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食品シリーズ

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Aging Control in Brain and Biomarker : Basic Research and Food Materials

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2009年5月30日　第1刷発行

監　修　大澤俊彦，丸山和佳子　(T0663)
発行者　辻　賢司
発行所　株式会社シーエムシー出版
東京都千代田区内神田1-13-1（豊島屋ビル）
電話03(3293)2061
大阪市中央区南新町1-2-4（椿本ビル）
電話06(4794)8234
http://www.cmcbooks.co.jp/

〔印刷　株式会社遊文舎〕

ISBN978-4-7813-0094-8 C3047 ¥65000E

Vitamin D Deficiency in Elderly Women in Nursing Homes: Investigation with Consideration of Decreased Activation Function from the Kidneys

Yasuhito Terabe, MD,[*] Atsushi Harada, MD, PhD,[†] Haruhiko Tokuda, MD, PhD,[‡] Hiroyasu Okuizumi, MD, PhD,[§‖] Masahiro Nagaya, MD, PhD,[#] and Hiroshi Shimokata, MD, PhD[§]

OBJECTIVES: To determine the approximate percentage of women in nursing homes who have vitamin D deficiency and to investigate whether, in assessing vitamin D status in elderly women, there are problems with measuring only 25 hydroxy-vitamin D_3 (25(OH)D_3) and whether decreased vitamin D activation as a result of poor renal function needs to be considered.

DESIGN: Cross-sectional study.

SETTING: Forty-eight nursing homes in Japan.

PARTICIPANTS: Four hundred three women with a mean age of 86.5 living in nursing homes who had participated in a clinical trial for hip protectors and were not bedridden.

MEASUREMENTS: At the start of the trial, in addition to general biochemical data, 25(OH)D_3, 1,25-dihydroxy-vitamin D_3 (1,25(OH)$_2D_3$), intact parathyroid hormone (intact PTH), calcium (Ca), phosphorus (P), bone alkaline phosphate (BAP), cross-linked *N*-telopeptide of type I collagen (NTx), and osteocalcin were measured in participants' blood, and statistical analysis was performed.

RESULTS: 25(OH)D_3, which is thought to reflect vitamin D status in the body, was surveyed and found to have a mean value of 16.7 ng/mL. 25(OH)D_3 was less than 16 ng/mL in 49.1% of all participants. Creatinine clearance (CCr) was less than 30 mL/min in 20.1% of participants. Participants with serum 25(OH)D_3 less than 16 ng/mL and CCr less than 30 mL/min had significantly higher levels of intact PTH and serum NTx. Participants with a CCr less than 30 mL/min had significantly lower levels of 1,25(OH)$_2D_3$.

CONCLUSION: Frail elderly adults living in nursing homes with poor renal function had lower 1,25(OH)$_2D_3$ and higher intact PTH levels and were thus thought to have poorer vitamin D activating capacity. Supplementation with cholecalciferol may be insufficient in people who have poor renal function. **J Am Geriatr Soc 60:251–255, 2012.**

Key words: 25-hydroxy-vitamin D_3; 1,25-dihydroxy-vitamin D_3; nursing homes

The importance of vitamin D for bones has been indicated in previous studies.[1,2] Frail elderly adults with limited ability to perform activities of daily living (ADL) who enter a nursing home are at high risk for low vitamin D as a result of poor nutrition and lack of sunlight. Vitamin D deficiency is an important risk factor for osteoporosis and fractures from falls in elderly adults.[3–5] When assessing serum 25 hydroxy-vitamin D_3 (25(OH)D_3) levels to define vitamin D deficiency, many reports have adopted a cutoff of 20 ng/mL.[6–8] It has also been reported that individuals with hip fracture or those with a history of falls have low 25(OH)D_3 levels.[9,10] Secondary hyperparathyroidism from poor renal function in elderly adults must also not be overlooked.[11] The group that is probably at the highest risk of falls and fractures is elderly women living in nursing homes who are not completely bedridden but have a mobility level of at least being able to move about in a wheelchair with assistance. The participants in this study were such a group of people, who had previously participated in a fracture prevention trial using hip protectors.[12] Vitamin D levels, renal function, and the relationship between the two were investigated in these women, and the approximate percentage of these nursing home residents who needed supplemental vitamin D was considered.

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DOI: 10.1111/j.1532-5415.2011.03826.x

JAGS 60:251–255, 2012

0002-8614/12/$15.00

METHODS

Participants were 403 women aged 70 and older (range: 70–103) who lived in 48 nursing homes from whom consent was obtained for participation in a fracture prevention trial using hip protectors.[12] They had a mobility level of at least being able to move about in a wheelchair with assistance. A history of bilateral hip fracture was a condition for exclusion. Written informed consent was obtained from all participants. The Ethics Committee of the National Center for Geriatrics and Gerontology approved the study. Blood was collected from participants as the 48 nursing homes in the southern part of central Japan were visited in turn between January 2005 and May 2008. At the start of the trial, in addition to general biochemical data, $25(OH)D_3$, 1,25-dihydroxy-vitamin D_3 ($1,25(OH)_2D_3$), intact parathyroid hormone (PTH), calcium (Ca), phosphorus (P), bone alkaline phosphate (BAP), cross-linked *N*-telopeptide of type I collagen (NTx), and osteocalcin were measured using participants' blood, and statistical analysis was performed. $25(OH)D_3$ was measured using the radioimmunoassay double antibody method. Frail elderly adults have little muscle, and even if creatinine (Cr) is in the normal range, it cannot be concluded that renal function is normal. For a simpler assessment of renal function, we estimated Cr clearance (CCr) with adjustments for age and body weight using the widely adopted Cockcroft-Gault formula.[13]

Statistical Analyses

SPSS (version 17.0, SPSS, Inc., Chicago, IL) was used in the statistical analysis. Adjustment was made for age as a control variable in partial correlation. Two-tailed significance probability <.05 was taken to be significant. The Student *t*-test was used to test for differences between the mean values of the two groups, with $P < .05$ taken to indicate significance. The Bonferroni test was used to compare the mean values in the groups, using a general linear model adjusted for age. $P < .05$ was taken to indicate a significant difference.

RESULTS

Participants were aged 70 were to 103 (mean 86.5). Mean $25(OH)D_3$ level, which is an indicator of vitamin D level, was low (16.7 ng/mL). The mean values for the following tests were: $1,25(OH)_2D_3$, 44.4 ± 17.5 pg/mL; intact PTH, 57.4 ± 38.7 pg/mL; BAP, 32.4 ± 13.2 U/L; osteocalcin, 7.8 ± 3.8 ng/mL; and NTx, 17.6 ± 9.7 nmol bone collagen equivalent/L. The percentile distribution in the $25(OH)D_3$ distribution is shown in Figure 1. When $25(OH)D_3$ concentration of less than 20 ng/mL was taken to indicate vitamin D deficiency, 78.1% of participants were found to be vitamin D deficient.

