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Psychosocial Factors Influencing Calcium Intake and Bone Quality in Middle-School Girls

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Abstract

Calcium intake has been associated with promoting bone health in children and adolescents, thus, preventing osteoporosis later in life. Behavior change such as increased calcium intake, as well as physiological factors such as bone quality, may be facilitated by psychosocial and environmental factors. The purpose of this study was to identify pathways by which psychosocial factors

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influence calcium intake and bone quality in middle-school girls. The study design was cross-sectional. Baseline data from the Incorporating More Physical Activity and Calcium in Teens (IMPACT) study, collected in 2001–2003, were utilized. IMPACT, was a 1 ½ years nutrition and physical activity intervention study, designed to improve bone density in 717 middle-school girls in Texas. Main outcome measures were: 1) calcium intake determined using mean milligrams of calcium consumed per day and number of glasses of milk consumed per day, and 2) bone quality determined using calcaneal stiffness index. Confirmatory factor analysis and path analysis were performed to identify the direct and indirect pathways used by various psychosocial factors such as knowledge, self-efficacy, outcome expectations and milk availability at home, to influence calcium intake and bone quality. Results showed that knowledge of osteoporosis and calcium rich foods had an indirect effect on calcium intake, with outcome expectations as the mediating variable ($\beta=0.035$ and $\beta=0.03$ respectively, $p < 0.05$). Calcium self-efficacy had a significant indirect effect on calcium intake, with outcome expectations as the mediator ($\beta=0.085$, $p < 0.05$). None of the variables significantly influenced bone quality. Thus, several direct and indirect pathways used to influence calcium intake among adolescent girls, were identified. These findings are critical for the development of effective interventions to promote calcium intake in this population.

Keywords

adolescent girls; osteoporosis; dietary intake; bone quality; calcium-rich foods

INTRODUCTION

Osteoporosis is a disease characterized by low bone mass and deterioration of bone tissue, leading to increased risk of bone fractures (1). Dietary factors such as calcium and vitamin D intake during childhood, are major determinants of osteoporosis later in life.(2) Up to 90 percent of peak bone mass is acquired by age 18 in girls and 20 in boys, which makes childhood a critical time to promote behaviors that improve bone health (3). These behaviors include consuming the recommended amount of calcium and vitamin D, engaging in regular physical activity, and avoiding smoking and alcohol (2–5). These modifiable behaviors are influenced by psychosocial and environmental factors which, in turn, mediate the associations between behavior and disease (6–9). While there is some literature examining the psychosocial correlates of calcium intake (10), one of the strongest determinants of bone mass, none have examined these interrelationships with respect to bone quality in adolescent girls. Since females are at a higher risk for osteoporosis (11), it can be advantageous to examine these relationships in a gender-specific manner.

The purpose of this study was to identify the pathways by which psychosocial factors such as knowledge of osteoporosis and calcium-rich foods, self-efficacy towards consuming calcium-rich foods, calcium outcome expectations, and milk availability, influence calcium intake and bone quality using path analysis in a cohort of adolescent females. The hypothesis was that these psychosocial factors interact and use various direct and indirect pathways to influence calcium intake and bone quality.

METHODS

This study was secondary data analysis using baseline data from The Incorporating More Physical Activity and Calcium in Teens (IMPACT) study. IMPACT was a 1 ½ -year quasi-experimental, school-based nutrition and physical activity intervention, conducted from 2001–2003, to promote bone mineral density (BMD) among middle school girls in central Texas (12). For the purpose of this study, constructs from the Social Cognitive Theory (6) were chosen to evaluate the dietary behavior of adolescents. The study population for this analysis consisted of 6th grade girls (n=12 schools, 717 girls) (Table 1). Details regarding participant recruitment are presented elsewhere (12, 13). Parental consent and student assent were obtained from all participants. Study approval was obtained from the University of Texas Health Science Center, Committee for Protection of Human Subjects (HSC-SPH-02-046).

