HEALTH EDUCATION RESEARCH
Vol.24 no.2 2009
Pages 173–184
Advance Access publication 21 March 2008

Psychosocial, environmental and behavioral factors associated with bone health in middle-school girls

Shreela V. Sharma[1]*, Deanna M. Hoelscher[2], Steven H. Kelder[2], R. Sue Day[1] and Albert Hergenroeder[3]

Abstract

The purpose of this study was to identify the psychosocial, environmental and behavioral factors associated with calcium intake, physical activity and bone health in a cohort of adolescent girls. Baseline data (N = 718 girls, mean age: 11.6 ±0.4 years) from the Incorporating More Physical Activity and Calcium in Teens (IMPACT) study conducted in Texas, 2001–03, were utilized for the analyses. Hierarchical linear regression was used to examine the associations of interest. Confounders adjusted for included ethnicity, menarchal status, body mass index and lactose intolerance. Several psychosocial and behavioral factors were significantly associated with bone quality. These included knowledge of calcium content of foods (β = 0.08, P = 0.016), self-efficacy toward consuming calcium-rich foods (β = 0.16, P = 0.047), physical activity self-efficacy (β = 0.20, P = 0.002), physical activity outcome expectations (β = 0.5, P = 0.004), family encouragement to do physical activity (β = 0.96, P = 0.027), friend engagement in physical activity (β = 1.3, P = 0.001) and participation in sports teams (β = 1.7, P < 0.001). Self-efficacy, social support and participation in sports teams appear to be strongly associated with bone health in adolescent girls. Future health education/health promotion programs need to address these factors for effective primary prevention of osteoporosis in this population.

[1]The University of Texas Health Science Center at Houston, School of Public Health Michael and Susan Dell Center for Advancement of Healthy Living, [2]The University of Texas School of Public Health, Austin Regional Campus Michael and Susan Dell Center for Advancement of Healthy Living and [3]Baylor College of Medicine, Texas Children's Hospital, Houston, TX, USA
*Correspondence to: S. Sharma.
E-mail: shreela.v.sharma@uth.tmc.edu

Introduction

Osteoporosis is a disease characterized by low bone mass and deterioration of bone tissue leading to increased risk of bone fractures [1]. The World Health Organization defines osteoporosis as bone mineral density (BMD) >2.5 standard deviation (SD) below the mean for normal young adults [1]. Fifty percent of all fractures in women >50 years are osteoporosis related [2]. It is highly age and gender related; currently >10 million people over the age of 50 in the United States have the disease, 80% of those being women [2, 3]. Another 34 million have osteopenia or low bone mass placing them at increased risk for osteoporosis. With the aging population, the prevalence of this disease is expected to increase rapidly. By 2010, ~12 million in the United States are expected to have osteoporosis and another 40 million will have low bone mass [3].

While genetics is a major determinant of bone mass, achievement of peak bone mass during the years of growth by behaviors such as increased calcium intake and physical activity during childhood and adolescence could delay and prevent the onset of bone loss later in life [4, 5]. Up to 90% of peak bone mass is acquired by age 18 years in girls and 20 years in boys, which makes childhood and adolescence a critical time to promote behaviors that increase bone health [5, 6].

doi:10.1093/her/cyn009

Literature shows that psychosocial and environmental factors mediate the associations between behavior and disease [7–10]. Behavior change is greatly facilitated by addressing these mediating factors. However, there are no studies examining multiple psychosocial and environmental correlates of calcium intake, physical activity and their relationship to bone health in a single cohort of adolescent females. Since psychosocial, behavioral and physical factors can potentially influence each other both theoretically and structurally [7], examination of these relationships for calcium intake and physical activity will provide new information on how these factors affect behavior and bone health and help to guide the design of effective osteoporosis prevention programs. Furthermore, since development of osteoporosis is highly gender specific with women clearly at a higher risk as compared with men [4, 11], it can be advantageous to examine these relationships in a gender-specific manner. The purpose of this study was to identify the psychosocial, environmental and behavioral factors associated with calcium intake, physical activity and bone health in a cohort of adolescent girls.

Table I. *Descriptive characteristics of female middle-school students, IMPACT study*

Variable	Number	Percent
Total	718	
BMI-for-age percentiles[a]		
<5th percentile	28	4
>5th to < 85th percentile	510	71
>85th to <95th percentile	105	15
>95th percentile	74	10
Ethnicity		
White	515	72
Hispanic	83	12
Black	39	5
Other	80	11
Onset of menses	140	20
	Mean	SD
Age (years)	11.6	±0.4

[a]Calculations and classifications are based on National Center for Health Statistics and National Center for Chronic Disease Prevention and Health Promotion growth charts with <5th percentile = underweight, >5th to <85th percentile = normal weight, >85th to <95th percentile = at risk for overweight and >95th percentile = overweight at risk for obesity.

