over-reporters of energy intake were identified based on the ratio of energy intake to estimated energy requirement, according to whether the individual's ratio was below, within, or above the 95% confidence limits of the expected ratio of 1.0 (<0.70, 0.70–1.30, and >1.30, respectively). Risk of being an under- or over-reporter of energy intake compared to an acceptable reporter was analyzed using multiple logistic regression. The percentage of under-, acceptable, and over-reporters of energy intake was 18.4, 73.1, and 8.4%, respectively. Under-reporting was associated with overweight or obesity, perception that one's own weight was too heavy or light, lower dietary consciousness, active lifestyle, living without family, and living in a city (compared with a metropolitan area). Over-reporting was associated with sedentary lifestyle only. This study of lean young Japanese women showed that energy intake misreporting, particularly under-reporting, was common and differential among populations. Particularly, perceived weight status was associated with under-reporting of energy intake, independent of actual weight status.
Key Words energy intake, under-reporting, body weight, young women, Japan

Although accurate assessment of habitual dietary intake is a prerequisite to studies of diet and health, the difficulty of obtaining dietary data that accurately represents what people usually eat is now generally recognized (*1*). Misreporting of dietary intake is a common phenomenon that appears to occur non-randomly (*1–4*) and to be selective for different kinds of foods and nutrients (*5–9*). The resulting potential for differential errors in dietary data complicates the interpretation of studies on diet and health and, at worst, might produce spurious diet-health relationships (*1, 3, 7*). Increasing our understanding of this serious issue therefore requires the identification of different characteristics associated with different kinds of misreporting of dietary intake.

Energy intake is the foundation of the diet, because all other nutrients must be provided within the quantity of food needed to fulfill the energy requirement. Reported energy intake is therefore a surrogate measure of the total quantity of food intake (*1*). In fact, under-reporting of energy intake has long been considered a serious problem in almost all dietary surveys (*1–4, 6–18*). In particular, overweight and obese people tend to under-report energy intake to a greater extent than lean people (*1–4, 6–18*). Moreover, recent studies have shown that, in addition to under-reporting, over-reporting of energy intake also needs to be taken into account, in some populations at least, such as those with low body mass index (BMI) (*3, 10, 12, 14*). Most of these studies have been conducted in Western countries (*1–3, 5–8, 10–16*), however, and research in non-Western countries such as Japan is sparse (*4, 9, 17, 18*). Because the ways people interpret and respond to dietary assessment may differ between Western countries and Japan, mainly due to large differences in dietary habits and body size, the accuracy of reported dietary intake may also differ, hampering the extrapolation of findings in Western countries to Japanese populations.

Here, to better understand the serious problem of dietary misreporting, the objective of this study was to

* Research Fellow of the Japan Society for the Promotion of Science, Japan
† Other members of the Freshmen in Dietetic Courses Study II Group have been listed previously (*Eur J Clin Nutr* **61**: 616–622, 2007).
E-mail: kenmrkm@m.u-tokyo.ac.jp

examine differences in dietary and non-dietary characteristics between under-, acceptable, and over-reporters of energy intake in a group of young Japanese women. A characteristic of young Japanese women is their relatively low BMI, which is nevertheless accompanied by excessive weight concerns and a strong desire for thinness (*19, 20*), a combination seldom observed in other countries. In particular, we investigated the hypothesis whether actual and perceived weight statuses were independently associated with energy intake misreporting in this unique population.

MATERIALS AND METHODS

Study population. The present study was based on data from the Freshmen in Dietetic Courses Study II, a cross-sectional, self-administered questionnaire survey among dietetic students (n=4,679) from 54 institutions in 33 of 47 prefectures in Japan. A detailed description of the study design and survey procedure has been published elsewhere (*21–24*). Briefly, a set of two questionnaires on dietary habits and other lifestyle behaviors during the preceding month was distributed to all students at orientation sessions or early lectures for freshman students who entered dietetic courses in April 2005, in almost all institutions within 2 wk after the course began. In accordance with the survey protocol, answered questionnaires were checked at least twice for completeness by trained survey staff (mostly registered dietitians) and, when necessary, forms were reviewed with the subject to ensure the clarity of answers.

In total, 4,394 students (4,168 women and 226 men) completed both questionnaires (response rate: 93.9%). For the present analysis, we selected female participants aged 18–20 y (n=4,060). We then excluded women who were in an institution where the survey was not conducted within 2 wk of entry (n=98) and those with missing information on the variables used (n=8). As some participants were in more than one exclusion category, the final analysis sample consisted of 3,956 women.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committee of the National Institute of Health and Nutrition, Japan. Written informed consent was obtained from all subjects; in this survey, the signature of the student on both of the questionnaires was considered to constitute informed consent by both the student and her parent(s)/caregiver(s).

Dietary intake. Dietary habits during the preceding month were assessed using a comprehensive self-administered diet history questionnaire (DHQ) (*4, 25–28*). Details of the DHQ's structure and method of calculating dietary intake have been published elsewhere (*4, 25–28*). Briefly, the DHQ is a structured 16-page questionnaire which asks about the consumption frequency and portion size of selected foods commonly consumed in Japan, as well as general dietary behavior and usual cooking methods (*25, 28*). Estimates of daily intake for foods (150 items in total), energy, and selected nutrients were calculated using an ad hoc computer algorithm for the DHQ (*25, 28*) based on the Standard Tables of Food Composition in Japan (*29*). Values of nutrient and food intake were energy-adjusted using the density method (i.e., percentage of energy for energy-providing nutrients and amount per 1,000 kcal of energy for other nutrients and foods) (*9*).

Validity of the DHQ with respect to commonly studied nutritional factors has been investigated (*4, 25–28*). Briefly, Pearson correlation coefficients were 0.48 for energy, 0.37–0.75 for energy-providing nutrients, and 0.38–0.68 for other nutrients between the DHQ and 3-d estimated dietary records in 47 women (*25*); 0.23 for sodium and 0.40 for potassium between the DHQ and 24-h urinary excretion in 69 women (*26*); 0.66 between the DHQ and serum phospholipid concentrations for marine-origin n-3 polyunsaturated fatty acids (sum of eicosapentenoic, docosapentaenoic, and docosahexaenoic acids) in 44 women (*27*); and 0.56 between the DHQ and serum concentrations for carotene in 42 women (*27*). Further, Pearson correlation coefficients between energy intake derived from the DHQ and total energy expenditure measured by doubly labeled water were 0.34 in 67 men and 0.22 in 73 women (*4*).

