European Journal of Clinical Nutrition (2005) 59, 177–184
 0954-3007/05 $30.00
www.nature.com/ejcn

ORIGINAL COMMUNICATION

Low calcium and vitamin D intake in healthy children and adolescents and their correlates

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Background: Optimal dietary calcium and possibly vitamin D intake throughout childhood and adolescence may enhance bone mineral accrual. Little data on the intake of these nutrients in Mediterranean countries exist, and predictors of their suboptimal intake are not well defined.
Objective: To evaluate systematically the effect of gender, lifestyle factors, and socioeconomic status on mean calcium and vitamin D intake in healthy school children and adolescents from Lebanon.
Design: A total of 385 students aged 10–16 y were selected from four public and four private schools between Fall 1999 and Spring 2000. Information on calcium and vitamin D intake, through a semiquantitative food frequency questionnaire that was validated against a 7-day daily record, and on socioeconomic and lifestyle factors were obtained.
Results: Only 12% of the students met the adequate intake (AI) recommendation of 1300 mg of calcium/day, and only 16% met the AI recommendation of 200 IU of vitamin D/day. Boys had a significantly higher mean daily calcium intake than girls. Socioeconomic status as assessed by children's pocket money was a predictor of higher calcium and vitamin D intake. Eating breakfast and physical activity were other correlates of daily calcium and vitamin D intake.
Conclusions: Only a minority of students in our study met the AI for calcium and vitamin D. Gender, lifestyle factors, and socioeconomic status were significant predictors of calcium and vitamin D intake. Our findings have important implications regarding the institution of dietary public health strategies to promote skeletal health in Mediterranean countries during a critical time for bone mass accrual.
European Journal of Clinical Nutrition (2005) **59,** 177–184. doi:10.1038/sj.ejcn.1602056
Published online 6 October 2004

Keywords: calcium intake; vitamin D intake; socioeconomic status; adolescents; Mediterranean

Introduction

Peak bone mass that is achieved by early adulthood and bone loss thereafter are the key determinants of osteoporotic fractures in later life (Hansen *et al*, 1991). Although genetic factors are the strongest predictors of bone mass accounting for 50–80% of its variance, several lifestyle factors such as nutrition, exercise, and smoking explain an additional 20–30% of bone mass variance (Krall & Dawson-Hughes, 1993; Nguyen *et al*, 1998). Adolescence is a critical time for peak bone mass accrual, and boys achieve a higher peak bone mass than girls (Bonjour *et al*, 1991; Matkovic *et al*, 1994; Boot *et al*, 1997). Optimizing calcium intake either through dairy products or supplements increases areal bone mineral density in children and adolescents by 4–8%, depending on the study and skeletal site measured (Johnston *et al*, 1992; Llyod *et al*, 1993; Lee *et al*, 1994, 1995; Chan *et al*, 1995; Bonjour *et al*, 1997; Cadogan *et al*, 1997; Merrilees *et al*, 2000). This effect is most pronounced in children with the lowest intake at entry (Llyod *et al*, 1993; Lee *et al*, 1994; Bonjour *et al*, 1997), and may not necessarily persist after discontinuation of the supplementation (Bonjour *et al*, 1999; Ghatge *et al*, 2001). Therefore, it is likely that only consistent optimal dietary calcium intake throughout childhood and most importantly adolescence will be associated with enhanced peak bone mass.

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Received 23 December 2003; revised 19 July 2004; accepted 11 August 2004; published online 6 October 2004

Unfortunately, several estimates for the mean intake of calcium in healthy adolescents have demonstrated it to be low (Bowering & Clancy, 1986; Fleming & Heimbach, 1994; Iuliano-Burns *et al*, 1999; Cruz, 2000; Stang *et al*, 2000; NHANES III), which is well below current recommendations derived from calcium balance studies including that of the adequate intake (AI), which is the amount of calcium that should be aimed at daily by healthy adolescents (National Institutes of Health Consensus Conference, 1994; Institute of Medicine, 1997; American Academy of Pediatrics, 1999).

Calcium is absorbed in the gut under the effect of $1.25(OH)_2$ vitamin D. Vitamin D, the precursor of this active metabolite, is mostly found in fortified milk, which contributes to more than two-third of the dietary calcium intake in children (Fleming & Heimbach, 1994). It is thus plausible that vitamin D intake is also suboptimal in healthy adolescents; however, studies on this topic are scarce (NHANES III). There are currently no guidelines for vitamin D supplementation after infancy, and it is often assumed that after age 1 y there is no need for vitamin D supplementation (Weaver *et al*, 1999). Indeed, we, and others demonstrated a high prevalence of vitamin D insufficiency or deficiency in healthy children (Oliveri *et al*, 1993; Guillemant *et al*, 1995, 1999; Docio *et al*, 1998; Lehtonen-Veromaa *et al*, 1999; El-Hajj Fuleihan *et al*, 2001). Whereas nutritional rickets had been associated with severe vitamin D deficiency, studies in South Africa, suggested that severe dietary deficiency of calcium can also cause rickets in the presence of vitamin D insufficiency, rather than deficiency (Thacher *et al*, 1999).