To further investigate $25(OH)D_3$, the partial correlation was first examined adjusted for age. There were significant positive correlations between $25(OH)D_3$ and $1,25(OH)_2D_3$ (correlation coefficient (r) = 0.149, $P = .003$), albumin ($r = 0.185$, $P < .001$), total cholesterol ($r = 0.165$, $P = .001$), blood urea nitrogen ($r = 0.116$, $P = .02$), Ca ($r = 0.153$, $P = .002$), and P ($r = 0.100$, $P = .04$). Significant negative correlations were shown with serum NTx ($r = -0.153$, $P = .002$) and intact PTH ($r = -0.178$, $P < .001$). It was then decided to further investigate intact PTH, which had shown a high correlation. Mean intact PTH levels in the group with a serum $25(OH)D_3$ concentration less than 12.0 ng/mL, 12.0 to 15.9 ng/mL, and 16.0 ng/mL or higher were 72.3 pg/mL, 60.4 pg/mL, and 51.1 pg/mL, respectively. Mean intact PTH level was significantly higher in participants with a serum $25(OH)D_3$ concentration less than 12.0 ng/mL ($P < .001$) and 12.0 to 15.9 ng/mL ($P = .02$) than in those with a concentration of 16.0 ng/mL or higher. Participants younger than 85 were then compared with those aged 85 and older to determine whether the various data differed depending on age (Table 1). Significant differences were seen in $25(OH)D_3$, $1,25(OH)_2D_3$, and intact PTH. Because $1,25(OH)_2D_3$, a form of activated vitamin D, also decreases with age, it was decided to investigate $1,25(OH)_2D_3$. First, in the age-adjusted partial correlation, $1,25(OH)_2D_3$ showed the strongest negative correlation with Cr ($r = -0.323$, $P < .001$). This finding suggests that renal function strongly affects $1,25(OH)_2D_3$. The relationship between $1,25(OH)_2D_3$ concentration and estimated CCr is shown in Table 2. $1,25(OH)_2D_3$ concentration was significantly lower in participants with CCr less than 30 mL/min. Similarly, intact PTH concentration was significantly higher in participants with CCr less than 30 mL/min, in whom $1,25(OH)_2D_3$ concentration was significantly lower (Table 2). A tendency was seen for $25(OH)D_3$ levels to be higher with lower CCr, and a significant difference was seen between groups with CCr of less than 30 and 45 mL/min or greater ($P < .05$, general linear model Bonferroni test). To improve understanding of how participants were distributed according to $25(OH)D_3$ concentration and CCr value, they were divided into four groups with $25(OH)D_3$ concentrations of less than 16 and 16 ng/mL and greater and CCr of less than 30 and 30 mL/min and greater. Concentrations of $1,25(OH)_2D_3$, intact PTH, and serum NTx of the groups were then compared (Table 3). Of 198 participants with $25(OH)D_3$ concentrations of less than 16 ng/mL, 36 (18.4%) had poor renal function (CCr < 30 mL/min), and of 205 participants with

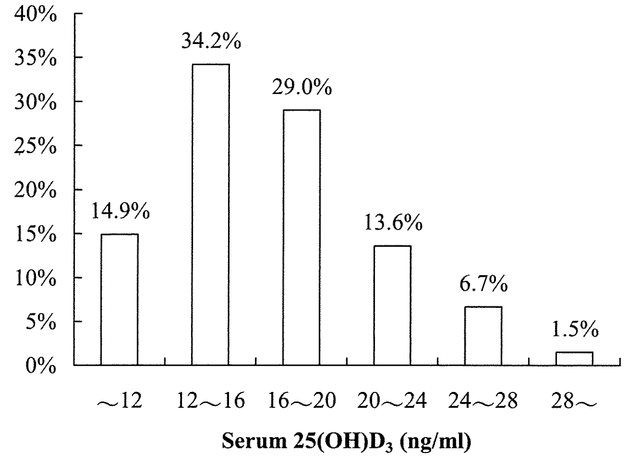

Figure 1. Percentile distribution of serum 25 hydroxy-vitamin D_3 ($25(OH)D_3$) concentrations. $25(OH)D_3$ level was < 20 ng/mL in 78.1% and < 16 ng/mL in approximately half.

Table 1. Comparison of Mean Data Values According to Age

Characteristic	Normal Range	Mean ± Standard Deviation		*P*-Value
		<85 (n = 139)	≥85 (n = 264)	
Age	—	79.1 ± 3.8	90.4 ± 3.7	<.001
Height, cm	—	145.2 ± 7.5	142.8 ± 7.2	.003
Weight, kg	—	44.1 ± 8.3	41.6 ± 7.5	.003
Body mass index, kg/m^2	—	20.7 ± 4.4	20.0 ± 3.3	.28
25 hydroxy-vitamin D_3, ng/mL	—	17.5 ± 4.9	16.3 ± 4.7	.01
1,25-dihydroxy-vitamin D_3, pg/mL	20–60	47.5 ± 18.1	42.7 ± 16.9	.008
Intact parathyroid hormone, pg/mL	10–65	51.6 ± 27.4	60.4 ± 43.2	.03
Albumin, g/dL	3.9–4.9	3.9 ± 0.3	3.9 ± 0.4	.01
Total protein, g/dL	6.5–8.2	6.9 ± 0.5	6.9 ± 0.5	.26
Total cholesterol, mg/dL	120–220	207.6 ± 38.0	195.9 ± 36.3	.003
Blood urea nitrogen, mg/dL	8–20	17.8 ± 6.5	18.7 ± 7.7	.25
Creatinine, mg/dL	0.5–0.8	0.66 ± 0.3	0.72 ± 0.4	.13
Creatinine clearance (Cockcroft-Gault formula), mL/min	—	55.2 ± 18.6	38.9 ± 12.7	<.001
Glomerular filtration rate (modified diet in renal disease formula), mL/min	—	73.9 ± 25.0	65.4 ± 22.1	.001
Calcium, mg/dL	8.7–10.1	8.8 ± 0.4	8.8 ± 0.5	.25
Phosphorus, mg/dL	2.5–4.5	3.6 ± 0.4	3.6 ± 0.5	.21
Aspartate aminotransferase, U/L	10–40	19.2 ± 6.2	19.7 ± 6.2	.39
Alanine aminotransferase, U/L	5–45	13.2 ± 7.5	11.5 ± 6.0	.02

Table 2. Comparison of 1,25-Dihydroxy-Vitamin D_3 ($1,25(OH)_2D_3$), Intact Parathyroid Hormone (PTH), and 25 Hydroxy-Vitamin D_3 ($25(OH)D_3$) Concentrations According to Creatinine Clearance (CCr)

CCr, mL/min	Mean (Standard Error)		
	$1,25(OH)_2D_3$, pg/mL	Intact PTH, pg/mL	25 Hydroxy-Vitamin D_3, ng/mL
<30.0 (n = 82)	33.0 (1.9)*	80.1 (4.3)*	17.9 (5.2)
30.0–44.9 (n = 160)	45.8 (1.3)	52.7 (3.0)	17.0 (4.9)
≥45 (n = 161)	48.8 (1.4)	50.5 (3.2)	15.9 (4.4)

* $P < .05$, general linear model Bonferroni test.

