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ORIGINAL

Risk factors for osteoporosis in elderly people with a cohort study – Using calcaneus stiffness as an index –

Yoshimi NAKAYAMA[1, 2], Fumio SAKAUCHI[2], Mitsuru MORI[2]

[1] Hokkaido Obihiro Public Health Center

[2] Department of Public Health, Sapporo Medical University School of Medicine

(Chief: Prof. M. Mori)

ABSTRACT

We investigated risk factors for decreased calcaneus stiffness as an index of osteoporosis in Japanese elderly persons with a cohort study.

Calcaneus stiffness was obtained through ultrasonographic heel measurement for 214 subjects (162 women and 52 men) who voluntarily participated in the baseline survey in 2000. Body mass index (BMI), medical history, oral health status, smoking cigarettes, alcoholic drinking, physical activities, and frequency of various foods intake were surveyed at that time. Stiffness was again measured among 93 subjects (70 women and 23 men) of them (43.5%) in the follow-up survey in 2005. Risk factors for decreased stiffness were evaluated using the unconditional logistic regression model adjusted for age and BMI by sex.

Tooth loss was not associated with risk of decreased stiffness. From the results of stiffness in 2005 as a dependent variable, less frequent intake of vinegared dishes (OR=3.9, 95%CI: 1.3-11.6) and seaweed (OR=4.5, 95%CI: 1.5-14.2) in females as well as less frequent intake of green or yellow vegetables in males (OR=28.0, 95%CI: 2.5-317.4) were significantly associated with risk of decreased stiffness. From the results of change in stiffness as a dependent variable, less frequent intake of soybean products except for fermented soybeans (OR=3.2, 95%CI: 1.1-9.1) was significantly associated with risk of decreased stiffness in females. None of the other variables were significantly associated with risk of decreased stiffness.

Dietary habits might play a role in calcium enrichment of the systemic bone. Further study is necessary to assess the relationship of dietary habits to risk of osteoporosis.

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Key words: Osteoporosis, Stiffness, Dietary habits

1 Introduction

Osteoporosis is a skeletal disorder leading to increased bone fragility and an increased risk of fracturing[1,2]. This is a major public problem in the elderly population as this disorder is generally increasing with age. Risk factors for osteoporosis have been extensively studied and it is said that age, thinness, smoking, menopause, alcohol, caffeine, medication (e.g., steroids), lack of calcium intake, lack of exercise, and heredity may increase the risk of osteoporosis[3,4]. Although there is a report showing that tooth loss was not directly associated with systemic bone density[5], several studies have suggested the association between systemic bone loss and tooth loss[6,7].

Most studies used dual-energy x-ray absorptiometry (DEXA) for measuring bone density, and DEXA measurement is the standard procedure in evaluating patients at risk for osteoporosis[8,9]. However, Yang et al.[8] reported that quantitative ultrasonography was significantly correlated with bone mineral density measured by DEXA. When stiffness of calcaneus measured with ultrasonography became lower, it has been shown that osteoporosis would be more likely present[10]. Ultrasonography is especially useful for the epidemiological survey in the community, because safeness would be guaranteed without using x-ray.

Epidemiological study has not been conducted thoroughly enough to assess the association between dietary habits and osteoporosis. Although the association between tooth loss and systemic bone loss has been researched in some studies, most of these study designs were a cross-sectional type. Limitation of cross-study design is well known with regard to identify a risk factor

of disease. Therefore, we investigated risk factors for decreased calcaneus stiffness as an index of osteoporosis in Japanese elderly persons with a cohort study.

2 Methods

2.1 Study subjects

People of over 60 years of age were recruited for early detection of osteoporosis and dental problems in October and November of 2000, in the Okhotsk area, located in the eastern part of Hokkaido, the northern island of Japan. Public announcement was distributed from municipal magazines of this area, and 214 people (162 women and 52 men) voluntarily participated in this baseline survey.

All of them were asked to participate in the follow-up survey in September and October of 2005, about 5 years later from the baseline survey, and 93 subjects (70 women and 23 men) of 214 subjects (43.5 %) participated in this follow-up survey. Among 121 non-participants, 11 subjects passed away, 13 entered into nursing homes or group homes, 9 moved out to other areas, and the residual 88 subjects declined to participate.

Before the survey was conducted, written informed consent was obtained from all the participants. This study had been approved by the Ethical Committee of Sapporo Medical University.

