Reduced Spinal Bone Mineral Density in Adolescents of an Ultra-Orthodox Jewish Community in Brooklyn

Wael Taha, MD*; Daisy Chin, MD*; Arnold I. Silverberg, MD‡; Larisa Lashiker, MD*; Naila Khateeb, MD§; and Henry Anhalt, DO*

ABSTRACT.
Objectives. Bone mass increases throughout childhood, with maximal bone mass accrual rate occurring in early to mid-puberty and slowing in late puberty. Prevention of osteoporosis and its morbidities depends primarily on the establishment of adequate peak bone mass.

Physical activity, calcium intake, and vitamin D stores (from sunlight conversion of precursors of vitamin D and to a lesser degree from dietary intake) are vital determinants of bone mineral density (BMD). BMD is further controlled by genetic and environmental factors that are poorly understood.

Observance of ultra-Orthodox Jewish customs may have a negative effect on the factors that promote bone health, and there have been anecdotal reports of higher fracture rates in this population. The ultra-Orthodox Jewish lifestyle encourages scholarly activity in preference to physical activity. Additionally, modest dress codes and inner-city dwelling reduce sunlight exposure. Orthodox Jews do not consume milk products for 6 hours after meat ingestion, leading to potentially fewer opportunities to consume calcium. Foods from the milk group are some of the best sources of dietary calcium.

Our aims are to examine BMD in a group of healthy ultra-Orthodox Jewish adolescents in an urban community and to attempt to correlate it to physical activity and dietary factors.

Design and Methods. We recruited 50 healthy, ultra-Orthodox Jews, ages 15 to 19 years (30 males and 20 females). None were taking corticosteroids or had evidence of malabsorption. All girls were postmenarchal and nulliparous. Pubic hair Tanner stage for boys and breast Tanner stage for girls were determined. Physical activity, calcium intake, and vitamin D stores were measured. Serum levels of calcium, phosphorus, protein, vitamin D, and height standard deviation scores were calculated.

Lumbar spine (L) BMD was assessed by dual energy radiography absorptiometry. The pediatric software supplied by Lunar Radiation Corporation, which contains gender- and age-specific norms, provided a z score for the lumbar BMD for each participant. L2 to L4 bone mineral apparent density (BMAD) was calculated from L2 to L4 BMD.

Results. BMD of L2 to L4 was significantly decreased compared with age/sex-matched normative data: mean z score was −1.25 ± 1.25 (n = 50). The mean L2 to L4 BMD z score ± standard deviation was −1.71 ± 1.18 for boys and −0.87 ± 1.04 for girls. Eight boys (27%) had L2 to L4 BMD z scores < −2.5, which defines osteoporosis in adulthood. Twenty-seven adolescents (54%), 16 boys and 11 girls, had Tanner stage V. Two participants (4%) had delayed development of Tanner stage V. Mean consumption of calcium by participants under 19 years old was 908 ± 506 mg/day (n = 46), which is lower than the adequate intake of 1300 mg/day for this age. The consumption of phosphorus was 1329 ± 606 mg/day, and the consumption of vitamin D was 286 ± 173 IU/day (n = 50). The mean serum 25(OH)D level was 18.4 ± 7.6 ng/mL, and the mean serum 1,25(OH)2D level was 71.1 ± 15.7 pg/mL (n = 50). Boys had significantly higher serum levels of 1,25(OH)2D than did girls (74.9 ± 16.46 pg/mL vs 65.25 ± 12.8 pg/mL, respectively). The serum levels of PTH, calcium, and protein were (mean ± standard deviation): 33 ± 16 pg/mL, 9.5 ± 0.69 mg/dL, and 7.8 ± 0.6 g/dL, respectively (n = 50).

L2 to L4 BMD z score had positive correlation with walking hours (r = 0.4). L2 to L4 BMD z score had negative correlation with walking hours of calcium (r = −0.33; n = 50). We could not find significant correlation between L2 to L4 BMD z scores for the entire cohort and any of calcium, vitamin D, phosphorus, or protein intake. However, the L2 to L4 BMD z scores of boys had positive correlation with calcium, phosphorus, and protein intake (r = 0.42, r = 0.44, and r = 0.43, respectively). After adjustment for Tanner stage, boys who had Tanner stage V (n = 16) had stronger positive correlation between L2 to L4 BMD z scores and calcium and protein intake (r = 0.55 and r = 0.57, respectively), as was the correlation between L2 to L4 BMD z score and weight-bearing activity and walking hours (r = 0.77 and r = 0.72, respectively; n = 16).