Non-dietary factors. Body weight and height were self-reported as part of the DHQ. BMI (kg/m^2) was calculated as body weight (kg) divided by the square of body height (m). Weight status was defined according to World Health Organization recommendations as follows (*30*): underweight (BMI: $<$18.5 kg/m^2), normal (BMI: $\geq$18.5 to $<$25 kg/m^2), overweight (BMI: $\geq$25 to $<$30 kg/m^2), and obese (BMI: $\geq$30 kg/m^2).

In a 12-page questionnaire on nondietary lifestyle during the preceding month, subjects reported self-perceived weight status (too heavy, somewhat heavy, just about right, somewhat light, or too light), whether currently trying to lose weight (no or yes), residential status (living with family, living alone, or living with others), and smoking status (never, former, or current). Dietary consciousness was assessed in the lifestyle questionnaire using the following question: 'How often do you think about diet or nutrients to maintain your health?' and classified into five categories (always, often, sometimes, seldom, or never). Residential areas, reported in the lifestyle questionnaire, were grouped into six regions (Hokkaido and Tohoku; Kanto; Hokuriku and Tokai; Kinki; Chugoku and Shikoku; and Kyushu) and into three municipality levels (ward (i.e., metropolitan area); city; and town and village).

Subjects also reported on the lifestyle questionnaire the time they usually got up and went to bed, which was used to calculate sleeping hours, and the frequency and duration of high-intensity activities (e.g., carrying heavy loads; bicycling, moderate effort; jogging; and singles tennis), moderate-intensity activities (e.g., carrying light loads; bicycling, light effort; and doubles tennis), walking, and sedentary activities (e.g., studying; reading; and watching television) during the preceding month. For subjects whose recorded total hours were $<$24 h, unrecorded hours were assumed to be spent on sedentary activities. For subjects whose recorded total hours were >24 h, the total number of hours spent daily was proportionately decreased to equal 24. Each activity was assigned a metabolic equivalent value from a previously published table (0.9 for sleeping, 1.5 for sedentary activity, 3.3 for walking, 5.0 for moderate-intensity activity, and 7.0 for high-intensity activity) (*31*). The number of hours spent per day on each activity was multiplied by the metabolic equivalent value of that activity, and all metabolic equivalent-hour products were summed to produce a total metabolic equivalent-hour score for the day. These were then divided by 24 h to give a physical activity level (PAL) value, and classified into four categories (sedentary (PAL: <1.4), low active (PAL: ≥1.4 to <1.6), active (PAL: ≥1.6 to <1.9), and very active (PAL: ≥1.9)) according to the US Dietary Reference Intakes (*32*).

Identification of misreporting of energy intake. We calculated each subject's estimated energy requirement (which is equal to total energy expenditure during weight stability) based on self-reported information on age, body height and weight, and physical activity, with the use of the following equation from the US Dietary Reference Intakes (*32*).

Estimated energy requirement (i.e., total energy expenditure during weight stability) [kcal/d]

$$=387-7.31\times\text{age [y]}+\text{physical activity coefficient [1.00 for sedentary, 1.14 for low active, 1.27 for active, and 1.45 for very active]}\times(10.9\times\text{body weight [kg]}+660.7\times\text{body height [m]})$$

This equation was developed for use in lean to obese women (≥19 y) from a meta-analysis of methodologically sound studies using doubly labeled water as the criterion measure of total energy expenditure (n=433, SE fit: 229.1, R^2: 0.79) (*32*). An investigation using two equations for normal weight women and for overweight women (*32*) provided similar results (data not shown), while an investigation among 18-y-old women (n=3,574) using two equations for normal weight girls (9–18 y) and for overweight girls (*32*) provided similar results (data not shown). In this paper, we present the results derived from all 3,956 women aged 18–20 y using the first-mentioned equation, which had a maximum number of subjects and a minimum number of different sources of error.

Subjects were identified as acceptable, under-, or over-reporters of energy intake based on their ratio of reported energy intake to estimated energy requirement, according to whether the individual's ratio was within, below, or above the 95% confidence limits of the expected ratio of 1.0. The 95% confidence limits (± 2 standard deviation (SD) cut-offs) were calculated according to the following equation (*33–35*).

95% confidence limit

$$=\pm2\times\sqrt{(CV^2_{rEI}/d+CV^2_{pER}+CV^2_{mTEE})}$$

CV_{rEI} is the within-person coefficient of variation in reported energy intake, d is the number of days of dietary assessment, CV_{pER} is the error in predicted energy requirement equation, and CV_{mTEE} is day-to-day variation in total energy expenditure measured by doubly labeled water (*33–35*). The values used were 23 for CV_{rEI} (*36, 37*), 30 for d (i.e., 1 mo), 11.5 for CV_{pER} (*32*), and 8.2 for CV^2_{mTEE} (*38*). The obtained 95% confidence limit was ±29.5 (%). Thus, acceptable reporters were defined as having a ratio of energy intake to estimated energy requirement in the range 0.70–1.30, under-reporters as a ratio <0.70, and over-reporters as a ratio >1.30.

Statistical analyses. All reported p values are 2-tailed, and p values of <0.05 were considered statistically significant. Mean differences in dietary characteristics between under-, acceptable, and over-reporters of energy intake were tested with one-way analysis of variance (ANOVA). When the overall p from ANOVA was <0.05, the post hoc Bonferroni test was performed. The chi-square test was used to test differences in proportions across categories of energy intake reporting.

The risk of being classified as an under-reporter of energy intake compared to an acceptable reporter, or as an over-reporter compared to an acceptable reporter, was estimated using logistic regression. First, crude odds ratios (ORs) and 95% confidence intervals (CIs) for the risk of being classified as an under- or over-reporter were calculated for each category of factors which are possibly associated with energy intake misreporting, namely weight status (reference: normal), self-perceived weight status (reference: just about right), whether currently trying to lose weight (reference: no), dietary consciousness (reference: always), physical activity (reference: sedentary), smoking status (reference: never), residential status (reference: living with family), region (reference: Hokkaido and Tohoku), and municipality level (reference: ward (i.e., metropolitan area)). Multivariate-adjusted ORs and 95% CIs were then calculated by entering all variables simultaneously into the regression model to assess the genuine effect on risk. All statistical analyses were performed using SAS statistical software (version 9.1, 2003, SAS Institute Inc, Cary, NC, USA).

