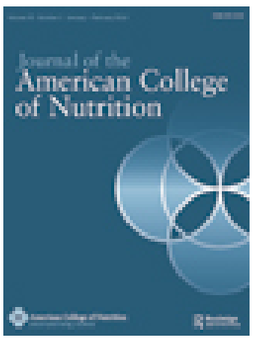

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Original Research

Calcium Intake and Bone Mass Development Among Israeli Adolescent Girls

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Key words: dietary calcium, double-blind method, bone development, bone density, adolescents, body weight, energy intake, Israeli, Arab

Objective: To determine the possible relationship between food and life style habits and bone health in adolescent Israeli females.

Methods: 2,000 adolescent Israeli Jewish and Arab high-school girls (mean age 14.5) completed a semi-quantitative food frequency questionnaire and a personal history questionnaire. 27 food components were calculated for each subject. Bone mineral content and density were determined for 112 subjects with calcium intake below 800 mg/day.

Results: Average calcium intake was found to be 1,260 mg/day, but 20% of all girls had a calcium intake below 800 mg/day. All low-energy diets were very low in calcium, as mean calcium intake per 1,000 calories was 411±128 grams. A large percentage of diets with less than 800 mg calcium were also deficient in phosphorus (95.2%), magnesium (84.8%), iron (90.5%) and zinc (100%). Due to differences in food sources, Jewish girls had more phosphorus in their diet, but less magnesium and iron compared to Arab girls. Calcium and zinc deficiencies in Jewish and Arab diets were similar. A negative correlation was found between body mass index (BMI) and age at menarche for all girls in the study. Bone mineral density (BMD) measured for girls with calcium intake below 800 mg/day distributed normally around the average when compared to age matched controls despite their low calcium intake. There was a strong positive correlation between BMD and bone mineral content (BMC) at all sites and body weights.

Conclusions: Low calcium intake, other nutritional deficiencies and delayed menarche due to low-energy diet in the growing period and in adolescence may prevent the formation of healthy bones. There is no evidence of lower bone mass among the low calcium intake group in the study population at this stage. It remains to be documented if the window of opportunity for optimal bone accretion for this group will be missed in the future, possibly leading to increased risk of osteoporosis.

INTRODUCTION

Some researchers believe that improving peak bone mass (PBM) could delay or even prevent osteoporosis [1,2]. The factors that determine PBM can be categorized as either fixed (i.e., genetic disposition, gender, general health state) or those that can be influenced (i.e., nutrition, physical activity, smoking, drug treatment choice) [3–6].

Balanced nutrition and adequate calcium intake in particular are major environmental factors believed to have a positive effect on bone accretion, operating within genetic boundaries [7–10]. The few clinical intervention studies that did not demonstrate significant association between calcium intake and bone density may have failed to do so due to confounding variables such as body weight of subjects, amount of physical activity and wide variation in subjects' age and sexual development stage. Taking these factors into consideration, new well-designed clinical studies have now established the positive influence of adequate calcium intake on bone gain during growth [11–16].

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A survey conducted by an Israeli female high-school student demonstrated the fact that problematic eating habits are more common among adolescent girls than boys, as girls show a greater tendency to go on low-energy (weight-watching) diets [17]. Consideration of this phenomenon and the well-established fact that women are at greater risk of developing osteoporosis served to define the study's target population as adolescent girls.

Presented here are the results of a survey of 2,000 adolescent girls in Israel. Nutritional and lifestyle habits and personal data were collected in an effort to define parameters believed to be related to bone health.

MATERIALS AND METHODS

A semi-quantitative food frequency questionnaire (FFQ) that included all known commercial dairy products (as a known calcium source) and all "typical" teenage foods (fast foods, snacks and the like) was developed. Reliability of the questionnaire was checked on a pilot group of 50 girls, who completed the survey once, then again two months later. There was a good and significant correlation between the calcium intake data obtained on both occasions ($r=0.525$, $p=0.007$). Validity for distribution of calcium intake was shown in previous work [18–20]. A computer program was designed to calculate the nutritional values of 27 nutrients in the questionnaire food products. Database values were taken from food tables of the Israeli Ministry of Health, information from Israeli food manufactures and international food composition tables [21–23].

In addition to this FFQ, the personal history questionnaire collected data about personal and medical history, lifestyle habits such as smoking and use of contraceptives, physical activity (reported as hours per week) and female development stage, established by age at menarche.

