

# The effect of past and present lifestyle, nutrition habits, and gender on bone mineral density

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## ABSTRACT

This study aimed to examine the gender and age differences of the quantitative osteo-sono assessment index (OSI) and the effects of the past and present lifestyle and nutrition habits on OSI in adult males and females from 20 to 70 years of age. The subjects were 155 males (20-79 years) and 399 females (20-78 years). The bone mass was estimated by the right-calcaneal OSI using an ultrasonic transmission method with an AOS-100 device (ALOKA). The frequency of tests for OSI in women tended to increase rapidly in the 50-70 age group requiring close examination or guidance. In 50-70 year-old females, the proportion of dairy products and vitamin D intake in the past (junior high school and high school days) was significantly lower in the group requiring close examination or guidance (OSI < 2.428) than in the normal group (OSI  $\geq$  2.428). That is, there was insufficient calcium intake (through dairy products) and vitamin D intake, which is instrumental in calcium absorption, (through fish, chicken eggs, and fungi) during puberty, when bone mass increases with skeletal growth. In conclusion, the number in the group requiring close examination or guidance was high for 50-70 year-old males and females. The OSI decreases rapidly in females after their 50s and the number in the group requiring close examination or guidance increased rapidly.

**Keywords:** Lifestyle Habit; Nutrition Habit; Ultrasound; Osteo-Sono Assessment Index; Gender

## 1. INTRODUCTION

Osteoporosis in elderly people markedly results in a de-

crease in activities of daily living (ADL) and quality of life (QOL) [1-4]. Aging is an important factor which affects bone mass and bone mineral density (BMD) [5]. BMD reaches its peak level from puberty to the time a person reaches their 20s and is maintained until their 40s, and then begins to decrease [2]. Nakata *et al.* [6] reported that because it is difficult to prevent osteoporosis in middle age with low peak bone mass, it is important to acquire basic eating and exercise habits during young adult age. Preventing a decrease of the peak bone mass through proper nutrition, exercise, sun bathing, etc. is very effective for preventing osteoporosis in old age [5]. It has been reported that eating habits in addition to exercise habits greatly affect bone formation [3,7]. Kim *et al.* [8] found that the loss of bone mineral content and bone mass with age differs by gender. Hence, the effect of lifestyle on BMD and bone mass after acquiring the peak bone mass should be studied according to gender and by using people of a wide age range.

Calcium ingestion during puberty markedly increases bone mass and may be an important factor in determining peak bone mass [2]. Bone mass in females decreases by about 3 percent a year with age after menopause [9]. Hence, increasing peak bone mass as much as possible during puberty is very important, and also the examination of relationships between BMD after adolescence and past (puberty) lifestyle habits will be essential.

Nakada *et al.* [10] confirmed that the effect of past and present lifestyle habits and nutrition on calcaneal quantitative osteo-sono index (OSI) in pre- and post-menopausal females. This study aimed to examine the OSI differences among different gender and age groups, and the effect of past and present lifestyle and nutrition habits on OSI in people from 20 to 70 years of age.

## 2. METHODS

### 2.1. Subjects

The subjects were 155 males (20-79 years of age) and

399 females (20-78 years of age). Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol.

## 2.2. Measurement of Bone Mineral Density and Setting of Osteo-Sono Assessment Index Group

The BMD was estimated by the right-calcaneus using an ultrasonic transmission method with an AOS-100 device (ALOKA). The calcaneal osteo-sono assessment was used osteo-sono assessment index (OSI:  $TI \times SOS^2$ ) by calculating the speed of sound (SOS) of an ultrasonic transmission in the calcaneus and transmission index (TI) referring to the report of Ishiguro *et al.* [11].

The Japan Osteoporosis Foundation [2] classified females into a close examination group (OSI < 80% of an average OSI = 2.158), a guidance required group (2.158  $\leq$  OSI < 90% of an average OSI = 2.428) and a normal group (OSI  $\geq$  2.428) based on an average OSI (OSI = 2.698) of females between 20 and 44 years old by osteo-sono assessment criteria. In this study, we combined the former 2 groups considering a sample size of each age level and compared the close examination and guidance required groups (OSI < 2.428) and the normal group (OSI  $\geq$  2.428). The appropriate criteria of OSI in males has not been reported. Hence, males were classified into a close examination and guidance required group (OSI < 90%) and a normal group (OSI  $\geq$  90%) based on an average OSI of people between 20 and 44 years old in reference to the females' assessment criteria in Japan Osteoporosis Foundation [2].