RESULTS

Mean values of physical characteristics were as follows: 18.1 (SD: 0.3) y for age, 1.58 (SD: 0.05) m for height, 52.3 (SD: 7.7) kg for weight, and 20.9 (SD: 2.8) kg/m^2 for BMI. Dietary characteristics across categories of reporting status of energy intake are shown in Table 1. Mean value of the ratio of energy intake to estimated energy requirement was 0.93 (SD: 0.28). The percentage of under-, acceptable, and over-reporters of energy intake was 18.4, 73.1, and 8.4%, respectively. Energy-adjusted intake of most nutrients and foods differed among the categories of energy reporting status. For nutrients, under-reporters had the highest intake of carbohydrate and the lowest intake of protein, fat, cholesterol, potassium, calcium, and vitamin A. Over-reporters had the highest intake of protein, fat, alcohol, potassium, iron, and vitamin A and the lowest intake of carbohydrate. For foods, under-reporters had the highest intake of rice and noodles and the lowest intake of confectioneries, fats and oils, fish and shellfish, meats, and soft drinks. Over-reporters had the highest intake

Table 1. Dietary characteristics across categories of reporting status of energy intake.

	All (n=3,956)		Under-reporters (n=729; 18.4%)		Acceptable reporters (n=2,893; 73.1%)		Over-reporters (n=334; 8.4%)		p (ANOVA)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Ratio of energy intake to estimated energy requirement	0.93	0.28	0.60[a]	0.08	0.94[b]	0.15	1.56[c]	0.32	<0.0001
Energy intake (kcal/d)	1,827	551	1,235[a]	196	1,840[b]	327	3,009[c]	650	<0.0001
Estimated energy requirement (kcal/d)	1,984	194	2,065[a]	222	1,969[b]	184	1,931[c]	164	<0.0001
Nutrient intake									
Protein (% of energy)	13.3	2.1	12.9[a]	2.2	13.4[b]	2.1	13.6[c]	2.5	<0.0001
Fat (% of energy)	29.5	6.0	26.5[a]	5.9	29.8[b]	5.5	33.9[c]	6.6	<0.0001
Carbohydrate (% of energy)	55.7	6.9	59.0[a]	6.8	55.4[b]	6.4	51.3[c]	7.7	<0.0001
Alcohol (% of energy)	0.3	1.6	0.3[a]	1.5	0.3[a]	1.4	0.6[b]	2.8	0.01
Dietary fiber (g/1,000 kcal)	6.5	2.1	6.5	2.4	6.5	2.0	6.6	2.1	0.88
Cholesterol (mg/1,000 kcal)	163.8	64.1	151.9[a]	71.8	165.8[b]	62.0	172.4[b]	61.4	<0.0001
Sodium (mg/1,000 kcal)	2,117	556	2,098	617	2,123	536	2,108	578	0.51
Potassium (mg/1,000 kcal)	1,079	286	1,047[a]	340	1,079[b]	269	1,142[c]	297	<0.0001
Calcium (mg/1,000 kcal)	266.6	99.7	256.2[a]	112.3	268.0[b]	97.0	276.5[b]	91.1	0.003
Iron (mg/1,000 kcal)	3.7	0.9	3.6[a]	1.0	3.7[a]	0.9	3.8[b]	0.9	0.002
Vitamin A (μg retinol equivalents/1,000 kcal)	290.7	248.9	265.2[a]	287.0	292.0[b]	234.2	335.6[c]	275.0	<0.0001
Folate (μg/1,000 kcal)	152.2	55.1	156.9[a]	69.3	151.2[b]	51.3	151.0[a,b]	51.0	0.04
Vitamin C (mg/1,000 kcal)	48.1	22.7	49.0[a,b]	26.6	47.5[a]	21.5	51.6[b]	23.0	0.004
Food intake (g/1,000 kcal)									
Rice	159.2	70.1	185.0[a]	79.4	157.8[b]	65.2	114.5[c]	64.1	<0.0001
Bread	28.3	21.8	29.2[a]	24.6	28.5[a]	21.2	24.8[b]	19.8	0.005
Noodles	36.8	32.7	43.3[a]	43.0	36.0[b]	30.3	29.1[c]	23.4	<0.0001
Confectioneries	38.1	17.6	35.2[a]	17.9	38.0[b]	16.8	44.9[c]	21.0	<0.0001
Fats and oils	13.6	6.7	11.9[a]	6.4	13.7[b]	6.4	16.3[c]	8.1	<0.0001
Fish and shellfish	30.2	17.7	27.5[a]	17.5	30.4[b]	17.0	34.1[c]	22.8	<0.0001
Meats	33.7	16.9	29.2[a]	14.9	34.2[b]	16.6	39.2[c]	21.1	<0.0001
Dairy products	83.9	71.4	79.9	76.5	85.1	71.0	82.5	62.2	0.20
Vegetables	127.4	81.0	126.4	98.9	126.7	75.0	134.8	87.6	0.22
Fruits	50.0	51.9	47.6[a]	53.8	48.8[a]	49.6	65.6[b]	63.9	<0.0001
Soft drinks	33.4	53.1	24.4[a]	40.1	33.7[b]	54.4	50.2[c]	62.4	<0.0001

[a,b,c] Mean values within a row with different superscript letters are significantly different, $p<0.05$ (post hoc Bonferroni test; when the overall p from ANOVA was <0.05 the post hoc Bonferroni test was performed).

of confectioneries, fats and oils, fish and shellfish, meat, fruits, and soft drinks and the lowest intake of rice, bread, and noodles. No differences were observed among the categories of energy reporting status for dietary fiber, sodium, dairy products, or vegetables.

Table 2 shows non-dietary characteristics across categories of reporting status of energy intake. While the proportion of overweight or obese subjects was small (6.2 and 1.3%, respectively), many subjects perceived their own weight as too heavy or somewhat heavy (17.4 and 57.1%, respectively), suggesting excessive weight concerns in spite of actual leanness. Weight status, self-perceived weight status, whether currently trying to lose weight, physical activity, and residential status was associated with energy reporting status. Under-reporters of energy intake had the highest proportion of overweight and obese subjects, subjects who perceived their own weight as too heavy or too light, subjects currently trying to lose weight, subjects with an active lifestyle, and subjects living alone. Over-reporters had the highest proportion of underweight subjects, subjects with a sedentary lifestyle, and subjects living with family.

ORs and 95% CIs for the risk of being an under-reporter compared to an acceptable reporter of energy intake are shown in Table 3. Results for crude and multivariate-adjusted models were generally similar. In multivariate analysis, overweight and obese, perceiving their own weight as too heavy or light, lower dietary consciousness, active lifestyle, living without family, and living in a city were associated with a higher risk of being an under-reporter of energy intake. Currently trying to lose weight was associated with a higher risk of being an under-reporter in the crude model, but the association disappeared after consideration of other factors.

