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BONE MINERAL DENSITY AND CONSUMPTION OF CALCIUM, CALCIUM-FORTIFIED FOOD AND CALCIUM SUPPLEMENTS BY WOMEN – A SHORT REPORT

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Key words: bone mineral density, calcium, dairy products, calcium-fortified food, supplements, women

Analyses were conducted for calcium intake from dairy products linked with the consumption of calcium supplements and consumption of calcium-fortified food in respect to bone mineral density (BMD) of women (n=39) aged 34-56 years. A relationship was demonstrated between bone mineral density (BMD) of the women and calcium intake from dairy products, calcium-fortified food products and calcium supplements. Low BMD of the women resulted from a very low intake of calcium from dairy products and restricted use of calcium supplements and/or consumption of calcium-fortified foods. Appropriate calcium intake from dairy products was insufficient to reach high BMD values. The high BMD values of the women were determined by calcium intake from calcium-fortified foods and the consumption of calcium supplements, and – to a lesser extent – by calcium intake from dairy products with an average calcium intake.

INTRODUCTION

An appropriate intake of calcium is acknowledged as a nutritional factor improving mineral density of the bone tissue and minimizing the risk of osteoporosis [Lorenc & Kaczmarewicz, 2006; NIH, 2001; Teegarden *et al*., 2005]. A view prevails that the intake of calcium in childhood and adolescence is of the utmost significance [Fisher *et al*., 2004; Matkovic *et al*., 2005; Nieves *et al*., 2008]. It enables achieving a high peak bone mass that constitutes a specific "deposit" for the subsequent years of life [Kanis & Gluer, 2000; Lorenc & Kaczmarewicz, 2006; NIH, 2001]. In turn, the impact of calcium intake on bone tissue density in the later decades of life is still recognized to a lesser extent [Kanis *et al*., 2005]. In adulthood, the significance of nutritional factors is likely to be diminished and the effect of the intake of calcium as well as protein, vitamin D, phosphates, alcohol, coffee or other nutritional factors may mainly be manifested by the impact on the rate of bone mass loss [Badurski *et al*., 2007; Lorenc & Kaczmarewicz, 2006; NIH, 2001].

An improper intake of calcium results chiefly from a low consumption of dairy products. They constitute the major source of calcium in diets of Europeans and provide from 60% to 80% of its total content [Kałuża *et al*., 2002; NIH, 2001; Szymelfejnik *et al*., 2006]. Investigations have shown that additional amounts of vitamins or minerals taken in the form of supplements or consumed with fortified foods are likely to improve diet quality and lower the risk of calcium deficiency [Bischoff-Ferrari *et al*., 2008; Di Daniele *et al*., 2004; Kałuża *et al*., 2004]. On the contrary, the use of vitamin supplements and/or minerals, especially in excessive quantities and without any control of a physician, may augment health risks and cause, among others, the shortening of lifespan [Brzozowska *et al*., 2004; Kałuża *et al*., 2004; Mulholland & Benford, 2007]. Calcium is a relatively often applied dietary supplement [Brzozowska *et al*., 2002; 2004; Kałuża *et al*., 2004; Murphy *et al*., 2007], and its intake requires research on the advisability of use and health implications.

The objective of the study was to determine the intake of calcium from dairy products in connection with the use of calcium supplements and consumption of calcium-fortified foods as well as to analyse its relation to the bone mineral density of women.

MATERIAL AND METHODS

Sample

The study covered 39 subjects at the age of 44.3±5.3 years (from 34 to 56 years), living in cities and villages of the Central Poland (Table 1). The sample was selected using the snowball method. The respondents participating in the study recommended their friends who met the sample criteria. The recruitment was also carried out through advertisements placed in the local press or posters pinned on information boards in clinics and information points in towns as well as through contact networks during the Świętokrzyskie Days of Prevention.

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TABLE 1. Sample characteristics.