Table 3. Comparison of 1,25-Dihydroxy-Vitamin D_3 ($1,25(OH)_2D_3$), Intact Parathyroid Hormone (PTH), and Cross-Linked *N*-Telopeptide of Type I Collagen (NTx) Concentrations According to Creatinine Clearance (CCr) and 25 Hydroxy-Vitamin D_3 ($25(OH)D_3$) Concentration

CCr, mL/min	Mean (Standard Error) $25(OH)D_3$, ng/mL: <16	≥16
<30		
$1,25(OH)_2D_3$), pg/mL	29.0 (2.7)*	36.3 (2.5)*
Intact PTH, pg/mL	104.8 (6.1)*	60.7 (5.4)
NTx, nmolBCE/L	28.3 (1.6)*	18.9 (1.4)
≥30		
$1,25(OH)_2D_3$, pg/mL	45.2 (1.2)	49.3 (1.3)
Intact PTH, pg/mL	55.1 (2.8)	48.1 (2.9)
NTx, nmolBCE/L	17.1 (0.7)	15.3 (0.7)

$1,25(OH)_2D_3$ levels were significantly lower in participants with CCr lower than 30 mL/min than those with CCr of 30 mL/min and higher. Mean intact PTH and NTx concentrations in participants with CCr lower than 30 mL/min and $25(OH)D_3$ of less than 16 ng/mL were significantly higher than in the other participants.
* $P < .05$, general linear Bonferroni test.

$25(OH)D_3$ concentrations of 16 ng/mL and higher, 45 (22.0%) had poor renal function. These percentages were approximately the same, but concentrations of intact PTH and NTx were significantly higher in the group with $25(OH)D_3$ of less than 16 ng/mL and CCr of less than 30 mL/min. In addition, in the group with CCr of less than 30 mL/min, $1,25(OH)_2D_3$ concentration was significantly lower than in the group with CCr of 30 mL/min and higher, regardless of $25(OH)D_3$ concentration.

DISCUSSION

Table 4 summarizes the reports on $25(OH)D_3$ concentration in elderly cohorts.[14–20] A comparison of reports in which participants were living in institutions and reports in which participants were living independently revealed lower levels of $25(OH)D_3$ in residents of institutions, who are thought to have greater difficulty with activities of daily living. Experts have proposed that $25(HO)D_3$ concentrations of 20 to 32 ng/mL, or roughly 30 ng/mL, are the minimum necessary concentration to prevent fractures.[21] A recent meta-analysis also reported that concentrations of 75 to 100 nmol/L balanced the benefits and risks of the health of elderly people.[22] Many studies take PTH to be an indicator of the cutoff value for $25(OH)D_3$ concentration.[6–8] When PTH is taken as an indicator, a $25(OH)D_3$ concentration of 20 ng/mL is taken as the cutoff

Table 4. Past Reports of 25 Hydroxy-Vitamin D_3 (25 $(OH)D_3$) Levels in Elderly Cohorts

Study Participants	n	Age, Mean	$25(OH)D_3$, ng/mL, Mean	References
Nursing home (Japan)	133	84.6	11.9	14
Nursing home or housebound (United States)	116	81	12.6	15
Nursing home (this study, Japan)	425	86.4	16.8	—
Nursing home (United States)	35	74	17.4	16
Independent women (Canada)	186	73	15.6	17
Independent women (France)	440	80	17.0	18
Community-dwelling elderly women (Japan)	2,007	75.4	24.2	19
Independent women (United States)	500	71	29.6	20

in many reports.[6–8] In the participants in this study, 78.1% had $25(OH)D_3$ levels less than 20 ng/mL. Another study reported that $25(OH)D_3$ of 20 ng/mL and greater is needed when intact PTH is taken as the indicator and that 28 ng/mL and greater is needed when bone density in the femoral neck is taken as the indicator.[6] From the present results, the cutoff value for $25(OH)D_3$ as an indicator of intact PTH was thought to be 16 ng/mL; 49.1% of participants had $25(OH)D_3$ of less than 16 ng/mL (Figure 1). In general, people with poor renal function have lower levels of $1,25(OH)_2D_3$, an activated form of vitamin D, as a result of poor vitamin D activating capacity. Moreover, secondary hyperparathyroidism from poor renal function is not unusual in elderly people.[11] In the present results as well, there was a strong negative correlation between 1,25 $(OH)_2D_3$ and CCr ($r = -0.323$, $P < .001$), which suggests that renal function strongly affects $1,25(OH)_2D_3$. As shown in Table 2, intact PTH levels were significantly higher and $1,25(OH)_2D_3$ significantly lower with a CCr of less than 30 mL/min. From this it can be conjectured that vitamin D activation in the kidneys may decrease in cases of secondary hyperparathyroidism from poor renal function. In addition, as shown in Table 3, the percentage of people with poor renal function (CCr < 30 mL/min) was nearly the same in participants with $25(OH)D_3$ levels greater and less than 16 ng/mL. Women with such vitamin D activating capacity made up 20.1% of all participants, although according to guidelines published in the United States in 2003[23] for bone metabolism disorders in individuals with chronic kidney disease, if PTH is measured and found to be high in people undergoing dialysis and those with chronic renal failure with less than 60% renal function, it is recommended that serum $25(OH)D_3$ be measured and vitamin D_2 be administered if it is less than 30 ng/mL. Considering these guidelines, a greater number of people would probably be judged to have poor renal function, although there are limitations to this investigation. All CCr values were derived through calculation, not from actual measurements of CCr or glomerular filtration rate (GFR). Cystatin C was not measured either. The Cockcroft-Gault formula was first used to calculate CCr, but the Modification of Diet in Renal Disease (MDRD) formula[24] was also used to investigate CCr. The correlation between CCr calculated using the Cockcroft-Gault formula and GFR calculated using the MDRD formula was high ($r = 0.769$, $P < .001$). Moreover, in the group with GFR of less than 50 mL/min (n = 84, 20.8%), a significant difference, similar to that in the results obtained with the Cockcroft-Gaults formula, was seen. Thus, although CCr obtained from calculations is not ideal, it seems to be reliable. In addition, intact PTH level may be a useful indicator in establishing a cutoff value for 25(OH) D_3 in frail elderly adults such as the present participants. Moreover, because plainly higher intact PTH levels were shown in participants with poor vitamin D activation in the kidneys, intact PTH may have an important role in considering vitamin D supplementation in frail elderly adults. Many experts recommend vitamin D supplementation with cholecalciferol when $25(OH)D_3$ level drops below 30 to 32 ng/mL. A recent Institute of Medicine report[25] recommends supplementation when $25(OH)D_3$ is less than 20 ng/mL, but it does not specifically address frail elderly adults. Vitamin D is not activated efficiently even with cholecalciferol supplementation in frail elderly adults, such as the present participants, who seem to have poor activation of vitamin D. Theoretically, therefore, it would seem that supplementation with a form of activated vitamin D such as paricalcitol or alfacalcidol may be beneficial in the case of frail elderly adults with poor renal function.

CONCLUSION

In this study, $25(OH)D_3$ levels were found to be low in women living in nursing homes who were at least able to move about in a wheelchair with assistance. Approximately 50% to 80% of participants were thought to be vitamin D deficient, although this depends somewhat on the cutoff value used for $25(OH)D_3$. In addition, approximately 20% of all participants were thought to have decreased vitamin D activating capacity in the kidneys. Such poor vitamin D activation capacity in the kidneys was present in a similar 20% of people whose $25(OH)D_3$ level was above the cutoff level (16 ng/mL). An unexpectedly large number of women in nursing homes thus had poor vitamin D activation secondary to poor renal function. For vitamin D supplementation, therefore, it may be necessary to make a comprehensive judgment with measurements of intact PTH and CCr or GFR and 1,25 $(OH)_2D_3$ rather than cholecalciferol supplementation based simply on $25(OH)_3$ level.