## 2.3. Lifestyle Habits and Nutrition Questionnaire

Lifestyle habits and nutrition were evaluated by questionnaires. The survey was carried out just before the measurement of OSI. Naka *et al.* [5] selected menopause, habitual milk intake, intensity of physical exercise, and awareness of eating habits and physical activity as lifestyle items. Tomita selected breakfast habits, milk and dairy products, fish and shellfish, meat products etc. in present and childhood (about 6-15 yr) as eating habit items. Elgán *et al.* [12] selected 10 items (dietary habits (i.e. sugar, fat, fiber, and fruit/vegetables), physical activity, smoking habits, alcohol consumption, time spent outdoors etc.) as lifestyle items. The Japan Osteoporosis Foundation [2] selected alcohol, tobacco, coffee, milk, dairy products, fish, meat, soy products, green and yellow vegetables, and natto as meal and articles of taste items for the interview sheet as examples of osteoporosis prevention. Referring to the above, this study selected the following 9 items to investigate the present eating habits: 1) sleeping time, 2) frequency of alcohol

consumption, 3) smoking habits, 4) skipping meals, 5) intake of dairy products (milk, cheese, yogurt, etc.), 6) intake of calcium supplements, 7) intake of vitamin D (fish, chicken egg, fungi), 8) intake of instant food (instant noodles, instant coffee, etc.), and 9) frequency of sun bathing. And, as the past (junior high school and high school days) states, 1) sleeping time, 2) skipping meals, 3) intake of dairy products, 4) intake of vitamin D, and 5) intake of instant food among the above 5 items were surveyed.

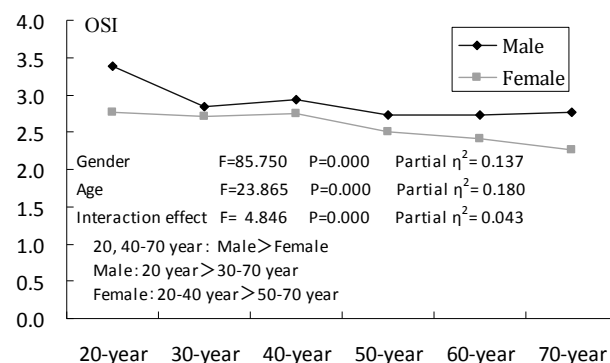
## 2.4. Data Analysis

Two-way (gender  $\times$  age) ANOVA was used to examine the age and gender differences of OSI. When a significant difference was found, multiple comparisons were performed by Bonferroni's method. In both males and females, cross tabulations by 20-40 year-olds and 50-70 year-olds were made up. A  $\chi^2$  test was used to examine the proportion of OSI groups. In each OSI group, cross tabulations by the past and the present lifestyle and nutrition ingestion habits were made up and then a test of independence was performed. When a significant difference was found, residual analysis was used. A probability level of 0.05 was indicative of statistical significance.

## 3. RESULTS

**Figure 1** shows the result of a two-way ANOVA (age  $\times$  gender). A significant interaction effect was found. The results of multiple comparisons showed gender differences, males having a higher OSI, except for 30 year-olds. In males, the OSI of 20 year-olds was significantly higher than that of 30-70 year-olds. In females, the OSI of 20-40 year-olds was significantly higher than that of 50-70 year-olds.