With permission from the local board of education, 2,000 female students, mean age 14.5 years (range 12 to 16 years), completed the study questionnaire in the presence of a trained dietitian. Demographic data of the study population is presented in Table 1. Of the study population, 1,350 girls were Jewish and 650 were Arab. The compliance rate was 99%, as the project was perceived to be a school task. One hundred eighty-seven questionnaires were discarded due to incorrect completion, in which it was evident that the girls did not comply with the requirements (including, for example, humorous remarks and unrealistic responses, such as extreme intakes). The adolescents whose questionnaires were discarded did not differ in age, weight or proportion of post-menarcheal girls from the girls that where included in the study.

After receiving approval from the hospital review board and financing from the Chief Scientist of the Israeli Ministry of Health, consent forms were completed by the parents of 112 girls from the low calcium intake group (mean intake 579 ± 60 mg Ca/day). Eighty-five girls were Jewish and 27 Arabs, mean age 14.7 ± 0.5; all girls were postmenarcheal, mean time since menarche 20 ± 11 months. Mean weight was 53 ± 8 kg, mean height 161 ± 6 cm. Bone mineral density (BMD) and bone mineral content (BMC) were measured at femoral neck (FN), lumbar spine (LS) and total body (TB) using the dual photon absorptiometry method (Lunar Corp) [24–25]. Nutritional and other data including religion, ethnicity, body measurements, health status and lifestyle factors were processed using the SPSS statistical package.

RESULTS

Mean calcium intake among the study population was 1,260 mg/day. In the study population, 20.4% of Jewish girls and 19.8% of Arab girls consumed less than 800 mg of calcium per day; 6.4% of Jewish and 7.3% of Arab girls consumed less than 500 mg/day (Fig. 1). Among girls who consumed below 800 mg calcium/day, a marked deficiency in phosphorus (in 95.2% of the girls), magnesium (in 84.8%), iron (in 90.5%) and zinc (in 100%) was also observed (Fig. 2).

While calcium and zinc dietary deficiencies were similar between the ethnic groups, iron and magnesium deficiencies were more common in the Jewish population, and phosphorus deficiencies were more common in the Arab population (Table 2). Regarding the former, Jews tended to eat poultry, whereas Arabs ate more lamb and beef, which are richer in iron and zinc. The latter results from differences in dietary composition: among Jewish girls, 18.3% of food intake was of dairy products rich in phosphorus, compared with 13.3% among Arab girls ($p<0.001$). Another distinction was the fact that Arab girls ate nuts and seeds, such as chickpeas and sesame paste, which are good sources of magnesium, at a rate five times higher than Jewish girls. The high vitamin C content of both subgroups'

Table 1. Demographic Data of Study Population

	Entire Group	Jewish Girls	Arab Girls	Significance
Age, years, mean ± SD	14.49 ± 0.63	14.54 ± 0.58	14.3 ± 0.78	$p < 0.0001$
(range)	(12–16)	(13–16)	(12–16)	
Weight, kg, mean±SD	49.4 ± 7.8	50.5 ± 7.7	45.6 ± 6.8	$p < 0.0001$
(range)	(30–80)	(30–80)	(30–65)	
Height, cm, mean±SD	161.1 ± 7.3	162.4 ± 6.8	156.0 ± 8.2	$p < 0.001$
(range)	(128–179)	(128–179)	(132–170)	

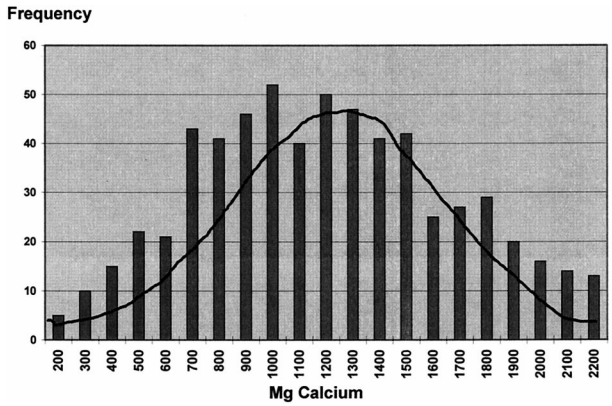

Fig. 1. Distribution of calcium intake compared with normal distribution.

diets (99% above US RDA in both) could be explained by the average fruit and vegetable consumption, which made up 55% of the Jewish population's diet and 60% of the Arab population's.