ACKNOWLEDGMENTS

We are grateful to the 48 nursing homes that cooperated in this study and the many staff members who collected data for this study.

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

This study was supported by a Research Grant for Comprehensive Research on Aging and Health from the Ministry of Health, Labour and Welfare of Japan in 2006 to 2008.

Author Contributions: Yasuhito Terabe: Analysis and interpretation of data, preparation of manuscript. Atsushi Harada: Study concept and design, preparation of manuscript. Haruhiko Tokuda: Acquisition of data, preparation of manuscript. Hiroyasu Okuizumi: Acquisition of participants, preparation of manuscript. Masahiro Nagaya: Acquisition of participants and data, preparation of manuscript. Hirashi Shimokata: Analysis and interpretation of data.

Sponsor's Role: None.

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RESEARCH

Original Research

Decreased Salt Intake in Japanese Men Aged 40 to 70 Years and Women Aged 70 to 79 Years: An 8-Year Longitudinal Study

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ABSTRACT

Background It is not known whether salt intake decreases over time in the same population. This study attempts to describe salt intake for 8 years according to age groups, and examines whether salt intake changes over time in community-dwelling middle-aged and elderly Japanese subjects.

Methods Data were collected as part of the National Institute for Longevity Sciences Longitudinal Study of Aging. Participants included 544 men and 512 women who participated in and completed all nutrition surveys from the first (1997-2000) to fifth (2006-2008) study waves. Each study wave was conducted for 2 years; in individuals, the entire follow-up period was 8 years. Salt and energy intake were calculated from 3-day diet records with photographs. The mixed-effects regression model was used for analysis of repeated measures of salt intake.

Results Mean age and salt intake for study participants at first participation in the survey were 56.5±9.3 years and 12.8±3.3 g/day in men and 55.8±9.4 years and 10.6±2.5 g/day in women, respectively. Mean energy intake decreased in men and women in all age groups from the first to fifth study waves. Eight-year longitudinal data showed that salt intake decreased in men. In stratified analyses by age, mean salt intake in men decreased 0.08 g/year among 40- to 49-year-olds, 0.09 g/year among 50- to 59-year-olds, 0.16 g/year among 60- to 69-year-olds, and 0.14 g/year among 70- to 79-year-olds. For women, mean salt intake decreased 0.08 g/year among 70- to 79-year-olds (P=0.098). After adjusting for energy intake, salt intake was decreased among 60- to 69-year-old men (P=0.049) and increased among 50- to 59-year-old women (P=0.015).

Conclusions Absolute salt intake was decreased among all age groups from 40 to 70 years in men and from 70 to 79 years in women. An increased focus on reducing energy intake resulted in only a modest decrease in salt intake. Although we observed a decline, salt intake still exceeded recommended levels. Efforts that focus on salt reduction are needed to address this important public health problem.

J Am Diet Assoc. 2011;111:844-850.

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Manuscript accepted: December 1, 2010.

0002-8223/$36.00
doi: 10.1016/j.jada.2011.03.020

Japanese have a higher salt intake than Westerners, and a high prevalence of hypertension (1-3). Sodium intake among Japanese and US participants in the International Study of Macro- and Micronutrients and Blood Pressure study (age range 40 to 59 years) was 4,651 mg/day and 3,660 mg/day (salt intake as converted using sodium intake of 11.8 g and 9.3 g), respectively (1). These intakes are above the current World Health Organization recommendation of <2,000 mg/day (4).

Excessive salt intake has adverse effects on blood pressure, and lower salt intake is recommended to prevent hypertension not only in Japan but also in other countries (5,6).

The National Nutrition Survey in Japan indicated that trends in salt intake among subjects aged 1 year and older gradually decreased from 14.0 g/day in 1975 to 11.0 g/day in 2005 (7). However, that survey was a cross-sectional study, and subjects were selected randomly at several survey districts every year (7). Thus, it is unknown if salt intake in the same population decreased over time.

Food consumption and nutrient intake among Japanese have changed markedly during the past 5 decades. For example, Westernization of the Japanese diet has led to decreased consumption of carbohydrates and increased consumption of fat and meat (7,8). In addition, diet differences by age have been reported (9,10). For example, fat density (per 1,000 kcal energy intake) tends to decline as subjects get older (10). To understand trends in salt intake among Japanese subjects, it is essential to examine longitudinal data by age group. To the best of our knowledge, there are no data from prospective cohort studies that focus on salt intake among Japanese subjects.

Our study attempts to describe the salt intake for 8 years according to age groups categorized according to the age at first participation of the study, and to examine the trends in salt intake over time in community-dwelling middle-aged and elderly Japanese subjects.

METHODS

Study Participants

Data for this survey were collected as part of the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA). In this project, the normal aging process has been assessed using detailed questionnaires and medical checkups, anthropometric measurements, physical fitness tests, and nutrition examinations. Details of the study of NILS-LSA are reported elsewhere (11). The initial survey of NILS-LSA involved 2,267 men and women aged 40 to 79 years, including almost 300 men and 300 women for each decade of life. Participants included were sex- and decade age-stratified random samples living in Obu-shi and Higashiura-cho, Aichi Prefecture, Japan. They have been followed every 2 years from the first study wave (November 1997 to April 2000), second study wave (April 2000 to May 2002), third study wave (May 2002 to May 2004), fourth study wave (June 2004 to July 2006), and fifth study wave (July 2006 to July 2008). Each study wave was conducted for 2 years; the total length of the first through fifth waves was 10 years. However in individuals the entire follow-up period was 8 years.

When participants could not be followed-up (eg, they transferred to another area, dropped out for personal reasons, or died), new age- and sex-matched subjects were randomly recruited. All study waves included nearly 1,200 men and 1,200 women. Among them, 621 men and 585 women participated in all five study waves. Some participants (77 men and 73 women) did not complete nutrition surveys from the first to fifth study wave at least one time. Thus, this study includes 544 men and 512 women who participated and completed in all nutritional surveys from the first to fifth study wave.

Age groups were categorized according to age at first participation of the study (November 1997 to April 2000). During an 8-year follow-up from the first to fifth study wave, most participants (446 men and 417 women) changed age groups. Among them, 39 men and 36 women changed age groups from 70 to 79 years to 80 to 89 years. To simplify the analysis, age groups categorized at first participation were used in all analyses.

Written informed consent was obtained from all participants. The Ethics Committee of the National Center for Geriatrics and Gerontology had already approved all procedures of the NILS-LSA.

Nutrition Assessments

Nutritional intakes were assessed by a 3-day diet record. The diet record was completed over 3 continuous days (2 weekend days and 1 weekday) (12). Foods, including seasonings, were weighed separately on a scale before cooking or portion sizes were estimated. Participants used a disposable camera to take photographs of meals before and after eating. Registered dietitians used the photographs to complete missing data, and telephoned participants to resolve any discrepancies or obtain further information when necessary. The averages of the 3-day food and 119 nutrient intakes were calculated, and food was divided into 18 groups according to the fifth edition of the Standard Tables of Food Composition in Japan and other sources (12). Mean salt intake (grams/day) and energy intake (kcal/day) calculated from the 3-day dietary record were used in this study.

