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Adolescents with Idiopathic Scoliosis are Not Osteoporotic

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Abstract:

In the past, prior studies have associated adolescent idiopathic scoliosis (AIS) to abnormalities in bone mineral density (BMD) such as “osteoporosis” or “osteopenia” based on their adult definitions, but in reality very few AIS patients have clinically abnormal BMD. Fracture risk has not been correlated to Z-scores in pediatric populations, so the terms “osteoporosis” and “osteopenia” can not be applied to AIS. Our study examined adolescents with and without scoliosis of varying weights to better understand the relationship of BMD to body mass index (BMI).

This cross-sectional retrospective study compared the dual photon X-ray absorptiometry (DXA) scans of hips and distal femora of 49 adolescents with idiopathic scoliosis and 40 normal control adolescents. Z-scores were compared using student’s t-test or simple linear regression procedures to discover correlations between Z-scores and clinical and demographic variables. In both populations, there was a strong correlation with z-scores and BMI ($p < .001$). Scoliosis had the effect of lowering the Z-score as if the individual had “lost” 3.4 BMI units. Essentially, thin subjects had lower BMD and heavy subjects had higher BMD. The impact of scoliosis reducing BMI scores by 3.4 units puts thin subjects in the “low for age” level while the effect is negligible in heavier subjects. There were no subjects in either group that met the International Society of Clinical Densitometry (ICSD) definition for “osteoporosis.”

Introduction:

Scoliosis is an abnormal lateral curvature of the spine. Adolescent idiopathic scoliosis (AIS) is the most common form in the US with a prevalence of approximately 3% (1). AIS is initially asymptomatic and painless with presentation of an unusual posture. Males and females are affected equally by AIS, but the risk of curve progression is seven times greater in females than in males (1). AIS is speculated to be a multifactorial disorder, but no single causative factor has been elucidated. Its associated pathology has been shown to include neuromuscular disorders, proprioceptive disorders, abnormalities of connective tissue, asymmetric growth, or abnormal growth disturbances but osseous changes are less obvious and infrequently reported (2,3). Prior studies have concluded that AIS patients are often “osteoporotic” (7,6,8,4) or “osteopenic” (5,3,2). However, the technical definition by the International Society of Clinical Densitometry (ICSD) is not applicable to pediatric populations, and may also be frightening and stigmatizing to the patient and family.

The definition of “osteoporosis” states that low bone mass and deterioration lead to fragility and an increase in fracture risk. But in pediatric populations, there is no known point that increase fracture risk occurs. In order to apply the “osteoporotic” label to pediatric populations, there must be evidence of an insufficiency fracture, or a fracture secondary to minimal trauma such as a fall from standing height. “Low bone density for age” is defined by the ICSD as a bone mineral density less than 2 standard deviations (SD) below the age-and-sex-matched mean or the Z-score. “Low bone density for age” is more applicable to pediatrics rather than “osteopenia” because fracture thresholds are unknown. This is in contrast to the extensive research in adults where “osteoporosis” is defined as BMD less than 2.5 SD below the young adult mean or T-score and “osteopenia” is less than 1.0 SD below the T-score.

The earlier studies that concluded adolescents with idiopathic scoliosis as “osteoporotic” or “osteopenic” also employed outdated and less sensitive modalities (4,6,9) such as the Singh index, dual-photon absorptiometry (DPA), and single-photon absorptiometry (SPA). Technology such as SPA are limited in that it is unable to directly measure the spine and hip where a higher percentage of trabecular bone is located (10). It is well understood that trabecular bone in these areas is the more sensitive measure of bone ‘health’ because it has the highest rate of turnover and is where the first signs of bone loss appear (2). Our study attempts to gather more reliable data with dual photon x-ray absorptiometry (DXA) of the lumbar spine and the proximal femora because of the high trabecular composition.

DXA measures all calcified tissue in the path of the scan at two energies to assess BMD, eliminating the influence of soft tissue without the need for a water bath to equalize soft tissue attenuation (11). It also eliminates the use of radioactive isotopes employed in SPA and DPA. DXA enables accurate assessment of BMD in all anatomic areas, minimizing scan time and radiation doses compared with other modalities (2). It is the current standard for BMD measurement.

Our study explores the impact of body size and composition on BMD. We intend to investigate if the low bone density for age is more related to the low BMI predominantly found in AIS rather than the mere presence of scoliosis.