Methods

This study uses baseline data from The Incorporating More Physical Activity and Calcium in Teens (IMPACT) study. IMPACT was a 1.5-year quasi-experimental, school-based nutrition and physical activity intervention program conducted from 2001 to 2003 to promote BMD among middle-school girls in central Texas [12] (D. M. Hoelscher, R. S. Day, S. H. Kelder, A. Hergenroeder, J. Ward, E. Baumler unpublished data). The baseline study population consisted of sixth-grade girls (n = 12 schools, 718 girls at baseline) (Table I). The response rate was 38% for all the girls. It is important to note that there were no significant sociodemographic and ethnic differences between the responders and non-responders and 100% of the required sample size was recruited [12] (D. M. Hoelscher, R. S. Day, S. H. Kelder, A. Hergenroeder, J. Ward, E. Baumler unpublished data). Parental consent and student assent were obtained from all study participants. Approval for the study was obtained from the University of Texas Health Science Center, Committee for Protection of Human Participants.

Data collection measures and variables of interest

Data collection of all baseline measures was conducted in Fall of 2001 at school sites by trained project staff.

Anthropometric measures

Digital scales (SECA 770 or Tanita BWB-800S) and stadiometers (Perspectives Enterprises, Portage, MI) were used for weight and height measurements, respectively, using a standardized protocol. Height and weight were used to calculate body mass index (BMI) using the formula weight (kg)/height (m)^2. Prevalence of overweight in the study participants was determined using age- and gender-specific BMI percentiles calculated using the measured height and weight. BMI >95th percentile for age and sex was considered overweight, and a BMI >85th percentile and <95th percentile for age and sex was considered at risk of overweight. Percentiles were determined using the Centers for Disease Control gender- and age-specific BMI charts [13]. Participants self-described their ethnicity as per a predetermined ethnic classification. Data on menarchal status were obtained by asking the girls if they had started menstruation. Table I presents the distribution of BMI and other demographic variables of interest.

Bone health

Quantitative ultrasound (QUS) has been shown to provide information on the qualitative and quantitative aspects of the bone tissue [14]. For this study, QUS was measured at the calcaneus using the Achilles+ Lunar G/GE Electronics ultrasound unit (Lunar, Madison, WI). QUS parameters measured were broadband ultrasound attenuation (BUA), speed of sound (SOS) and a clinical index named stiffness index (SI). SI was calculated automatically by the machine using the formula: $SI = (0.67 \times BUA + 0.28 \times SOS) - 420$. Os calcis, a weight-bearing site with trabecular bone, has BMD values that follow a similar pattern to that of the proximal femur [14]. Thus, changes in the bone should be reflective of changes in the BMD of the proximal femurs.

Food frequency questionnaire

The interviewer-administered food frequency questionnaire (FFQ) was used to assess frequency of consumption of various foods as well as the mean portion size consumed during the last week. The FFQ was adapted from a previous instrument developed to assess calcium intake among adults [15, 16]. A list of foods for inclusion on the FFQ was generated using data from the 1994–96 Continuing Survey of Food Intakes of Individuals [16] as well as other sources of child dietary data to determine the most important food sources of calcium in the diets of children and adolescents and to account for secular trends in calcium-fortified foods (e.g. orange juice). The food list was specifically developed to assess total diet and to allow the investigation of food consumption patterns, as well as to provide nutrient intake estimates. Separate questions were included to assess vitamin and mineral supplementation. An open-ended section at the end of the questionnaire allowed students to enter foods that were not on the FFQ.

Total energy intake and intake of 112 macro- and micronutrients were calculated using the Food Frequency Data Entry and Analysis Program [17, 18], a microcomputer program developed for the data entry and analysis of the FFQ using nutrient and gram-weighted data from the food intake analysis System [18]. The FFQ was used to determine the mean milligrams of calcium consumed per day.

Self-administered physical activity checklist

The self-administered physical activity checklist (SAPAC) is a self-reported questionnaire used to obtain information on the participation of physical activities during the previous day. SAPAC consists of 21 physical activities, spaces for listing up to four ‘other’ activities and an additional section for reporting TV/video viewing at three time periods during the previous day: before, during and after school. This instrument has been used extensively among seventh and eighth graders in the Coordinated Approach to Child Health (CATCH) trial [19] with acceptable validity and reliability [20, 21]. For the current study, SAPAC was adapted to include a weekend version, as well as to distinguish between high-impact and low-impact activities. For example, the calisthenics category was divided into two categories—one that included stretching exercises and one that included weight-bearing physical activity (WBPA) such as jumping jacks. The SAPAC was also tailored toward girls and included activities such as gymnastics, dance and cheerleading. Each student completed three administrations of the SAPAC, including two random weekdays and one weekend day. The SAPAC was used to calculate the mean minutes of physical activity per day as well as the minutes of moderate-to-vigorous, vigorous and WBPA.

Calcium, osteoporosis and physical activity survey

Psychosocial variables were assessed on all participants in school using the 85-item calcium, osteoporosis and physical activity (COPA) questionnaire. The COPA was developed by the study investigators, adapting questions from previous instruments [21]. For the purpose of this study, we included questions addressing (i) knowledge of osteoporosis (7 items) and calcium-rich foods (9 items), (ii) self-efficacy of consuming calcium-rich foods (9 items) and engaging in WBPA (12 items), (iii) outcome expectations (positive beliefs about the benefits) of consuming calcium-rich foods (7 items) and physical activity (11 items), (iv) environmental factors such as neighborhood safety (1 item) and milk availability at home (1 item), (v) behavioral factors such as participation in sports teams (1 item) and (vi) family and friend social support (engagement and encouragement) to be physically active (4 items). COPA was pre-tested using a sample of sixth- and seventh-grade students in a school that did not participate in IMPACT showing good reliability [13]. Individual-level measures and protocols are on the project Web site at http://www.sph.uth.tmc.edu/dellhealthyliving/default.aspx?id=4011.