Table 4 shows ORs and 95% CIs for the risk of being an over-reporter compared to an acceptable reporter of energy intake. Results for crude and multivariate-adjusted models were generally similar again. On multi-

Table 2. Non-dietary characteristics across categories of reporting status of energy intake.

	All (n=3,956)		Under-reporters (n=729; 18.4%)		Acceptable reporters (n=2,893; 73.1%)		Over-reporters (n=334; 8.4%)		p[1]
	n	%	n	%	n	%	n	%	
Weight status									<0.0001
Underweight (BMI: <18.5 kg/m^2)	576	14.6	83	11.4	427	14.8	66	19.8	
Normal (BMI: ≥18.5 to <25 kg/m^2)	3,080	77.9	545	74.8	2,287	79.1	248	74.3	
Overweight (BMI: ≥25 to <30 kg/m^2)	247	6.2	77	10.6	151	5.2	19	5.7	
Obese (BMI: ≥30 kg/m^2)	53	1.3	24	3.3	28	1.0	1	0.3	
Self-perceived weight status									<0.0001
Too heavy	690	17.4	200	27.4	430	14.9	60	18.0	
Somewhat heavy	2,260	57.1	386	53.0	1,702	58.8	172	51.5	
Just about right	830	21.0	113	15.5	637	22.0	80	24.0	
Somewhat light	151	3.8	22	3.0	111	3.8	18	5.4	
Too light	25	0.6	8	1.1	13	0.5	4	1.2	
Currently trying to lose weight									0.003
No	2,528	63.9	426	58.4	1,889	65.3	213	63.8	
Yes	1,428	36.1	303	41.6	1,004	34.7	121	36.2	
Dietary consciousness									0.42
Always	775	19.6	136	18.7	578	20.0	61	18.3	
Often	2,162	54.7	381	52.3	1,597	55.2	184	55.1	
Sometimes	571	14.4	113	15.5	410	14.2	48	14.4	
Seldom	390	9.9	84	11.5	269	9.3	37	11.1	
Never	58	1.5	15	2.1	39	1.4	4	1.2	
Physical activity									<0.0001
Sedentary	2,323	58.7	321	44.0	1,769	61.2	233	69.8	
Low active	1,317	33.3	305	41.8	927	32.0	85	25.5	
Active	242	6.1	76	10.4	150	5.2	16	4.8	
Very active	74	1.9	27	3.7	47	1.6	0	0	
Smoking status									0.30
Never	3,827	96.7	698	95.8	2,809	97.1	320	95.8	
Former	68	1.7	15	2.1	46	1.6	7	2.1	
Current	61	1.5	16	2.2	38	1.3	7	2.1	
Residential status									0.0002
Living with family	3,508	88.7	612	84.0	2,592	89.6	304	91.0	
Living alone	365	9.2	96	13.2	247	8.5	22	6.6	
Living with others	83	2.1	21	2.9	54	1.9	8	2.4	
Region									0.44
Hokkaido and Tohoku	388	9.8	69	9.5	293	10.1	26	7.8	
Kanto	1,358	34.3	230	31.6	1,003	34.7	125	37.4	
Hokuriku and Tokai	552	14.0	110	15.1	392	13.6	50	15.0	
Kinki	783	19.8	139	19.1	581	20.1	63	18.9	
Chugoku and Shikoku	427	10.8	93	12.8	302	10.4	32	9.6	
Kyushu	448	11.3	88	12.1	322	11.1	38	11.4	
Municipality level									0.047
Ward (i.e., metropolitan area)	784	19.8	122	16.7	598	20.7	64	19.2	
City	2,570	65.0	505	69.3	1,855	64.1	210	62.9	
Town and village	602	15.2	102	14.0	440	15.2	60	18.0	

[1] Chi-square test.

variate analysis, a higher risk of being an over-reporter of energy intake was associated with sedentary lifestyle only. Underweight was associated with higher risk of being an over-reporter in crude model, but the association disappeared after consideration of other factors.

DISCUSSION

In this study in lean young Japanese women, misreporting, particularly under-reporting, of energy intake was common and differently distributed among populations. Under-reporting was associated with overweight or obesity, perceiving one's own weight as too heavy or

Table 3. Risk of being an under-reporter of energy intake compared to being an acceptable reporter of energy intake.

	n of under-reporters/ acceptable reporters	Crude model[1]			Multivariate-adjusted model[2]		
		OR	95% CI	*p*	OR	95% CI	*p*
Weight status							
Underweight (BMI:<18.5 kg/m^2)	83/427	0.82	0.63, 1.05	0.11	0.91	0.66, 1.25	0.55
Normal (BMI: 18.5 to<25 kg/m^2)	545/2,287	1 (reference)			1 (reference)		
Overweight (BMI: 25 to<30 kg/m^2)	77/151	2.14	1.60, 2.86	<0.0001	1.52	1.10, 2.12	0.01
Obese (BMI: 30 kg/m^2)	24/28	3.60	2.07, 6.25	<0.0001	2.68	1.48, 4.86	0.001
Self-perceived weight status							
Too heavy	200/430	2.62	2.02, 3.40	<0.0001	2.03	1.47, 2.79	<0.0001
Somewhat heavy	386/1,702	1.28	1.02, 1.61	0.04	1.19	0.92, 1.53	0.19
Just about right	113/637	1 (reference)			1 (reference)		
Somewhat light	22/111	1.12	0.68, 1.84	0.66	1.17	0.69, 1.99	0.57
Too light	8/13	3.47	1.41, 8.56	0.007	4.06	1.57, 10.50	0.004
Currently trying to lose weight							
No	426/1,889	1 (reference)			1 (reference)		
Yes	303/1,004	1.34	1.13, 1.58	0.0006	1.11	0.93, 1.34	0.25
Dietary consciousness							
Always	136/578	1 (reference)			1 (reference)		
Often	381/1,597	1.01	0.82, 1.26	0.90	1.14	0.91, 1.44	0.26
Sometimes	113/410	1.17	0.89, 1.55	0.27	1.28	0.95, 1.72	0.11
Seldom	84/269	1.33	0.98, 1.81	0.07	1.54	1.11, 2.14	0.01
Never	15/39	1.64	0.88, 3.05	0.12	2.23	1.16, 4.28	0.02
Physical activity							
Sedentary	321/1,769	1 (reference)			1 (reference)		
Low active	305/927	1.81	1.52, 2.16	<0.0001	1.92	1.60, 2.31	<0.0001
Active	76/150	2.79	2.07, 3.77	<0.0001	3.28	2.40, 4.48	<0.0001
Very active	27/47	3.17	1.94, 5.16	<0.0001	3.90	2.36, 6.47	<0.0001
Smoking status							
Never	698/2,809	1 (reference)			1 (reference)		
Former	15/46	1.31	0.73, 2.36	0.37	1.08	0.58, 2.01	0.81
Current	16/38	1.70	0.94, 3.06	0.08	1.45	0.78, 2.70	0.24
Residential status							
Living with family	612/2,592	1 (reference)			1 (reference)		
Living alone	96/247	1.65	1.28, 2.12	0.0001	1.95	1.50, 2.55	<0.0001
Living with others	21/54	1.65	0.99, 2.75	0.06	1.79	1.05, 3.05	0.03
Region							
Hokkaido and Tohoku	69/293	1 (reference)			1 (reference)		
Kanto	230/1,003	0.97	0.72, 1.31	0.86	0.88	0.64, 1.21	0.43
Hokuriku and Tokai	110/392	1.19	0.85, 1.67	0.31	1.08	0.75, 1.56	0.68
Kinki	139/581	1.02	0.74, 1.40	0.92	0.89	0.64, 1.26	0.52
Chugoku and Shikoku	93/302	1.31	0.92, 1.86	0.13	1.05	0.72, 1.53	0.79
Kyushu	88/322	1.16	0.82, 1.65	0.41	1.15	0.79, 1.68	0.47
Municipality level							
Ward (i.e., metropolitan area)	122/598	0.75	0.60, 0.93	0.01	0.71	0.56, 0.90	0.005
City	505/1,855	1 (reference)			1 (reference)		
Town and village	102/440	0.85	0.67, 1.08	0.18	0.85	0.66, 1.09	0.20