Other Measurements

Blood pressure was measured by an automated sphygmomanometer (BP-203RVII, Omron Colin, Tokyo, Japan) after participants had been comfortably seated for at least 5 minutes. Weight and height were measured under a fasting state to the nearest 0.1 kg and 0.1 cm, respectively, with subjects wearing light clothing and no shoes. Body mass index was calculated as weight/height^2 (kg/m^2).

Statistical Analyses

All statistical analyses were conducted with Statistical Analysis System (version 9.1.3, 2006, SAS Institute, Cary, NC) and were done separately by sex. Participants were categorized into four age groups (40 to 49, 50 to 59, 60 to 69, and 70 to 79 years) according to age at first participation.

Comparisons between continuous variables were performed by analysis of variance and trend test. Linear regression models were constructed using the PROC GLM procedure to examine the association between age groups and energy or salt intake.

For analyses of repeated measures of salt intake, the mixed-effects regression model (Proc Mixed) was used. This method is a generalized form of linear regression analysis that allows for repeated measures on each participant while accounting for the considerable variation across participants in overall average salt intake. To estimate the main effects of salt intake by study wave, age group and the interaction of study wave×age group were substituted into the model. Each study wave was conducted for 2 years; the entire follow-up period for each participant was 8 years.

To eliminate the effects of total amounts of food intake on salt intake, a subsequent model included energy intake into covariates in the mixed-effects regression analyses. In addition, linear changes in salt intake over 8 years for each age group were estimated according to the slope of salt intake (grams/day) and the interception based on the mixed-effects regression analyses. Linear changes in energy-adjusted salt intake by age group were also estimated according to the slope of salt intake (grams/day) and the interception.

All reported P values were two-sided. A $P<0.05$ was considered statistically significant, and a $P<0.1$ was considered marginally statistically significant.

RESULTS

Mean (standard deviation) age, average daily dietary intake from 3-day diet records, body mass index, and blood

Table 1. Mean age, average daily dietary intake from 3-day diet records, body mass index, and blood pressure at first participation (first study wave) in the Japanese Longitudinal Study of Aging

	Men (n=544)			Women (n=512)		
Characteristic	**Mean±standard deviation**	**Min**	**Max**	**Mean±standard deviation**	**Min**	**Max**
Age (y)	56.5±9.3	40	79	55.8±9.4	40	78
Nutrition						
Salt (g/d)	12.8±3.3	5	28	10.6±2.5	3	23
Energy (kcal/d)	2,382.4±405.1	1,057	4,433	1,940±308.7	970	2,988
Protein (g/d)	89.5±16.4	39	148	75.2±14.4	40	136
Fat (g/d)	62.2±16.8	17	144	55.7±15.0	21	118
Carbohydrate (g/d)	330.6±67.6	155	608	277.3±48.9	146	483
Salt/energy (g/1,000 kcal)	5.4±1.2	2	10	5.5±1.2	2	10
Body mass index	23.0±2.7	15	33	22.6±2.9	15	38
Systolic blood pressure (mm Hg)	123.0±17.5	72	204	121.2±19.5	78	193
Diastolic blood pressure (mm Hg)	77.0±10.4	52	114	73.7±11.1	49	114

Table 2. Mean energy and salt intake according to age group[a] from the first to fifth study wave in the Japanese Longitudinal Study of Aging

		Study Wave						
Intake	**n**	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**ANOVA[b] *P* value**	**Trend *P* value**
		←——— *mean±standard deviation* ———→						
Energy intake (kcal/d)								
Men (y)								
40-49	149	2,434±418	2,345±372	2,384±360	2,326±385	2,309±362	0.037	0.007
50-59	192	2,414±405	2,359±383	2,321±362	2,305±364	2,314±342	0.024	0.003
60-69	140	2,338±401	2,277±385	2,224±402	2,181±340	2,132±328	<0.001	<0.001
70-79	63	2,264±356	2,181±340	2,123±329	2,045±303	2,024±359	<0.001	<0.001
Women (y)								
40-49	156	1,957±292	1,891±332	1,930±300	1,876±273	1,867±291	0.039	0.010
50-59	174	1,976±314	1,895±303	1,889±283	1,845±308	1,852±288	<0.001	<0.001
60-69	126	1,919±317	1,853±308	1,848±294	1,786±285	1,757±275	<0.001	<0.001
70-79	56	1,828±294	1,781±300	1,754±285	1,723±264	1,680±257	0.007	0.003
Salt intake (g/d)								
Men (y)								
40-49	149	12.37±3.01	11.63±2.56	12.18±2.56	11.92±2.19	11.67±2.48	0.060	0.098
50-59	192	13.04±3.24	12.19±2.87	12.54±2.76	12.46±2.75	12.19±2.52	0.020	0.026
60-69	140	13.11±3.69	12.25±2.87	12.52±2.69	12.28±2.58	11.72±2.74	0.003	0.001
70-79	63	12.41±3.09	11.93±2.60	11.73±2.59	11.50±2.44	11.23±2.74	0.146	0.010
Women (y)								
40-49	156	10.28±2.46	9.81±1.95	10.17±2.00	10.39±1.74	9.95±2.02	0.086	0.899
50-59	174	10.83±2.44	10.22±2.02	10.80±2.16	10.48±1.92	10.86±2.58	0.028	0.560
60-69	126	10.76±2.43	10.36±2.29	10.85±2.31	10.60±1.80	10.32±2.25	0.237	0.311
70-79	56	10.81±2.97	10.14±2.49	10.48±2.38	10.19±2.28	10.04±2.17	0.469	0.157

[a]Age groups were categorized according to the age at first participation.
[b]ANOVA=one-way analysis of variance.

pressure of participants at first participation are shown in Table 1. Mean age of study participants was 56.5±9.3 years for men and 55.8±9.4 years for women. Average daily salt intake was 12.8±3.3 g/day in men and 10.6±2.5 g/day in women; energy intake was 2,382.4±405.1 kcal/day in men and 1,940.0±308.7 kcal/day in women.

Most dietary intakes were higher in men than in women, although intakes of several food items, including fruit, milk, and confectioneries, were higher in women (data not shown). Mean dietary intake was close to the data of the National Nutrition Survey (7), which indicated that the diet of this sample was comparable to that of average Japanese subjects.

