Published in final edited form as:
J Phys Act Health. 2009 September ; 6(5): 606–616.

A Path Analysis to Identify the Psychosocial Factors Influencing Physical Activity and Bone Health in Middle-School Girls

Shreela V. Sharma,
Epidemiology Dept, University of Texas Health Science Center at Houston, TX

Deanna M. Hoelscher,
Michael & Dell Center for Advancement of Healthy Living, University of Texas School of Public Health, Austin Regional Campus

Steven H. Kelder,
University of Texas School of Public Health, Austin Regional Campus

Pamela M. Diamond,
Health Promotion Behavioral Sciences Dept, University of Texas Health Science Center at Houston, TX

R. Sue Day, and
Epidemiology Dept, University of Texas Health Science Center at Houston, TX

Albert C. Hergenroeder
Texas Children's Hospital, Baylor College of Medicine, Houston, TX

Abstract

Background—The purpose of this study was to identify pathways used by psychosocial factors to influence physical activity and bone health in middle-school girls.

Methods—Baseline data from the Incorporating More Physical Activity and Calcium in Teens (IMPACT) study collected in 2001 to 2003 were used. IMPACT was a 1 1/2 years nutrition and physical activity intervention study designed to improve bone density in 717 middle-school girls in Texas. Structural Equations Modeling was used to examine the interrelationships and identify the direct and indirect pathways used by various psychosocial and environmental factors to influence physical activity and bone health.

Results—Results show that physical activity self-efficacy and social support (friend, family engagement, and encouragement in physical activity) had a significant direct and indirect influence on physical activity with participation in sports teams as the mediator. Participation in sports teams had a direct effect on both physical activity ($\beta = 0.20$, $P < .05$) and bone health and ($\beta = 0.13$, $P < .05$).

Conclusion—The current study identified several direct and indirect pathways that psychosocial factors use to influence physical activity and bone health among adolescent girls. These findings are critical for the development of effective interventions for promoting bone health in this population.

Keywords

adolescent girls; osteoporosis; behavior; bone quality

Background

Osteoporosis is 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 > 2.5 standard deviations below the mean for normal young adults.[1] It is highly age and gender related; currently more than 10 million people over the age of 50 in the U.S. 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.

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

Literature shows that psychosocial and environmental factors mediate the associations between behavior and disease.[5–8] Behavior change is greatly facilitated by addressing these mediating factors. The Social Cognitive Theory (SCT) postulates that psychosocial, behavioral and physical factors potentially influence each other both theoretically and structurally,[5,9] There are several studies that have examined and identified the pathways used by various psychosocial factors to influence physical activity,[10–14] however, none have examined these interrelationships with respect to bone health in a cohort of adolescent girls. Furthermore, since development of osteoporosis is highly gender specific,[15] it can be advantageous to examine these relationships in a gender-specific manner. This may be especially true, since research has shown that participation in physical activity for girls is greater in girls-only classes or team sports.[16] The purpose of this study was to identify the pathways in which psychosocial factors, such as knowledge, physical activity self-efficacy, outcome expectations, social support, participation in sports teams, and neighborhood safety, interact to influence physical activity and bone health using path analysis in a cohort of adolescent females.

Methods

This study uses baseline data from The Incorporating More Physical Activity and Calcium in Teens (IMPACT) study. IMPACT was a 1 1/2-year quasi-experimental, school-based nutrition and physical activity intervention program conducted from 2001 to 2003 to promote bone mineral density among 718 middle school girls in central Texas.[17,18]

For the purpose of this study, constructs from the Social Cognitive Theory (SCT) were chosen to evaluate the eating and physical activity behavior of adolescents. The SCT was chosen because of its comprehensive nature and it addresses both the psychosocial dynamics influencing health behavior and methods for promoting behavior change. The SCT states that human behavior is continually influences by the environment and personal factors and they all interact.[5] The personal factors include individual capabilities to symbolize behavior, to anticipate outcomes of the behavior, to learn by observing others, to have confidence in performing a behavior, to self-determine or self-regulate behavior and to reflect on and analyze experience.[5]

The baseline study population consisted of 6th grade girls (n = 12 schools, 718 girls; Table 1). The response rate was 38% for all 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.[17,18] 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

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 using a standardized protocol. Height and weight were used to calculate body mass index (BMI) using the formula weight (kg)/height (m).[2] Height and weight measurements were obtained on 717 participants. Prevalence of overweight in the study participants was determined using the Centers for Disease Control age and gender-specific BMI charts to calculate BMI percentiles.[19] BMI ≥ 95th percentile for age and sex was considered overweight, and a BMI ≥ 85th percentile and < 95th percentile was considered at risk for overweight. Participants self-described their ethnicity as per a predetermined ethnic classification (White, Hispanic, Black, Other). Data on menarcheal status was obtained by asking the girls if they had started menstruation. Table 1 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.[20] 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 × BUA + 0.28 × SOS)—420. Os calcis, a weight-bearing site with trabecular bone, has bone mineral density (BMD) values that follow a similar pattern to that of the proximal femur.[21] Thus, changes in the bone should be reflective of changes in the BMD of the proximal femurs.