Data collection measures: Data collection of all baseline measures was conducted in the Fall of 2001, at school sites, by trained project staff. All measures and protocols are on the project website at: <http://www.sph.uth.tmc.edu/dellhealthyliving/default.aspx?id=4011>

Anthropometric measures

Digital scales (SECA 770 or Tanita BWB-800S, Perspectives Enterprises, Portage, MI) and stadiometers (Perspectives Enterprises, Portage, MI) were used for weight and height measurements, using a standardized protocol. Height (cm) and weight (kg) were used to calculate body mass index (BMI) percentiles in order to determine weight status (14).

Bone quality

Quantitative Ultrasound (QUS) has been shown to provide information on elasticity and trabecular connectivity of bone tissue in post-menopausal women (15) with good precision on children ages 6 to 13 (16). For IMPACT, QUS was measured at the calcaneus using the Achilles+ Lunar G/GE Electronics ultrasound unit (Lunar, Madison, WI). Each girl's right foot was measured with the Achilles+ Food-Sizing System before using the ultrasound machine, and pediatric shims were used to properly situate the foot in the machine. Information about the participant's age, gender, subject ID, shim size and foot was entered into the machine. Two ultrasound machines were used. A reliability assessment to assess the correlation of repeated measures among the two machines was 0.95. QUS parameters measured were broadband ultrasound attenuation (BUA), speed of sound (SOS) and a clinical index named Stiffness Index (SI). Stiffness Index was automatically calculated by the machine using the formula: $SI = (0.67 \times BUA + 0.28 \times SOS) - 420$. The Os calcis is a weight-bearing site with trabecular bone and has bone mineral density (BMD) values that follow a similar pattern to that of the proximal femur (15).

Food Frequency Questionnaire (FFQ)

The interviewer-administered FFQ was used to assess frequency of consumption of various foods and the mean portion size consumed during the previous week. Intake of 112 foods, including 52 nutrients, was calculated using the Food Frequency Data Entry and Analysis Program (17), 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.

Calcium, Osteoporosis and Physical Activity (COPA)

Psychosocial variables were assessed using the self-administered 85-item Calcium, Osteoporosis and Physical Activity (COPA) questionnaire. COPA was developed by adapting questions from previous instruments (19, 20) and measured psychosocial constructs for calcium intake and physical activity behaviors. For the purpose of this study, the following items were included: a) knowledge of osteoporosis (7 items) and knowledge of calcium-rich foods (9 items), b) self-efficacy of consuming calcium-rich foods (9 items), c) outcome expectations (positive beliefs about the benefits) of consuming calcium-rich foods (7 items), d) milk availability at home (1 item) and, e) glasses of milk consumed per day (1 item). Internal consistency was determined using Cronbach's alpha (α) for knowledge of osteoporosis ($\alpha=0.44$) and calcium rich foods ($\alpha=0.24$), calcium self-efficacy ($\alpha=0.65$) and outcome expectations ($\alpha=0.65$).

Statistical analysis

Descriptive statistics were calculated for demographic characteristics such as age, ethnicity, menarchal status and body mass index. The predictor variables of interest included; knowledge of calcium-rich foods, knowledge of osteoporosis, self-efficacy towards consuming calcium-rich foods, outcome expectations of consuming calcium-rich foods, and milk availability at home. The primary outcome variables were: 1) calcium intake: measured by mean milligrams of calcium consumed per day (FFQ) and glasses of milk consumed per day (COPA), which were combined to make calcium intake; and 2) bone quality, measured by the calcaneal SI (QUS).

