Original Article

Relationship between skipping breakfast and bone mineral density in young Japanese women

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Back ground and aims: It is well known that insufficient nutrient intake leads to poor bone status. To find a simple evaluation method for prevention of nutrition intake disorder, a cross-sectional study with 275 healthy Japanese female students aged 19-25 was conducted. Methods: Anthropometric parameters, bone mineral density (BMD) at lumbar and total hip, bone metabolic markers and physical activity were measured in study participants and the frequency of skipping meals (breakfast, lunch, supper), and absolute values for nutrient intakes were assessed using a Diet History Questionnaire. Results: The frequency of skipping breakfast significantly correlate to total energy intake (ρ = -0.276, p<0.001). BMI, total intake of energy, intake of protein, intake of phosphate, and energy expenditure positively correlated significantly to BMD at lumbar and total hip (p<0.05) using simple linear regression. BMI (regression coefficient (b))=0.088, p<0.001), bone alkaline phosphatase (b= -0.050, p=0.012), total energy expenditure (b=0.019, p<0.001), and frequency of skipping breakfast (b= -0.018, p=0.048) were independent risk factors for lower total hip BMD by multiple regression analysis. The total hip BMD in participants who skipped breakfast three or more times was significantly lower than in those who did not skip breakfast (p=0.007). Conclusions: In conclusion, managing the frequency of skipping breakfast and reducing it to <3 times per week may be beneficial for the maintenance of bone health in younger women.

Key Words: skipping breakfast, bone mineral density, nutrient intake, physical activity, younger women

INTRODUCTION

In recent years, several studies have reported on the habit of skipping meals as part of a contemporary lifestyle and the rate of skipping meals has increased worldwide.[1-3] The habit of skipping breakfast, in particular, has become widespread in the United States[1,2] with the rate of breakfast skipped in adults increasing from 14% to 25% during the 25 years from 1965 to 1991.[4] In the Netherlands, the frequency of skipping breakfast was increased in adolescents,[5] the estimated rate of skipping breakfast in female adults was 22% in Japan.[3]

Skipping meals leads to insufficient intake of essential nutrients and is associated with negative impacts on body weight and lean volume. Furthermore, the timing of skipping meals and type of foods consumed are known to affect body weight. It was reported that an intake of less than 70% of required total energy intake per day by noon results in a decline in body weight.[6] In previous study, a larger body mass index (BMI) or overweight was observed in those who skip breakfast.[7,8] On the other hand, Cho *et al* reported that lower BMI was observed in those who skip breakfast.[9] Insufficient nutrient intake may affect bone mineral density (BMD), since it is well known that BMI is strongly correlated with BMD.[10-13]

Compared to calculating the quantity of individual nutrient intakes, management of the frequency of meal skipping is considered an easier method for avoiding inadequate nutrient intake.

In the present study, we attempted to clarify the contribution of the frequency of skipping meals to absolute nutrient intake, and its impact on BMD.

MATERIALS AND METHODS

Subjects

We conducted a cross-sectional study with 275 female students aged 19-25 who were attending the Nursing School of Tokyo Women's Medical University, Tokyo, Japan. These students were healthy female volunteers who gave prior written informed consent. Subjects who had conditions or were receiving medications that could affect bone mass and subjects who were suspected of having anorexia nervosa by the criteria of Diagnostic and

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Statistical Manual of Mental Disorders, fourth edition (DSM-IV) and amenorrhea by interview of menstrual situation were excluded from the study. The study protocol was approved by the ethics committee of Tokyo Women's Medical University.

Background characteristics of the study subjects

Information about current age, age at menarche, birth weight, and current menstrual status was obtained by interview. Anthropometric parameters including height and body weight were measured and used to calculate the BMI. In addition, BMD of the lumbar vertebra 2-4 ($L_{2\text{-}4}$) and total hip (hip), were measured using the QDR 4500 DXA bone densitometer (Hologic, Waltham, MA, USA). The manufacturer's phantom was scanned daily for quality control and to correct instrument drift. Our observed coefficient of variation for the day-to-day quality control scans was 0.7%.

Blood samples were collected from the participants and separated into serum in order to measure bone metabolic markers, cross linked N-telopeptide of type I collagen (NTX) and bone-specific alkaline phosphatase (BAP). Serum NTX was measured by enzyme-linked immunosorbent assay (Osteomark NTX serum, Alere) and serum BAP was measured by chemiluminescent enzyme immunoassay (Ostase, Beckman Coulter). The coefficients of variations were less than 15% and 6.5%, respectively. Time in the day of blood sampling and menstrual situation of participant was not regarded.