[1] Each of the variables listed was entered into the model separately.
[2] All the variables listed were entered into the model simultaneously.

light, lower dietary consciousness, active lifestyle, living without family, and living in a city (compared with a ward (metropolitan area)); while over-reporting was associated with sedentary lifestyle. The most impressive finding was the association of perceived weight status with energy under-reporting, independent of actual weight status. To our knowledge, this is the first study to examine characteristics associated with under- and over-reporting of energy intake in young Japanese women, with consideration of individual physical activity level.

In this study of young Japanese women, about one-

Table 4. Risk of being an over-reporter of energy intake compared to being an acceptable reporter of energy intake.

	n of over-reporters/ acceptable reporters	Crude model[1]			Multivariate-adjusted model[2]		
		OR	95% CI	p	OR	95% CI	p
Weight status							
Underweight (BMI: <18.5 kg/m^2)	66/427	1.43	1.07, 1.91	0.02	1.33	0.92, 1.90	0.13
Normal (BMI: ≥18.5 to<25 kg/m^2)	248/2,287	1 (reference)			1 (reference)		
Overweight (BMI: ≥25 to<30 kg/m^2)	19/151	1.16	0.71, 1.90	0.56	0.93	0.54, 1.59	0.79
Obese (BMI: ≥30 kg/m^2)	1/28	0.33	0.05, 2.43	0.28	0.20	0.03, 1.53	0.12
Self-perceived weight status							
Too heavy	60/430	1.11	0.78, 1.59	0.56	1.21	0.79, 1.86	0.38
Somewhat heavy	172/1,702	0.81	0.61, 1.07	0.13	0.85	0.62, 1.17	0.32
Just about right	80/637	1 (reference)			1 (reference)		
Somewhat light	18/111	1.29	0.75, 2.24	0.36	1.17	0.66, 2.09	0.58
Too light	4/13	2.45	0.78, 7.70	0.12	2.22	0.69, 7.18	0.18
Currently trying to lose weight							
No	213/1,889	1 (reference)			1 (reference)		
Yes	121/1,004	1.07	0.84, 1.35	0.58	1.20	0.92, 1.55	0.17
Dietary consciousness							
Always	61/578	1 (reference)			1 (reference)		
Often	184/1,597	1.09	0.81, 1.48	0.57	1.08	0.79, 1.48	0.63
Sometimes	48/410	1.11	0.75, 1.65	0.61	1.13	0.75, 1.70	0.57
Seldom	37/269	1.30	0.85, 2.01	0.23	1.27	0.81, 1.99	0.30
Never	4/39	0.97	0.34, 2.81	0.96	0.84	0.29, 2.47	0.75
Physical activity							
Sedentary	233/1,769	1 (reference)			1 (reference)		
Low active	85/927	0.70	0.54, 0.90	0.007	0.68	0.53, 0.89	0.005
Active	16/150	0.81	0.48, 1.38	0.44	0.78	0.45, 1.33	0.36
Very active	0/47	—	—	—	—	—	—
Smoking status							
Never	320/2,809	1 (reference)			1 (reference)		
Former	7/46	1.34	0.60, 2.98	0.48	1.19	0.53, 2.71	0.67
Current	7/38	1.62	0.72, 3.65	0.25	1.60	0.69, 3.68	0.27
Residential status							
Living with family	304/2,592	1 (reference)			1 (reference)		
Living alone	22/247	0.76	0.48, 1.19	0.23	0.76	0.48, 1.20	0.24
Living with others	8/54	1.26	0.60, 2.68	0.54	1.25	0.58, 2.68	0.57
Region							
Hokkaido and Tohoku	26/293	1 (reference)			1 (reference)		
Kanto	125/1,003	1.40	0.90, 2.18	0.13	1.43	0.91, 2.25	0.12
Hokuriku and Tokai	50/392	1.44	0.87, 2.36	0.15	1.38	0.82, 2.32	0.23
Kinki	63/581	1.22	0.76, 1.97	0.41	1.24	0.76, 2.02	0.40
Chugoku and Shikoku	32/302	1.19	0.69, 2.05	0.52	1.23	0.70, 2.15	0.48
Kyushu	38/322	1.33	0.79, 2.24	0.29	1.31	0.76, 2.25	0.34
Municipality level							
Ward (i.e., metropolitan area)	64/598	0.95	0.70, 1.27	0.71	1.04	0.76, 1.42	0.83
City	210/1,855	1 (reference)			1 (reference)		
Town and village	60/440	1.21	0.89, 1.63	0.23	1.19	0.87, 1.63	0.27

[1] Each of the variables listed was entered into the model separately.
[2] All the variables listed were entered into the model simultaneously.

fourth of the participants were classified as either under- or over-reporters of energy intake (18.4 and 8.4%, respectively). In Western countries, the percentage of under-reporters ranged from 3 to 54% and that of over-reporters from 0.1 to 22% (*2, 3, 6, 7, 10–16*). In a Japanese study using total energy expenditure measured by doubly labeled water (n=140), 44% of subjects were defined as under-reporters and 20% as over-reporters (*4*). Other studies in Japan using the ratio of reported energy intake to estimated basal metabolic rate without consideration of individual physical activity reported that the prevalence of under-reporters was 20–37% while that of over-reporters was 2–10% (*17, 18*). Although comparisons of the prevalence of misreporting of energy intake between studies are hampered by differences in the criteria used to classify under- and over-reporting, dietary assessment instruments, and population characteristics, these findings suggest that not only under- but also over-reporting of energy intake is likely in many dietary surveys in both Western and Japanese populations.