Statistical analysis

STATA version 9.2 (STATA Corp., College Station, TX) statistical software was used for all data analyses. Descriptive statistics of baseline and demographic characteristics such as age, sex, ethnicity, puberty status (as defined by menarche) and BMI as obtained from the questionnaires were calculated. In addition, percent of overweight participants as calculated using BMI was calculated.

The psychosocial, environmental and behavioral factors measured using the COPA were the predictor variables of interest. These included knowledge of calcium-rich foods, knowledge of osteoporosis, self-efficacy toward consuming calcium-rich foods and engaging in physical activity, outcome expectations of consuming calcium-rich foods and engaging in physical activity, physical activity social support, neighborhood safety toward engaging in physical activity, milk availability at home and participation in sports teams.

The primary outcome variables of interest were (i) calcium intake: measured by mean milligrams of calcium consumed per day (FFQ) and glasses of milk consumed per day (COPA), (ii) physical activity: measured by mean minutes of physical activity per day (SAPAC) and number of jumping activities per week (COPA) and (iii) bone quality: measured by the calcaneal SI (QUS).

Table II presents the distribution of the predictor and outcome variables of interest along with the internal consistency and test–retest reliability of the scales used.

All variables were checked with regard to their distribution (normality) with the use of frequency distributions, scatter plots and histograms. Means, SDs, median, modes, skewness and kurtosis were computed. Milligrams of calcium consumed per day and mean minutes of physical activity per day were not normally distributed. These two variables were transformed using log transformations which normalized the variables. Results presented are those using the transformed variables.

Confounder assessment

The primary confounders adjusted for in these analyses were age, menarchal status, BMI and ethnicity. Literature has shown that these factors are significantly associated with BMD, calcium intake and physical activity behaviors [4, 11, 20, 22]. Lactose intolerance was also adjusted for in all analyses involving calcium intake since participants with lactose intolerance could be consuming lower amounts of dairy-based calcium-containing foods [23].

This study not only examined the variation among schools but also considered the variation among individuals nested within schools thus controlling for cluster effects [24, 25]. A multilevel or hierarchical regression modeling technique using STATA ‘xtmixed’ program was used for analysis since the students were nested within schools. Hierarchical linear regression was used to determine which of the psychosocial and environmental factors were significantly associated with calcium intake, physical activity and calcaneal bone quality. Significance level for all analyses was set at 0.05.

Table II. *Descriptive statistics of variables of interest, IMPACT study*

Variable	Mean (SD)	Range	Cronbach's alpha	Test–retest reliability
Calcium intake				
mg day^{-1a}	1321.3 (±754.8)	154.3–5268.8	N/A	N/A
Glasses of milk per day	1.9 (±1.3)	0–5		0.44
Physical activity				
Mean min day^{-1}	108.7 (±64.6)	25–407.5	N/A	N/A
Jumping activities per week	3.04 (±2.1)	0–7		0.63
Bone quality				
Calcaneal SI	73.8 (±14.9)	34.7–130.1	N/A	N/A
Knowledge of				
Osteoporosis (% correct)	26.4 (±16.6)	0–85.7	0.19	0.61–0.90
Calcium content of foods (% correct)	66.1 (±16.3)	0–100	0.41	0.57–0.80
Self-efficacy				
Calcium	29.8 (±6.6)	9–45	0.65	0.28–0.62
Physical activity	44.2 (±9.7)	12–60	0.87	0.14–0.82
Outcome expectations				
Calcium	17.9 (±2.9)	7–25	0.54	0.48–0.59
Physical activity	22.1 (±2.9)	11–30	0.36	0.36–0.75
Physical activity social support				
Family encouragement	3.6 (±1.2)	1–5		
Family engagement	3.1 (±1.1)	1–5	0.68	N/A
Friend encouragement	2.5 (±1.2)	1–5		
Friend engagement	3.6 (±1.3)	1–5		
Neighborhood safety	3.1 (±1.3)	1–5	N/A	N/A
Participation in sports teams	1.6 (±1.3)	0–4	N/A	0.62
Milk availability at home	3.8 (±0.5)	0–4	N/A	0.72

N/A = not applicable or available.
[a]Density values for calcium reported.

Results

The IMPACT data set contained a total of 718 girls at baseline, 72% of who were white and 25% were at risk for overweight or overweight (BMI for age ⩾ 85th percentile) (Table I).

Table II presents the descriptive statistics of the various dependent and independent variables of interest with the means, SD, range at baseline as well as reliability coefficients. Overall, results show that the mean calcium intake per day of the participants was higher than the recommended 1200 mg day^{-1} (mean 1321 ±754.8) [26] and participants were doing more than the recommended physical activity of 60 min day^{-1} (mean 108.7 ±64.6) [26]. Knowledge of osteoporosis was low with only 26% of the participants having a correct response. Most participants reported a high perception of neighborhood safety and scores for participation in sports teams were low for the girls with 28% of the girls participating in zero teams and 53% participating in only one sports team.