Categories	Total	Tercile of BMD		
		T1	T2	T3
Number of subjects	39	12	14	13
Age* (years)	44.3±5.3 (42.6; 46.0)	47.4±5.0 (44.2; 50.6)	42.9±4.4 (40.4; 45.5)	43.0±5.5 (39.7; 46.3)
Hormonal status (% of the sample)				
regular menstruations	64	42	86	62
irregular menstruations	15	17	7	23
has not menstruated for at least 6 months	21	42	7	15

BMD – bone mineral density; *age expressed as mean value ± standard deviation; () – 95% mean confidence interval.

Selection criteria included: aged under 60 years, lack of nutrition disorders, no extreme sports activities at an advanced level, lack of diseases or previous surgical operations, and not taking drugs (for more than a year) likely to disturb hormonal balance, metabolism and bone metabolism [Bandurski *et al*., 2007]. Interviews and questionnaires were conducted at homes of the respondents by one well-trained pollster. The examinations were performed at the respondents' homes.

The hormonal status of the women was determined during interviews based on the regularity of menstruation (self-declared). Regular menstruations were declared by 64% of the sample, 15% of women menstruated irregularly and 21% of the respondents underwent menopause, *i.e*. had not menstruated for at least 6 months (Table 1).

Dairy products and calcium intake assessment

The intake of dairy products was determined with the method of the food frequency consumption using a validated ADOS-Ca questionnaire [Szymelfejnik *et al*., 2006]. The questionnaire enabled gathering data on the customary frequency and size of portions (in the last 6 months) of usually consumed 11 groups of dairy products: cheese, white fresh cheese, melted cheese, natural and fruit yoghurt, buttermilk/kefir, sour cream/sweet cream, ice cream in the season and outside the season, sweet homogenized white cheese and Fromage type cheese. Eight categories of consumption frequency of the products were converted into the mean frequency of consumption (th-times/day) using indices of consumption frequency stipulated during validation procedure of the questionnaire [Szymelfejnik *et al*., 2006]. Next, calculations were performed for the mean intake of dairy products (g/person/day) and the mean intake of calcium from dairy products (mg/person/day) with the use of Food Composition Tables [Kunachowicz *et al*., 2005]. The content of calcium in a daily diet (DD) was computed based on the mean intake of calcium from dairy products and a regression equation determined during validation of the ADOS-Ca questionnaire [Szymelfejnik *et al*., 2006]. In the validation studies it was found that dairy products were the source of approx. 74% of calcium in a daily diet.

An individual risk of the insufficient intake of calcium from DD was evaluated for each of the women [Normy żywienia…, 2008]. Calculations were made for z-values of an individual intake of calcium (D/SD_D) in respect of the adequate intake (AI) of calcium. Afterwards, the women were divided into 3 categories of calcium intake:

- insufficient ($D/SD_D<-1$),
- sufficient ($D/SD_D>1$),
- unspecified ($D/SD_D = -1 \div 1$).

A population risk of an inadequate intake of calcium from DD was estimated by determining the percentage of women with calcium intake below the adequate intake (AI).

During interviews, data were also collected on the customary frequency of consumption of:

- calcium-fortified ready-to-eat breakfast cereals,
- calcium-fortified juices.

An answer cafeteria contained 8 categories of frequency: (1) never, (2) <once a week, (3) 1÷2 times/week, (4) 3÷4 times/week, (5) 5÷6 times/week, (6) once a day, (7) 2 times/day, (8) ≥3 times/day, and "I do not know". Additional questions referred to taking calcium supplements (yes/no/I do not know) and their customary quantity taken in the last 6 months.

Bone tissue status assessment

The bone mineral density was evaluated by means of a pDEXA densitometer. Bone mineral density (BMD) was determined with the double-energy X-ray absorptiometry (DXA). Measurements were made for the distal area of radial bone and elbow bone.

The women were divided into three subgroups (T1, T2, T3) according to tercile ranges of their BMD values (T1: <358 mg/cm^2; T2: 358÷401 mg/cm^2; T3>401 mg/cm^2).