Although peak bone mass is strongly influenced by genetic factors, the full genetic potential is only attained if nutrition, physical activity, and other lifestyle factors are optimized. Socioeconomic status (SES) is an important predictor of nutritional adequacy at extremes of the life span cycle (James *et al*, 1997; Harries *et al*, 2000; Wyatt & Triana Tejas, 2000). However, to the best of our knowledge, the associations among these variables and calcium and vitamin D intakes have not been well investigated in children and adolescents. Finally, whereas most studies demonstrating that the intake of calcium and vitamin is suboptimal in children and adolescents were implemented in Western countries, it is unclear that the same applies to Mediterranean countries known for their high intake of dairy products (Appel *et al*, 1997). The purpose of this study was to evaluate systematically the impact of gender, lifestyle factors, and SES on the consumption of calcium and vitamin D in healthy adolescents from a Mediterranean country during the critical time of peak bone mass accrual. The goals of the paper were to demonstrate the following:

1. Children and adolescents consume suboptimal amounts of both calcium and vitamin D, with boys having significantly higher calcium and vitamin D intakes than girls.
2. Children/adolescents who regularly eat breakfast have a better calcium and vitamin D intake than those who do not.
3. Socioeconomic background and parents' education would be anticipated to be significant predictors of their children's nutritional intake of calcium and vitamin D.

Such investigation would have an important impact on the planning of public health strategies in Mediterranean countries aimed at optimizing peak bone mass.

Methods

Sample size and protocol

Four private and four public schools in Greater Beirut, Lebanon were targeted for subject selection. Out of 10 schools originally contacted, eight approved to participate through personal contact with the school administrators. The schools were chosen to represent the major geographical areas of Greater Beirut. The private schools were categorized as high SES and the public schools as low SES. The survey included 385 adolescents aged between 10 and 16 y, during the period extending from October 1999 to January 2000. They were selected from a list providing the names of all the students aged 10–16 y within each school. From this list, students who were absent were excluded; then from each class approximately half the number of students were chosen at random and interviewed. The dietary survey was conducted by a student holding a BS in nutrition and constituted the material for her master thesis in nutrition (AK).

The estimation for sample size was based on an assumption that only 50% of students would fulfill the criteria for an adequate intake of calcium (Iuliano-Burns *et al*, 1999; Cruz, 2000). The following equation was used to estimate the sample size $n = Z^2_{1-\alpha/2}\, P\,(1-P)/d^2$, where n is the sample size, $Z = 1.96$, P is the estimated proportion (50%), and d is the desired precision (0.05). According to this formula the sample size needed is 384 students.

Questionnaire

Information was obtained using a validated food frequency questionnaire (FFQ) designed with the advice and supervision of nutritionists (AK, RT), a biostatistician (MD), and physicians (MN, MC, GE-HF) at the American University of Beirut. The questionnaire included nine sections. Sections 1–3 involved questions on school type, anthropometry, and socioeconomic status. Sections 4 and 5 investigated dietary habits of the students using a semiquantitative FFQ, which included food from the five categories of the food pyramid. Within each category, the choice of the food items was based on their calcium/vitamin D content, and the probability of their consumption by children and adolescents in our country. Foods that are likely to be consumed by teenagers were included (see below). Section 6 measured physical

activity levels that included mainly weight-bearing exercise types that are beneficial for bone mass: walking, jogging, swimming, tennis, and aerobics. Sections 7–9 investigated smoking, alcohol consumption, and sun exposure during the different seasons (summer, fall, and winter). No students use sunscreen regularly, but only 5% use sunscreen when skiing and 29% when at the beach. Girls who were veiled, and students who used sunscreens on the beach or when skiing, were considered to have no exposure to sunlight.

Calcium and vitamin D assessment

Information on calcium and vitamin D intake was gathered from sections 4 and 5 using a semiquantitative FFQ. Selection of items was based relative to the food composition of the Lebanese diet, frequency of use, and relative importance of food items as a calcium source. Additional subgroup items were added for high calcium content such as milk and derivatives. The total number of foods was 33 items, of which 45% belonged to the dairy groups. The questionnaire included the following food items: milk and dairy products including 14 calcium-enriched items such as milk, yogurt, strained yogurt, milkshakes, pudding, ice cream, cheese, pizza, cheesecake, cheeseburger, macaroni with cheese, cheese deserts, cheese strudel, and chocolate. Items on meat, fish, cereals and bread, vegetables, nuts, and fruits were also included. Adequacy of calcium and vitamin D intake in the subjects was assessed using the AI guidelines of 1300 mg of calcium and 200 IU of vitamin D (Dietary Reference Intakes reports). Students were asked whether they were taking calcium and/or vitamin D supplements. Estimation of the calcium content of products known to be imported from Western countries was derived from Mahan and Krause (Mahan & Escott-Stump, 1996). For local meals, calcium content was derived using the food tables of Pellet and Shadaverian (Pellet & Shadaverian, 1970). Estimation of the vitamin D content of food was derived from Mahan and Krause (Mahan & Escott-Stump, 1996).