2.2 The baseline survey in 2000

At the baseline survey, public health nurses interviewed the subjects with the structured questionnaire. The surveyed items were demographic factors including age and sex, history of systematic diseases, experience of smoking (current or past smoking), experience of alcohol drinking (current or past drinking), pain in the foot or lumbago, physical activities in the past 10 years, present eating frequency of foods such as milk, cheese or yogurt, small fish, fish, meat, green or yellow vegetables, vinegared dishes, soybeans products, seaweed, processed foods, and so on.

Dental examination was conducted by a trained dentist (the first author) under sufficient artificial light, with dental mirrors, and explorers. The contents of the dental examination were diagnoses of dental caries (treated teeth, untreated teeth, and missing teeth). DMF (Decayed, Missing and Filled teeth) was defined as the total number of decayed teeth, missing teeth, and filled teeth per person.

Anthropometric measurements and measurement of calcaneus stiffness were done by a clinical technologist. Body mass index (BMI) was obtained by dividing weight in kilograms by height in meters squared. Ultrasonographic heel measurement (A-1000 Express from Lunar, U. S. A) was used for calcaneus stiffness.

2.3 The follow-up survey in 2005

Interview items at the follow-up survey in 2005 were almost the same as the baseline survey. The dental examination was conducted by the same dentist as in the baseline survey. Anthropometric measurements and measurement of calcaneus stiffness were also performed by a clinical technologist in the follow-up survey using the same devices.

2.4 Statistical analyses

We compared the baseline data of 93 participants with the data of 121 non-participants using Student's t-test and Wilcoxon rank-sum test by sex, and we compared the baseline data with the follow-up data using the McNemar's test and the Spearman rank correlation test by sex. The adjusted odds ratios (OR) and their 95 % confidence interval (CI) of various variables for stiffness in 2005 were estimated with the unconditional logistic regression model. Those for change of stiffness (stiffness in 2005 minus stiffness in 2000) were also estimated with the same method. Tests of statistical significance were based on a two-sided P value, and the α-error was set at the 5 % level. The SAS system (ver. 9.1) was employed for the analysis.

3 Results

Table 1 shows results from comparison of the baseline data in 2000 of the 93 follow-up participants with the data of the 121 non-participants. Age, height, weight, BMI, missing teeth and Stiffness were not significantly different for either the males or the females.

Tables 2 and 3 show results from comparison of the data at the baseline survey in 2000 years with the data at the follow-up survey in 2005. As shown in Table 2, the average age at the baseline survey was 74.7 years (the standard deviation, SD 3.1) for males and 71.9 years (SD 4.7) for the females. Stiffness index was quite similar between the data at the baseline survey and at the follow-up survey for both the males and females. Statistically significant positive correlations were found between stiffness in 2000 and in 2005 in the males (Spearman rank correlation coefficient, $r=0.81$, $p < 0.0001$, the figures were not shown) as well as in the females ($r=0.83$, $p < 0.0001$). BMI was also similarly correlated between

2000 and 2005 (males; r=0.91, p < 0.0001, females; r=0.83, p < 0.0001, the figures were not shown).

As shown in Table 3, missing teeth (p=0.0253) and DMF (p=0.0143) had significantly increased from 2000 to 2005 for the females. However, edentulous jaws were not significantly changed for either the males or the females.

Table 4 shows age and BMI adjusted odds ratios for stiffness in 2005 by sex. We divided stiffness as well as number of missing teeth by the median of both males and

Table 1 Comparison of baseline characterisitics in the follow-up participants and in the follow-up non-participants by sex.

		Males			Females		
Variables		Participants (n=23)	Non-participants (n=29)	p-value	Participants (n=70)	Non-participants (n=92)	p-value
Age (year)	Mean±SD	74.7±3.1	75.1±4.8	p=0.7541#	71.9±4.7	73.3±5.5	p=0.0873#
Height (cm)	Mean±SD	160.2±6.8	157.9±5.0	p=0.1758#	148.1±5.5	147.7±5.5	p=0.6497#
Weight (kg)	Mean±SD	60.5±8.0	60.0±6.2	p=0.783#	53.1±6.5	52.8±8.5	p=0.8496#
BMI	Mean±SD	23.6±3.0	24.1±2.4	p=0.5456#	24.2±2.8	24.2±3.5	p=0.9843#
Missing teeth	Mean±SD	20.8±9.4	15.6±10.4	p=0.1495$	18.1±9.2	19.9±8.4	p=0.2912$
Stiffness	Mean±SD	76.4±14.0	71.7±15.2	p=0.1403$	56.5±12.7	54.6±13.1	p=0.1969$

SD: standard deviation

#: Student's t-test

$: Wilcoxon rank-sum test

Table 2 Comparison of body characterisitics in the baseline survey in 2000 and at the follow-up survey in 2005 by sex.