Self Administered Physical Activity Checklist (SAPAC)—The 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. The SAPAC has been successfully validated against the heart rate monitors (r = .57) and Caltrac accelerometers (r = .30) in 5th grade children.[22] For the current study, SAPAC was adapted to include a weekend version, and to distinguish between high impact and low impact activities. The SAPAC was 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.

Calcium, Osteoporosis and Physical Activity (COPA) 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.[23,24] We included questions addressing: a) knowledge of osteoporosis (7 items) and knowledge of calcium-rich foods (9 items); b) self-efficacy of consuming calcium-rich foods (9 items) and engaging in weight bearing physical activity (12 items); c) outcome expectations (positive beliefs about the benefits) of physical activity (11 items); d) neighborhood safety (1 item); e) behavioral factors such as glasses of milk consumed per day (1 item), number of jumping activities per week (1 item), participation in sports teams (1 item); and f) family and friend social support (engagement and encouragement) to be physically active (4 items). COPA was pretested using a sample of 6th and 7th grade students in a school that did not participate in IMPACT showing good test-retest reliability (N = 94; Table 4).[18] Since the response scales went from lower to higher scores, higher amounts on the scales indicate higher values of the construct.

Statistical Analysis

Descriptive statistics of baseline and demographic characteristics such as age, ethnicity, menarcheal status, body mass index as obtained from the questionnaires were calculated. Pearson's product-moment correlation coefficients were also calculated between predictor and outcome variables.

The predictor (latent) variables of interest included knowledge of calcium-rich foods, knowledge of osteoporosis, self-efficacy toward engaging in physical activity, outcome expectations of engaging in physical activity, physical activity social support, neighborhood safety toward engaging in physical activity, and participation in sports teams. Internal consistency for scales was evaluated using Cronbach's alpha on all 718 participants. Test-retest reliability coefficients were also obtained by administering the questionnaire 9 to 14 days apart during the pilot testing on 94 participants (Table 4).

The primary outcome variables were: 1) physical activity: measured by mean minutes of physical activity per day (SAPAC) and number of jumping activities per week (COPA); and 2) Bone quality measured by the calcaneal SI (QUS).

Path Analysis—Path analysis was used to determine the pathways by which the psychosocial, behavioral, and environmental variables interact to influence physical activity and bone health at baseline. The relationship between these psychosocial and behavioral factors is rarely bivariate;[25] a full multivariate analysis is necessary to obtain the true nature of these associations.[26,27] A structural model with both latent and manifest variables was tested using a covariance matrix as input and maximum likelihood estimation. This type of analyses provides a comprehensive picture of the nature of the associations between the predictor and dependent variables of interest.

Figure 1 presents a set of hypotheses about the relations between variables. The latent variables are depicted in ovals and observed variables are in rectangles. The latent variables are hypothesized to cause covariation among a set of observed variables which include mean minutes of physical activity per day, number of jumping activities per week, and the calcaneal SI. Path analysis is a comprehensive approach to testing hypotheses about relations among observed and latent variables.[25–27]

Assessment of Model Fit—A preliminary analysis was conducted to test the validity of the measurement portion of the model using Confirmatory Factor Analysis (CFA). Practical indices of fit for CFA include the chi-square, Root Mean Square Error of Approximation (RMSEA), normed and nonnormed fit indices (NFI, NNFI),[28] and the nonnormed comparative fit indices (CFI).[29] Values for NFI, NNFI and CFI range from 0 to 1 and are derived from the comparison of a hypothesized model with the independent model, with a value greater than 0.90 indicating an acceptable fit to the data. The current benchmark is 0.95. By convention, there is a good model fit if RMSEA is less than or equal to 0.05 and there is adequate fit if RMSEA is less than or equal to 0.08.[28–30]

Following the CFA, the relationship between the latent variables (psychosocial, environmental, and behavioral factors at baseline) was simultaneously tested using path analysis using LISREL 8.7[31] statistical software. Missing values were handled in LISREL via imputation (as is typical in this software), ie, by substitution of missing values for real values obtained from another participant that had a similar response pattern over a set of matching variables. Participants with missing values were eliminated after imputation. Less than 5% of the sample had missing values for the variables of interest and < 1% of the sample was eliminated after imputation. The final sample size for the analysis after multiple imputations was n = 715. The adequacy of the structural model was tested using the chi-square goodness-of-fit test. Standardized parameter estimates representing direct and indirect effects were obtained at baseline. Significance level was set at 0.05.