Validation of questionnaire

Validation of the questionnaire was obtained through gathering of accuracy and reproducibility estimates in a sample of subjects of similar age. Accuracy was derived by comparing the FFQ to a 7-day food diary record in a sample of 10 children age 13(2) y. The correlation between the two questionnaires was 0.62 for calcium intake overall, and 0.74 for calcium intake from dairy, comparable to published data (Ilich *et al*, 1994). Furthermore, there was no significant difference between calcium intake overall, and calcium intake from dairy, when comparing the FFQ and the 7-day diary records ($P=0.2$ and 0.9, respectively). Reproducibility was assessed in 10 different subjects, mean age 12.75 (1.07) y, by administering the FFQ to the same subject twice 2 weeks apart. The correlation between the two was 0.72, comparable to the published data (Rockett *et al*, 1995).

Correlates of SES status

In addition to type of school (private *vs* public), other correlates of SES were obtained and included: father's working status and educational level, mother's working status and educational level, and weekly pocket money received by the student in dollars. The yearly fees in private schools for the age range studied varied between 2000 and 7000 US$.

Statistical analysis

Results were expressed as mean ($\pm$s.d.) for all variables except calcium intake and calcium from dairy intake and vitamin D intake, which were expressed as mean (CI), as they were not normally distributed. Comparison of continuous variables between various subgroups of subjects was performed using a two-tailed *t*-test. The relationship between various continuous variables such as calcium intake, vitamin D intake, sun exposure, physical activity, age, BMI, and soft drink consumption was evaluated using a Pearson correlation coefficient. χ^2 analysis was used to compare discrete variables between various subgroups of subjects. Stepwise linear multivariate regression analysis was performed. The dependent variables of interest were total calcium intake and vitamin D intake, which were log transformed to obtain a normal distribution of the outcome variable to fit the conditions of a linear regression model. The main correlates examined were gender, eating breakfast, soft drink consumption, exercise/week, sun exposure during fall, winter and summer, type of school, SES, and weekly pocket money. The analyses were performed using SPSS software version 10.0 (SPSS, Chicago, IL, USA).

Results

Characteristics of the study group

The characteristics of the study group are shown in Table 1. There were 207 girls and 178 boys with a mean age of 13 (1.8) y, almost equally distributed between private and public schools. A substantial proportion of students (>75%) consumed breakfast, an important source of calcium and vitamin D. A very small proportion of students were taking calcium or vitamin D supplements, more so in those belonging to private schools. Overall, only 20% of mothers worked, and 43% of fathers completed secondary school. These proportions were higher in parents of children who belonged to private schools as opposed to public schools (Table 1).

Calcium intake, vitamin D intake, sun exposure, and sports activity in the overall study group and by gender

In the study group overall, the mean daily calcium intake was 816 (776,855) mg, and the mean daily vitamin D intake was 129 (116,142) IU. Almost 80% of daily calcium intake came from dairy products. Only 12% of student met the AI

Table 1 Characteristics of the study participants[a]

Variable (N)	*Total (385)*	*Private schools (202)*	*Public schools (183)*	P-*value**
Age (y)	12.87±1.81	12.51±1.62	13.28±1.92	0.000
BMI (kg/m^2)	20±4	20±4	21±4	0.1
Weekly pocket money ($)	7.7±7	8.1±7	7±8	0.3
Breakfast intake Yes/No	305 (79%)/80 (21%)	155 (77%)/47 (23%)	150 (82%)/33 (18%)	0.2
Calcium supplement use	17 (4.5%)	13 (6.5%)	4 (2.2%)	0.2
Vitamin D supplement use	20 (5.3%)	15 (8%)	5 (3%)	0.4
Fathers' education				
Less than secondary	188 (49%)	61 (31%)	127 (69%)	0.000
Completed secondary	144 (43%)	112 (65%)	32 (20%)	0.000
Mothers' education				
Less than secondary	218 (57%)	77 (38%)	141 (77%)	0.000
Completed secondary	134 (35%)	109 (54%)	25 (14%)	0.000
Mother work status				
Housewife	306 (80%)	152 (76%)	154 (85%)	0.8
Working	76 (20%)	49 (24%)	27 (15%)	0.8
Father work status				
Unemployed/retired	20 (5%)	10 (5%)	10 (5%)	0.02
Working	353 (92%)	189 (94%)	164 (90%)	0.02

[a]Numbers represent mean±s.d. for continuous variables and *N* (%) for numbers and proportions.
* *P*-values for *t*-test and χ^2 test.

Table 2 Calcium intake, vitamin D intake, sun exposure, sports, and soft drinks consumption within each type of school by gender[a]

	Private schools (N)			*Public schools* (N)		
	Total (202)	*Girls (128)*	*Boys (74)*	*Total (183)*	*Girls (79)*	*Boys (104)*
Total calcium intake (mg/day)	842 [786,897]	786 [719,853]*	939 [843,1035]**	786 [783,844]	673 [595,750]	873 [793,952]**
From dairy (mg/day)	697 [646,748]	645 [585,705]*	787 [696,878]**,***	581 [537,625]	506 [445,567]	638 [576,670]**
Total vitamin D intake (IU/day)	145 [125,166]	143 [118,168]*	150 [113,186]	111 [97,124]	95 [76,114]	123 [103,142]**
Sun exposure (min/day)						
Summer	120 (188)	98 (165)*	158 (217)**	91 (106)	52 (69)	121 (119)**
Fall	36 (38)	32 (36)*	41 (39)	33 (37)	21 (32)	42 (39)**
Winter	20 (34)	20 (37)*	19 (29)	11 (21)	8 (19)	13 (22)**
Exercise (min/week)	161 (223)	83 (122)	297 (286)**	217 (262)	84 (180)	318 (270)**
Soft drinks (glasses/week)	5 (7)	4.5 (6)	6 (8)***	8 (10)	5.5 (6)	9.5 (12)**