Path analysis—Path analysis was used to determine the pathways by which the psychosocial and environmental variables interact to influence calcium intake and bone quality at baseline. A structural model with both latent and manifest variables was tested using a covariance matrix as input and maximum likelihood estimation. Confirmatory Factor Analysis (CFA) was conducted to test the validity of the measurement portion. Practical indices of fit for CFA include the chi-square, Root Mean Square Error of Approximation (RMSEA), normed and non-normed fit indices (NFI, NNFI) (21) and the non-normed comparative fit indices (CFI) (22). All CFA and path analysis were conducted using LISREL 8.7 statistical software (Scientific Software International Inc., Lincolnwood, IL). Missing values were handled via imputation. Less than 5% of the sample had missing values for the variables of interest and < 1% of the sample was eliminated after imputation. After multiple imputations, the final sample size for the CFA and path analysis was 715 participants. The adequacy of the model was tested using the chi-square goodness-of-fit test. Standardized parameter estimates were obtained and significance level was set at $p < 0.05$. Because mean milligrams of calcium intake per day was skewed to the right, a natural log transformation was done to achieve normality.

RESULTS AND DISCUSSION

The results of the path analysis with the standardized regression coefficients are presented in Figure 1. This model showed good-fit indices with a chi-square of 80.20 (df=35, p-value=0.00002), RMSEA=0.042, NFI=0.95, NNFI=0.96, CFI=0.97. The R-square indicates 14% of the variance in calcium intake, can be explained by this model.

Table 1 presents the Means \pm Standard Deviations and frequency distributions for the various variables of interest. Of the 717 girls, 72% were non-Hispanic white and 25% were overweight or obese (BMI \geq 85th percentile for age and gender) (Table 1). Most participants consumed more than the recommended amount of calcium/day (1321.3 \pm 754.8) and most consumed approximately 2 glasses of milk/day. This could be because milk availability at home was high (3.8 \pm 0.5 on a scale of 0 to 4). Additionally, milk availability was significantly correlated with both milligrams of calcium and glasses of milk consumed/day ($r=0.15$ and $r=0.23$ respectively, $p < 0.01$). Finally, path analysis showed that milk availability at home directly influenced calcium intake ($\beta=0.28$, $p < 0.05$). These findings are important because while it might seem intuitive, emphasizing the importance of milk availability to parents and schools is worthy. Recent studies state that calcium intakes of adolescents and pre-adolescents are strongly associated with availability of milk and/or calcium-rich beverages at meals (23, 24).

Only 26.4% of the participants had correct knowledge of osteoporosis. However, knowledge of calcium-rich foods was high with 66.1% responding correctly (Table 1). Pearson's correlation coefficients showed that knowledge of osteoporosis and calcium-rich foods, calcium self-efficacy and outcome expectations, were all positively correlated with calcium intake ($r=0.12-0.23$; $p < 0.01$). Knowledge of calcium-rich foods was correlated with calcium self-efficacy and outcome expectations ($r=0.12$ and 0.14 respectively, $p < 0.01$). Path analysis showed that knowledge of osteoporosis and calcium-rich foods directly influenced outcome expectations ($\beta=0.12$ and 0.14 respectively, $p < 0.05$); but, only knowledge of osteoporosis directly influenced self-efficacy ($\beta=0.08$, $p < 0.05$). Neither of the knowledge variables directly influenced calcium intake, but, each had an indirect effect with outcome expectations as the mediator (knowledge of osteoporosis $\beta=0.03$, $p < 0.05$; knowledge of calcium-rich foods: $\beta=0.035$, $p < 0.05$). Since knowledge has been posited to be positively associated with intake (25–27), this could explain the relatively high calcium intake seen in this group. These results indicate that knowledge alone, without addressing the mediating variables, may *not* produce behavior change.

Calcium self-efficacy was significantly correlated with outcome expectations ($r=0.24$, $p < 0.01$). Also, self-efficacy had a direct influence on outcome expectations ($\beta=0.34$, $p < 0.05$) and a significant indirect effect on calcium intake, with outcome expectations as the mediator ($\beta=0.085$, $p < 0.05$). This indirect influence of self-efficacy on calcium intake could be because individuals with a higher confidence towards choosing calcium containing foods could have higher outcome expectations, which could lead to higher calcium intake. Studies in adults have demonstrated self-efficacy to be a better predictor of engaging in osteoporosis-preventive behaviors compared to other factors (28–30). This study is the first to demonstrate such relationship in adolescent girls.