Baseline predictors of calcium intake and physical activity

Calcium intake

Table III shows the bivariate and multivariate associations between the psychosocial predictors and calcium intake at baseline. Overall, several psychosocial and environmental factors such as knowledge of calcium-rich foods, self-efficacy toward consuming calcium-rich foods, calcium outcome expectations and milk availability at home were significantly positively associated with mean milligrams of calcium consumed per day and number of glasses of milk consumed per day.

Table III. *Associations between psychosocial, environmental factors and calcium intake, IMPACT study*

Variable	Calcium intake			
	mg Ca per 1000 kcal day^{-1}[a]		Glasses of milk consumed per day	
	β[b] (95% CI) (*P* value)	β[c] (95% CI) (*P* value)	β[b] (95% CI) (*P* value)	β[c] (95% CI) (*P* value)
Knowledge of				
Osteoporosis	0.002 (−0.0001, 0.003) (0.071)	0.001 (−0.006, 0.003) (0.242)	0.0008 (−0.005, 0.007) (0.798)	−0.0014 (−0.006, 0.004) (0.612)
Ca content of foods	0.003 (0.001, 0.004) (**0.002**)*	0.003 (0.001, 0.004) (**0.001**)*	0.002 (−0.004, 0.008) (0.598)	0.002 (−0.003, 0.007) (0.499)
Ca self-efficacy	0.014 (0.010, 0.018) (**0.000**)*	0.012 (0.008, 0.016) (**0.000**)*	0.05 (0.037, 0.066) (**<0.0001**)*	0.04 (0.025, 0.051) (**0.000**)*
Ca outcome expectations	0.015 (0.006, 0.024) (**0.002**)*	0.010 (0.008, 0.020) (**0.034**)*	0.08 (0.047, 0.114) (**<0.0001**)*	0.06 (0.027, 0.091) (**0.000**)*
Milk availability at home	0.130 (0.074, 0.185) (**0.000**)*	0.093 (0.038, 0.150) (**0.001**)*	0.6 (0.42, 0.807) (**<0.0001**)*	0.44 (0.255, 0.630) (**0.000**)*

Adjusted and unadjusted beta coefficients (β) are presented. Ca = calcium; CI = confidence interval.
[a]Results presented are following log transformation of milligrams of calcium intake per day.
[b]Bivariate analysis using hierarchical linear regression (unadjusted β presented).
[c]Multivariate analysis using hierarchical linear regression adjusted for baseline menarchal status, ethnicity, BMI and lactose intolerance. *Significant at $P < 0.05$.

Physical activity

Bivariate and multivariate associations between the psychosocial and environmental predictors and physical activity at baseline are shown in Table IV. Results showed that, after adjusting for confounders, physical activity self-efficacy, outcome expectations, social support and participation in sports teams were significantly associated with mean minutes of physical activity per day and number of days per week of jumping activities.

Baseline predictors of calcaneal bone quality

Table V shows the associations between the calcaneal bone quality and the behavioral, psychosocial and environmental factors. Of all the predictor variables, results show that, knowledge of calcium content of foods (β = 0.08, P = 0.016), physical activity outcome expectations (β = 0.5, P = 0.004), family encouragement (β = 0.96, P = 0.027) and friend engagement in physical activity (β = 1.3, P = 0.001) and participation in sports teams (β = 1.7, P < 0.001) were significant predictors of bone quality. Interestingly, calcium intake and leisure-time physical activity were not significantly associated with calcaneal bone quality.

Discussion

This study examined the association of multiple psychosocial, behavioral and environmental factors with calcium intake, physical activity and bone quality among sixth-grade girls in Texas.

Knowledge of calcium-rich foods, self-efficacy toward consuming calcium-rich foods, outcome expectations of consuming calcium-rich foods and milk availability at home were significant predictors of calcium intake. These findings suggest that interventions addressing calcium intake among adolescents should consider these psychosocial and environmental factors if behavior change is desired. For knowledge, the results indicate that the majority of participants (66%) had the correct knowledge of calcium content of foods. Since knowledge has been posited to be positively associated with intake

Table IV. *Psychosocial, environmental, behavioral factors associated with physical activity, IMPACT study*