[a]Calcium and vitamin D intake expressed as mean±CI , whereas for other variables numbers they are expressed as mean±s.d.
*Significant difference ($P<0.05$) between means of girls by school type.
**Significant difference ($P<0.05$) between means of girls and boys within each school type.
***Significant difference ($P<0.05$) between means of boys by school type.

recommended intake of 1300 mg of calcium and only 16% met the AI recommendation of 200 IU of vitamin D. There were clear gender differences in mean daily intake of calcium, averaging 743 (692,794) mg/day in girls and 900 (839,961) mg/day in boys, $P<0.0001$. Only 9.7% of girls and 15% of boys met the 1300 mg/day recommendation for daily calcium intake, whereas there were no gender differences in the overall study group in mean daily vitamin D intake, and boys spent significantly more time in the sun during summer averaging 136±167 min/day, as compared to 80±138 min/day in girls, $P<0.0001$. Boys also exercised for significantly longer times, spending 310±276 min/week as compared to 83±146 min/week in girls, $P<0.0001$. When similar analyses were conducted within each type of school, the same pattern described above for the overall group was observed, with the exception that in public schools, there were also gender differences in vitamin D intake (Table 2).

Lifestyle correlates of calcium and vitamin D intake

Children and adolescents who ate breakfast had a mean calcium intake of 858 (814,900) mg and a mean daily vitamin D intake of 135 (121,149) IU, which were higher than corresponding intakes in children who did not eat breakfast averaging 656 (561,752) mg and intake of 105 (74,136) IU, $P<0.05$ for calcium only. There were positive correlations between minutes of exercise per week and calcium intake $R=0.22$, $P<0.0001$, and also between

exercise and vitamin D intake $R=0.10$, $P=0.05$. Overall, 38 out of 207 girls were veiled and had a mean vitamin D intake of 95 (72,118) (69) IU/day as compared to 131 (111,152) (135) IU/day in the girls who were unveiled, $P<0.05$. There was an inverse correlation between BMI and both calcium and vitamin D intake, $R=-0.25$, and -0.19, respectively, $P<0.05$. Boys from public schools, but not private schools, consumed significantly more soft drinks than girls (Table 2). In addition, there was a positive correlation between weekly soft drink consumption and daily calcium intake $R=0.13$, $P=0.01$. There was a significant positive correlation between calcium and vitamin D intake (Figure 1).

Calcium intake, vitamin D intake, sun exposure and sports activity by SES

There was a highly significant positive correlation between the amount of weekly pocket money and daily intake of both calcium ($R=0.17$, $P<0.01$), and vitamin D ($R=0.13$, $P<0.01$). Girls but not boys belonging to public schools had a lower mean daily intake of calcium, vitamin D intake, and had lower sun exposure during all seasons than those belonging to private schools (Table 2). Children of mothers who worked or completed secondary school had higher intakes of calcium and vitamin D, higher sun exposure than those of lower SES levels (data not shown). In general, children of mothers and/or fathers who had higher education were more likely to meet the AI guidelines for calcium and vitamin D (data not shown). Only 10% of children in public schools and 20% of those attending private schools met the AI recommendation of 1300 mg of calcium/day, $P=0.005$, for difference between schools.

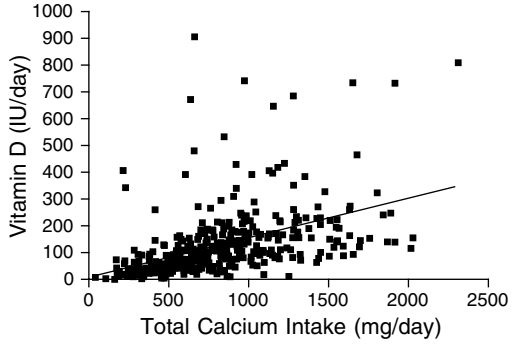

Figure 1 Relationship between vitamin D intake (IU/day) and total calcium intake (mg/day) in 385 study participants, $R=0.46$, $P<0.0001$.

Multivariate analyses for correlates of calcium and vitamin D intakes

Calcium intake. The following variables were significant correlates of log calcium intake: intake of breakfast, BMI, exercise per week, pocket money per week, sun exposure in the fall, mother's education, and soft drink consumption per week, with a cumulative $R^2=0.22$, $P<0.05$ (Table 3).

Vitamin D intake

Similarly, the following variables were significant correlates of log vitamin D intake: breakfast intake, BMI, mother's work, and pocket money per week, with a cumulative $R^2=0.11$, $P<0.05$ (Table 3).

Discussion

Our study revealed that a substantial proportion of healthy children and adolescents from a Mediterranean country consumed suboptimal amounts of calcium and vitamin D as defined by AI standards. We demonstrated that gender, lifestyle, and socioeconomic factors were important correlates of the daily intake of these nutrients. In the multivariate model, lifestyle and SES variables prevailed as the significant predictors of the daily intake of these nutrients, which are important for skeletal growth and development.