		Males (n=23)		Females (n=70)	
Variables		2000	2005	2000	2005
Age (year)	Mean±SD	74.7±3.1	79.7±3.2	71.9±4.7	76.7±4.5
Height (cm)	Mean±SD	160.2±6.8	160.3±6.9	148.1±5.5	148.5±5.6
Weight (kg)	Mean±SD	60.5±8.0	59.1±8.5	53.1±6.5	51.7±7.2
BMI	Mean±SD	23.6±3.0	23.0±3.1	24.2±2.8	23.5±3.2
Stiffness	Mean±SD	76.4±14.0	75.6±15.7	56.5±12.7	57.4±13.5

SD: standard deviation

Table 3 Comparison of tooth characteristics in 2000 and in 2005 by sex.

	Males (n=23)			Females (n=70)		
	2000	2005	p-value	2000	2005	p-value
Filled teeth						
≦3 (≦6 for females)	14	15		36	37	
≧4 (≧7 for females)	9	8	p=0.3173	34	33	p=0.5637
Mean±SD	4.6±6.3	4.1±6.0		7.2±6.9	7.0±6.8	
Decayed teeth						
0	21	20		59	59	
≧1	2	3	p=0.5637	11	11	p=1.0000
Mean±SD	0.1±0.4	0.3±0.9		0.4±1.6	0.4±1.4	
Missing teeth						
≦20 (≦17 for females)	7	6		32	27	
≧21 (≧18 for females)	16	17	p=0.3173	38	43	p=0.0253
Mean±SD	20.8±9.4	21.9±8.7		18.1±9.2	18.9±8.8	
DMF						
≦25	6	4		24	18	
≧26	17	19	p=0.1573	46	52	p=0.0143
Mean±SD	25.5±5.6	26.3±4.5		25.7±3.2	26.3±2.8	
Edentulous jaw						
No	14	13		49	47	
Yes	9	10	p=0.3173	21	23	p=0.1573

DMF: Total number of decayed teeth, missing teeth or filled teeth per person.

p-value: McNemar's test

S: standard deviation

females. The female subjects who had not frequently eaten vinegared dishes (OR=3.9, 95 % CI: 1.3-11.6) or seaweed (OR=4.5, 95 % CI: 1.5-14.2) were more likely to have low stiffness than those who had eaten them frequently. The male subjects who had not frequently eaten green or yellow vegetables were more likely to have low stiffness than those who had eaten them frequently (OR=28.0, 95 % CI: 2.5-317.4). However, low stiffness was not associated with systematic disease, pain in the foot or lumbago, missing teeth, DMF, edentulous jaw, smoking, drinking, physical activities, frequency of drinking milk, eating cheese or yogurt, small fish, meat, fish,

Table 4 Age and BMI adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for stiffness in 2005 with the logistic regression analysis by sex.