Mean energy and salt intake according to age group from the first to fifth study waves are shown in Table 2. Mean energy intake was decreased in men and women in all age groups in the first to fifth study waves (analysis of variance $P<0.05$, trend $P<0.05$). Mean salt intake from

Table 3. Mixed-effects regression analyses of main effects of salt intake (g/day) for 8 years[a] in Japanese Longitudinal Study of Aging

Variable	Model 1[b]		Model 2[c]	
	F	*P* value	*F*	*P* value
Men (n=544)				
Study wave (5 categories)[d]	28.07	<0.001	5.21	0.023
Age group (4 categories)[e]	2.11	0.099	3.80	0.010
Interaction of study wave×age group	0.97	0.406	0.32	0.813
Energy intake (kcal/d)	—	—	631.20	<0.001
Women (n=512)				
Study wave (5 categories)[d]	3.46	0.063	1.69	0.194
Age group (4 categories)[e]	1.41	0.238	3.16	0.024
Interaction of study wave×age group	1.02	0.382	1.05	0.370
Energy intake (kcal/d)	—	—	617.17	<0.001

[a]Eight years was the entire follow-up period in individuals from first to fifth study waves.
[b]Model 1: Study-wave, age group, and interaction of study-wave×age group were entered into the mixed-model analyses.
[c]Model 2: Model 2 included energy intake into the covariates in model 1.
[d]Five categories: First to fifth study-waves.
[e]Four categories: 4 age groups (40-49, 50-59, 60-69, 70-79 years) were categorized according to age at first participation.

the first to fifth study waves decreased among 50- to 59-year-old and 60- to 69-year-old men (analysis of variance $P<0.05$, trend $P<0.05$). In men, salt intake at each study wave was higher among 50- to 59-year-olds and 60- to 69-year-olds than in 40- to 49-year-olds and 70- to 79-year-olds. There was no consistent change in salt intake in women across each age group or study wave.

The mixed-effects regression analyses of the main effects of salt intake for 8 years are shown in Table 3. The main effect of study wave was statistically significant, and after adjustment for energy intake, the main effects of study wave and age group in men and age group in women were significant.

Estimated linear changes in salt intake for 8 years by age group were estimated according to the slope of salt intake. Among men, the slope of salt intake (grams/day) per study wave declined by age group with values of 0.15 g among 40- to 49-year-olds ($P=0.057$), 0.19 g among 50- to 59-year-olds ($P=0.007$), 0.32 g among 60- to 69-year-olds ($P<0.0001$), and 0.29 g among 70- to 79-year-olds ($P=0.017$), respectively. Because each study wave was conducted for 2 years, mean salt intakes in men decreased 0.08 g/year among 40- to 49-year-olds, 0.09 g/year among 50- to 59-year-olds, 0.16 g/year among 60- to 69-year-olds, and 0.14 g/year among 70- to 79-year-olds. For women, the slope of salt intake (grams/day) per study wave among 70- to79-year-olds showed a decline toward a lower intake of 0.17 g or 0.08 g/year, although this value was marginally significant ($P=0.098$).

Estimated linear changes in salt intake by age group after adjusting for energy intake are shown in the Figure. In men, a 0.14-g per study wave decline was observed among 60- to 69-year-olds, which represented a decline of 0.07 g/year ($P=0.049$). In women, a 0.13-g per study wave increase was observed among 50- to 59-year-olds, which represented an increase of 0.06 g/year ($P=0.015$).

DISCUSSION

Eight-year longitudinal data showed that the trends in salt intake declined in men from age 40 to 79 years and in women from age 70 to 79 years among community-dwelling middle-aged and elderly Japanese subjects. After adjusting for energy intake, the trends in salt intake declined among 60- to 69-year-old men; on the other hand, among 50- to 59-year-old women, the trend in salt intake increased. This is the first longitudinal study to assess trends in salt intake stratified by age group categorized according to the age at first participation in the study among middle-aged and elderly Japanese people.

The slope of salt intake by age group declined from 0.08 g/year in 40- to 49-year-olds to 0.16 g/year in 60- 69-year-olds in men and 0.08 g/year in 70- to 79-year-olds in women. Moderate reductions in salt intake decrease systolic blood pressure (13). Intervention trials have shown that sodium reduction lowers blood pressure by 1.7 mm Hg/1 g/24 hour (2), and that increases in sodium intake by 11.7 g/day elevated 24-hour systolic blood pressure by 9 mm Hg among patients with hypertension (14). These studies support the effectiveness of salt restriction in the treatment of hypertension. The World Health Organization has estimated that reducing dietary sodium intake by 50 mmol (2.9 g salt) per day would lead to a 22% reduction in the number of deaths from stroke and a 16% reduction in deaths from coronary heart disease (15).

To estimate changes in blood pressure in this study, we performed subanalyses to examine linear changes in systolic blood pressure or diastolic blood pressure for 8 years by age group. In both men and women, the slope of systolic or diastolic blood pressure per study wave did not significantly decline in any age group (data not shown). In addition, the association between blood pressure and salt intake for 8 years, analyzed by the mixed effect model, was not statistically significant in any age group. Excessive salt intake is a known risk factor for hypertension, although several other risk factors, including age, body weight, and alcohol consumption, are also risk factors for hypertension (16). In this study, absolute salt intake declined in all age groups; however, the amount of salt reduction in this study might be too small to change blood

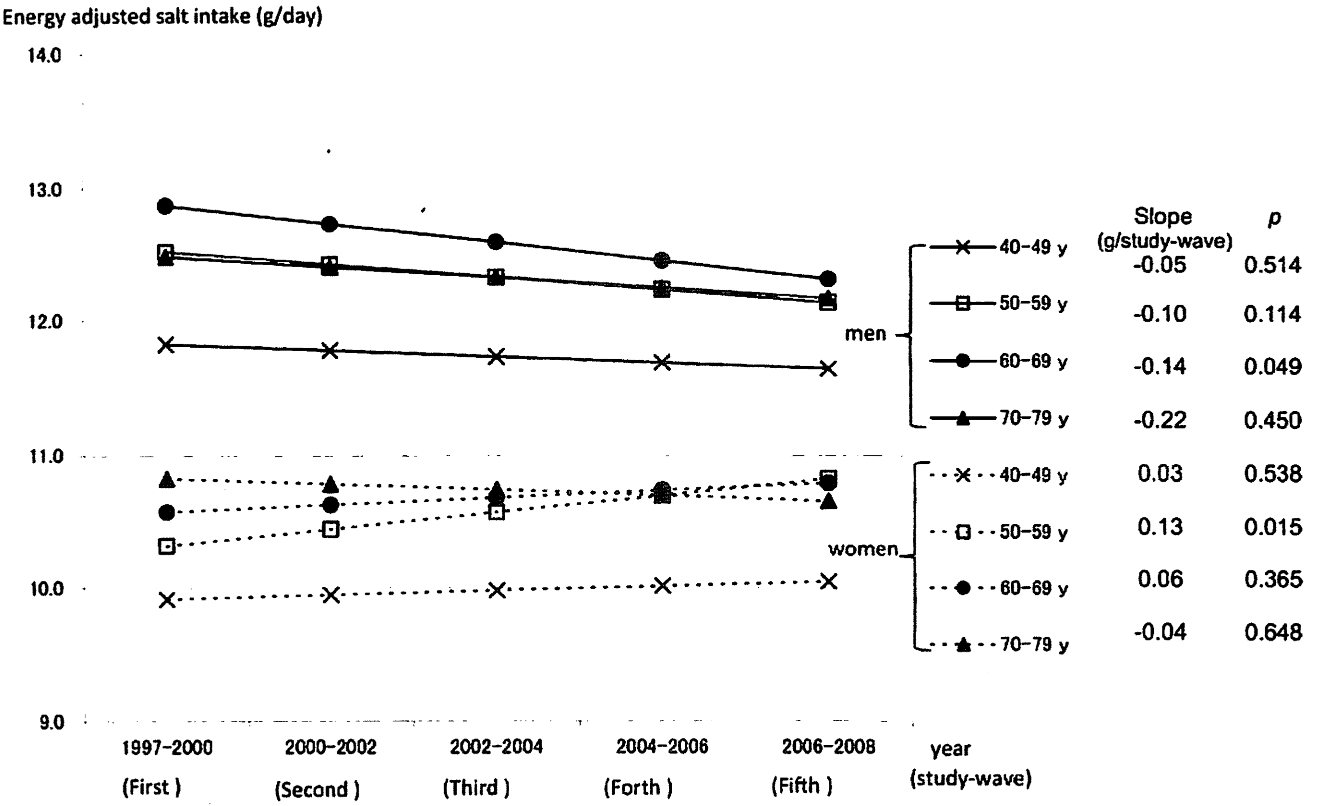

Figure. Estimated linear changes in energy adjusted for salt intake for 8 years[a] by age groups in the Japanese Longitudinal Study of Aging. [a]Eight years was the entire follow-up period in individuals from first to fifth study waves.

pressure. In addition, blood pressure may have been affected by the other above-mentioned risk factors.