Statistical analysis

The intake of calcium was expressed by mean value ($\bar{x}$) and standard deviation (SD), however, its distribution did not follow the normal distribution. The mean intakes of calcium from dairy products and daily food rations in the tercile groups (T1-T2-T3) and in pairs were compared with the Kruskal-Wallis test. Because the calcium intake did not have normal distribution, the comparison of the mean values was of secondary importance in the interpretation of the results concerning the calcium intake. Such a method of data presentation was used to facilitate the comparison of the authors' data with the results obtained by other researchers. The qualitative data, *i.e*. trait distribution and correspondence analysis, were of the essential significance in the interpretation of the results. Distributions of traits were compared using the chi^2 test and the test for structure indicators.

Qualitative relations between the intake of calcium and calcium-fortified products, taking calcium supplements and bone tissue mineral status were evaluated with the analysis of correspondence (Burt's tables). They were included in the analysis of correspondence as the 4 following traits: calcium intake (categories: insufficient/sufficient/unspecified), taking calcium supplements (yes/no), taking calcium-fortified ready-to-eat breakfast cereals or calcium-fortified juices (yes/no), and bone mineral density (terciles: T1, T2, T3).

For the purpose of this analysis, the answer "I don't know" was re-coded into the answer "no". The T1, T2, T3 women did not differ in age or hormonal status (Table 1). Therefore, these traits were excluded from the correspondence analysis. The results of the correspondence analysis were presented in a figure in the system of two coordinates. Both dimensions explained together 52% of inertia, dimension 1: 30% of inertia, dimension 2: 22% of inertia. The statistical analysis was conducted by means of the Statistica PL v. 8.0 software.

RESULTS

The mean intake of calcium from DD by the women amounted 612 mg/day (Table 2). The women from the group T1 consumed significantly less calcium from DD as compared to the women from groups T2 and T3 (on average: 217 mg/day *vs*. 858 mg/day and 711 mg/day, respectively). Insufficient intake of calcium from DD (z-value of the individual intake <-1) was stated for all women from the group T1 as well as for a significantly lower percentage of the women from groups T2 (29%) and T3 (31%).

Distribution of the frequency of consumption of calcium-fortified ready-to-eat breakfast cereals by the women did not differ significantly between the tercile groups of BMD. Those products were consumed with a various frequency by 51% of the women, with most of the women (26%) consuming them with the frequency less than once a week. In contrast, significant differences were observed in the distribution of frequency consumption of calcium-fortified juices. Various consumption frequency of juices was stated for the highest percentage of the women from group T3 (85%), as compared to the women from groups T2 and T1 (64% and 42%, respectively).

No significant differences were observed between the women from groups T1, T2 and T3 in the case of taking calcium supplements. They were used by 28% of the women, the majority of whom were taking them without any consultation

TABLE 2. Calcium intake (mean value ± standard deviation) from dairy products and daily diet (DD), consumption of calcium supplements and consumption of calcium-fortified foods by the women in respect to their bone mineral density (BMD).

Categories	Percentage of sample (%)			
	Total	Tercile of BMD		
		T1	T2	T3
Calcium from dairy products (mg/person/day)#	453±715 (386; 813)	$161^{a,b}$±108 (118; 947)	635^{a}±1096 (279; 1281)	526^{b}±423 (243; 727)
Calcium from DD (mg/person/day)#	612±967 (521; 1098)	$217^{a,b}$±146 (160; 1280)	858^{a}±1481 (377; 1731)	711^{b}±572 (328; 982)
Calcium intake from DD**				
Insufficient $D/SD_D<-1$	51	100	29	31
Unspecified $D/SD_D=-1\div1$	41	0	57	61
Sufficient $D/SD_D>1$	8	0	14	8
Percentage of subjects with calcium intake form DD <AI	90	100	86	85
Ready-to-eat breakfast cereals fortified with calcium				
never	44	42	43	46
< once a week	26	33	29	15
1÷2 times/week	15	8	14	23
3÷4 times/week	5	0	7	8
once a day	5	8	0	8
I don't know	5	8	7	0
Calcium-fortified juices*				
never	23	50	14	8
< once a week	38	25	21	69
1÷2 times/week	18	17	29	8
3÷4 times/week	5	0	14	0
once a day	3	0	0	8
I don't know	13	8	21	8
Taking calcium supplements				
Yes	28	25	21	38
No	67	75	71	54
I don't know	5	0	7	8