	Males			Females		
Variables in the survey in 2000	Stiffness≦75	Stiffness≧76	OR (95 % CI)	Stiffness≦55	Stiffness≧56	OR (95 % CI)
Systematic disease: Absence	5	4	1.0	9	8	1.0
Presence	7	7	0.9 (0.2−5.0)	26	27	0.5 (0.1−1.7)
Pain in the foot or lumbago: No	3	4	1.0	14	12	1.0
Yes	9	7	1.8 (0.3−11.2)	21	23	0.8 (0.3−2.2)
Number of missing teeth: ≦25 (≦ 19 for females)	6	6	1.0	14	21	1.0
≧26 (≧ 20 for females)	6	5	1.0 (0.2−5.5)	21	14	1.6 (0.6−4.7)
DMF: ≦25	4	2	1.0	8	16	1.0
≧26	8	9	0.2 (0.0−2.6)	27	19	1.8 (0.6−5.5)
Edentulous jaw: No	7	7	1.0	22	27	1.0
Yes	5	4	1.1 (0.2−6.3)	13	8	1.7 (0.6−5.4)
Experience of smoking: No	2	4	1.0	31	32	1.0
Yes	10	7	3.8 (0.4−32.4)	4	3	1.2 (0.2−6.2)
Experience of drinking: No	6	6	1.0	31	33	1.0
Yes	6	5	0.8 (0.1−4.2)	3	2	1.4 (0.2−9.4)
Duration of physical activities per day: ≧1 hours	4	7	1.0	19	17	1.0
≦30 minutes	8	4	4.5 (0.7−29.1)	16	18	0.7 (0.2−1.8)
Frequency of milk: Everyday	6	8	1.0	18	20	1.0
≦5 times a week	6	3	2.5 (0.4−15.9)	17	15	1.9 (0.6−5.4)
Frequency of cheese or yogurt: ≧Twice a week	2	3	1.0	20	18	1.0
Seldom	10	7	2.5 (0.3−20.9)	15	16	0.9 (0.3−2.4)
Frequency of Small fish: ≧4 times a week	3	3	1.0	9	16	1.0
≦3 times a week	9	8	0.8 (0.1−7.0)	26	19	2.4 (0.8−7.0)
Frequency of Meat: ≧4 times a week	4	1	1.0	10	7	1.0
≦3 times a week	8	10	0.2 (0.0−2.1)	25	28	0.8 (0.2−2.5)
Frequency of Fish: ≧4 times a week						
(Everyday for females)	8	5	1.0	18	12	1.0
≦3 times a week	4	6	0.3 (0.0−1.9)	17	23	0.4 (0.1−1.2)
(≦5 times a week for females)						
Frequency of green or yellow vegetables: Everyday	2	9	1.0	24	29	1.0
≦5 times a week	10	2	28.0 (2.5−317.4)	11	6	2.5 (0.7−8.5)
Frequency of vinegared dishes: ≧Twice a week						
(≧4 times a week for females)	6	6	1.0	15	24	1.0
Seldom	6	5	1.3 (0.2−6.8)	20	11	3.9 (1.3−11.6)
(≦3 times a week for females)						
Frequency of Soybean products other than natto (fermented soybeans):						
≧ 4 times a week	6	4	1.0	21	21	1.0
≦ 3 times a week	6	7	0.4 (0.1−2.6)	14	13	1.1 (0.4−3.2)
Frequency of fermented soybeans: ≧4 times a week	5	2	1.0	10	14	1.0
≦3 times a week	7	9	0.3 (0.0−2.4)	25	21	2.1 (0.7−6.3)
Frequency of seaweed: ≧4 times a week	4	3	1.0	14	23	1.0
≦3 times a week	8	8	0.6 (0.1−4.4)	21	12	4.5 (1.5−14.2)
Frequency of processed foods: ≧Twice a week	3	5	1.0	15	11	1.0
Seldom	9	6	3.5 (0.5−23.5)	20	23	0.6 (0.2−1.8)

Systematic disease: Diabetes mellitus, cardiovascular disease, stroke, cancer, and so on.

DMF: Total number of decayed teeth, missing teeth, and filled teeth per person.

fermented soybeans, soybean products except for fermented soybeans, processed food.

Table 5 shows age and BMI adjusted odds ratios for change from 2000 to 2005 in stiffness by sex. We divided change of stiffness into below minus 1 and more than 0 both in males and females. The female subjects who had not frequently eaten soybean products except for fermented soybeans were more likely to have decreased stiffness than those who had eaten them frequently (OR=3.2, 95 % CI: 1.1-9.1). However, change of stiffness was not associated with systematic disease, pain in the foot or lumbago, missing teeth, DMF, edentulous jaw, smoking, drink-

Table 5 Age and BMI adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for change of stiffness from 2000 to 2005 with the logistic regression analysis by sex.