In this lean Japanese population, we found that overweight and obese subjects were more likely to under-report energy intake. This finding is consistent with numerous previous findings in Western countries (*1–3, 6, 7, 10–16*) and Japan (*4, 17, 18*). Further, subjects who perceived their own weight as too heavy were predominant, and were more likely to under-report energy intake, independent of their actual weight status. Moreover, under-reporting was also independently associated with perceiving one's weight as too light. This may be due to the excessive weight concerns and strong desire for thinness commonly observed in young Japanese women, irrespective of actual weight status (*19, 20*). A similar independent influence of both actual weight status and perceived weight consciousness on under-reporting has been observed in other obese populations (*10, 14*).

In this study, higher physical activity was associated with under-reporting of energy intake. This appears reasonable, given that active subjects with greater energy requirements can fall into the category of under-reporting (*39*). A similar association was observed in Japanese adult men and women (*4*). Although several studies have suggested an association between smoking status and energy misreporting (*1, 3, 7, 14, 16*), we found no such association, possibly due to the small percentage of former and current smokers in the present study. We found some influence of variables related to residence (residential status and municipality level) on energy under-reporting, which is in accordance with several previous studies (*3, 14*). In contrast to a previous study (*14*), lower dietary consciousness was associated with energy under-reporting, which may reflect carelessness or poor memory of dietary habits, or factors potentially associated with dietary reporting such as knowledge of food and diet and enthusiasm in dietary assessment (*18*).

While previous studies have suggested several lifestyle factors as a risk factor of energy over-reporting, including low BMI (*3, 10, 12, 14*), none of these factors, including weight status, was associated with the risk of an being over-reporter in this study of relatively lean young Japanese women (except for sedentary lifestyle). On this basis, over-reporting may be a random rather than a systematic phenomenon compared with under-reporting, in the present population at least.

Consistent with previous Western studies (*1, 3, 7, 10, 12–14, 16*), energy-adjusted nutrient and food intakes differed among under-, acceptable, and over-reporters of energy intake, although nutrient and food intake in Japanese subjects appears to provide no clue as to whether the diet of under- and over-reporters is healthier or unhealthier than that of acceptable reporters (*9, 17*). This supports the hypothesis that the under- and over-reporting of foods is selective and that this selective misreporting affects the energy-adjusted nutrient and food intake in a biased way (*5–9*), which in turn affects the diet-disease relationships thereby obtained (*1, 3, 7*).

Several limitations of the present study deserve mention. First, the participants selected were female dietetic students, not a random sample of Japanese people. To minimize the influence of nutritional education, the present survey was conducted in most institutions within 2 wk after the course began. Nevertheless, the participants may have had healthier dietary habits and lifestyles than the general population, although with regard to the reported intake of energy, fat, and carbohydrate and BMI at least, mean and SD values in the present study were reasonably comparable to those of a representative sample of Japanese women aged 15–19 y (1,852 (SD: 480) kcal/d, 29.3% (SD: 6.8%) of energy, 55.5% (SD: 7.8%) of energy, and 20.7 (SD: 3.0) kg/m^2, respectively) (*40*). Our results might not therefore be extrapolatable to the general Japanese population.

At present, the only way to obtain unbiased information on energy requirements in free-living settings is to use doubly labeled water as a biomarker (*1*). This technique is expensive and impractical for application to large-scale epidemiologic studies, and alternative procedures are accordingly used (*3, 7–18*). In the present study, we calculated estimated energy requirements based on self-reported information on age, body height and weight, and physical activity with the use of an equation from the US Dietary Reference Intakes (*32*). Although the equation was developed based on a large number of highly accurate measurements of total energy expenditure by the doubly labeled water method, these were predominantly conducted in Caucasians (*32*), and might therefore be inappropriate for the present Japanese population. Moreover, this calculation used self-reported rather than measured body weight and height, although previous studies have generally shown that while weights are on average underestimated and heights are on average overestimated, the correlations between self-reported and measured values are markedly high (*41, 42*). Additionally, we are unable to determine whether the associations found between misreporting of energy intake and several characteristics are true, or were artifacts caused by the procedure used to identify misreporters or to calculate energy requirements.

Energy intake was assessed using a self-administered dietary assessment questionnaire (i.e., DHQ). Actual dietary habits were not observed and, as is often the case in such dietary questionnaires (*6, 43–46*), the validity of the DHQ in terms of energy intake appears somewhat insufficient against total energy expenditure as measured by doubly labeled water (*4*). Thus, the present findings might be specific to this dietary assessment questionnaire and should be interpreted in this context, albeit there is some evidence that people tend to report dietary intake similarly across dietary assessment methods (*1*).

All the variables used in this study were based on self-reporting, which might have been biased and hence influenced the results. For example, BMI calculated based on self-reported measures are generally underestimated, although the correlation between self-reported and measured BMI is markedly high (*41, 42*). It is thus likely that the percentages of overweight and obese subjects based on self-reported data in this study are underestimated, which might have influenced the results by attenuating or strengthening the association.

In conclusion, this study in lean young Japanese women showed that misreporting, particularly underreporting, of energy intake was common and differently distributed among populations. Under-reporting was associated with overweight or obesity, perception that one's weight was too heavy or light, lower dietary consciousness, active lifestyle, living without family, and living in a city (compared with a ward (metropolitan area)); while over-reporting was associated with a sedentary lifestyle. The most impressive finding was the association of perceived weight status with energy under-reporting, independent of actual weight status. These results suggest that dietary data in young Japanese women should be treated and interpreted with marked caution. Further studies are needed to examine whether the associations observed in the present study are commonly observed across different dietary assessment methods and in other populations.

Acknowledgments

This study was supported by grants from the Ministry of Health, Labour, and Welfare of Japan. None of the authors had any personal or financial conflict of interest to declare.