All the variables were entered as a continuous in the final model and were assessed for their normality (skewness and kurtosis). Mean minutes of physical activity was skewed to the right and not normally distributed. Hence, a natural log transformation was done on the variable for the final model. This transformation resulted in the variable being fairly normally distributed.

Results

Description of the Dataset and Examination of Variables

The IMPACT data set contained a total of 718 girls at baseline. Height and weight information as well as ethnic classification was obtained on 717 girls, 72% of who were non-Hispanic white and 25% were at risk for overweight or overweight (Table 1).

Table 2 presents the descriptive statistics of the various dependent and independent variables at baseline. The dependent variables included mean minutes of physical activity per day, number of jumping activities per week and the calcaneal stiffness index. The independent variables included knowledge of calcium-rich foods and osteoporosis, self-efficacy toward engaging in physical activity, physical activity outcome expectations, social support, neighborhood safety, and participation in sports teams. Overall, results show that participants were doing more than the recommended physical activity[32] of 60 minutes/day (Mean 108.7 ±64.6). 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 showed that 28% of the girls were participating in zero teams while 72% participated in at least one sports team.

Table 3 presents the Pearson's product-moment correlation coefficients between psychosocial predictor variables and physical activity and bone quality at baseline. Physical activity self-efficacy, outcome expectations, friend and family engagement/encouragement in physical activity, and participation in sports teams were significantly correlated with mean minutes of physical activity per day or number of jumping activities per week, with correlation coefficients ranging from 0.17 to 0.29 ($P < .01$). Physical activity outcome expectations and participation in sports teams showed significant correlations with the Stiffness Index ($r = .11$ and 0.14 respectively, $P < .01$).

Table 4 shows that knowledge of osteoporosis was significantly correlated with knowledge of calcium intake ($r = .15$, $P < .05$). Physical activity self-efficacy was significantly correlated with knowledge of osteoporosis ($r = .08$), physical activity outcome expectations ($r = .42$), social support ($r = .29$ to 0.36, $P < .05$), and participation in sports teams ($r = .35$, $P < .05$). Neighborhood safety was also significantly correlated to self-efficacy ($r = .09$, $P < .05$), family encouragement to perform physical activity ($r = .12$, $P < .05$), and friend engagement in physical activity ($r = .15$, $P < .05$). Table 4 also presents the reliability coefficients (Cronbach's alpha and test-retest reliability) for knowledge of osteoporosis (α=0.44), calcium-rich foods (α=0.24), self-efficacy (α=0.87), outcome expectations (α=0.36), and social support (α=0.68).

The CFA was performed using knowledge of osteoporosis, knowledge of calcium-rich foods, physical activity self-efficacy, physical activity outcome expectations, and physical activity social support (Table 5). Participation in sports teams and neighborhood safety were single items (measured using one question) from the COPA and hence were not included in the CFA.

For knowledge of calcium-rich foods and osteoporosis, the original scale with the individual items did not show a good model fit with fit indices <0.90. Item parceling[33] was performed on both knowledge variables since the initial CFA revealed that there were some items with low loadings. The knowledge variables showed a good fit with fit indices >0.95 (Table 5). However, the final structural model fit was not adequate with CFI, NNFI, and NFI <0.90. In addition, our results showed that knowledge did not significantly influence physical activity self-efficacy, outcome expectations or physical activity behavior. Hence, the final model did not include the two knowledge variables.

Neighborhood safety was also excluded from the final model since it did not appear to significantly influence neither physical activity behavior nor bone health and also did not show a good model fit (fit indices <0.90) when included in the model.

Final Path Model

The results of the path analysis with the standardized regression coefficients for physical activity are presented below in Figure 2. This model had a good fit with a chi-square = 305.36 (df = 110, P = .0), RMSEA = 0.052, NFI = 0.93, NNFI = 0.93 and a CFI = 0.95. Figure 2 indicates that physical activity self-efficacy has a significant direct and indirect effect on physical activity behavior with participation in sports teams as the mediating variable (β= 0.33 for direct effect and β=0.04 for indirect effect, $P < .05$). Physical activity self-efficacy also significantly influences outcome expectations (β=0.71, $P < .05$). Social support has a significant direct and indirect effect on physical activity behavior (β= 0.26 for direct effect, β= 0.04 for indirect effect, $P < .05$). Participation in sports teams appears to directly influence both physical activity (β=0.20, $P < .05$) and SI (β= 0.13, $P < .05$). However, physical activity does not appear to significantly influence stiffness index (β=0.01, $P > .05$). R-square indicates that 29% of the variance in physical activity and bone health can be explained by this model.

Discussion

Results identified several direct and indirect psychosocial correlates of physical activity and bone health, specifically physical activity self-efficacy, outcome expectations, social support, and participation in sports teams.