	Physical activity			
	Mean min day^{-1a}		Days week^{-1} jumping activities	
	β^b (95% CI) (*P* value)	β^c (95% CI) (*P* value)	β^b (95% CI) (*P* value)	β^c (95% CI) (*P* value)
Knowledge of				
Osteoporosis	0.001 (0.002, 0.004) (0.521)	0.009 (−0.001, 0.004) (0.568)	0.002 (0.007, 0.011) (0.644)	0.003 (−0.006, 0.011) (0.594)
Calcium content of foods	−0.004 (−0.007, −0.0006) (**0.018**)*	−0.003 (−0.007, −0.0006) (**0.017**)*	−0.007 (−0.017, 0.002) (0.143)	0.007 (−0.017, 0.002) (0.148)
Physical activity self-efficacy	0.016 (0.011, 0.021) (**0.000**)*	0.017 (0.011, 0.022) (**0.000**)*	0.06 (0.046, 0.076) (<**0.001**)*	0.06 (0.047, 0.079) (<**0.0001**)*
Physical activity outcome expectations	0.038 (0.021, 0.056) (**0.000**)*	0.038 (0.021, 0.056) (**0.000**)*	0.13 (0.077, 0.182) (<**0.001**)*	0.13 (0.08, 0.186) (<**0.0001**)*
Physical activity social support				
Family encouragement	0.099 (0.058, 0.139) (**0.000**)*	0.095 (0.054, 0.136) (**0.000**)*	0.32 (0.192, 0.443) (<**0.001**)*	0.32 (0.197, 0.450) (<**0.0001**)*
Family engagement	0.108 (0.064, 0.154) (**0.000**)*	0.108 (0.062, 0.153) (**0.000**)*	0.35 (0.212, 0.487) (<**0.001**)*	0.36 (0.219, 0.501) (<**0.0001**)*
Friend encouragement	0.103 (0.064, 0.142) (**0.000**)*	0.098 (0.587, 0.137) (**0.000**)*	0.35 (0.228, 0.470) (<**0.001**)*	0.35 (0.228, 0.470) (<**0.0001**)*
Friend engagement	0.137 (0.10, 0.175) (**0.000**)*	0.134 (0.094, 0.170) (**0.000**)*	0.45 (0.339, 0.569) (<**0.001**)*	0.46 (0.345, 0.579) (<**0.0001**)*
Neighborhood safety	0.008 (−0.032, 0.048) (0.702)	0.004 (−0.037, 0.044) (0.863)	0.1 (−0.023, 0.224) (0.114)	0.09 (−0.025, 0.226) (0.119)
Participation in sports teams	0.125 (0.089, 0.161) (**0.000**)*	0.122 (0.085, 0.158) (**0.000**)*	0.33 (0.214, 0.442) (<**0.001**)*	0.33 (0.212, 0.442) (<**0.0001**)*

Adjusted and unadjusted beta coefficients (β) are presented; CI = confidence interval.
[a]Results presented are following log transformation of mean minutes of physical activity per day.
[b]Bivariate analysis using hierarchical linear regression (unadjusted β presented).
[c]Multivariate analysis using hierarchical linear regression adjusted for baseline menarchal status, ethnicity and BMI. *Significant at $P < 0.05$.

Table V. *Psychosocial, environmental and behavioral factors associated with bone quality, IMPACT study*

Predictor variables	Bone quality	
	SI	
	β^b (95% CI) (*P* value)	β^c (95% CI) (*P* value)
mg Ca consumed per 1000 kcal day^{-1}	0.001 (−0.832, 0.876) (0.959)	0.002 (−0.002, 0.006) (0.383)
Glasses of milk drunk per day	0.01 (−0.003, 0.006) (0.426)	0.14 (−0.689, 1.011) (0.709)
Physical activity		
Mean min day^{-1a}	0.003 (0.014, 0.022) (0.688)	0.005 (−0.011, 0.021) (0.538)
Mean minutes moderate to vigorous per day	0.009 (−0.014, 0.032) (0.472)	0.03 (−0.003, 0.061) (0.077)
Mean minutes vigorous per day	0.03 (−0.003, 0.066) (0.075)	0.03 (−0.003, 0.061) (0.077)
Mean minutes weight bearing per day	0.013 (−0.007, 0.034) (0.188)	0.02 (−0.002, 0.034) (0.084)
Jumping activities per week	−0.13 (−0.671, 0.407) (0.631)	−0.006 (−0.499, 0.486) (0.980)
Knowledge of osteoporosis	0.001 (−0.07, 0.067) (0.959)	0.007 (−0.055, 0.069) (0.082)
Knowledge of calcium content of foods	0.05 (−0.02, 0.119) (0.162)	0.08 (0.014, 0.144) (**0.016**)*
Calcium self-efficacy	0.13 (−0.042, 0.301) (0.141)	0.16 (0.002, 0.317) (**0.047**)*
Physical activity self-efficacy	0.13 (0.017, 0.249) (**0.025**)*	0.20 (0.099, 0.317) (**0.0002**)*
Calcium outcome expectations	−0.3 (−0.682, 0.102) (0.146)	−0.07 (−0.449, 0.285) (0.662)
Physical activity outcome expectations	0.6 (0.207, 1.007) (**0.003**)*	0.5 (0.174, 0.917) (**0.004**)*
Physical activity social support		
Family encouragement	1.13 (0.212, 2.061) (**0.016**)*	0.96 (0.107, 1.818) (**0.027**)*
Family engagement	0.19 (−0.848, 1.235) (0.716)	0.58 (−0.392, 1.544) (0.243)
Friend encouragement	0.50 (−0.405, 1.415) (0.276)	0.52 (−0.315, 1.354) (0.222)
Friend engagement	1.1 (0.184, 1.94) (**0.018**)*	1.3 (0.535, 2.16) (**0.001**)*
Neighborhood safety	0.7 (−0.224, 1.575) (0.141)	0.5 (−0.368, 1.30) (0.273)
Participation in sports teams	1.7 (0.886, 2.569) (<**0.0001**)*	1.7 (0.969, 2.51) (<**0.001**)*
Milk availability at home	0.35 (−2.02, 2.72) (0.772)	0.8 (−1.38, 3.01) (0.466)

Adjusted and unadjusted β are presented. Ca = calcium; CI = confidence interval.
[a]Results presented are following log transformation of mean minutes of physical activity per day.
[b]Bivariate analysis using hierarchical linear regression (unadjusted β presented).
[c]Multivariate analysis using hierarchical linear regression adjusted for baseline menarchal status, ethnicity and BMI. *Significant at $P < 0.05$.