Methods:

This cross-sectional study retrospectively analyzed 49 preoperative DXA scans for AIS patients aged 11 to 20 years from the Carrie Tingley Hospital Pediatric Orthopaedic Clinic and compared that data to an institutionally recruited control group of 40 normal age, sex, and BMI matched adolescents.

Approximately 20 AIS patients received DXA scans prior to 6/7/05, and approval was granted by the University of New Mexico Human Research Review Committee (HRRC) to retrospectively review these records. Since then, all patients undergoing DXA scanning have stated at the time of their scan whether or not their data may be included in the databases, so adolescents with scoliosis studied after this date will be included in the database if they have given written consent.

The DXA scans of all adolescents with idiopathic scoliosis from Carrie Tingley Hospital were examined and data was extracted into a database examined statistically for correlation among factors collected in the routine DXA questionnaire and dictated report. The data extracted is: height, weight, ethnicity, medical and surgical diagnoses, family history of osteoporosis, daily dairy and soda intake, intake of multivitamin or calcium supplementation, ambulatory status, menarchal status, fracture history, Cobb angle, severity of axial rotation and bone density data as gm/cm² and Z-score. The bone mineral density (BMD) at various regions of interest (lumbar spine, proximal femora, distal femora) scanned were compared to the control group to determine the relationship of the expected mean for age and sex. BMD measurements were done for the lumbar spine, one or both proximal femora, and one or both distal femora using Hologic Delphi W densitometer (Hologic, Inc., Bedford, MA). These measurements were compared to pediatric databases (13,14,15) to determine a Z-score, comparing each subject to an age-and-sex matched mean with a numerical expression relating to the number of standard deviations above or below the mean (10).

The HRRC approved obtaining DXA scans for a control group, which was voluntarily recruited from adolescents presenting to orthopaedic clinics at Carrie Tingley Hospital. Participation was offered to patients age 10-22 years in good health with no metabolic disease, no fracture in the last two years, no prior surgeries in test locations, no dietary abnormalities, not currently on medications such as steroids, bisphosphonates, chemotherapy, or seizure prophylaxis as well as the absence of pregnancy. There was no monetary incentive.

The main limitation of DXA scans in the scoliotic population is that BMD is dependent on bone size. BMD is calculated from bone mineral content (BMC) and the area of the bone scan. In scoliotic patients, the axial rotation of the spine can alter the geometry of

the bone scan thus affecting the area and providing erroneous BMD. The rotation can increase the apparent vertebral segment area by as much as 20%, which may result in falsely lower estimates of BMD (12). For this reason, DXA scans of the lumbar spine in scoliotic patients can be unreliable and so were not used to compare the control group.

To accurately compare the two groups, a single Z-score was derived by averaging the left and right proximal femora. The distal femora scans analyze three regions corresponding to cancellous metaphysis, transitional bone, and the cortical diaphysis. These three scores were averaged to form a composite Z-score for each femur and then the two composite Z-scores were averaged to form a single Z-score for the distal femur.

Statistical analysis consist of analyzing the mean values of BMD, height, weight, and BMI to the institutional control group using the two-tailed Student's *t* test or simple linear regression procedures to explore the relationships between Z-scores and the individual clinical and demographic variables. The normality assumption for the continuous variables was evaluated using the Shapiro-Wilks test. Manual forward selection was used and R² adjusted for degrees of freedom was used to choose between competing models. Calculations were made with Statigraphic Plus for Windows, Version 4.1, Manugistics, Inc., Rockville, MD. Two tailed tests we used and p-values of 0.05 were considered significant.

Results:

Forty-nine AIS patients were compared to 40 control subjects. Table 1 demonstrates the characteristics of each group. Forty-three percent indentified themselves as non-Hispanic Caucasian; 20% as mixed ethnicity, predominantly Caucasian/Hispanic; 20% as Hispanic; and 13% did not identify. Spinal curves in scoliotics reanged from 19 degrees to 96 degrees, averaging 51 degrees. None of the differences in means between the two groups were statistically significant. The menarche of the scolotic group averaged 6 months later than the control, but this was not statistically significant.

Forty-three of the 49 patients with scoliosis (87.8%) had normal BMD or within 2 SD of the age-and-sex matched mean.