Measurement of dietary habit and physical activity

Dietary habits during the month prior to the study were assessed in the participants using a validated, self-administered Diet History Questionnaire (DHQ),[14,15] and daily consumption of major nutrients such as total energy intake, proteins, lipids, carbohydrates, calcium, phosphate, vitamin D, and vitamin K was calculated. Detailed descriptions of the methods used for calculating dietary intake and the validity of the DHQ have been published elsewhere. The subjects were asked about their habit of skipping meals (breakfast, lunches and suppers) and the frequency per week.

Physical activity of the study participants was calculated by Lifecorder EX wear for one week, a uniaxial accelerometer (Suzuken Co Ltd, Nagoya, Japan) that is used to calculate total energy expenditure as well as daily energy expenditure during physical activity.[13]

Statistical analysis

In the descriptive analysis of background characteristics, the numerical data were expressed as the mean±SD. First, the contribution of the frequency of skipping meals (breakfast, lunch, supper) to intake of nutrients was assessed by Spearman's rank test. The association between BMD and categories of skipping meals, BMI, NTX, BAP, total expenditure energy and energy expenditure during exercise were then evaluated using Spearman's rank correlation. Finally, stepwise regression analysis was used to estimate factors that independently contribute to BMD. Final candidate variables for multiple regression analysis were selected among significant variables in single liner analysis. T-test analysis was used to evaluate the threshold of frequency of meal skipping that leads to decreased BMD. All reported p values are two-sided with a significance level of 5%. All statistical analyses were performed using the JMP (Japanese version 9.0.0, SAS Institute, Cary, NC, USA).

RESULTS

Background characteristics of the participants

All surveys were conducted during the wintertime (from December 2003 to February 2004). The mean age and body weight of the 275 participants were 20.6±1.4 years and 53.5±7.5 kg, respectively. Total hip BMD was 0.90±0.10 g/cm^2 and lumbar vertebra ($L_{2\text{-}4}$) BMD was 1.00±0.11 g/cm^2. The other demographics measured are shown in Table 1. The mean values for intake of various nutrients by the participants were similar to the national averages in their coevals such as calcium: 445 mg, vitamin D: 6.7 g in Japanese female (20 to 29 years).[15] The number (%) of participants who skipped meals more than once per week was 142 participants (51.6%) with breakfast, 36 participants (13.1%) with lunch and 43 participants (15.6%) with supper.

Relationship of time of skipping meals and nutrient status

To clarify which meals when skipped are associated with insufficient intake of nutrients including calcium and phosphate, the correlation between the frequency of meal skipping and absolute intake value was evaluated for each meal (Table 2). The frequency of skipping breakfast most strongly contributed to total intake of energy (ρ = -0.276, p <0.001), and was significantly associated with all nutrient parameters. The intake of energy and carbohydrate significantly correlate to frequency of skipping lunches and supper. The intake of vitamin K contributes to the frequency of skipping lunches and the intake of vitamin D correlate to the frequency skipping of supper.

Correlation between BMD and nutrient status and physical activity

BMI, BAP, intake of protein and energy expenditure contributed significantly to $L_{2\text{-}4}$ and hip BMD (Table 3). Intake of total energy, lipid, carbohydrate, phosphate, vitamin D, vitamin K, and frequency of skipping breakfast, on the other hand, contributed significantly only to total hip BMD.

The significant negative correlation was observed between body weight and frequency of skipping breakfast (ρ = -0.142, p=0.019).

Multiple regression analysis for hip BMD

To evaluate the independency of candidate factors shown to be associated with decreased hip BMD by correlation analysis, stepwise regression analysis was performed (Table 4). BMI, BAP, total energy expenditure, and frequency of skipping breakfast were independent risk factors for lower hip BMD. The frequency of skipping breakfast did not significantly contribute to $L_{2\text{-}4}$ BMD by multiple regression analysis.

Relationship between the frequency of breakfast skipping and total hip BMD

The participants were divided into three groups based on

Table 1. Demographics of participants

	mean	SD	min	max
Age, years	20.6	1.4	19	25
Height, cm	159	5.0	145	174
Weight, kg	53.5	7.5	37.6	81.5
BMI, kg/m^2	21.2	2.7	15.2	31.2
Post-menarche, years	8.6	1.8	5	14
NTX, nMBCE/L	13.4	4.2	6.0	31.2
BAP, U/L	22.5	5.9	10.7	53.3
L_{2-4} BMD, g/cm^2	1.00	0.11	0.74	1.30
Hip BMD, g/cm^2	0.90	0.10	0.63	1.24
Daily energy and nutrient intakes				
Total energy, kcal	1870	630	690	6130
Protein, g	62	23	19	181
Lipid, g	61	27	10	175
Carbohydrate, g	250	74	111	689
Calcium, mg	520	260	100	1870
Phosphate, mg	970	390	280	2860
Vitamin D, g	12.2	8.2	0.5	57.3
Vitamin K, g	290	210	40	1670
Total energy expenditure, kcal/day	1820	170	1360	2300
Exercise energy expenditure, kcal/day	222	75.6	56	497
Frequency of skipping meal, times/week				
Breakfast	1.7	2.2	0	7
Lunche	0.2	0.8	0	5
Supper	0.5	1.3	0	7

NTX type I collagen cross-linked N-telopeptides, *BAP* bone-specific alkaline phosphatase, *BMD* bone mineral density.