Several factors are thought to contribute to the decline of salt intake seen in this study. First, obesity has gradually increased among Japanese men and middle-aged women; in parallel, metabolic syndrome, especially in men, has become a public health issue (17). The Japanese government developed a standard program to reduce visceral obesity that included weight control with restriction of total amounts of food intake (18). The decline of salt intake is mainly achieved by a decline in the quantity of food in the whole diet. Furthermore, Dietary Reference Intakes for Japanese and Healthy Japan 21 proposed by the Japan Ministry of Health, Labor, and Welfare recommend restricting dietary salt intake to <10 g/day for men and <8 g/day for women to achieve antihypertensive effects (19,20). Data on the importance of salt restriction are spread by public health practices and health education, and may have contributed to the decrease in salt intake over time seen in this study. In terms of salt consumption, "Food for special dietary uses" designated by the Japan Ministry of Health, Labor, and Welfare, is becoming more popular in Japan. New low-salt products such as low-salt soy sauce and low-salt *miso* have become available. These new products are essential, as soy sauce and *miso* are staple seasonings in Japanese cuisine. In the International Collaborative Study of Macronutrients, Micronutrients and Blood Pressure study (1), it was reported that sodium intake among Japanese mainly came from soy sauce, commercially processed fish/seafood, salted soups, and preserved vegetables (1). In addition, salt was usually added during home cooking and at the table. In our study, salt intake was assessed by a 3-day diet record. Trained registered dietitians estimated the weight of salt within the dish from diet records and photographs. All food sources, including commercial foods in the diet records, were coded. Thus, we could not examine changes in salt from food sources for methodologic reasons. In addition, Westernization of the Japanese diet during the past five decades might have led to reduced salt intake—the Japanese diet has dramatically changed from a traditional Japanese diet containing high-salt baked fish, *miso* soup, and Japanese pickles to a Westernized diet that contains less salt (21).

Mean energy intake from the first to fifth study waves was decreased in all age groups in both men and women, indicating that the total amount of food intake decreased with age. To eliminate the effects of total amount of food intake on salt intake, adjustment for energy intake was performed. Results showed that the trend of energy-adjusted salt intake declined only among male participants aged 60 to 69 years. This means that a tendency to decrease salt intake was strong in this generation. The reason for this finding may be that the prevalence of circulatory disease, as represented by hypertension, is high among Japanese men aged 60 to 69 years (22). Thus, these participants might make a conscious effort to restrict salt intake.

On the other hand, among women aged 50 to 59 years, the trend of energy-adjusted salt intake increased. This may imply that women aged 50 to 59 years prefer a saltier diet. Losses in both taste and smell occur during the normal aging process and with various diseases (23,24). In particular, the ability to recognize salty and bitter tastes is reported to decline with age, whereas the perception of sweet and sour tastes does not typically decline (25). Elderly male and female subjects have been shown to prefer higher concentrations of salt in cross-sectional studies (26-28). Higher salt intake among women aged 50 to 59 years might be caused by a decline in the perception of the taste of salt as well as an increased preference for salt (26,29-31). Considering that the mean age of menopause among Japanese women is 50.5 years (32), and the association between salty taste preferences and hypertension becomes stronger in women aged 50 years and older (33), it is possible that advising women older than age 50 years to reduce salt consumption might be an effective public health initiative.

Absolute salt intake was decreased among all age groups from the 40s to 70s in men and among 70- to 79-year-old women, but it did not reach the recommended dietary salt intake of <10 g/day for men and <8 g/day for women (19,20). The Dietary Reference Intakes for Japanese in 2010 (34) suggested greater restrictions in the upper recommended limit of salt intake—that is, 9 g/day for men and 7.5 g/day for women. Salt intake is still high in Japan, and promotion of salt restriction is important. Nutrition habits formed during childhood are difficult to change among elderly people, who prefer to stick to old customs (35). For example, strict restriction of salt intake from about 13 g/day (the mean salt intake in Japan) down to 6 g/day was thought to cause loss of appetite and decrease quality of life in elderly people (3). Therefore, it has been recommended that salt intake be initially restricted to below 10 g/day, and then slowly decreased thereafter (3). To prevent higher salt intake by elderly people, it may be useful to encourage a taste for less salt in childhood so that better dietary habits can be more easily carried over into adulthood.

Our study had several limitations. Eight years was too short a period to investigate trends in salt intake. However, because data from this study are drawn from NILS-LSA, a population-based prospective cohort study, future analyses will be able to examine ongoing trends in salt intake. In addition, adjustment for a wide range of potential confounding variables, including a history of hypertension, medications, or dietary interventions, was not performed. Because seniors are thought to have a higher incidence of these factors than younger participants, this lack of adjustment could have affected our results. In a subanalysis, we estimated linear changes in salt intake by age group after adjusting for a history of hypertension at first participation, and findings in this study did not change (data not shown). Drewnowski and colleagues (36) reported that factors other than salt preferences, including concerns about nutrition and health, might influence dietary salt consumption. Further analyses are needed to adjust for potential confounding variables that may affect salt intake.

One strength of our study was that it assessed trends of salt intake in the same population stratified by age groups. To the best of our knowledge, there are no longitudinal data that assess salt intake. Furthermore, our data have the advantage of investigating mean daily salt consumption using a 3-day diet record with photographs. The dietary study protocol has not changed from the baseline study, and most of the trained registered dietitians remained on board. The degree of agreement in dietary coding of salt intake between dietitians was high (data not shown), and the registered dietitians meet twice a month to adjust for differences of dietary coding based on a 3-day dietary record from the baseline survey. In addition, the average salt or dietary intake in the present study was similar to that given in Japanese participants aged 40 to 59 years in the International Collaborative Study of Macronutrients, Micronutrients and Blood Pressure (1) or the National Nutrition Survey in Japan (7). Therefore, our results may be more applicable in community-dwelling middle-aged and elderly subjects.

Another strength is that salt intake was analyzed by age group. Food consumption and nutrient intake among Japanese have changed during the past 5 decades. For example, Westernization of the Japanese diet has led to decreased consumption of carbohydrates and increased consumption of fat and meat (7,8). In addition, age differences in diet have been reported (9,10), with fat density (per 1,000 kcal energy intake) among older age groups showing a declining trend (10). In fact, food consumption was different among age cohorts in our subjects. Among both men and women, older age groups tended to eat more vegetables, fruits, dairy products, and fish, and less meats and fats compared with younger age groups (data not shown). Salt intake at each study wave was higher among those aged 50 to 59 years and 60 to 69 years than those aged 40 to 49 years and 70 to 79 years. Because dietary content differs between generations, it is essential to examine data separated by age groups to understand trends in salt intake among Japanese subjects.