Table 3 Stepwise linear regression model with model estimates

Overall N = *385*	*Variable*	*Beta estimate*	R^{2a}	P-*value*
Log total calcium intake	Breakfast intake	0.16	0.079	0.000
	BMI	−1.4E-02	0.125	0.000
	Exercise hour per week	1.4E-04	0.160	0.003
	Pocket money dollars/week	3.6E-03	0.186	0.020
	Sun exposure in fall min/day	8.7E-04	0.204	0.004
	Mothers' education	5.1E-02	0.214	0.008
	Soft drinks consumption/week	3.2E-03	0.224	0.018
Log total vitamin D intake	Breakfast intake	0.20	0.039	0.000
	BMI	−2.1E-02	0.063	0.000
	Mothers' working status	0.18	0.091	0.001
	Pocket money dollars/week	8.3E-03	0.108	0.004

[a]Cumulative R^2 in each row shown as additional significant variables on bivariate analyses were added to the model.

Calcium intake

Several previous studies have examined the calcium intake of children and adolescents and found it to be generally low when compared to the daily requirements based on balance studies in this age group (Bowering & Clancy, 1986; Fleming & Heimbach, 1994; Iuliano-Burns *et al*, 1999; Cruz, 2000; Stang *et al*, 2000). These estimates have varied between 600 and 1400 mg/day, with clear gender differences, girls consistently having a significantly lower calcium intake than boys (Bowering & Clancy, 1986; Iuliano-Burns *et al*, 1999; Cruz, 2000; Stang *et al*, 2000). Surprisingly, the lowest estimates were reported from studies conducted in Spain, Greece, and Portugal, countries known to have a Mediterranean diet that is particularly enriched in calcium (Cruz, 2000). It is interesting to note that estimates from these studies were quite comparable to those demonstrated in our study, probably reflecting the Westernization of the adolescent diet in these countries (Cruz, 2000). To date, the largest and most comprehensive survey on calcium and vitamin D intake in adolescents is that of the National Health and Nutrition Evaluation Survey III conducted between 1988 and 1994 (NHANES III). Compared to our subjects, age-matched boys from North America had a higher mean calcium intake averaging between 1100 and 1200 mg/day, whereas estimates in girls were more comparable to our findings, averaging 800 mg/day (NHANES III). Such suboptimal intakes are a cause of concern, since girls belong to the gender that is at higher risk for lower peak bone mass and osteoporosis (Bonjour *et al*, 1991; Llyod *et al*, 1993; Matkovic *et al*, 1994; Chan *et al*, 1995). In addition, in the NHANES II survey, dairy products were the major sources of calcium in children and adolescents (Fleming & Heimbach, 1994; Iuliano-Burns *et al*, 1999), findings that are quite compatible with ours.

Vitamin D intake

Studies evaluating vitamin D intake in adolescents are scarce. In the NHANES III survey, the mean vitamin D intake was much higher than ours, averaging 270–280 IU in boys and 180–220 IU daily in girls, but still coming slightly short of the AI recommendation in a significant proportion of girls (NHANES III). Such intakes would correspond to mean serum 25 OH D levels fluctuating between 26 and 36 ng/ml, levels that are not expected to jeopardize skeletal integrity (Looker *et al*, 2002). Vitamin D is most commonly and abundantly found in fortified milk, eggs, liver, and fish such as herring, mackerel, or tuna canned in oil (Bouillon *et al*, 1998). Except for milk, adolescents are not very likely to consume these food items on a regular basis. In our study, boys had a higher intake of calcium, including calcium from dairy, and a higher vitamin D intake than girls, findings quite consistent with previous studies (Bowering & Clancy, 1986; Iuliano-Burns *et al*, 1999; Cruz, 2000; Stang *et al*, 2000; NHANES III). The other potential source of vitamin D is medicinal supplements. However, only a very small proportion of children were taking any calcium or vitamin D supplements, findings comparable to those of several other studies examining the vitamin–mineral supplement use in this age group (Bowering & Clancy, 1986; Looker *et al*, 1987; Stang *et al*, 2000). To date, the question of whether suboptimal intakes of vitamin D, such as the ones reported in this study, may have deleterious effects on the skeletal maturation of children and adolescents remains unresolved. We and others have previously suggested that it may negatively affect bone mass accrual, but this hypothesis remains to be proven (Docio *et al*, 1998; El-Hajj Fuleihan *et al*, 2001; Outila *et al*, 2001). One recent study suggests that it may indeed be the case (Lehtonen-Veromaa *et al*, 2002).