Discussion of Results of CFA and Path Analysis

The initial path analysis model included knowledge of calcium rich foods and osteoporosis along with the other psychosocial, environmental, and behavioral variables (Figure 1). Results showed that neither of the two knowledge variables influenced physical activity behavior nor bone health. These results concur with previously performed regression analyses[34] which also showed a marginal association between knowledge, physical activity, and bone health. Reviews of the literature on the correlates of physical activity in children and adolescents found an inconsistent association between knowledge and behavior.[35,36] These results convey an important message to interventionists that knowledge, without addressing the mediating variables such as self-efficacy and outcome expectations, will probably not produce a significant change in physical activity. Neighborhood safety was another variable included in the initial model which did not directly or indirectly influence physical activity or bone health. Motl et al[11]., reported similar results in a cross-sectional study assessing the effect of neighborhood safety, social support, and perceived equipment accessibility in 1,655 12th grade adolescent girls using a path analysis approach. However, some studies, using a regression analysis approach, have shown an association between neighborhood safety and physical activity.[37–39] The lack of association seen in our study could be due to many reasons. Neighborhood safety was measured using only one self-reported item on the COPA which could have rendered the results nonsignificant. Studies that have used multiple items have found significant associations.[37,38] 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.

The current study identifies self-efficacy toward physical activity as a significant factor directly and indirectly influencing physical activity. These results concur with Bungum et al[40] who examined the associations between psychosocial factors and physical activity in 520 adolescent males and females. Results showed that, for both males and females, attitudes, enjoyment, and self-efficacy were significantly associated with intentions to be physically active. These results clearly suggest that increased confidence in performing a behavior increases the likelihood of performing that behavior.[5] Dishman et al[13] and Motl et al[14] evaluated the effects of a school-based intervention on variables derived from the Social Cognitive Theory such as self-efficacy, outcome expectations, as mediators of change in physical activity in 2087 adolescent girls. Results showed that self-efficacy was not only cross-sectionally associated with physical activity but, also mediated the effect of the intervention on physical activity. These results, along with those of the current study, emphasize the importance of including self-efficacy when designing effective intervention programs for disease prevention.

In addition, our results showed that social support directly influences physical activity behavior. The literature supporting these positive associations seen between physical activity and social support is strong. Prochaska et al[41] 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. Sallis et al[35] found peer support to be significantly associated with vigorous physical activity among female girls from Massachusetts in grades 7 through 9. O’Dea et al[42] reported parental support and involvement in activities to be strongly associated with physical activity and, more recently, Duncan et al[43] found friend social support to be most highly related to physical activity among youth between the ages of 10 and 14. Trost et al,[10] using a path analysis, reported a direct and indirect effect of parental support on physical activity through its influence on self-efficacy among 388 youth in 7th–12th grade. Finally, Saunders et al[12] in a path analysis of subjective norms, social provisions, and family support for predicting intention, moderate-to-vigorous physical activity (MVPA) and team sports involvement, concluded that family support predicted team sports involvement more strongly than MVPA. These findings, suggest that peers and parents may take a prominent role in influencing physical activity among adolescent girls and indicate the need for including this component when developing and implementing health promotion programs.

In sum, the current study identified participation in sports teams as a significant mediating variable for the correlations between self-efficacy, social support, and physical activity. This indicates that while social support and self-efficacy are important factors to consider when trying promote physical activity, sports team participation may be an important means of increasing physical activity behaviors. These results concur with the results of multiple regression analysis that identified participation in sports teams as a significant predictor of physical activity and bone health,[34] as well as those of Saunders et al[12] who concluded that family support strongly predicted team sports involvement among adolescent girls in the eighth grade.

In addition, in our study, participation in sports teams was the only variable that had a direct influence on the bone stiffness index. Leisure-time physical activity, had no significant influence on stiffness index. 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 strongly influence 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. Further, sports teams often participate in weight lifting as part of their conditioning program also putting stress on bones. Sports activities give a sustained impact for a season (several months) with a positive effect on BMD.[44] These results have strong policy implications with respect to the Title IX act which calls for equality in sports team participation for girls.[45] These results provide more physiological evidence on the benefits of sports teams participation and the Title IX act.

Furthermore, the direct correlation of social support and participation in sports teams emphasizes the importance of peer and family influences on health which should be adequately addressed when trying to increase sports team participation.

Our analysis identified some key pathways influencing physical activity behavior and bone health. Currently, the literature that has attempted path analysis to identify pathways used by various psychosocial factors to influence physical activity and bone health in a cohort of adolescent girls is scarce. Wu et al[46] examined gender differences in the psychosocial factors related to physical activity among Taiwanese adolescents. They concluded that peer influences had direct and indirect paths to physical activity in both genders and self-efficacy was the strongest correlate of physical activity. Dishman et al[13] and Motl et al,[14] using a path analysis approach, identified self-efficacy as an important correlate as well as a mediator of intervention effect on physical activity behavior in adolescent girls using a randomized controlled trial design. These results lend support to our study which also identified social support and self-efficacy as significant correlates of physical activity. Our study also identified participation in sports teams as an important correlate of physical activity and a mediator in the associations of self-efficacy and social support with physical activity. The results of this study especially stress the relevance of interrelationships between personal factors such as self-efficacy, social factors such as peer and parental support, and behavioral factors such as participation in sports teams in producing behavior change and influencing bone health.