Nineteen of the 49 scoliotic patients (39%) were underweight with a BMI \leq 18. Six of the 49 scoliosis patients (12%) had Z-scores less than 2 SD below age-and-sex matched mean, thus meeting the ISCD criteria for "low bone density for age." All but one of these six patients had a BMI \leq 18; the remianing had a BMI of 21.1. No subject suffered an insufficiency fracture.

Fifteen of the 40 control subjects (37%) were underweight (BMI \leq 18), but only one of the 40 control subjects (2.5%0 had Z-scores that were less than 2 SD below age-and-sex-matched mean. She had a BMI of 21.1 and had not experienced an insufficiency fracture.

A multivariate model with “Average Hip Z-score” as the dependent variable was fitted to explore the simultaneous effect of multiple variables. No interaction terms were significant. The model containing both “BMI” and “scoliosis” as independent variables was strongest ($F=14.36$, $p<0.0001$). R^2 was 28.2%, indicating that 28.2% of the variation observed in the dependent variable, “Average Hip Z-score,” is accounted for by two independent variables, BMI and scoliosis. The regression coefficients for each independent variable are given in Table 2.

Similarly, a multivariate model with “Average Femur Z-score” as the dependent variable was fitted. No interaction terms were significant. The model containing both BMI and scoliosis was strongest ($F=12.43$, $p=0.0001$, $R^2=37.2\%$). The regression coefficients are given in Table 3.

Discussion:

This study demonstrated the impact of BMI on BMD. In the scoliotic patients of normal and heavy weight, their Z-scores were slightly lower but around the mean when compared to the normobaric controls while thin subjects were more likely to have a lower BMD. Our data supports the common deduction that heavy subjects generally have BMD above the mean, and thin subjects have a higher risk for low BMD.

While our study showed the effect of scoliosis on the Z-score was significant, it was much smaller effect relative to the impact of BMI on the Z-score. For example, in the hip Z-scores, the regression coefficient of the scoliosis variable was 0.32 while the regression coefficient of the BMI was 0.093. This means that the Z-score is decreased by 0.32 from baseline if scoliosis is present, while the Z-score is increased by 0.093 from baseline for each “unit” increase of BMI. Our sample had BMI values ranging from 13-45 “units,” so if 0.093 is multiplied by 13-45, the effect of BMI is much larger than scoliosis. The magnitude of the effect of having scoliosis is similar to decreasing the BMI by 3.4 units ($0.32/0.093 = 3.4$). Essentially, scoliosis does play a role in lowering BMD, but it plays a much smaller part than BMI. In thin patients, this “scoliosis effect” is noticeable in already low Z-scores, but in heavier patients with more of a BMI buffer the effect remains the BMD within the normal range. In summary, BMI plays a larger role in impacting BMD in comparison to the presence of scoliosis, although scoliosis still plays a small but significant role.

It has been reported and our study supports that scoliosis patients have lower BMD than normobaric control patients, but it is also well known that scoliosis creates a growth disturbance which often lowers the BMI and, subsequently, fosters a relative osteopenia. This study elicits that the main driving force for the BMD abnormalities in these low BMI scoliotics is the growth disturbance with a slight contribution from the scoliosis.

*This paper was expanded from the manuscript submitted to Spine journal for publication.

Student's Role:

My role as the student researcher covered literature review, protocol development, data input, problem solving, application of the scientific theory, data management, preliminary data analysis, writing HRRC proposals for the study and control group, aide in abstract submission, recruitment flyer design and distribution, and additional input on other research projects.

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Tables:

Table 1: Characteristics of the control group and the AIS group. Ranges in parenthesis.

	N	Age	Height	Weight	BMI	Menarche
Control	40	13.7 y	63.4 cm	55.6 kg	20.9	12.1 y
	35 female	(10-17)	(53-71)	(26.9-133.6)	(15.5-44.7)	(10-16)
	5 male					n=18
Scoliosis	49	14.1 y	63.1 cm	49.5 kg	19.9	12.6 y
	43 female	(11-20)	(51-83)	(26.3-93.6)	(13.5-34.3)	(10-15)
	6 male					n=27

Table 2: Result of multivariate model using BMI and Scoliosis as independent variables, looking at Hip Z-score

Variable	Regression Coefficient	p-value
BMI	0.0093	<.0001
Scoliosis	0.32	0.0053

Table 3: Result of Multivariate model using BMI and Scoliosis as independent variable, looking at Femur Z-score

Variable	Regression Coefficient	p-value
BMI	0.17	<0.0001
Scoliosis	0.36	0.02