A highly significant relationship was established (r = 0.76, $p<0.001$) between calcium and energy intake: 97% of girls consuming less than 1,200 calories per day (due to following a weight-watching diet) consumed less than 800 mg calcium/day; 50% of these consumed less than 500 mg calcium/day. In the group that consumed 2,500 calories/day or more, only 4% had a calcium intake below 800 mg/day. The mean calcium intake per 1,000 calories was 411 ± 128 grams, median 393 grams. No correlation was found between caloric or calcium density distribution and the age of the girls. These data indicate that it is virtually impossible to meet the needs for calcium intake while consuming a low energy diet. Relative protein intake increased with the decrease of energy intake. Among girls with an intake below 1,200 calories/day, 15% to 17% of total calories came from protein, compared to 13.5% in girls with higher energy intake. This difference was not statistically significant.

Other lifestyle factors affecting bone health for which data was gathered included smoking, physical activity and age at menarche. A few girls smoked sporadically, although none were Arab or religious Jews. Mean physical activity was low, 3.5 ± 2.6 hours/week, and took place primarily in school training programs. In the study population, 97.4% of girls had reached menarche at the time of the survey. All girls in the survey had a lower body mass index (BMI) than the parallel age group of American girls [26]. Arab girls had slightly lower BMI values than their Jewish counterparts (Fig. 3). A significant inverse correlation was observed between the BMI and age at menarche (r=0.27, $p<0.001$) among both the Arab and Jewish populations (Table 3).

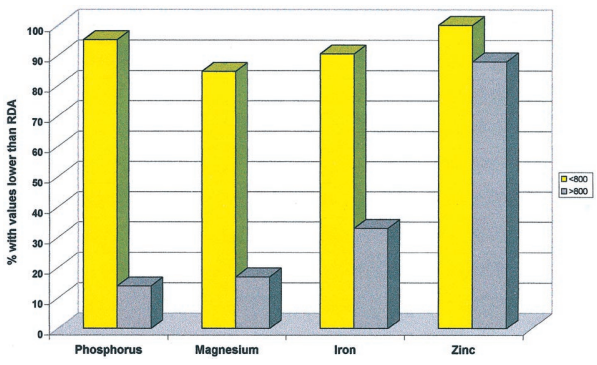

Fig. 2. Percent of population with mineral and trace element intake lower than recommended daily allowance by calcium intake level.

Table 2. Percent of Ethnic Group Consuming Less than Recommended Daily Allowances for Selected Nutrients

	Jews	Arabs	Statistical Significance
Phosphorus	30.4	43.8	$p < 0.009$
Magnesium	32.9	18.8	$p < 0.005$
Iron	46.7	29.2	$p < 0.001$
Vitamin C	1.1	1.0	NS
Zinc	91.8	93.8	NS
Calcium	51.2	47.9	NS

For the 112 girls from the low calcium intake group (mean intake 579 mg calcium/day ±160, mean age 14.9, all postmenarcheal girls), BMD measurements were TB 1.05 ± 0.07 g/cm^2, LS (L2-L4) 1.08 ± 0.12 g/cm^2 and FN 0.99 ± 0.11 g/cm^2. When compared with the normal BMD for age-matched controls from the Lunar normative database for the American population, Z scores distributed normally around average, despite the fact that the girls were all on a low calcium intake (Fig. 4) [27].

Both BMC and BMD showed a strong positive correlation to weight at all measurement sites. For BMC, TB r= 0.77, $p<0.0001$; LS r=0.49, $p<0.0001$, and FN r=0.55, $p<0.0001$. For BMD, TB r=0.57, $p=0.0001$; LS r=0.43, $p=0.0001$, and FN r=0.38 $p=0.0001$. BMD and BMC at all sites were also

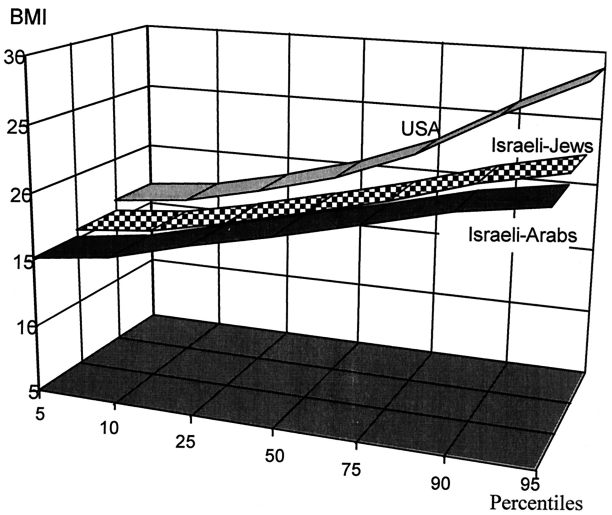

Fig. 3. Percentiles of Body Mass Index (W/S^2), for girls age 14.5, from the USA survey compared with Israeli Jewish and Arab girls.