significant differences between tercile groups T1-T2-T3 at $p<0.05$; a-a, b-b – significant differences in groups between T1, T2, T3 at $p<0.05$; () – 95% mean confidence interval; *$p<0.05$, **$p<0.001$.

with a physician in a dose of one pill of a calcium-containing supplements per day (9 out of 11 women). The other women declared taking 2 pills of such a supplements per day.

The analysis of correspondence demonstrated a correlation between the traits examined. The women constituted 3 clusters (Figure 1). The first cluster (C1) was made by the women characterised by an insufficient intake of calcium, the lowest bone mineral density (T1) and not consuming calcium-fortified foods and not taking calcium supplements. A strong correlation was observed for the insufficient calcium intake and the lowest BMD value (T1). Both the traits were located close to each other (in the same quarter of the system of coordinates) and formed a subgroup of cluster C1 (cluster C1a). Cluster C2 was made by the women with an average value of mineral bone density (T2) and a sufficient intake of calcium. In turn, cluster C3 included women with unspecified intake of calcium but consuming calcium-fortified foods and taking calcium supplements as well as having the highest value of bone mineral density (T3).

DISCUSSION

A relationship was demonstrated between bone mineral density of the women and calcium intake from food and non-food sources. Women with the lowest values of bone mineral density (the lower tercile of BMD) were shown to consume lower quantities of calcium from dairy products, which determined their calcium intake negligibly exceeding 200 mg/day. Simultaneously, the smallest percentage of those women were improving their calcium intake balance by consuming calcium-fortified foods. In addition, the women at the highest risk osteoporosis were taking calcium supplements equally infrequently as those at a lesser risk of osteoporosis. This indicates that persons with a low intake of calcium undertake actions aimed at improving diet balance by consuming calcium-fortified foods or using non-food source of calcium less frequently. It confirms that persons with health disorders usually have worse eating habits than those without such disorders. Such relations were observed in the Bogalusa Heart Study conducted for the metabolic syndrome risk and intake of vegetables and fruit [Yoo *et al*., 2004]. The results obtained in this study suggest the existence of similar relations between the osteoporosis risk and the intake of calcium and/or dairy products.

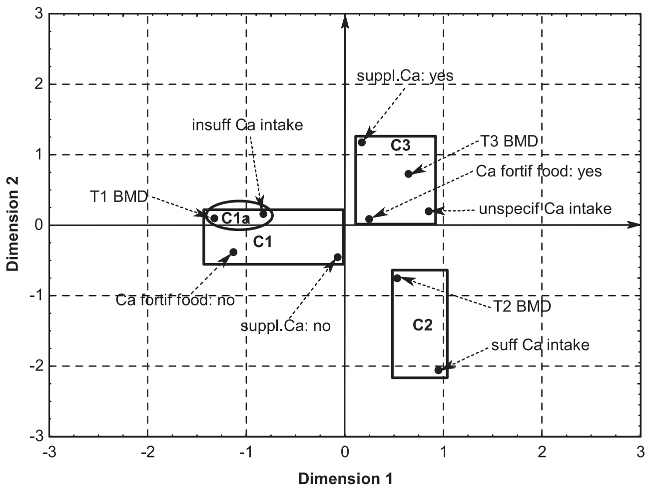

FIGURE 1. Relationship between calcium intake from a daily diet (DD) and calcium-fortified food products, consumption of calcium supplements and bone mineral density.