Correlates of calcium and vitamin D intakes

In our study, the significant correlates of calcium and vitamin D intake were exercise, sun exposure, and SES, as assessed by several markers of these variables. It is not surprising that calcium and vitamin D intakes correlated with sun exposure and exercise, which are the surrogate markers of a healthy lifestyle. The impact of SES on nutrition has been previously documented by other investigators in older age groups (James *et al*, 1997; Harries *et al*, 2000). Baba *et al* (1991) have demonstrated that children from Lebanese public schools had more stunting and wasting than those attending private schools, and that preschoolers from lower socioeconomic backgrounds had lower intakes of basic nutrients such as vitamin A, D, and calcium (Baba *et al*, 1996). Similarly, analyses based on the NHANES II data set revealed a positive relationship between parent's education and income level with supplement use in children (Bowering & Clancy, 1986). Furthermore, more recent data from NHANES III also reveals ethnic differences in both calcium and vitamin D intake in adolescents (NHANES III; Mahan & Escott-Stump, 1996). The significant correlation between mean calcium intake and soft drinks consumption in not novel (Barr, 1994), and may be explained through SES. Indeed, the more affluent adolescents have a higher calcium intake and consume more soft drinks. Our findings of a significant impact of SES on calcium and vitamin D intake may have important implication on public health initiatives at several levels including students, parents, and educators.

Effect of breakfast

In this study, children who ate breakfast had a calcium intake that, on the average, was 200 mg higher than that of children who skipped breakfast. This may partially account for our observed gender differences in calcium intake, since boys were more likely to consume breakfast than girls. It has been suggested that dairy products are a superior source of calcium supplementation due to their persistent effect on bone mass postdiscontinuation in supplementation trials, and the fact that they may have a direct anabolic effect on bone due to their protein content and/or effect on the IGF1 axis (Eastell & Lambert, 2002). Whereas it has been

erroneously argued that optimizing the intake of dairy products in adolescents may result in weight gain, our study as well as others demonstrated a negative correlation between dairy products and weight/or BMI (Carruth & Skinner, 2001). This suggests that children who eat dairy products are less likely to eat other high caloric foods and more likely to follow a healthy lifestyle, as we demonstrated.

Limitations to the study

As in any cross-sectional survey, there are several limitations to our study. These include the potential of recall bias pertaining to information gathered on any lifestyle measure assessed in this study. For dietary surveys, this recall bias may be less likely when an FFQ is used, as compared to the use of a dietary recall format. Furthermore, students are unlikely to comply with dietary recall forms, which also tend to be cumbersome with large sample sizes. Finally, it has been demonstrated that an adequately designed FFQ is a simple and convenient method for gathering dietary information in a large sample size. Furthermore, our validation studies compare well with similar ones previously published (Ilich *et al*, 1994; Rockett *et al*, 1995). In addition, in the case of calcium intake, it was demonstrated to correlate well with a 4-day weighed food record in postmenopausal woman (Angus *et al*, 1989) and with a 1-day food-intake record in adolescents (Barr, 1994). The questionnaire was administered to all students in the period of October 1999–January 2000, and therefore does not take into account potential seasonal variations in nutrient intake. Indeed, dairy product intake has been reported to be lower in Canadian girls during winter, as compared to summer (Iuliano-Burns *et al*, 1999). We may have underestimated therefore, the average yearly intake of these nutrients in our students, as we did not cover the summer months. In general, although all food intake records suffer from limitations, the FFQ form is an accepted one in the literature (Angus *et al*, 1989; Barr, 1994; Ilich *et al*, 1994; Rockett *et al*, 1995; Sempos *et al*, 1999).

Conclusion

Healthy children and adolescents from a Southern Mediterranean country have suboptimal intakes of calcium and vitamin D during a critical time of skeletal development. Subgroups of particularly higher risk are girls, students with a less healthy lifestyle, and those who come from lower SES backgrounds. Public health strategies should be targeted not only to students of both sexes but also to parents, schools administrators, and health educators, especially those families from a less favorable SES background. Low-fat milk or low-fat flavored yogurt may be ideal vehicles to promote skeletal health due to their enrichment in both calcium and vitamin D, their nutritive value including protein content, their relatively low cost, and hence easy accessibility to children/adolescents of all socioeconomic backgrounds.

Acknowledgements

We acknowledge the support from the administrators, parents, and students from all schools who participated in the survey and made the study possible.

References

American Academy of Pediatrics. Committee on nutrition (1999): Calcium requirements of infants, children, and adolescents. *Pediatrics* **104**, 1152–1156.

Angus RM, Sambrook PN, Pocock NA & Eisman JA (1989): A simple method for assessing calcium intake in Caucasian women. *J. Am. Diet. Assoc.* **89**, 209–214.

Appel L, Moore T, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, Bray GA, Vogt TM, Cutler JA, Windhauser MM, Lin PH & Karanja N (1997): A clinical trial of the effects of dietary patterns on blood pressure. *N. Engl. J. Med.* **336**, 1117–1124.

Baba NH, Hamadeh S & Adra N (1991): Nutritional status of Lebanese school children from different socioeconomic background. *Ecol. Food Nutr.* **25**, 183–192.

Baba NH, Shaar K, El-Sheikh Ismail L & Adra N (1996): Comparison of nutritional status of preschool children at day care centers and at home from different socioeconomic backgrounds in Beirut. *J. Hum. Nutr. Diet.* **9**, 89–103.

Barr SI (1994): Associations of social and demographic variables with calcium intakes of high school students. *J. Am. Diet. Assoc.* **94**, 260–266.

Bonjour JP, Carrie AL, Ferrari S, Clavien I, Solsman D, Theintz G & Rizzoli R (1997): Calcium-enriched foods and bone mass growth in prepubertal girls: a randomized double-blind, placebo controlled trial. *J. Clin. Invest.* **99**, 1287–1294.