	Males			Females		
Variables in the survey in 2000	Change of stiffness≦−1	Change of stiffness ≧0	OR (95 % CI)	Change of stiffness≦−1	Change of stiffness≧0	OR (95 % CI)
Systematic disease: Absence	5	4	1.0	8	9	1.0
Presence	8	6	1.0 (0.2−5.9)	18	35	0.5 (0.2−1.7)
Pain in the foot or lumbago: No	4	3	1.0	8	18	1.0
Yes	9	7	0.9 (0.1−5.5)	18	26	1.6 (0.6-4.6)
Number of missing teeth: ≦25 (≦19 for females)	7	5	1.0	12	23	1.0
≧26 (≧20 for females)	6	5	0.8 (0.1−4.5)	14	21	1.3 (0.5−3.8)
DMF: ≦25	5	1	1.0	10	14	1.0
≧26	8	9	0.1 (0.0−1.6)	16	30	0.7 (0.2−2.1)
Edentulous jaw: No	8	6	1.0	17	32	1.0
Yes	5	4	0.8 (0.1−4.7)	9	12	1.4 (0.5−4.1)
Experience of smoking: No	4	2	1.0	24	39	1.0
Yes	9	8	0.4 (0.0−3.5)	2	5	0.6 (0.1−3.6)
Experience of drinking: No	5	6	1.0	24	40	1.0
Yes	8	4	2.4 (0.4−13.4)	1	4	0.4 (0.0−3.9)
Duration of physical activities per day: ≧1 hours	5	6	1.0	12	24	1.0
≦30 minutes	8	4	2.8 (0.5−17.0)	14	20	1.4 (0.5−3.7)
Frequency of milk: Everyday	9	5	1.0	14	24	1.0
≦ 5 times a week	4	5	0.3 (0.0−2.1)	12	20	1.1 (0.4−2.9)
Frequency of cheese or yogurt: ≧ Twice a week	2	3	1.0	14	24	1.0
Seldom	11	6	3.1 (0.4−27.1)	11	20	1.0 (0.4−2.6)
Frequency of Small fish: ≧ 4 times a week	4	2	1.0	7	18	1.0
≦ 3 times a week	9	8	0.6 (0.1−5.8)	19	26	1.9 (0.6-5.4)
Frequency of Meat: ≧ 4 times a week	3	2	1.0	5	12	1.0
≦ 3 times a week	10	8	1.0 (0.1−8.4)	21	32	1.7 (0.5−5.5)
Frequency of Fish: ≧ 4 times a week						
(Everyday for females)	7	6	1.0	11	19	1.0
≦ 3 times a week	6	4	1.5 (0.2−9.3)	15	25	1.1 (0.4−3.0)
(≦ 5 times a week for females)						
Frequency of green or yellow vegetables: Everyday	7	4	1.0	17	36	1.0
≦ 5 times a week	6	6	0.5 (0.1−2.7)	9	8	2.5 (0.8−7.7)
Frequency of vinegared dishes: ≧ Twice a week						
(≧ 4 times a week for females)	6	6	1.0	13	26	1.0
Seldom	7	4	1.8 (0.3−9.7)	13	18	1.5 (0.5−3.9)
(≦ 3 times a week for females)						
Frequency of Soybean products other than natto (fermented soybeans):						
≧ 4 times a week	6	4	1.0	11	31	1.0
≦ 3 times a week	7	6	0.5 (0.1−3.5)	14	13	3.2 (1.1−9.1)
Frequency of fermented soybeans: ≧ 4 times a week						
≦ 3 times a week	5	2	1.0	9	15	1.0
Frequency of seaweed: ≧ 4 times a week	8	8	0.2 (0.0−2.0)	17	29	1.0 (0.3−2.7)
≦ 3 times a week	5	2	1.0	14	23	1.0
Frequency of processed foods: ≧ Twice a week	8	8	0.4 (0.1−3.4)	12	21	0.9 (0.4−2.5)
Seldom	5	3	1.0	9	17	1.0
Systematic disease: Diabetes mellitus, cardiovascular disease, stroke, cancer, and so on	8	7	0.6 (0.1−4.1)	17	26	1.2 (0.4−3.4)

DMF: Total number of decayed teeth, missing teeth, and filled teeth per person.

ing, physical activities, frequency of drinking milk, eating cheese or yogurt, small fish, meat, fish, green or yellow vegetables, vinegared dishes, fermented soybeans, seaweed, processed food.

4 Discussion

May et al.[11] suggested tooth loss was associated with lower bone mineral density at the hip and spine in men, although they used self-reported tooth loss for the analysis. Taguchi et al.[12] reported that women with fractures of the thoracic spine compared with women without those were more likely to lose teeth by a cross-sectional study. Several cross-sectional studies also found the number of missing teeth with osteoporotic women were more than those with normal women[2,13,14]. Several other cross-sectional studies reported that tooth loss was associated with bone mineral density loss in women[6,15-17]. Krall et al.[7] indicated women who lost teeth during the 7-year follow-up experienced less favorable changes in bone mineral density in the whole body, hip, and spine compared with women who lost no teeth. However, tooth loss was not significantly associated with decreased stiffness in our cohort study, similar to several reports[5,18].