[27–29], this could explain the relatively high intake of calcium seen in this group of girls. However, we also found low knowledge of osteoporosis (26%), thus suggesting the need for further examination of knowledge since these results could influence calcium intake.

The significant association between self-efficacy toward eating calcium-rich foods, outcome expectations and calcium intake suggests that an increased confidence in performing a behavior and high perception of positive benefits may contribute to behavior change (7). These results concur with Lee and Reicks (9), who identified psychosocial factors associated with calcium intake in 105 adolescent girls. Results showed that knowledge about calcium sources and recommendations and liking the taste of dairy were positively associated with calcium intakes. Connors *et al.* [30] identified milk preferences, health beliefs, cafeteria rules, milk flavor, product packaging, modeling by adults and shared experiences as factors influencing milk-drinking behaviors of elementary school children in North Texas ($n = 41$). Our results also identified milk availability at home as a significant predictor of calcium intake. This suggests that it is important for milk or milk products to be available for calcium consumption to take place. While this appears to be intuitive, emphasizing the importance of milk availability to the parents and schools in future interventions is worthy.

Our study also identified several psychosocial predictors of physical activity, such as self-efficacy, outcome expectations and social support. The significance of social support indicates that while it is good to encourage adolescents to be physically active, it is also important to do physical activity with them. These results concur with those of Springer *et al.* [12], who identified significant correlations (r = 0.10 to 0.12, $P < 0.05$) between family and friend engagement and encouragement and physical activity behavior in the IMPACT population. Our results found significant effects not only for both peer and parental support but also for engagement and encouragement in physical activity among adolescent girls. The literature supporting these positive associations seen between physical activity and social support is strong. Sallis *et al.* [31] reported parental and peer influences to be significant correlates of self-reported physical activity among middle-school students in California but found peer support to be the strongest. Prochaska *et al.* [32] found peer support to be significantly associated with vigorous physical activity among female girls from Massachusetts in grades 7 through 9. O'Dea [33] reported parental support and involvement in activities to be strongly associated with physical activity and, more recently, Duncan *et al.* [34] found friend social support to be most highly related to physical activity among youth between the ages of 10 and 14. These findings, along with the current study's findings, suggest that peers and parents may take a prominent role in influencing physical activity among adolescent girls and clearly indicate the need for including this component when developing and implementing health promotion programs.

Table II shows that participation in sports teams was low with 80% of the girls participating in zero or one team. This could be because sports team participation in these schools starts in the seventh grade whereas the participants were in the sixth grade at baseline. While associations between physical activity and bone quality were not significant, participation in sports team was positively associated calcaneal bone quality. Thus, bone quality appears to be influenced by physical activity that occurs during organized sports activities which are typically periods of high-intensity, vigorous activities performed for a few hours and consistently over time rather than general leisure-time physical activity. Participation in sports teams might be a stronger predictor of calcaneal bone quality versus walking or other sporadic weight-bearing activities which might not put a significant amount of stress on the bone, thus explaining the lack of association between physical activity and calcaneal bone quality. Sports activities give a sustained impact, e.g. daily practices, for a season (several months) with a positive effect on BMD [35]. This could also be due to the fact that students who had higher social support from parents were also more likely to participate in team sports. This is important because of all the variables, social support and participation in sports teams had the strongest association with calcaneal SI. These results further emphasize the importance of peer and family influences on health which needs to be adequately addressed when trying to increase sports team participation.

While some studies support the contribution of neighborhood safety to performing physical activity [36–38], our results did not show any such association. However, there was little variability in the data, with >70% of the participants stating that it is almost always or always safe to play in the neighborhood. Secondly, neighborhood safety was measured using only one self-reported item on the COPA which could have rendered the results non-significant. Studies that have used multiple items have found significant associations [36, 37]. Another factor could be the sociodemographic distribution of the study sample. The IMPACT study population was primarily White, middle-class girls living in relatively safe neighborhoods. Future studies exploring neighborhood safety need to include either objective or measures with multiple scales in more diverse populations.

Our results showed no significant associations between calcium intake, general physical activity and calcaneal bone quality. These results do not concur with those of Robinson *et al.* [39] who found a positive correlation between calcaneal SI, calcium intake and hours spent doing high-impact physical activity. However, this discrepancy could be attributed to several factors. The sample size used by Robinson *et al.* [39] was much smaller with 114 girls from one school and the participants were older (14–18 years) indicating that they were post-pubertal. The IMPACT study had 718 girls who were mostly pre-pubertal at baseline. Since ~35% of peak BMD is achieved during puberty [5], these differences could account for much the discrepancy seen in the results observed. Most of the females in our study sample were pre-menstrual (~80%), 11–12 years old as opposed to their older sample. Studies have also shown BMD to be highly correlated with ethnicity with Caucasians at a higher risk as compared with other ethnic groups [5]. However, our study population was predominantly Caucasian and did not have sufficient power to examine ethnic differences. Furthermore, there was little variability in the calcaneal SI in this age group which could have also rendered the results not significant.