Bonjour JP, Slosman D, Barclay D & Rizzoli R (1999): A significant effect of calcium-enriched foods on bone mineral mass gain is maintained more than 3 years after discontinuation of the intervention. *J. Bone. Miner. Res.* **14** (Suppl 1), S311 (Abstract).

Bonjour JP, Theintz G, Buchs B, Slosman D & Rizzoli R (1991): Critical years and stages of puberty for spinal and femoral bone mass accumulation during adolescence. *J. Clin. Endorinol. Metab.* **73**, 555–563.

Boot AM, deRidder MAJ, Pols HA, Krenning EP & deMuinck Keizer-Schrama SMPF (1997): Bone mineral density in children and adolescents: relation to puberty, calcium intake, and physical activity. *J. Clin. Endocrinol. Metab.* **82**, 57–62.

Bouillon R, Carmeliet G, Daci E, Segaert S & Verstuyf A (1998): Vitamin D metabolism and action. *Osteoporos. Int.* **8** (Suppl), S13–S19.

Bowering J & Clancy KL (1986): Nutritional status of children and teenagers in relation to vitamin and mineral use. *J. Am. Diet. Assoc.* **86**, 1033–1038.

Cadogan J, Eastell R, Jones N & Barker ME (1997): Milk intake and bone mineral acquisition in adolescent girls. *BMJ* **315**, 1255–1260.

Carruth BR & Skinner JD (2001): The role of dietary calcium and other nutrients in moderating body fat in preschool children. *Int. J. Obes. Relat. Metab. Disord.* **25**, 559–566.

Chan GM, Hoffman K & McMurray M (1995): Effect of dairy products on bone and body composition in pubertal girls. *J. Pediatr.* **126**, 551–556.

Cruz JA (2000): Dietary habits and nutritional status in adolescents over Europe-Southern Europe. *Eur. J. Clin. Nutr.* **54** (Suppl 1), S29–S35.

Dietary Reference Intakes reports, seewww.nap.edu.

Docio S, Riancho JA, Perez A, Olmos JM, Amado JA & Gonzallez-Macias J (1998): Seasonal deficiency of vitamin D in children: a potential target for osteoporosis preventing strategies. *J. Bone Miner. Res.* **13**, 544–548.

Eastell R & Lambert H (2002): Diet and healthy bones. *Calcif. Tissue Int.* **70**, 400–404.

El-Hajj Fuleihan G, Nabulsi M, Choucair M, Salamoun M, Hajj Chahine C, Kizirian A & Tannous R (2001): Hypovitaminosis D in healthy school children. *Pediatrics* **107**, E53.

Fleming KH & Heimbach JT (1994): Consumption of calcium in the US: Food sources and intake levels. *J. Nutr.* **124**, 1426S–1430S.

Ghatge KD, Lambert HL, Barker ME & Eastell R (2001): Bone mineral gain following calcium supplementation in teenage girls is reversed two years after withdrawal of the supplement. *J. Bone. Miner. Res*. **16** (Suppl 1), S173 (Abstract).

Guillemant J, Cabrol S, Allemandou A, Peres G & Guillemant S (1995): Vitamin D dependent seasonal variation of PTH in growing male adolescents. *Bone* **17**, 513–516.

Guillemant J, Taupin HTLe, Tarigh N, Alemandou A, Peres G & Guillemant S (1999): Vitamin D status during puberty in French healthy male adolescents. *Osteoporos. Int.* **10**, 222–225.

Hansen MA, Overgaard K, Riis BJ & Christiansen C (1991): Role of peak bone mass and bone loss in postmenopausal osteoporosis: 12 year study. *Br. Med. J.* **303**, 961–964.

Harries S, Soteriades E, Coolidge JAS, Mudgal S & Dawson-Hughes B (2000): Vitamin D insufficiency and hyperparathyroidism in a low income, multiracial, elderly population. *J. Clin. Endocrin. Metab.* **85**, 4125–4130.

Ilich JZ, Hsieh LC, Tzagournis MA & Matkovic V (1994): Validation of food frequency method for assessing calcium intake in children: comparison with 3-day dietary records. *Faseb. J.* **8**, A179 (Abstract).

Institute of Medicine, Food and Nutrition Board (1997): *Dietary Reference. Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Washington DC: National Academy Press.

Iuliano-Burns S, Whiting SJ, Faulkner RA & Bailey DA (1999): Levels, sources, and seasonality of dietary calcium intake in children and adolescents enrolled in the university of Saskatchewan pediatric bone mineral accrual study. *Nutr. Res*. **19**, 1471–1483.

James WP, Nelson M, Ralph A & Leather S (1997): The contribution of nutrition to inequalities in health. *BMJ* **314**, 1545–1549.

Johnston CC, Miller IZ, Slemenda CW, Reister TK, Hui S, Christian JC & Peacock M (1992): Calcium supplementation and increases in bone mineral density in children. *N. Engl. J. Med.* **327**, 82–87.

Krall EA & Dawson-Hughes B (1993): Heritable and lifestyle determinants of bone mineral density. *J. Bone Miner. Res*. **8**, 1–9.