**Table 1** shows the result of  $\chi^2$  test (age  $\times$  gender) in each OSI group. The frequency of the group requiring



**Figure 1.** Result of two-way ANOVA (age  $\times$  gender) in OSI.

**Table 1.** Result of  $\chi^2$  test (age  $\times$  gender) in each OSI group.

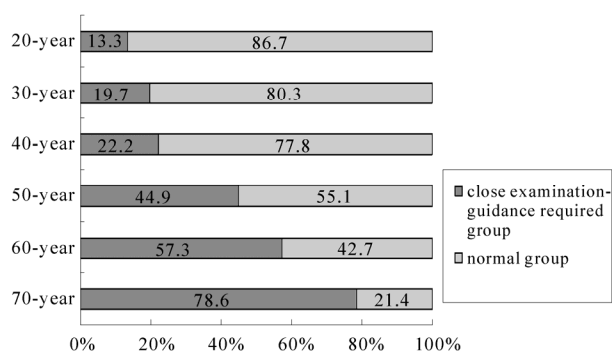
gender	OSI group	20-40 year-olds	50-70 year-olds	$\chi^2$	$\rho$	$\phi$
Male	normal	59 (72%)	33 (45%)	11.451	0.000	0.285
	A close examination-guidance required	23 (28%)	40 (55%)			
Female	normal	155 (81%)	99 (48%)	46.21	0.000	0.349
	A close examination-guidance required	37 (19%)	108 (52%)			

close examination or guidance showed a significant difference in males and females. The Average OSI of 20-44 year-old males was 3.034 and 90% of that corresponds to 2.731. We used this value as the judgment criteria for the group requiring close examination or guidance, similar to the female group. The number of male subjects corresponding to less than OSI = 2.731 in males out of the 20-40 year-olds and 50-70 year-olds were 23 and 40, respectively.

**Figure 2** shows the percentage of females in the group requiring close examination or guidance. The percentage tended to increase rapidly after 50 years of age (30-40 year-olds: about 1.5-1.7 times of 20 year-olds, 50 year-olds: about 3.4 times of 20 year-olds, 60 year-olds: about 4.3 times of 20 year-olds, and 70 year-olds: about 5.9 times of 20 year-olds).

**Table 2** (20-40 years-old males) and **Table 3** (50-70 year-old males) show the cross tabulations of the frequency of OSI groups and the frequency of the present and past lifestyle and nutrition habits. A test of independence showed significant differences in the frequency in the intake of vitamin D in the 50-70 year-old males. However, the results of residual analysis showed no significant differences in any category. In the 20-40 year-old males, there were no significant differences in all present lifestyle and nutrition ingestion habit items.

**Table 4** (20-40 year-old females) and **Table 5** (50-70 year-old females) show the cross tabulations of the frequency of OSI groups and the frequency of the present

**Figure 2.** Frequency of OSI in the close examination-guidance required group in female.

and past lifestyle and nutrition habits. In the 20-40 year-old females, a test of independence showed significant differences in sleeping time. However, the results of residual analysis showed no significant differences in any category. A test of independence showed significant differences in the intake of dairy products and vitamin D in the past in the 50-70 year-old females. The results of residual analysis showed significant differences in the intake of dairy products in the past; the normal group showed a higher proportion of subjects with a greater weekly intake (dairy products:  $z = 2.95 > 2.64$ , Vitamin D:  $z = 2.75 > 2.64$ ,  $p < 0.05$ ).

#### 4. DISCUSSION

The Japan Osteoporosis Foundation [2] reported that average OSI of 20 and 44 years old females (6096 people) was OSI =  $2.698 \pm 0.298$ . From the present result (OSI =  $2.742 \pm 0.350$ ), it is considered that the OSI of females in this study was the standard. The gender differences of the OSI were found in all age groups, males being higher, except for 30 year-olds. In males, the age differences were found between the 20 year-old group and age groups after 30, and the OSI tended to remain the same level or to decrease slightly after their 30 s. However, in females, the OSI tended to be maintained in the 20-40 year-olds and to decrease sharply after their 50 s. Kim *et al.* [8] reported that bone mineral content in males decreased 0.3 kg per each decade from their 20 s to 40 s, kept almost the same level from their 40 s to their 60 s, and decreased 0.3 kg from their 60 s to their 70 s. In females, the bone mineral content changed little from their 20 s to their 40 s and decreased markedly from their 60 s to 70 s. It is thought that OSI is higher in males than in females and its decrease tendency with age differs largely by gender because of the sharp decrease observed in females beginning in their 50 s. And, the proportion in the group requiring close examination or guidance based on the judgment criteria by the Japan Osteoporosis Foundation [2] was higher in 50-70 year-olds than in 20-40 year-old males and females, but tended to increase sharply after 50 s (**Figure 2**) in females. This is thought to relate to the marked decrease of