Finally, it is important to note that the participants, on an average, had a higher intake of calcium and did more physical activity than recommended. While it might appear that investing resources into developing bone health promotion programs in this population may not be needed, one should consider that calcium intake and physical activity were based on self-report measures and it is typical for dietary intake and physical activity to be overreported [20], thus limiting the interpretation of these results. Also, literature has shown that as students go from middle school to high school, there is a significant decline in physical activity [40] but a significant increase in BMD with 35% of peak BMD occurring during puberty [5]. Also, sex differences in BMD have been observed as early as 4 years old with females exhibiting a 13% increase in BMD from ages 11–13 years. These results indicate that middle-school might be the right time to implement health promotion programs aimed at reinforcing these healthy eating and physical activity behaviors, especially in females.

Strengths and limitations

In addition to contributing to the literature on bone health in adolescent girls, this study is among the first to examine the association of multiple psychosocial and environmental factors with calcium intake, physical activity and bone health in a cohort of adolescent girls. The large sample size also lends sufficient power to the study. These strengths notwithstanding, some limitations should be considered when interpreting study findings. The cross-sectional nature of the study limits any causal conclusions. The response rate was low (38%). However, 100% of the required sample size was obtained and also the responders were not significantly different from the non-responders. The self-report methods utilized also may have led to skewed estimates of dietary intake and physical activity. While the FFQ has been established as an instrument with adequate validity for measuring dietary intake [41, 42], there could be potential measurement error related to inaccurate estimation of portion sizes or faulty food item recall [43]. The FFQ also tends to overestimate dietary intake and may be better for surveillance rather than intervention work (R. S. Day, D. M. Hoelscher, S. H. Kelder, A. Hergenroeder unpublished data). The FFQ was also limited to assessing dietary intake only during the school week and not all 7 days. For physical activity, the self-administered SAPAC questionnaire could potentially result in overreporting of physical activity performed thus biasing the results away from the null. However, both SAPAC and COPA have been validated with good validity, reliability. Finally, most of the females were white, pre-menstrual (~80%), 11–12 years old resulting in limited generalizability of the results to other ethnic or age groups.

Conclusions

Our study identified multiple psychosocial, environmental and behavioral predictors of calcium intake, physical activity and bone health in a single cohort of adolescent girls. Participation in sports teams and social support were of particular importance for bone health. Given the rising prevalence of osteoporosis in the US population, these results are timely and addressing these mediating factors is critical when designing osteoporosis prevention programs to promote bone health. Future research should examine the pathways used by these psychosocial and environmental factors in influencing behavior and bone health and explore causal relationship of these psychosocial factors and calcium intake, physical activity and bone health using a prospective design.

Funding

The National Institute of Child Health and Human Development (R01 HD37767–04); Clinicaltrials.gov Identifier (NCT00067925).

Acknowledgements

The authors of the manuscript would like to acknowledge the database management team and extend appreciation to the research assistants responsible for recruitment, data collection and entry. We would also like to acknowledge the funding agency for making it possible for us to conduct the study.

Conflict of interest statement

None declared.

References

1. World Health Organization. Diet, nutrition and the prevention of chronic diseases. *WHO Tech Rep Ser* 1990; **794**: 1–204.
2. National Osteoporosis Foundation. *Fast Facts*. Available at: http://www.nof.org/osteoporosis/diseasefacts.htm. Accessed: 20 February 2007.
3. US Department of Health and Human Services. *Surgeon General's Report on Bone Health*. Available at: http://www.surgeongeneral.gov/library/bonehealth/content.html. Accessed: 12 February 2007.
4. Prentice A. Diet, nutrition and the prevention of osteoporosis. *Public Health Nutr* 2004; **7**: 227–43.
5. Ondrak KS, Morgan DW. Physical activity, calcium intake and bone health in children and adolescents. *Sports Med* 2007; **37**: 587–600.
6. Gordon CM. Normal bone accretion and effects of nutritional disorders in childhood. *J Womens Health. (Larchmt)* 2003; **12**: 137–43.
7. Bandura A. Social cognitive theory of self-regulation. *Organ Behav Hum Decis Process* 1991; **50**: 248–87.
8. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity. *Annu Rev Public Health* 2001; **22**: 309–35.
9. Lee S, Reicks M. Environmental and behavioral factors are associated with the calcium intake of low-income adolescent girls. *J. Am Diet Assoc* 2003; **103**: 1526–9.
10. Morgan C, McKenzie TL, Sallis JF *et al*. Personal, social, and environmental correlates of physical activity in a bi-ethnic sample of adolescents. *Pediatr Exerc Sci* 2003; **15**: 288–301.
11. Bengochea EG, Spence JC, McGannon KR. Gender differences in perceived environmental correlates of physical activity. *Int J Behav Nutr Phys Act* 2005; **2**: 12–20.
12. Springer AE, Kelder SH, Hoelscher DM. Social support, physical activity and sedentary behavior among 6th-grade girls: a cross-sectional study. *Int J Behav Nutr Phys Act* 2006; **6**: 8.
13. Centers for Disease Control and Prevention. *BMI—Body Mass Index. About BMI for Children and Teens*. Available at: http://www.cdc.gov/nccdphp/dnpa/bmi/childrens_BMI/about_childrens_BMI.htm. Accessed: 12 March 2007.
14. Sahota O, San P, Cawte SA *et al*. A comparison of the longitudinal changes in quantitative ultrasound with dual-energy X-ray absorptiometry: the four-year effects of hormone replacement therapy. *Osteoporos Int* 2000; **11**: 52–8.
15. Martinez ME, Giovannucci EL, Colditz GA *et al*. Vitamin D, and the occurrence of colorectal cancer among women. *J Natl Cancer Inst* 1996; **88**: 1375–82.
16. Tippett KS, Cypel YS. Design and operation the continuing survey of food intakes by individuals and the diet and health knowledge survey, 1994–96. NFS report, no. 96–1. [Washington, D.C.]: U.S. Dept. of Agriculture, Agricultural Research Service.
17. The University of Texas-Houston, School of Public Health. *Food Frequency Data Entry and Analysis Program.*1995. Version 2.0.
18. The University of Texas-Houston, School of Public Health. *Food Intake Analysis System*:1996. Version 3.0.
19. Saunders RP, Pate RR, Felton G *et al*. Development of questionnaires to measure psychosocial influences on children's physical activity. *Prev Med* 1997; **26**: 241–7.
20. Sallis JF, McKenzie TL, Elder JP *et al*. Sex and ethnic differences in children's physical activity: discrepancies between self-report and objective measures. *Pediatr Exerc Sci* 1998; **10**: 277–84.
21. Edmundson E, Parcel GS, Feldman HA *et al*. The effects of the child and asdolescent trial for cardiovascular health upon psychosocial determinants of diet and physical activity behavior. *Prev Med* 1996; **25**: 442–54.
22. Guo Y, Zhao LJ, Shen H *et al*. Genetic and environmental correlations between age at menarche and bone mineral density at different skeletal sites. *Calcif Tissue Int* 2005; **77**: 356–60.
23. Swagerty DL Jr, Walling AD, Klein RM. Lactose intolerance. *Am Fam Physician* 2002; **65**: 1845–50.
24. Murray DM. *Design and Analysis of Group-Randomized Trials*. Oxford University Press: New York, 1998.
25. Snijders TAB, Bosker RJ. *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling*. Thousand Oaks, CA: Sage Publications Inc; 1999.