REFERENCES

1) Livingstone MBE, Black AE. 2003. Markers of the validity of reported energy intake. *J Nutr* **133**: 895S–920S.
2) Tooze JA, Subar AF, Thompson FE, Troiano R, Schatzkin A, Kipnis V. 2004. Psychosocial predictors of energy underreporting in a large doubly labeled water study. *Am J Clin Nutr* **79**: 795–804.
3) Mattisson I, Wirfalt E, Aronsson CA, Wallstrom P, Sonestedt E, Gullberg B, Berglund G. 2005. Misreporting of energy: prevalence, characteristics of misreporters and influence on observed risk estimates in the Malmo Diet and Cancer cohort. *Br J Nutr* **94**: 832–842.
4) Okubo H, Sasaki S, Rafamantanantsoa HH, Ishikawa-Takata K, Okazaki K, Tabata I. 2008. Validation of self-reported energy intake by a self-administered diet history questionnaire using the doubly labeled water method in 140 Japanese adults. *Eur J Clin Nutr* **62**: 1343–1350.
5) Poppitt SD, Swann D, Black AE, Prentice AM. 1998. Assessment of selective under-reporting of food intake by both obese and non-obese women in a metabolic facility. *Int J Obes Relat Metab Disord* **22**: 303–311.
6) Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S, Sharbaugh CO, Trabulsi J, Runswick S, Ballard-Barbash R, Sunshine J, Schatzkin A. 2003. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol* **158**: 1–13.
7) Rosell MS, Hellenius MLB, De Faire UH, Johansson GK. 2003. Associations between diet and the metabolic syndrome vary with the validity of dietary intake data. *Am J Clin Nutr* **78**: 84–90.
8) Heitmann BL, Lissner L. 1995. Dietary underreporting by obese individuals: is it specific or non-specific? *BMJ* **311**: 986–989.
9) Murakami K, Sasaki S, Takahashi Y, Uenishi K, Yamasaki M, Hayabuchi H, Goda T, Oka J, Baba K, Ohki K, Kohri T, Watanabe R, Sugiyama Y. 2008. Misreporting of dietary energy, protein, potassium and sodium in relation to body mass index in young Japanese women. *Eur J Clin Nutr* **62**: 111–118.
10) Lutomski JE, van den Broeck J, Harrington J, Shiely F, Perry IJ. 2011. Sociodemographic, lifestyle, mental health and dietary factors associated with direction of misreporting of energy intake. *Public Health Nutr* **14**: 532–541.
11) Nielsen BM, Nielsen MM, Toubro S, Pedersen O, Astrup A, Sorensen TI, Jess T, Heitmann BL. 2009. Past and current body size affect validity of reported energy intake among middle-aged Danish men. *J Nutr* **139**: 2337–2343.
12) Klingberg S, Hallenberg E, Lorentzon M, Mellstrom D, Ohlsson C, Hulthen L. 2008. Characteristics of under- and over-reporters of energy intake among 18–20-year-old males: the Gothenburg Osteoporosis and Obesity Determinants (GOOD) study. *Public Health Nutr* **11**: 1117–1123.
13) Bedard D, Shatenstein B, Nadon S. 2004. Underreporting of energy intake from a self-administered food-frequency questionnaire completed by adults in Montreal. *Public Health Nutr* **7**: 675–681.
14) Johansson L, Solvoll K, Bjorneboe GEA, Drevon CA. 1998. Under- and overreporting of energy intake related to weight status and lifestyle in a nationwide sample. *Am J Clin Nutr* **68**: 266–274.
15) Ferrari P, Slimani N, Ciampi A, Trichopoulou A, Naska A, Lauria C, Veglia F, Bueno-de-Mesquita HB, Ocke MC, Brustad M, Braaten T, Tormo JM, Amiano P, Mattisson I, Johansson G, Welch A, Davey G, Overvad K, Tjonneland A, Clavel-Chapelon F, Thiebaut A, Linseisen J, Boeing H, Hemon B, Riboli E. 2002. Evaluation of under- and overreporting of energy intake in the 24-hour diet recalls in the European Prospective Investigation into Cancer and Nutrition (EPIC). *Public Health Nutr* **5**: 1329–1345.
16) Johansson G, Wikman A, Ahren AM, Hallmans G, Johansson I. 2001. Underreporting of energy intake in repeated 24-hour recalls related to gender, age, weight status, day of interview, educational level, reported food intake, smoking habits. *Public Health Nutr* **4**: 919–927.
17) Okubo H, Sasaki S. 2004. Underreporting of energy intake among Japanese women aged 18–20 years and its association with reported nutrient and food group intakes. *Public Health Nutr* **7**: 911–917.
18) Okubo H, Sasaki S, Hirota N, Notsu A, Todoriki H, Miura A, Fukui M, Date C. 2006. The influence of age and body mass index to relative accuracy of energy intake among Japanese adults. *Public Health Nutr* **9**: 651–657.
19) Hayashi F, Takimoto H, Yoshita K, Yoshiike N. 2006. Perceived body size and desire for thinness of young Japanese women: a population-based survey. *Br J Nutr* **96**: 1154–1162.
20) Kagawa M, Kuroiwa C, Uenishi K, Mori M, Dhaliwal S, Hills AP, Binns CW. 2007. A comparison of body perceptions in relation to measured body composition in young

Japanese males and females. *Body Image* **4**: 372–380.

21) Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. 2007. Association between dietary fiber, water and magnesium intake and functional constipation among young Japanese women. *Eur J Clin Nutr* **61**: 616–622.

22) Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. 2007. Dietary fiber intake, dietary glycemic index and load, and body mass index: a cross-sectional study of 3931 Japanese women aged 18–20 years. *Eur J Clin Nutr* **61**: 986–995.

23) Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. 2007. Monetary costs of dietary energy reported by young Japanese women: association with food and nutrient intake and body mass index. *Public Health Nutr* **10**: 1430–1439.

24) Murakami K, Sasaki S, Okubo H, Takahashi Y. 2009. Neighborhood socioeconomic status in relation to dietary intake and body mass index in female Japanese dietetic students. *Nutrition* **25**: 745–752.

25) Sasaki S, Yanagibori R, Amano K. 1998. Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**: 203–215.

26) Sasaki S, Yanagibori R, Amano K. 1998. Validity of a self-administered diet history questionnaire for assessment of sodium and potassium: comparison with single 24-hour urinary excretion. *Jpn Circ J* **62**: 431–435.

27) Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y, Toyooka T. 2000. Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol* **46**: 285–296.

28) Murakami K, Sasaki S, Takahashi Y, Okubo H, Hirota N, Notsu A, Fukui M, Date C. 2008. Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. *Br J Nutr* **99**: 639–648.

29) Science and Technology Agency. 2005. Standard Tables of Food Composition in Japan, 5th revised and enlarged ed. Printing Bureau of the Ministry of Finance, Tokyo (in Japanese).

30) World Health Organization. 1998. Obesity: Preventing and Managing the Global Epidemic. International Obesity Task Force. World Health Organization, Geneva.

31) Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, Paffenbarger RS Jr. 1993. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* **25**: 71–80.

32) Institute of Medicine. 2002. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids, Part I. National Academy Sciences, Washington, DC.

33) McCrory MA, Hajduk CL, Roberts SB. 2002. Procedures for screening out inaccurate reports of dietary energy intake. *Public Health Nutr* **5**: 873–882.

34) Huang TT, Roberts SB, Howarth NC, McCrory MA. 2005. Effect of screening out implausible energy intake reports on relationships between diet and BMI. *Obes Res* **13**: 1205–1217.

35) Huang TT, Howarth NC, Lin BH, Roberts SB, McCrory MA. 2004. Energy intake and meal portions: associations with BMI percentile in U.S. children. *Obes Res* **12**: 1875–1885.

36) Black AE. 2000. Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. *Int J Obes Relat Metab Disord* **24**: 1119–1130.

37) Black AE. 2000. The sensitivity and specificity of the Goldberg cut-off for EI:BMR for identifying diet reports of poor validity. *Eur J Clin Nutr* **54**: 395–404.

38) Black AE, Cole TJ. 2000. Within- and between-subject variation in energy expenditure measured by the doubly-labelled water technique: implications for validating reported dietary energy intake. *Eur J Clin Nutr* **54**: 386–394.

39) Barnard JA, Tapsell LC, Davies PSW, Brenninger VL, Storlien LH. 2002. Relationship of high energy expenditure and variation in dietary intake with reporting accuracy on 7 day food records and diet histories in a group of healthy adult volunteers. *Eur J Clin Nutr* **56**: 358–367.

40) Ministry of Health, Labour and Welfare of Japan. 2009. The National Health and Nutrition Survey in Japan, 2006. Daiichi Shuppan Publishing, Tokyo (in Japanese).

41) Gorber SC, Tremblay M, Moher D, Gorber B. 2007. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obes Rev* **8**: 307–326.

42) Wada K, Tamakoshi K, Tsunekawa T, Otsuka R, Zhang H, Murata C, Nagasawa N, Matsushita K, Sugiura K, Yatsuya H, Toyoshima H. 2005. Validity of self-reported height and weight in a Japanese workplace population. *Int J Obes* **29**: 1093–1099.

43) Bathalon GP, Tucker KL, Hays NP, Vinken AG, Greenberg AS, McCrory MA, Roberts SB. 2000. Psychological measures of eating behavior and the accuracy of 3 common dietary assessment methods in healthy postmenopausal women. *Am J Clin Nutr* **71**: 739–745.

44) Kroke A, Klipstein-Grobusch K, Voss S, Moseneder J, Thielecke F, Noack R, Boeing H. 1999. Validation of a self-administered food-frequency questionnaire administered in the European Prospective Investigation into Cancer and Nutrition (EPIC) Study: comparison of energy, protein, and macronutrient intakes estimated with the doubly labeled water, urinary nitrogen, and repeated 24-h dietary recall methods. *Am J Clin Nutr* **70**: 439–447.

45) Sawaya AL, Tucker K, Tsay R, Willett W, Saltzman E, Dallal GE, Roberts SB. 1996. Evaluation of four methods for determining energy intake in young and older women: comparison with doubly labeled water measurements of total energy expenditure. *Am J Clin Nutr* **63**: 491–499.

46) Andersen LF, Tomten H, Haggarty P, Lovo A, Hustvedt BE. 2003. Validation of energy intake estimated from a food frequency questionnaire: a doubly labelled water study. *Eur J Clin Nutr* **57**: 279–284.

Japanese Clinical Medicine

OPEN ACCESS
Full open access to this and thousands of other papers at http://www.la-press.com.

ORIGINAL RESEARCH

Improvement of Quality of Life (QOL) in Osteoporotic Patients by Elcatonin Treatment: A Trial Taking the Participants' Preference into Account

K. Yoh[1], T. Uzawa[2], T. Orito[3] and K. Tanaka[4]

[1]Orthopedic Department, Hyogo Medical College Sasayama Medical Center, Sasayama, Hyogo, Japan. [2]Asahi Kasei Pharma Co. Ltd. Pharmaceuticals Sales Division, [3]Orito Orthopedic Surgery Clinic, [4]Department of Food and Nutrition, Kyoto Women's University. Corresponding author email: tanakak@kyoto-wu.ac.jp

Abstract: Osteoporosis is associated with compromised quality of life (QOL), to which pain has the most important contribution. Elcatonin, a derivative of calcitonin, is widely used in the treatment of osteoporosis in two ways. One is as the inhibitor of osteoclastic bone resorption. The other is for osteoporosis-related pain based on the unique analgesic effects of elcatonin. Since pain is subjective in nature, and QOL is the only clinical outcome representing the patients' subjective perception of health status, pain associated with osteoporosis would be best evaluated based on QOL assessment. Evidence based medicine gives the highest remarks to the double-blinded, randomized controlled trial, which, however, cannot be free from methodological problems on some occasions. For example, it is practically impossible to remain blinded in the trial of a potent analgesia, which in turn causes biases. Thus, the significance of taking the patients' preference into account is increasingly acknowledged. In this study, 45 osteoporotic patients were given brochures describing the pros and cons on the three treatment choices; calcium and alfacalcidol, additional use of elcatonin, and additional use of bisphosphonate. Those who favored elcatonin were older, had more vertebral fractures, and lower QOL scores. QOL was evaluated before and three months after the treatment using SF-8; the most widely used generic questionnaire, and RDQ; a lumbago-specific measure. Elcatonin treatment improved physical function, general health, and vitality of SF-8, and RDQ score. Although this is a preliminary study, our results suggest that patients with vertebral fracture(s) have impaired QOL and more likely to favor elcatonin treatment expecting analgesia.

Keywords: osteoporosis, elcatonin, patient preference trial, quality of life

Japanese Clinical Medicine 2012:2 9–14

doi: 10.4137/JCM.S8291

This article is available from http://www.la-press.com.