**Table 2.** Present and past lifestyle and nutrition habits and the OSI of 20-40-year-olds males.

<b>Sleeping time</b>		Less than 6 hours	More than 6 hours-less than 7 hours	More than 7 hours-less than 8 hours	More than 8 hours	$\chi^2$	$\rho$	$\varphi$
Present	Normal	12	33	12	1	2.817	0.421	0.19
	CEGR	4	14	3	2			
Past	Normal	9	20	18	6	0.981	0.806	0.11
	CEGR	2	9	9	2			
<b>Alcohol intake</b>		No	1-3 times a month	1-3 times a week	nearly every day	3.277	0.351	0.20
Present	Normal	13	15	16	15			
		CEGR	5	10	3	5	0.109	0.947
Present	Normal	28	14	17				
		CEGR	10	6	7		0.568	0.451
Past	Normal	45	12					
		CEGR	19	3			0.371	0.831
Present	Normal	10	25	24				
		CEGR	5	8	10		0.371	0.831
Past	Normal	7	23	27				
		CEGR	4	9	10		3.691	0.158
Present	Normal	40	14	5				
		CEGR	20	3	0		1.130	0.568
Present	Normal	7	37	15				
		CEGR	1	15	7		0.311	0.856
Past	Normal	3	34	17				
		CEGR	1	16	6		2.425	0.297
Present	Normal	9	20	30				
		CEGR	2	12	9		0.39	0.823
Past	Normal	3	30	24				
		CEGR	2	11	10		1.734	0.42
Present	Normal	14	24	20				
		CEGR	5	13	5			

Note: CEGR:close examination or guidance required group

**Table 3.** Present and past lifestyle and nutrition habits and the OSI of 50-70-year-olds males.

<b>Sleeping time</b>		Less than 6 hours	More than 6 hours-less than 7 hours	More than 7 hours-less than 8 hours	More than 8 hours	$\chi^2$	$\rho$	$\phi$
Present	Normal	6	14	11	1	3.316	0.345	0.21
	CEGR	9	13	13	6			
Past	Normal	1	11	17	1	2.89	0.409	0.21
	CEGR	2	14	13	4			
<b>Alcohol intake</b>		No	1-3 times a month	1-3 times a week	nearly every day	1.095	0.778	0.12
Present	Normal	9	1	5	17			
	CEGR	15	2	4	20			
<b>Smoking</b>		No	Have a habit	Quit				
Present	Normal	11	6	13				
	CEGR	11	7	23				
<b>Skip a meal</b>		No	Breakfast	Lunch	Supper	2.272	0.321	0.18
Present	Normal	25	3	1	0			
	CEGR	39	2	0	0			
Past	Normal	21	4	1	0			
	CEGR	33	4	0	0			
<b>Intake of dairy products</b>		No	1-3 times a month	4-7 times a week				
Present	Normal	5	13	14				
	CEGR	9	14	18				
Past	Normal	11	12	7				
	CEGR	21	13	3				
<b>Intake of Ca supplement</b>		No	Rarely	Continuous		0.595	0.743	0.09
Present	Normal	27	3	2				
	CEGR	34	4	1				
<b>Intake of vitamin D</b>		No	1-3 times a week	4-7 times a week				
Present	Normal	1	23	8				
	CEGR	2	31	8				
Past	Normal	0 (-1.80)	20 (-1.20)	8 (2.56)				
	CEGR	4 (1.80)	31 (1.20)	2 (-2.56)				
<b>Intake of instant food</b>		No	1-3 times a month	More than once a week		2.797	0.247	0.20
Present	Normal	6	18	8				
	CEGR	13	15	12				
Past	Normal	14	10	5				
	CEGR	16	14	6				
<b>Sunbathing</b>		No	1-3 times a week	More than 4 times a week				
Present	Normal	6	12	12				
	CEGR	4	18	18				

Note: CEGR: close examination or guidance required group, \* $P < 0.05$ , Number shown in parentheses is the Z score of the residual analysis.