Explanations: "insuff Ca intake" – insufficient intake of calcium from DD; "suff Ca intake" – sufficient intake of calcium from DD; "unspecif Ca intake" – unspecified intake of calcium from DD; "suppl.Ca: yes" – taking calcium supplements; "suppl.Ca: no" – not taking calcium supplements; "Ca fortif food: yes" – consumption of calcium-fortified ready cereal breakfast products or drinking calcium-fortified juices; "Ca fortif food: no" – no consumption of calcium-fortified ready cereal breakfast products or calcium-fortified juices; "T1 BMD" – the lowest tercile of bone mineral density; "T2 BMD" – median tercile of bone mineral density; "T3 BMD" – the highest tercile of bone mineral density.

The research demonstrated that the appropriate calcium intake from dairy products was linked with an average bone mineral density (median tercile of BMD). It confirms previous reports showing that a high calcium intake from food and/or a high intake of dairy products is insufficient to diminish the risk osteoporosis, especially in post-menopausal women [Feskanich *et al*., 2003]. It may additionally be speculated that the level of calcium consumption by the women from the middle BMD tercile was too low (*ca.* 850 mg/day on average) to achieve a desired effect. In their investigation conducted with young women, Teegarden *et al*. [2005] demonstrated an increase in BMD values upon nutritional intervention and increased calcium intake (mainly from dairy products) to a level of 1200-1300 mg/day, *i.e*. higher by about 50% than that of the women examined in our study. These observations may explain some contradictory opinions on the role of dietary calcium in minimizing the osteoporosis risk and point to complex determinants of bone metabolism in the adults [Badurski *et al*., 2007; Lorenc & Kaczmarewicz, 2006; NIH, 2001].

The women from the middle and the upper tercile of bone mineral density were shown to consume similar quantities of calcium (at a level of 700-850 mg/day) and to more often drink calcium-fortified juices. The analysis of correspondence demonstrated, however, that the highest value of bone mineral density (the upper tercile of BMD) depended on taking calcium supplements and consuming calcium-fortified foods, and – to a lesser extent – on calcium intake from food, as the calcium intake from a daily diet by the women from that cluster (C3) was evaluated as unspecified [Normy żywienia…, 2008]. The results obtained in this study indicate that maintaining high bone mineral density by women requires a supply of calcium from dietary sources and supplements when no significant changes are made in eating habits. It confirms the significance of calcium supplementation for the bone mineral density [Bischoff-Ferrari *et al*., 2008; Di Daniele *et al*., 2004]. The results of a study by the research group of Di Daniele [2004] have formed the basis for recommending calcium (and vitamin D) supplementation as a strategy in the prevention of bone mass loss in women in the early post-menopausal period. However, relations between calcium intake from food and other sources and metabolism of the bone tissue in adult persons are highly complex and depend, among others, on calcium intake in childhood and adolescence [Matkovic *et al*., 2005; Nieves *et al*., 2008].

Nonetheless, this study has some limitations. The relations described refer to the average consumption of dairy products and calcium. The calcium intake by the women ranged from 500 to 1100 mg/day (95% of mean confidence interval) and thus any discussion should be conducted in respect to the women only in this range of calcium intake. For this reason, it is impossible to determine the effect of an increased intake calcium from food on bone mineral density and the corresponding significance of calcium intake from supplements and/or calcium-fortified foods.

CONCLUSIONS

A relationship was demonstrated between the bone mineral density of the women and calcium intake from dairy products, calcium-fortified foods and calcium supplements. The low BMD of the women resulted from a very low intake of calcium from dairy products and restricted use of calcium supplements and/or consumption of calcium-fortified foods. Appropriate calcium intake from dairy products was insufficient to reach high BMD values. The high BMD values of the women were determined by calcium intake from calcium-fortified foods and the consumption of calcium supplements, and – to a lesser extent – by calcium intake from dairy products with an average calcium intake.

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