Strengths and Limitations

Some limitations should be considered in interpreting the study's findings. This was a secondary data analysis, thus the results are exploratory rather than confirmatory; however, since this study was done using baseline data from an intervention study, the study design is appropriate. In addition, the study design is cross-sectional and hence causality cannot be determined. The response rate was low (38% of all the eligible girls), however, 100% of the required sample for adequate power was recruited. Thus, the sample size was large enough to lend sufficient power to the study (n = 715). Another limitation of the study was the low internal consistency of some of the psychosocial scales as determined using the Cronbach's alpha. Typically, a Cronbach's alpha of >0.70 is considered adequate. The scales for knowledge of osteoporosis, calcium-rich foods, and physical activity outcome expectations had a Cronbach's alpha of <0.50 indicating low internal consistency among the items included in the scales which could have also rendered these variables as not significant in the final model.

Measurement of physical activity was primarily conducted via self-administered questionnaires which could potentially result in over-reporting of physical activity performed thus biasing the results away from the null. However, both SAPAC and COPA have been validated with good validity, reliability, and correlations with other markers such as the accelerometer.[18,22] In addition, the SAPAC was administered on three separate days, including one weekend day, providing a good estimate of the daily minutes of physical activity.

Other limitations include the relative ethnic homogeneity of the sample, which reduces the generalizability of the results to ethnically diverse adolescent girls 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 model and found similar results.[34] Also, the correlation with other markers, specifically accelerometers, would be beneficial to explicitly state what those other correlations signify. Nonetheless, this study is among the first to examine pathways used by psychosocial, environmental, and behavioral factors to influence physical activity and bone health in a homogenous, large cohort of 717 female adolescents.

Conclusion

This study suggests that self-efficacy, social support, and participation in sports teams are interrelated in their influence on physical activity in girls. This study establishes a sound foundation for further investigation of the variables under discussion in the adolescent/young adult age group, perhaps with the use of a prospective design. Such a design would provide us additional valuable information, beyond what is possible with a static cross-sectional picture of the study population. The results of this study are especially critical when developing effective interventions addressing physical activity or bone health in adolescents and pave the way for future research involving primary prevention of osteoporosis.

Acknowledgments

The authors would like to acknowledge Roy Allen for database management and extend our appreciation to the research assistants responsible for recruitment, data collection and entry. This work was supported by National Institute of Child Health & Human Development (NICHD) R01 HD37767–04. Clinicaltrials.gov Identifier: NCT00067925.

References

1. World Health Organization. Diet, nutrition and the prevention of chronic diseases. WHO Technical Report Series. 1990; 794:1–204. [PubMed: 2120854]
2. National Osteoporosis Foundation. Fast facts. [Accessed February 20, 2007]. Available at http://www.nof.org/osteoporosis/diseasefacts.htm
3. USDHHS. Surgeon general's report on bone health. [Accessed February 12, 2007.]. Available at http://www.surgeongeneral.gov/library/bonehealth/content.html
4. Ondrak KS, Morgan DW. Physical activity, calcium intake and bone health in children and adolescents. Sports Med. 2007; 37:587–600. [PubMed: 17595154]
5. Bandura A. Social cognitive theory of self-regulation. Organ Behav Hum Decis Process. 1991; 50:248–287.

6. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity. Annu Rev Public Health. 2001; 22:309–335. [PubMed: 11274524]
7. Lee S, Reicks M. Environmental and behavioral factors are associated with the calcium intake of low-income adolescent girls. J Am Diet Assoc. 2003; 103:1526–1529. [PubMed: 14576721]
8. Morgan C, McKenzie TL, Sallis JF, Broyles SL, Zive MM, Nader PR. Personal, social, and environmental correlates of physical activity in a bi-ethnic sample of adolescents. Pediatr Exerc Sci. 2003; 15:288–301.
9. Glanz, K.; Rimer, BK.; Lewis, FM. Health Behavior and Health Education. 3. San Francisco, CA: Jossey-Bass Publications; 2002.
10. Trost SG, Sallis JF, Pate RR, Freedson PS. Evaluating a model of parental influence on youth physical activity. Am J of Prev Med. 2003
11. Motl RW, Dishman RK, Saunders RP, Dowda M, Pate RR. Perceptions of physical and social environment variables and self-efficacy as correlates of self-reported physical activity among adolescent girls. J Pediatr Psychol. 2007; 32(1):6–12. [PubMed: 16707779]
12. Saunders RP, Motl RW, Dowda M, Dishman RK, Pate RR. Comparison of social variables for understanding physical activity in adolescent girls. Am J Health Behav. 2004; 28(5):426–436. [PubMed: 15482972]
13. Dishman RK, Motl RW, Saunders RP, et al. Self-efficacy partially mediates the effect of a school-based intervention among adolescent girls. Prev Med. 2004; 38:628–636. [PubMed: 15066366]
14. Motl RW, Dishman RK, Ward DS, et al. Perceived physical environment and physical activity across one year among adolescent girls: self-efficacy as a possible mediator? J Adolesc Health. 2005; 37:403–408. [PubMed: 16227126]
15. Bengochea EG, Spence JC, McGannon KR. Gender differences in perceived environmental correlates of physical activity. IJBNPA. 2005; 2:12–20. [PubMed: 16159404]
16. Sallis JF, Zakarian JM, Hovell MF, Hofstetter CR. Ethnic, socioeconomic, and sex differences in physical activity among adolescents. J Clin Epidemiol. 1996; 49:125–134. [PubMed: 8606313]
17. 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; 3:8. [PubMed: 16600030]
18. Hoelscher D. Unpublished data.
19. Centers for Disease Control and Prevention. BMI-body mass index. about BMI for children and teens. [Accessed 3/12, 2007.]. Available at http://www.cdc.gov/nccdphp/dnpa/bmi/childrens_BMI/about_childrens_BMI.htm
20. Pate RR, Saunders RP, Ward DS, Felton G, Trost SG, Dowda M. Evaluation of a community-based intervention to promote physical activity in youth: Lessons from active winners. Am J Health Promot. 2003; 17:171–182. [PubMed: 12545585]
21. Sahota O, San P, Cawte SA, Pearson D, Hosking DJ. 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; 11:52–58. [PubMed: 10663359]
22. Sallis JF, Strikmiller PK, Harsha DW, et al. Validation of interviewer- and self administered physical activity checklists for fifth grade students. Med Sci Sports Exerc. 1996; 28:840–851. [PubMed: 8832538]
23. 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; 10:277–284.
24. Edmundson E, Parcel GS, Feldman HA, et al. The effects of the child and adolescent trial for cardiovascular health upon psychosocial determinants of diet and physical activity behavior. Prev Med. 1996; 25:442–454. [PubMed: 8812822]
25. Loehlin, JC. Latent Variable Models: An Introduction to Factor, Path, and Structural Analysis. Hillsdale, N.J: Lawrence Erlbaum Associates; 1998.
26. Klem, L. Path analysis. In: Grimm, LG.; Yarnold, PR., editors. Reading and Understanding Multivariate Statistics. Washington, D.C: American Psychological Association; 1995. p. 65-98.
27. Klem, L. Structural equation modeling. In: Grimm, LG.; Yarnold, PR., editors. Reading and Understanding More Multivariate Statistics. Washington, D.C: American Psychological Association; 2000. p. 227-259.

28. Bentler PM, Bonett DG. Significance tests and goodness of fit in the analysis of covariance structures. Psychol Bull. 1980; 88:588–606.
29. Bentler PM. Comparative fit indexes in structural models. Psychol Bull. 1990; 107:238–246. [PubMed: 2320703]
30. Kline, RB. Principles and Practice of Structural Equation Modeling. 2. New York: Guilford Press; 2004.
31. Jöreskog, KG.; Sörbom, D. LISREL 8.7 for windows. Lincolnwood, IL: Scientific Software International, Inc; 2004.
32. Dietary guidelines for Americans. [Accessed 1/30, 2007.]. Available at www.health.gov/dietaryguidelines/dga2005
33. Bandalos, DL.; Finney, SJ. Item parcelling issues in structural equation modelling. In: Marcoulides, GA.; Schumaker, RE., editors. New Developments and Techniques in Structural Equation Modelling. Mahwah, N.J: Lawrence Erlbaum; 2001. p. 269-297.
34. Sharma S, Hoelscher DM, Kelder S, Hergenroeder A. Psychosocial, environmental and behavioral predictors of calcium intake, physical activity and bone health in middle-school girl. Health Education Research. Published March 21, 2008.
35. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000; 32:963–975. [PubMed: 10795788]
36. Kohl HW III, Hobbs KE. Development of physical activity behaviors among children. Pediatrics. 1998; 101:549. [PubMed: 12224661]
37. Molnar BE, Gortmaker SL, Bull FC, Buka SL. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. Am J Health Promot. 2004; 18(5):378–386. [PubMed: 15163139]
38. Gomez JE, Johnson BA, Selva M, Sallis JF. Violent crime and outdoor physical activity among inner-city youth. Prev Med. 2004; 39(5):876–881. [PubMed: 15475019]
39. Nelson MC, Gordon-Larsen P, Song Y, Popkin BM. Built and social environments associations with adolescent overweight and activity. Am J Prev Med. 2006; 31(2):109–117. [PubMed: 16829327]
40. Bungum T, Dowda M, Weston A, Trost SG, Pate RR. Correlates of physical activity in male and female youth. Pediatr Exerc Sci. 2000; 12:71–79.
41. Prochaska JJ, Rodgers MW, Sallis JF. Association of parent and peer support with adolescent physical activity. Res Q Exerc Sport. 2002; 73:206–210. [PubMed: 12092896]
42. 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. [PubMed: 12669014]
43. Duncan SC, Duncan TE, Strycker LA. Sources and types of social support in youth physical activity. Health Psychol. 2005; 24:3–10. [PubMed: 15631557]
44. Lloyd T, Chinchilli VM, Johnson-Rollings N, Kiesel-horst K, Eggli DF, Marcus R. Adult female hip bone density reflects teenage sports-exercise patterns but not teenage calcium intake. Pediatrics. 2000; 106:40–44. [PubMed: 10878147]
45. Carpenter, LJ.; Acosta, RV. Title IX. Champaign, IL: Human Kinetics; 2005.
46. Wu SY, Pender N, Noureddine S. Gender differences in the psychosocial and cognitive correlates of physical activity among taiwanese adolescents: A structural equation modeling approach. Int J Behav Med. 2003; 10:93–105. [PubMed: 12763704]