**Table 4.** Present and past lifestyle and nutrition habits and the OSI of 20-40-year-olds females.

<b>Sleeping time</b>		Less than 6 hours	More than 6 hours-less than 7 hours	More than 7 hours-less than 8 hours	More than 8 hours	$\chi^2$	$\rho$	$\phi$
Present	Normal	49 (0.54)	70 (-2.15)	35 (2.38)	1 (-1.11)	8.359	0.039*	0.21
	CEGR	10 (-0.54)	24 (2.15)	2 (-2.38)	1 (1.11)			
Past	Normal	21	50	39	9	7.405	0.060	0.22
	CEGR	1	11	11	6			
<b>Alcohol intake</b>		No	1-3 times a month	1-3 times a week	nearly every day	3.537	0.316	0.14
Present	Normal	47	63	21	23			
		CEGR	14	9	5	8		
<b>Smoking</b>		No	Have a habit	Quit		0.458	0.795	0.05
Present	Normal	128	13	13				
		CEGR	29	4	4			
<b>Skip a meal</b>		No	Breakfast	Lunch	Supper	2.393	0.495	0.11
Present	Normal	125	17	3	4			
		CEGR	29	6	0	0		
Past	Normal	110	30	0	0	0.113	0.737	0.03
	CEGR	26	6	0	0			
<b>Intake of dairy products</b>		No	1-3 times a month	4-7 times a week		0.699	0.705	0.06
Present	Normal	15	62	78				
		CEGR	2	16	19			
Past	Normal	16	58	72		2.592	0.274	0.12
	CEGR	2	18	13				
<b>Intake of Ca supplement</b>		No	Rarely	Continuous		1.483	0.476	0.09
Present	Normal	113	29	12				
		CEGR	30	6	1			
<b>Intake of vitamin D</b>		No	1-3 times a week	4-7 times a week		2.501	0.286	0.11
Present	Normal	8	88	58				
		CEGR	3	25	9			
Past	Normal	4	86	49		4.167	0.125	0.16
	CEGR	3	18	7				
<b>Intake of instant food</b>		No	1-3 times a month	More than once a week		5.915	0.052	0.18
Present	Normal	28	56	69				
		CEGR	2	11	24			
Past	Normal	22	76	45		0.060	0.970	0.02
	CEGR	4	16	9				
<b>Sunbathing</b>		No	1-3 times a week	More than 4 times a week		2.545	0.280	0.12
Present	Normal	43	62	47				
		CEGR	14	10	13			

Note: CEGR: close examination or guidance required group, \* $P < 0.05$ , Number shown in parentheses is the Z score of the residual analysis.

**Table 5.** Present and past lifestyle and nutrition habits and the OSI of 50-70-year-olds females.

<b>Sleeping time</b>		Less than 6 hours	More than 6 hours-less than 7 hours	More than 7 hours-less than 8 hours	More than 8 hours	$\chi^2$	$\rho$	$\phi$
Present	Normal	19	49	26	2	2.401	0.493	0.11
	CEGR	26	50	26	6			
Past	Normal	5	25	36	11	0.506	0.917	0.06
	CEGR	4	26	32	13			
<b>Alcohol intake</b>		No	1-3 times a month	1-3 times a week	nearly every day			
Present	Normal	57	13	11	18	1.191	0.755	0.08
	CEGR	62	19	10	16			
<b>Smoking</b>		No	Have a habit	Quit				
Present	Normal	81	9	7		0.822	0.633	0.06
	CEGR	93	8	5				
<b>Skip a meal</b>		No	Breakfast	Lunch	Supper			
Present	Normal	87	5	0	1	3.444	0.328	0.13
	CEGR	95	3	3	1			
Past	Normal	66	12	0	0	2.224	0.329	0.12
	CEGR	72	10	2	0			
<b>Intake of dairy products</b>		No	1-3 times a month	4-7 times a week				
Present	Normal	3	30	65		3.592	0.116	0.13
	CEGR	7	41	57				
Past	Normal	14(-0.18)	44(-0.93)	27(2.95*)		9.751	0.008*	0.24
	CEGR	24(0.18)	50(0.93)	11(-2.95*)				
<b>Intake of Ca supplement</b>		No	Rarely	Continuous				
Present	Normal	73	11	15		0.803	0.669	0.06
	CEGR	73	16	15				
<b>Intake of vitamin D</b>		No	1-3 times a week	4-7 times a week				
Present	Normal	8	51	39		0.108	0.947	0.02
	CEGR	10	54	43				
Past	Normal	5(-1.38)	42(-1.82)	36(2.75*)		8.189	0.017*	0.22
	CEGR	10(1.38)	53(1.82)	19(-2.75*)				
<b>Intake of instant food</b>		No	1-3 times a month	More than once a week				
Present	Normal	35	30	31		0.727	0.695	0.06
	CEGR	34	32	40				
Past	Normal	30	39	14		0.372	0.830	0.05
	CEGR	33	35	13				
<b>Sunbathing</b>		No	1-3 times a week	More than 4 times a week				
Present	Normal	12	35	47		0.955	0.620	0.07
	CEGR	17	38	44				