None of the psychosocial variables or calcium intake had an influence on the SI. While some studies (4, 5) have examined the relationship between calcium consumption and bone health, a few (10, 29) have studied the relationship between psychosocial factors and calcium consumption in adolescents; and none have assessed their relationship with calcaneus SI. The lack of association between calcium intake and SI seen in the present study are not echoed by others that have demonstrated a positive effect of calcium supplementation among boys and girls (4, 5). However, in these studies, BMD was measured versus the present study where SI scores were used. Additionally, calcium supplementation was not measured in the present study. The lack of association could be attributed to using the QUS SI score versus the dual-energy x-ray absorptiometry (DXA) BMD value (30). While studies have shown a strong correlation between QUS and DXA in older women (31, 32), the relationship in adolescent girls has not yet been studied. However, Jaworski et al., reported in a study on 6 to 13 year old children, that the precision of QUS measurements in children was comparable to the precision in adults using a new positioning system (16). Finally, most study participants were meeting the recommendations for calcium. This suggests that the effects of calcium intake on bone quality might be most obvious when calcium intake is insufficient.

The strengths notwithstanding, this study has several limitations. Given the cross-sectional study design, causality cannot be determined. Other limitations include the relative ethnic homogeneity of the sample, which reduces generalizability and eliminates the ability to assess these relationships in different racial/ethnic groups. Finally, no covariates were adjusted for in the analysis. However, a recent article published by the investigative team assessed these relationships using a multivariate regression and found similar results (13).

CONCLUSION

The results of the path analysis identified some direct and indirect pathways which influence calcium intake but *not* bone quality in adolescent girls. The current study provides avenues for developing effective intervention strategies when addressing calcium intake in adolescents. Future studies need to evaluate the causal mechanisms influencing calcium intake and bone health in a diverse cohort of adolescent girls using a prospective design.

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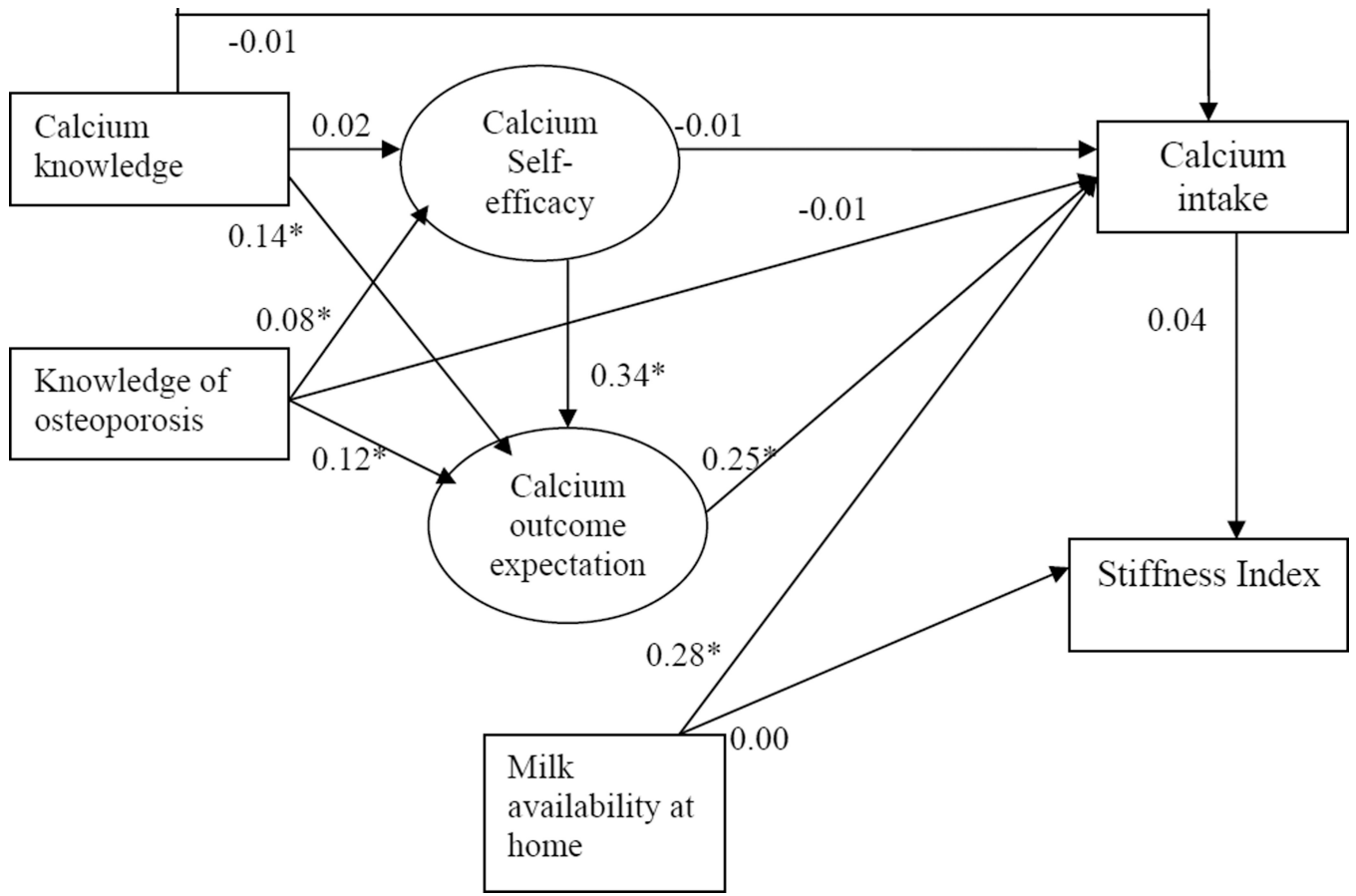