26. U.S. Department of Health and Human Services and U.S. Department of Agriculture. Dietary Guidelines for Americans, 2005. 6th edn. Washington, DC: U.S. Government Printing Office, January 2005. Available at: www.health.gov/dietaryguidelines/dga2005. Accessed: 1 March 2007.
27. Krebs-Smith SM, Heimendinger J, Patterson BH *et al*. Psychosocial factors associated with fruit and vegetable consumption. *Am J Health Promot* 1995; **10**: 98–104.
28. Guthrie JF, Fulton LH. Relationship of knowledge of food group servings recommendations to food group consumption. *Fam Econ Nutr Rev* 1995; **8**: 2–17.
29. Harnack L, Block G, Subar A *et al*. Association of cancer prevention-related nutrition knowledge, beliefs, and attitudes to cancer prevention dietary behavior. *J Am Diet Assoc* 1997; **97**: 957–65.
30. Connors P, Bednar C, Klammer S. Cafeteria factors that influence milk-drinking behaviors of elementary school children: grounded theory approach. *J Nutr Educ* 2001; **33**: 31–6.
31. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc* 2000; **32**: 963–75.
32. Prochaska JJ, Rodgers MW, Sallis JF. Association of parent and peer support with adolescent physical activity. *Res Q Exerc Sport* 2002; **73**: 206–10.
33. O'dea JA. Why do kids eat healthful food? Perceived benefits of and barriers to healthful eating and physical activity among children and adolescents. *J Am Diet Assoc* 2003; **103**: 497–501.
34. Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. *Health Psychol* 2005; **24**: 3–10.
35. Lloyd T, Chinchilli VM, Johnson-Rollings N *et al*. Adult female hip bone density reflects teenage sports-exercise patterns but not teenage calcium intake. *Pediatrics* 2000; **106**: 40–4.
36. Molnar BE, Gortmaker SL, Bull FC *et al*. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. *Am J Health Promot* 2004; **18**: 378–86.
37. Gomez JE, Johnson BA, Selva M *et al*. Violent crime and outdoor physical activity among inner-city youth. *Prev Med* 2004; **39**: 876–81.
38. Nelson MC, Gordon-Larsen P, Song Y *et al*. Built and social environments associations with adolescent overweight and activity. *Am J Prev Med* 2006; **31**: 109–17.
39. Robinson ML, Winters-Stone K, Gabel K *et al*. Modifiable lifestyle factors affecting bone health using calcaneus quantitative ultrasound in adolescent girls. *Osteoporos Int* 2007; **18**: 1101–7.
40. Aaron DJ, Storti KL, Robertson RJ *et al*. Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. *Arch Pediatr Adolesc Med* 2002; **156**: 1075–80.
41. McPherson S, Hoelscher D, Alexander M *et al*. *Validity and Reliability of Dietary Assessment in School-Age Children*. Boca Raton, FL: CRC Press 2002. p. 495–522.
42. McPherson RS, Hoelscher DM, Alexander M *et al*. Dietary assessment methods among school-aged children: validity and reliability. *Prev Med* 2000; **31**: S11–33.
43. Cavadini C, Decarli B, Dirren H *et al*. Assessment of adolescent food habits in Switzerland. *Appetite* 1999; **32**: 97–106.

Received on September 5, 2007; accepted on January 3, 2008