Table 2. Association between frequency of skipping each meal and absolute daily intake of nutrients

Time of meal skipped	vs. variable	ρ	*p*
Frequency of breakfast	Total energy intake, kcal	-0.276	<0.001
	Protein, g	-0.251	<0.001
	Lipid, g	-0.160	0.008
	Carbohydrate, g	-0.371	<0.001
	Calcium, mg	-0.238	<0.001
	Phosphate, mg	-0.264	<0.001
	Vitamin D, g	-0.130	0.031
	Vitamin K, g	-0.216	<0.001
Frequency of lunches	Total energy intake	-0.148	0.014
	Protein, g	-0.108	0.074
	Lipid, g	-0.080	0.184
	Carbohydrate, g	-0.205	0.001
	Calcium, mg	-0.094	0.120
	Phosphate, mg	-0.104	0.086
	Vitamin D, g	-0.094	0.119
	Vitamin K, g	-0.150	0.013
Frequency of supper	Total energy intake	-0.131	0.030
	Protein, g	-0.109	0.070
	Lipid, g	-0.105	0.084
	Carbohydrate, g	-0.163	0.007
	Calcium, mg	-0.036	0.554
	Phosphate, mg	-0.089	0.142
	Vitamin D, g	-0.175	0.004
	Vitamin K, g	-0.111	0.067

the frequency of breakfast skipping (those who did not skip breakfast; those who skipped breakfast 1 or 2 times; and those who skipped breakfast 3 or more times) to ensure there were enough participants in each group for analysis, and hip BMD was compared. Hip BMD in the group that skipped breakfast 1 to 2 times per week was lower compared to those who did not skip breakfast, but the difference was not statistically significant. Hip BMD in participants who skipped breakfast three or more times, however, was significantly lower than in those who did not skip breakfast (p=0.071, p=0.007, respectively; Figure 1).

Table 3. Contribution of nutrient status and physical activity to L_{2-4} and hip BMD

Variables	L_{2-4} BMD (g/cm^2)		Hip BMD (g/cm^2)	
	R	*p*	R	*p*
Age, years	-0.021	0.728	-0.104	0.085
BMI, kg/m^2	0.420	<0.001	0.429	<0.001
NTX, nMBCE/L	-0.059	0.331	-0.003	0.957
BAP, U/L	-0.166	0.006	-0.140	0.020
Daily energy and nutrient intakes				
Total energy, kcal	0.102	0.091	0.152	0.012
Protein, g	0.122	0.043	0.166	0.006
Lipid, g	0.068	0.262	0.158	0.009
Carbohydrate, g	0.093	0.123	0.119	0.049
Calcium, mg	0.066	0.279	0.091	0.131
Phosphate, mg	0.117	0.054	0.163	0.007
Vitamin D, g	0.101	0.094	0.183	0.002
Vitamin K, g	0.084	0.166	0.149	0.014
Frequency of skipping breakfast	-0.094	0.122	-0.156	0.010
Total energy expenditure, kcal/day	0.408	<0.001	0.417	<0.001
Exercise energy expenditure, kcal/day	0.220	<0.001	0.194	0.002

NTX type I collagen cross-linked N-telopeptides, *BAP* bone-specific alkaline phosphatase, *BMD* bone mineral density.

Table 4. Multiple regression analysis for hip BMD

Item	Regression coefficient (b)	SE	t	*p*
BMI, kg/m^2	0.088	0.021	4.2	< 0.001
BAP, U/L	-0.050	0.020	-2.5	0.012
Total Energy expenditure, kcal/day	0.069	0.019	3.6	< 0.001
Frequency of skipping breakfast	-0.018	0.009	-2.0	0.048

BAP bone-specific alkaline phosphatase, *BMD* bone mineral density, *SE* standard error.