Figure 1. Results of the path analysis for calcium intake and bone quality. Standardized coefficients are presented
 * significant at $p < 0.05$

Table 1

Descriptive characteristics of study participants, dependent and independent variables of interest, IMPACT study, 2001–2003.

Variable	Number	Percent
BMI-for-age percentiles ^a	717	4
< 5th percentile	28	71
5th to <85th percentile	510	15
85th to <95th percentile	105	10
95th percentile	74	
Ethnicity	717	72
White	515	12
Hispanic	83	5
Black	39	11
Other	80	
Onset of menses	140	20
	Mean (SD)	Range
Age (years)	11.6 (±0.4)	10–13
Calcium intake	1321.3 (±754.8)	154.3–5268.8
Milligrams calcium consumed/day	1.9 (±1.3)	0–5
Glasses of milk consumed/day		
Bone quality	73.8 (±14.9)	34.7–130.1
Calcaneus stiffness index (SI)		
Knowledge of:	26.4 (±16.6)	0–85.7
Osteoporosis (% correct)	66.1 (±16.3)	0–100
Calcium content of foods (% correct)		
Self-efficacy towards calcium-rich foods ^b	29.8 (±6.6)	9–45
Calcium outcome expectations ^c	17.9 (±2.9)	7–35
Milk availability at home ^d	3.8 (±0.5)	0–4

^aBody Mass Index- for-age percentile 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 overweight and 95th percentile = obese.

^bSelf-efficacy towards calcium-rich foods was measured using nine items on the COPA, with scores ranging from 1 to 5 for each item. These scores were then summed to develop the scale for self-efficacy with the lowest possible score being 9 and highest possible being 45.

^cCalcium outcome expectations was measured using seven items on the COPA, with scores ranging from 1 to 5 for each item. These scores were then summed to develop the scale for outcome expectations with the lowest possible score being 7 and highest possible being 35.

^dMilk availability at home was measured using one item, "Milk is available at my house", with scores ranging from 0 (never) to 4 (All the time). Mean scores are presented.