Table 3. Age at Menarche by Mean Body Mass Index (BMI)

Mean BMI kg/M^2	Age of Menarche (years)
20.71	<12
20.13	12
19.07	13
18.35	14
17.92	NoPeriod

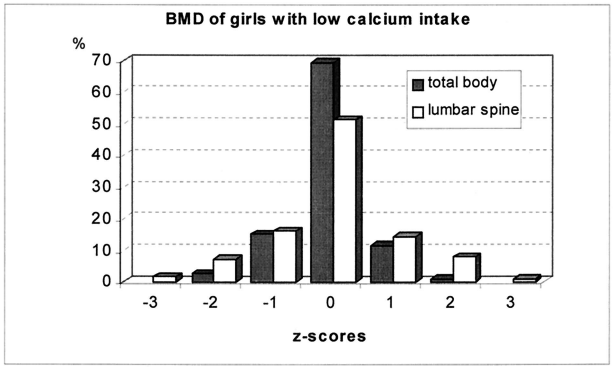

Fig. 4. Z scores of subjects' bone mineral density at two measurement sites, compared with age matched controls.

positively correlated with BMI, but the correlation was not as strong as with weight alone. Ethnicity had no affect on bone mass.

DISCUSSION

The results of this study describe the nutritional habits of Jewish and Arab Israeli adolescent girls from the perspective of bone health issues and peak bone mass (PBM) formation. Whereas mean calcium intake was satisfactory (1,260 mg/day) compared with data from other surveys [28–31], we demonstrated that 20% of the girls consumed less than 800 mg calcium per day. All girls on low-energy diets (<1,200 calories/day) had a low calcium intake (<800 mg/day). Mean calcium intake per 1,000 calories was 411 grams, putting all girls on low-energy diets in the calcium deficient group and at a disadvantage for bone mass accretion during the critical growth period.

Additional nutrient deficiencies identified in the low-calcium diet group were phosphorus, magnesium, iron and zinc. Whereas iron has no known effect on bone health, zinc, phosphorus and magnesium do play a role [32]. In the body, 85% of phosphorus and 60% of magnesium is set in bone tissue. Zinc has a role in bone metabolism and development, and there is a positive correlation between zinc levels and bone strength [33–35]. Therefore, calcium cannot be the only dietary issue addressed when considering optimal bone mass achievement. Nutritional needs for phosphorus and magnesium must also be considered, as has been done in studies in which milk provided the main source of added calcium [36–38].

Another factor that may affect the PBM is the negative correlation between body mass index and later age at menarche. The bulk of bone accretion is achieved by age 16 in girls, and estrogen levels play an important positive role in this process. Late menarche combined with low energy and low calcium diets may well deprive girls of the adequate chance to maximize peak bone density, a finding supported by a number of other studies [39–41].

Data about the prevalence of low energy diets among adolescent girls around the world emphasize the importance of this issue. According to a survey by the World Health Organization, an average of 10% of girls reported dieting by age 11 and 25% by age 15. Israel was reported to have the highest level of girls on diet for each age group. As many as 60% of girls aged 15 in the United States believed they should be dieting. The report also indicated that most girls on low energy diets do not get professional guidance; only 50% of dieters drink milk once a day, an amount far from assuring prevention of calcium and other nutrient deficiencies hazardous for bone health [42,43].

Other interesting data possibly related to bone health were provided by food source distribution data. More than 50% of the Middle Eastern diet is based on fruits and vegetables, some of which contain high concentrations of phytic and oxalic acids. These elements are able to form nearly insoluble compounds that are not absorbed by the body and are therefore eliminated in the feces [44]. These elements are believed to influence the body's absorption and utilization of minerals, particularly calcium, phosphate, iron, and magnesium, all of which were found to be deficient in the diets of the low calcium group.

In conclusion, these study findings demonstrate that adolescent Israeli girls, both Arab and Jewish, may constitute a group at risk for developing less than optimal peak bone mass, due to their nutritional habits. Lack of adequate energy intake, accompanied by inadequate intake of calcium, magnesium and phosphorus may combine to cause irreversible damage by jeopardizing the formation of healthy bones during adolescent years. Although bone mass distribution in the low calcium intake group did not differ from the normative adolescent data for population with variable calcium intake, it is possible that each individual did not reach her optimal PBM within genetic boundaries, especially given the fact that calcium supplementation studies demonstrated greater bone accretion during the calcium enriched nutrition period [15,16]. Failure to achieve high peak bone mass may result in the earlier onset of osteoporosis. These findings thus render appropriate dietary interventions and education, which can to a significant degree ameliorate the relevant nutritional deficiencies, crucial for Israeli adolescent girls determined to be at risk.

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