Lee WT, Leung SS, Leung DM, Tsang HS, Lau J & Cheng JC (1995): A randomized double-blind controlled calcium supplementation trial, and bone and height acquisition in children. *Br. J. Nutr.* **74**, 125–139.

Lee WTK, Leung SS, Wang SH, Xu YC, Zeng WP, Lau J, Oppenheimer SJ & Cheng JC (1994): Double-blind controlled calcium supplementation and bone mineral accretion in children accustomed to low calcium diet. *Am. J. Clin. Nutr.* **60**, 744–750.

Lehtonen-Veromaa M, Mottonen T, Irjala K, Karkainen D, Lamberg-Allardt C, Hakols P & Viikari J (1999): Vitamin D intake is low and hypovitaminosis D common in healthy 9- to 15-year-old Finnish girls. *Eur. J. Clin. Nutr.* **53**, 746–751.

Lehtonen-Veromaa M, Mottonen T, Nuotio I, Irjala K, Leinao A & Viikari J (2002): Vitamin D and attainment of peak bone mass among peripubertal Finnish girls: a 3-y prospective study. *Am. J. Clin. Nutr.* **76**, 1446–1453.

Llyod T, Andon MB, Rollings N, Martel JK, Laudis JR, Demers LM, Eggli DF, Kieselhorst K & Kulin HE (1993): Calcium supplementation and bone mineral density in adolescent girls. *JAMA* **270**, 841–844.

Looker AC, Dawson-Hughes B, Calvo MS, Gunter EW & Sahyoun NR (2002): Serum 25-hydroxy vitamin D status of adolescents and adults in two seasonal subpopulations from NHANES III. *Bone* **30**, 771–777.

Looker AC, Sempos CT, Johnson CL & Yetley EA (1987): Comparison of dietary intakes and iron status of vitamin–mineral supplement users and non-users, aged 1–19 years. *Am. J. Clin. Nutr.* **46**, 665–672.

Mahan LK & Escott-Stump S (1996): *Krause's Food, Nutrition, and Diet Therapy*, 9th Edition. W.B. Saunders Company: Philadelphia, USA.

Matkovic VJT, Jelic T, Wardlaw GM, Ilich JZ, Goel PK, Wright JK, Andon MB, Smith KT & Heaney RP (1994): Timing of peak bone mass in Caucasian females and its implication for the prevention of osteoporosis. *J. Clin. Invest.* **93**, 799–808.

Merrilees MJ, Smart EJ, Gilchrist NL, Frampton C, Turner JG, Hooke E, March RL & Maguire R (2000): Effect of dairy food supplements on bone mineral density in teenage girls. *Eur. J. Nutr.* **39**, 256–262.

National Institutes of Health Consensus Conference (1994): NIH consensus development panel on optimal calcium intake. *JAMA* **272**, 1942–1948.

Nguyen TV, Howard GM, Kelly PJ & Eisman JA (1998): Bone mass, lean mass and fat mass: same genes or same environment? *Am. J. Epidemiol.* **147**, 3–16.

NHANES III: http://www.cdc.gov/nchs/data/series/sr_11/sr11_245.pdf.

Oliveri MB, Ladizesky M, Mautalen CA, Alonso A & Martinez L (1993): Seasonal variations of 25 hydroxyvitamin D and parathyroid hormone in Ushuaia (Argentina), the southernmost city in the world. *J. Bone Miner. Res*. **20**, 99–108.

Outila TA, Karkkainen MUM & Lamberg-Allardt CJE (2001): Vitamin D status affects serum parathyroid hormone concentrations during winter in female adolescents: associations with forearm bone mineral densirty. *Am. J. Clin. Nutr.* **74**, 206–210.

Pellet PL & Shadaverian S (1970): *Food Composition: Tables for Use in the Middle East*, 2nd Edition, Beirut, Lebanon: Heidelberg Press.

Rockett HR, Wolf AM & Colditz GA (1995): Development and reproducibility of a food frequency questionnaire to assess diets of older children and adolescents. *J. Am. Diet. Assoc.* **95**, 336–340.

Sempos CT, Liu K & Ernst N (1999): Food and nutrient exposures: what to consider when evaluating epidemiologic evidence. *Am. J. Clin. Nutr.* **69** (Suppl), 1330S–1338S.

Stang J, Story MT, Harnack L & Neumark-Sztainer D (2000): Relationships between vitamin and mineral supplement use, dietary intake, and dietary adequacy among adolescents. *J. Am. Diet. Assoc.* **100**, 905–910.

Thacher TD, Fisher PR, Pettifor JM, Lawson JO, Isichei CO, Reading JC & Chang GM (1999): A comparison of calcium, vitamin D or both for nutritional rickets in Nigerian children. *N. Engl. J. Med.* **341**, 563–568.

Weaver CM, Peacock M & Johnston CC (1999): Adolescent nutrition in the prevention of postmenopausal osteoporosis. *J. Clin. Endocrinol. Metab*. **84**, 1839–1843.

Wyatt CJ & Triana Tejas MA (2000): Nutrient intake and growth of preschool children from different socioeconomic regions in the city of Oaxaca, Mexico. *Ann. Nutr. Metab*. **44**, 14–20.