In this cohort study, less frequent intake of vinegared dishes, seaweed and soybean products was shown to be associated with decreased stiffness in females, and less frequent intake of green or yellow vegetables was shown to be associated with decreased stiffness in males. Green or yellow vegetables are included absorbable calcium[19]. Kishi et al.[20] suggested that dietary vinegar affected intestinal calcium absorption. Seaweed high in lysine and arginine aid in the increased absorption of calcium[21]. Zhang et al.[22] reported that higher soy protein and isoflavone intake were significantly associated with lower risk of fracture in postmenopausal women. Harkness et al.[23] suggested that soy isoflavone was effective to significantly decrease bone resorption in postmenopausal women. Dietary habits might play a role in calcium enrichment of systemic bone.

Lack of exercise, smoking and alcohol are commonly known as risk factors for osteoporosis[3,4]. However, these were not significantly associated with decreased stiffness in our cohort study. Among females, we guessed that low smoking rates and low alcohol drinking rates might be related to these results.

There are some limitations to our study. First, our measurement method of bone density was different than prior studies. Most studies used DEXA (dual-energy x-ray absorptiometry). However, Yang et al.[8] reported that quantitative ultrasonography was siginificantly correlated with bone mineral density by DEXA. Secondly, we didn't inquire about eating volume. If we checked not only eating frequency but also the eating volume, our results could provide more valid information. Thirdly, the proportion of the subjects participated in the follow-up survey among the subjects participated in the baseline survey was not high enough (43.5％), and this fact might be a source of selection bias. However, after evaluating possible non-response bias, there were no significant differences in age, height, weight, BMI, number of missing teeth and stiffness between the participants and the non-participants in the follow-up survey (Table1). Fourthly, as subjects were invited to public participation, it might cause self-selection bias that people who are strongly health conscious got together. Further study is necessary to assess the relationship of dietary habits to risk of osteoporosis.

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Address for correspondence:
Yoshimi Nakayama
Department of Public Health, Sapporo Medical University
School of Medicine, South 1, West 17, Chuo-ku, Sapporo 060-8556 Japan
TEL: 011-611-2111(2742)
FAX: 011-641-8101
E-mail : nakayo@sapmed.ac.jp

コホート研究による高齢者の骨粗鬆症のリスク要因について
―踵骨のstiffness値を指標として―

中山佳美[1, 2)]，坂内文男[2)]，森　　満[2)]

[1)] 北海道帯広保健所

[2)] 札幌医科大学医学部公衆衛生学講座（主任　森　満　教授）

我々は，骨粗鬆症の指標として踵骨のstiffness値を用い，日本の高齢者において，これを減少させるリスク要因をコホート研究により調査した．2000年の基礎調査に参加した214人（男性52人，女性162人）から，踵骨超音波法による踵骨のstiffness値，BMI，現病歴，口腔内状況，喫煙状況，飲酒状況，身体活動性，食習慣を調査した．2005年の追跡調査に参加したのは93人（男性23人，女性70人，参加者率43.5％）で，再び，踵骨超音波法による踵骨のstiffness値を測定した．Stiffness値を減少させるリスク要因の分析は，条件なしロジスティック回帰分析を用い，性別に分け，年齢とBMIを調整した．喪失歯数とstiffness値の減少には，関連性がみられなかった．目的変数を2005年のstiffness値とした場合，女性においては，酢の物（OR＝3.9，95％CI: 1.3-11.6）及び海草（OR＝4.5，95％CI: 1.5-14.2）の摂取頻度が少ない者，男性においては緑黄色野菜（OR＝28.0，95％CI: 2.5-317.4）の摂取頻度が少ない者が，stiffness値が有意に低かった．目的変数をstiffness値の5年間の変化量とした場合，女性において，納豆を除く大豆製品（OR＝3.2，95％CI: 1.1-9.1）の摂取頻度が少ない者は，stiffness値が有意に減少した．他の要因は，stiffness値の減少に関連性がみられなかった．食習慣は，全身の骨のカルシウムを豊富にする役割を果たしているかもしれない．骨粗鬆症と食習慣との関連性を評価するためには，さらに研究が必要である．