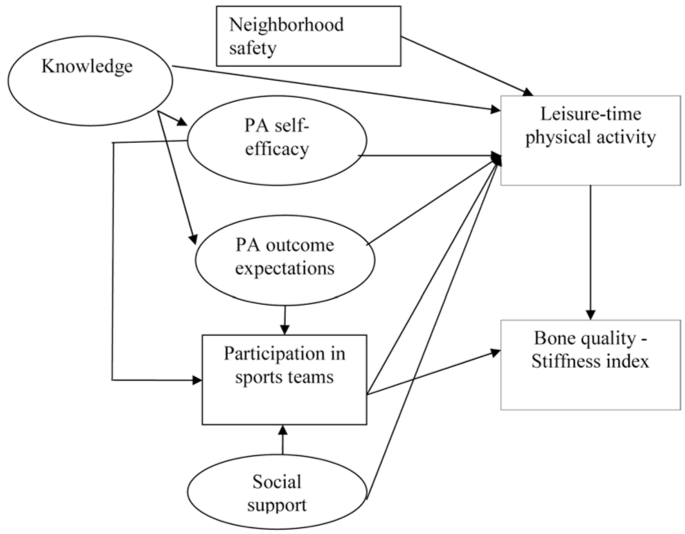

Figure 1.
Hypothesized pathways between the psychosocial, environmental variables, physical activity, and bone quality. PA, physical activity; * significant at $P < .05$.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

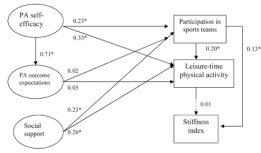

Figure 2.
Results of the path analysis for physical activity and bone quality. Standardized coefficients are presented. PA, physical activity; * significant at $P < .05$

Table 1

Descriptive Characteristics of Female Middle School Students, IMPACT Study

Variable	Number	Percent
Total[a]	718	
BMI-for-age percentiles[b]	717	
< fifth percentile	28	4%
> fifth to <85th percentile	510	71%
>85th to <95th percentile	105	15%
>95th percentile	74	10%
Ethnicity	717	
White	515	72%
Hispanic	83	12%
Black	39	5%
Other	80	11%
Onset of menses	140	20%

[a]Mean age (years) is 11.6, SD +0.4.

[b]Body 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 <fifth percentile = underweight, >fifth to <85th percentile = normal weight, >85th to <95th percentile = at risk for overweight and >95th percentile = overweight at risk for obesity.

Table 2

Descriptive Statistics of Variables of Interest, IMPACT Study

Variable	Mean (SD)	Range
Physical activity		
Mean minutes/day	108.7[a] (+64.6)	25–407.5
Jumping activities/week	3.04[a] (+2.1)	0–7
Bone quality		
Calcaneal stiffness index	73.8[a] (+14.9)	34.7–130.1
Knowledge of:		
Osteoporosis (% correct)	26.4 (+16.6)	0–85.7
Calcium-rich foods (%correct)	66.1 (+16.3)	0–100
Physical activity self-efficacy	44.2[a] (+9.7)	12–60
Physical activity outcome expectations	22.1[a] (+2.9)	11–30
Physical activity social support		
Family encouragement	3.6[a] (+1.2)	1–5
Family engagement	3.1[a] (+1.1)	1–5
Friend encouragement	2.5[a] (+1.2)	1–5
Friend engagement	3.6[a] (+1.3)	1–5
Neighborhood safety	3.1[a] (+1.3)	1–5
Participation in sports teams	1.6[a] (+1.3)	0–4

Abbreviations: SD, standard deviation.