DISCUSSION

It is well known that lower body weight has adverse effects on future health in younger women. Blum *et al* reported that low body weight and low BMI at menarche were significant predictors of reduced bone mass in 40-45 year old healthy premenopausal women.[16] Moreover, a systematic review and meta-analysis showed that women who are underweight are at increased risk of maternal underweight and preterm birth.[17] Adequate weight control is therefore important for bone health and the future health of a woman's child. In Japan, the rate of low body weight (BMI <18.5) in 20-year old women was reported to be 29% and the Ministry of Health, Labour and Welfare is taking measures to reduce this rate to 20%. Managing weight by controlling nutrient intake is useful in theory, but in actuality the calculation of detailed quantities of nutrient intakes is difficult. We therefore used the frequency of skipping meals as a surrogate index and evaluated its relationship to BMD in younger (20-25 years old) women. The contribution of skipping breakfast to body weight, health-compromising behaviors, and obesity treatment has been previously reported.[18-25]

In the present study, the frequency of skipping breakfast was higher than the frequency of skipping lunch and supper, and a significant negative correlation was observed between the frequency of skipping meals and absolute intake of nutrients. The correlation between intake of nutrition and frequency of skipping breakfast was relatively higher than the frequency of skipping lunches or supper. Therefore, management of skipping breakfast may be important to secure quantity of nutrient required in a day. The frequency of skipping breakfast was an inde-

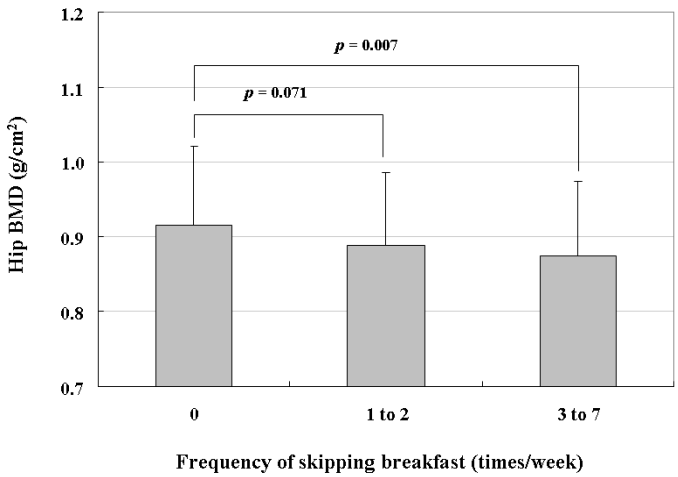

Figure 1. Relationship between the frequency of skipping breakfast and hip BMD

pendent risk factor for lower hip BMD, and the threshold for this effect was over 3 meals/week. Managing the frequency of skipping breakfast is thought to be a simple and useful method for maintenance of bone health in younger women.

The present study has several limitations. Firstly, since the study was carried out using a cross-sectional method by only Japanese population in one urban area, future effects on weight change could not be determined. Longitudinal effects in other races should be assessed in future studies. Secondly, the reasons for skipping meals were not investigated. This is important to assess in order to develop strategies to avoid meal skipping. Our previous study found a significant association between nutrient intake patterns of daughters and their mothers suggesting that one reason for meal skipping in younger women may be explained by familial habit.[26,27] Strategies for changing these habits should therefore be targeted at the mother.

In conclusion, managing the frequency of skipping breakfast and reducing it to <3 times per week may be beneficial for maintenance of bone health in younger women.

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AUTHOR DISCLOSURES

All of the authors state that they have no conflicts of interest.

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Original Article

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日本年輕女性不吃早餐與骨密度之相關

背景及目的：已知營養素攝取不足會導致較差的骨質狀況。為尋找一簡單評估方法以預防營養攝取失調，進行此橫斷性研究。共 275 名年齡在 19-25 歲的健康日本女學生參與。方法：測量研究參與者的體位參數、腰椎及全臀部的骨密度、骨代謝標記及體能活動；以飲食歷史問卷評估略過三餐(早、中、晚餐)的頻率及營養素攝取的絕對量。結果：未吃早餐的頻率與總熱量攝取量有顯著相關性(ρ= -0.276, p<0.001)。簡單線性迴歸顯示 BMI、總熱量攝取量、蛋白質攝取量、磷攝取量及能量消耗與腰部及臀部的骨密度(p<0.05)有正相關。多元回歸分析顯示 BMI(迴歸係數(b)=0.088, p<0.001)、骨質鹼性磷酸酶(b= -0.050, p=0.012)、總熱量消耗(b=0.019, p<0.001)及不吃早餐頻率(b= -0.018, p=0.048)是較低的臀部骨密度的獨立危險因子。每週略過早餐 3 次或以上者，比起那些每天吃早餐者，有較低的臀骨密度(p=0.007)。總結而言，改善年輕女性不吃早餐的頻率，如降低至每週少於 3 次，可能對於維持骨骼健康有益。

關鍵字：不吃早餐、骨密度、營養素攝取、體能活動、年輕女性