CONCLUSIONS

Eight-year longitudinal data showed that the trend of absolute salt intake declined among all age groups from the 40s to 70s in men and among those aged 70 to 79 years in women. However, the increased focus on reducing energy intake has resulted in only a modest decrease in salt intake. Although we observed a decline, salt intake still exceeded recommended levels. Efforts that focus on salt reduction are needed to address this important public health problem.

STATEMENT OF POTENTIAL CONFLICT OF INTEREST: No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT: This work was supported in part by grants from the Japanese Ministry of Education, Culture, Sports, Science, and Technology (no. 22790584 to R.O.).

ACKNOWLEDGEMENTS: The authors thank the study participants and their colleagues in the NILS-LSA for conducting the survey for this study.

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Geriatrics Gerontology INTERNATIONAL 1st Impact Factor in June 2010 Medline Indexed

Geriatr Gerontol Int 2011; **11:** *39–49*

ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Spatiotemporal components of the 3-D gait analysis of community-dwelling middle-aged and elderly Japanese: Age- and sex-related differences

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Aim: To describe age- and sex-related differences in gait patterns of community-living men and women using 3-D gait analysis.

Methods: Subjects (n = 2006) aged 40–84 years participated in the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA). Spatiotemporal components, including velocity, step length, step frequency, and double support time during a gait cycle, were calculated from 3-D coordinates and vertical force data. Velocity, step length and step frequency were normalized by leg length and acceleration due to gravity, and double support time was normalized to gait cycle duration.

Results: Spatiotemporal walking variables of brisk velocity and step length were significantly greater in men than in women, while comfortable velocity and comfortable and brisk step frequencies and double support times were greater in women than in men. Age-related changes were marked at 70–84 years in most spatiotemporal variables in both sexes during comfortable walking. During brisk walking, age-related changes were observed from a younger age than during comfortable walking, and there were sex-related differences.

Conclusion: The age-related gait alteration was obvious among those aged 70 years and older, and it accelerated markedly in women's brisk walking intensity. **Geriatr Gerontol Int 2011; 11: 39–49.**

Keywords: aging, gait, sex, velocity, walking.

Accepted for publication 27 April 2010.

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Author contributions: W. D. designed the study, obtained the funding, analyzed data and drafted the original article; R. K. interpreted data and advised on revising the article; K. H. Y. supervised data processing and prepared the article; and F. A. and H. S. originated the study, created the gait analysis program, supervised all aspects of its implementations, and contributed to obtaining the funding and revising the article. All authors conducted epidemiological studies on geriatric disease and human aging in Obu, Aichi, Japan, and read and approved the manuscript.

doi: 10.1111/j.1447-0594.2010.00632.x

Introduction

Age-related impairment of ambulatory ability is a critical component for inhibiting activities of daily living (ADL). For instance, decreased gait velocity observed in elderly is an indicator of common distinct diseases[1,2] and falls,[3–6] which lead to functional dependence[7–11] or death.[12] The prevalence and incidence of gait disorders increase with age in elderly persons.[13,14] The early presence of dynamic postural stability may provide more essential information for preserving adequate mobility, delaying the onset of functional decline and encouraging early appropriate lifestyle changes to promote active healthy aging.[6,8,10,11,15]

Previous studies examined age-related changes in spatiotemporal gait parameters including velocity, step length, step frequency (cadence) and selected stride time variables (single and double support time and swing time).[7,8,10,16–21] These performance-based gait variables were often measured by a 3-D gait system that computes the motions of the body center of mass (COM) and each segment, which can accurately evaluate the control of dynamic balance during walking.[22,23] The COM velocity on the 3-D gait system identified the effect of age on older gait in limited comparison between young and older groups.[24–26] It showed that the 3-D analyses conducted have not determined from which age group the accelerated decline of gait started. The collection of data using a large sample size with a broad age range could resolve the issue.

Age-related gait studies have recruited either men or women, or both sexes have been analyzed together: a few studies previously focused on sex-related changes on gait pattern with advancing age. Callisaya *et al.*[8] revealed the effects of sex and age on gait velocity in elderly men and women aged 60–86 years. The results of other studies of various age ranges and groups[17,19,27] to determine which sex shows an earlier age of accelerated gait velocity decrease have differed. The conflicts may partly depend on the sampling and subject characteristics.

Therefore, to understand the aging process in gait measures across the adult lifespan, a large sample size ranging from young or middle-aged to elderly men and women should be warranted. We decided to reinvestigate the previous findings. In the present study, the gait of elderly subjects was investigated based on comfortable and brisk spatiotemporal gait parameters with a 3-D gait analysis system; a large number of subjects were recruited. We found the age-related changes in gait by sex among middle-aged and elderly men and women in Japan. This may contribute to a beneficial effect on assessing gait in elderly people and making an adequate walking exercise program suitable for targeted age groups.

Methods

Study sampling

The present gait analysis is part of the third phase of the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA); this study includes medical, physiological, nutritional and psychological examinations. The study began in November 1997 (the first phase), and the third phase lasted from May 2002 to May 2004. The subjects were age- and sex-stratified random samples of the population, aged 40–84 years, who lived in Obu-shi and Higashiura-cho, Aichi, Japan. These participants were chosen from the residents registered with local governments. All subjects lived or had lived at their home in the community and had Japanese nationality.[28] The NILS-LSA was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology. Details of the NILS-LSA have been previously published.[28,29]

Of 2378 men and women aged 40–84 years in the third phase examination, 1017 men and 989 women (84.2% of all participants, Table 1) completed the walking tests and were included in the present analysis. The participants also completed a structured questionnaire dealing with their socioeconomic characteristics, cardiovascular risk factors and medical history.[28,29] Exclusion criteria included a current medical history of arthritis[6,8] and fractures (musculoskeletal disorders),[30] stroke[1] and Parkinson's disease (neurological disorders),[8,31] and ischemic heart disease and chronic bronchitis (Table 1).[32,33] These diseases were checked and excluded as the possible cause of gait disorders or spatiotemporal gait parameter changes by a physician before the walking tests. One participant who was diagnosed with dementia was excluded because she had a limited ability to comprehend or execute the test, which was judged by a physician. The existence of walking difficulty in activities of daily living (ADL)[11,15] was also excluded (Table 1). The participants who met the above-mentioned requirements and could walk 10 m independently without a walking aid were included in the current gait analysis and therefore 372 participants of the third phase examination were totally excluded.

Protocol

All participants wore short-sleeved T-shirts and shorts for testing. Shoes were made from the same material that had a vinylon/polyester and cotton blended upper part and a urethane foam outsole (Moonstar, Fukuoka, Japan), and were selected to exactly fit each participant's feet. Ten 2.5-cm diameter optical markers were placed on the participants' left and right sides on the fifth metatarsal heads, the lateral malleoli, the lateral epicondyles, and one-third of the way along the straight lines from the greater trochanters to the anterior