[a]Higher numbers indicate higher values on the construct.

Dependent variables: mean minutes of physical activity per day, number of jumping activities per week, calcaneal stiffness index.

Independent variables: knowledge of osteoporosis, calcium-rich foods, self-efficacy, outcome expectations, social support, neighborhood safety, participation in sports teams.

Table 3

Pearson's Product-Moment Correlation Coefficients Between Psychosocial Predictor Variables, Physical Activity, and Bone Health at Baseline, IMPACT Study

	Physical activity		Bone quality
Variable	**Mean mins/day**	**Days/wk jumping**	**Stiffness index**
Knowledge osteoporosis	0.02	−0.01	−0.02
Calcium knowledge	−0.09	−0.06	0.04
Physical activity SE	0.24[a]	0.29[a]	0.09
Physical activity OE	0.17[a]	0.19[a]	0.11[a]
Physical activity social support			
Family encouragement	0.19[a]	0.19[a]	0.09
Family engagement	0.19[a]	0.19[a]	0.006
Friend encouragement	0.21[a]	0.23[a]	0.05
Friend engagement	0.24[a]	0.29[a]	0.10
Neighborhood safety	−0.01	0.06	0.04
Participation in sports teams	0.27[a]	0.22[a]	0.14[a]
Mean	108.7	3.04	73.8
SD	64.6	2.1	14.9
Range	25–407.5	0–7	34.7–130.1

Abbreviations: mg, milligrams; mins, minutes; wk, week; SE, self efficacy; OE, outcome expectations.

[a] significant at $P < .01$.

Table 4

Bivariate Pearson's Product-Moment Correlations Between Psychosocial Variables for Baseline Data, IMPACT Study

Variable	OsK	CaK	PASE	PAOE	FamEnc	FamEng	FrEnc	FrEng	Safety	ParST
Osteoporosis knowledge (OsK)	1.00									
Calcium knowledge (CaK)	0.15[a]	1.00								
Physical activity SE (PASE)	0.08[a]	0.02	1.00							
Physical activity OE (PAOE)	0.11[a]	0.04	0.42[a]	1.00						
Social support										
Family encouragement (FamEnc)	0.10[a]	0.13[a]	0.35[a]	0.23[a]	1.00					
Family engagement (FamEng)	0.07	0.03	0.33[a]	0.25[a]	0.30[a]	1.00				
Friend encouragement (FrEnc)	0.14[a]	−0.03	0.29[a]	0.23	0.31[a]	0.43[a]	1.00			
Friend engagement (FrEng)	0.08	−0.02	0.36[a]	0.18[a]	0.30[a]	0.24[a]	0.47[a]	1.00		
Neighborhood safety (Safety)	−0.03	0.07	0.09[a]	0.07	0.12[a]	0.01	0.03	0.15[a]	1.00	
Participation in sports team (ParST)	0.04	0.08[a]	0.35[a]	0.19[a]	0.22[a]	0.22[a]	0.19[a]	0.25[a]	0.07	1.00
Mean	26.4	66.1	44.2	22.1	3.6	3.1	2.5	3.6	3.1	1.6
SD	16.6	16.3	9.7	2.9	1.2	1.1	1.2	1.3	1.3	1.3
Range	0–85.7	0–100	12–60	11–30	1–5	1–5	1–5	1–5	1–4	0–4
Cronbach's α	0.44	0.24	0.87	0.36	0.68[b]	0.68[b]	0.68[b]	0.68[b]	N/A	N/A
Test-retest reliability	0.61–0.90	0.57–0.80	0.14–0.82	0.36–0.75	N/A	N/A	N/A	N/A	N/A	0.62

Abbreviations: SE, self efficacy; OE, outcome expectations; N/A, not applicable.

[a] significant at $P < .05$.

[b] Since social support was grouped together as one scale for the path analysis, internal consistency for the social support scale was determined.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 5

Summary of Fit Statistics Using Confirmatory Factor Analysis (CFA) for the Psychosocial Variables of Interest, Baseline IMPACT Data

Variable	Chi-square	df	RMSEA	NFI	NNFI	CFI
Osteoporosis knowledge[a]	9.56	8	0.017	0.94	0.98	0.99
Calcium knowledge[a]	9.56	8	0.017	0.94	0.98	0.99
Physical activity SE	183.55	53	0.059	0.93	0.94	0.95
Physical activity OE	183.55	53	0.059	0.93	0.94	0.95
Social support	19.21	2	0.11	0.96	0.89	0.96

Abbreviations: df, degrees of freedom; RMSEA, Root Mean Square Error of Approximation; NFI, normed fit index; NNFI, non normed fit index; CFI, comparative fit index.

[a]CFA for knowledge variables following item parceling.