Note: CEGR: close examination or guidance required group, \* $P < 0.05$ , Number shown in parentheses is the Z score of the residual analysis.

bone mass with a rapid decline of estrogen levels in postmenopausal females [13]. The OSI is generally higher in males than females. Average OSI of 20-44 years people also in this study showed a significant gender difference (males: OSI =  $3.034 \pm 0.396$ , females: OSI =  $2.742 \pm 0.350$ ,  $t = 5.283$ ,  $P = 0.000$ ). The proper criteria has not been reported for males, so this study conveniently utilized the adult female criteria creation method developed by the Japan Osteoporosis Foundation [2]. It is considered that males' OSI level is higher and thus the criteria for the group requiring close examination or guidance differs between genders. Hence, from now, the OSI standard for males will need to be hastily created based on a large amount of data.

The group requiring close examination or guidance in 50-70 year-old females had a lower proportion of subjects with weekly intake (4-7 times a week) of dairy products and vitamin D (fish, chicken egg, fungi) in the past than the normal group. Tomita *et al.* [7] reported that, in the study of junior college dietetics students, the intake of milk, dairy products, and vegetables on a routine basis is useful to increase bone mass. Nakata *et al.* [6] reported that calcaneal OSI in women's junior college students was higher in the high milk intake group. The three year longitudinal study by Dawson-Hughes *et al.* [14] found that the proper intake of vitamin D in addition to calcium intake reduces the decline of BMD. It was reported also that inadequate metabolism of vitamin D decreases calcium absorption in both osteoporotics and elderly subjects [15]. From the present results, it is considered that the 50-70 year-old females belonging to the group requiring close examination or guidance were deficient in calcium intake through dairy products and intake of vitamin D which is very important for the absorption of calcium during puberty to increase bone mass with skeletal growth. In addition, the above suggests that it is important to have adequate calcium and vitamin D intake in puberty in addition to old age.

Meanwhile, males showed an insignificant relationship between OSI and items involving the present and past lifestyle and nutrition habits. Because they do not have a large physiological change as females when they experience menopause in middle age, the effect of the intake of calcium and vitamin D during puberty on maintenance of BMD and bone formation may be lower than in females. Many bone fractures that occur in elderly people are of the femoral neck and this fracture causes bedriddenness and disturbances of gait. Therefore preventing the cause, osteoporosis, is very important [2,5].

From now, it will be necessary to compare bone mineral density between young adults and the elderly longitudinally, and to examine the combined effect of the past

and present lifestyle and exercise habits on BMD.

In summary, the OSI is higher in males than females and it is higher in 20 year-olds than 30-70 year-olds in males and is higher in 20-40 year-olds than 50-70 year-olds in females. The proportion of the group requiring close examination or guidance is high in 50-70 year-olds, particularly in females with a rapid increase after their 50s. The 50-70 year-old females in the group requiring close examination or guidance were deficient in calcium intake through dairy products in addition to the intake of vitamin D, which is important for the absorption of calcium during puberty when bone mass increases with skeletal growth. The intake of calcium and vitamin D during puberty may be very important to prevent the decrease of bone mineral density in old age.

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