By multiple regression analysis with stepwise selection, sex, walking hours, weight-standard deviation scores, and serum PTH predicted 54% of the variability in L2 to L4 BMD z score. Sex, walking hours, and age predicted 65% of the variability in L2 to L4 BMD.

Conclusions. Lumbar BMD is significantly decreased in ultra-Orthodox Jewish adolescents living in an urban community. Boys had profoundly lower spinal BMD than did girls. Previous studies have introduced estrogen as a critical factor in bone mineralization. However, the role of estrogen is still controversial. Our investigation of the significant determinants of BMD proved that sex is...
adolescence is the time of peak bone mass accrual. Bone mass increases throughout childhood, with maximal bone mass accrual rate occurring in early to mid-puberty and slowing in late puberty.1–5 Prevention of osteoporosis and its morbidities depends largely on the establishment of adequate peak bone mass.6 Prime determinants of bone mineral density (BMD), in addition to sex steroids, are physical activity, calcium intake, and vitamin D stores (from sunlight conversion of precursors to vitamin D and to a lesser degree from dietary intake).7–12 BMD is further controlled by genetic and environmental factors that are poorly understood.13–15

Approximately 5% to 10% of America’s Jewish population is Orthodox.16 A significant number define themselves as ultra-Orthodox. Observance of ultra-Orthodox Jewish customs may have a negative effect on the factors that promote bone health, and there have been anecdotal reports of higher fracture rates in this population. The ultra-Orthodox Jewish lifestyle encourages scholarly activity in preference to physical activity. Additionally, modest dress codes and inner-city dwelling reduces sunlight exposure. Orthodox Jews do not consume milk products for 6 hours after meat ingestion, leading to potentially fewer opportunities to consume calcium. Foods from the milk group are some of the best sources of dietary calcium.15–21

In general, adolescents have been reported to have less than the recommended intake of calcium.22–24 Our aims are to determine the BMD in a group of healthy ultra-Orthodox Jewish adolescents and to evaluate the factors that contribute to bone mass when in compliance with ultra-Orthodox Jewish practices.

METHODS

Participants

The participants were 32 boys and 20 girls, ages 15 to 19 years, recruited through an advertisement placed in a newspaper popular with the ultra-Orthodox Jewish community. The recruitment of girls took place in November and December, whereas the recruitment of boys took place in April and May. Two boys were excluded because of having Crohn’s disease25,26 and allergy to milk.27,28 All participants were healthy, white, and free of any medications that might affect calcium metabolism. None reported smoking or consuming alcohol. The girls were postmenarchal and pill-free. Participants and parents provided informed consent to participate in this cross-sectional study. Institutional review board approval was granted. Incentive amount of $100 was offered to each participant on completion of the study.

Study Design

The study protocol for each participant was performed in 1 day. Calcium, phosphorus, protein, vitamin D, and calorie intake were assessed using a comprehensive food questionnaire referring to what has been eaten over the last year. The questionnaire (K-95-1 eating survey) was developed and analyzed by the Harvard Medical School, Channing Laboratory (Boston, MA). The validity of the food frequency questionnaire was previously described.29–31

Physical activity was assessed by a questionnaire developed by our division. The participants were asked to estimate all their daily walking as minutes per day for each day of the previous week and then to calculate the sum as minutes per week. Walking time was considered in separate (hours/week) and was added to the time spent in the rest of the listed activities to calculate weight-bearing activity time (hours/week). Seasonal differences were ruled out because all participants were evaluated during the school year.

All participants gave their medical history and had a physical examination. The physical examination and pubic hair Tanner stage assessment were performed by 1 author for all of the boys. For the girls, the physical examination and breast Tanner stage assessment were performed by another author. The delay of Tanner stage development was defined as <2 standard deviation (SD) delay from the mean age at which the stage should be reached.32,33 Measurements of height (cm) and weight (kg) were made by standardized equipment. The participant’s height in stockings was recorded to the nearest 1 cm, on a wall-mounted stadiometer. The participant’s weight was measured to the nearest 0.5 kg, with minimal clothing. Body mass index (BMI) was calculated as weight (kg)/height (m2). Standard deviation scores (SDS) for height, weight, and BMI were calculated using normative data.34 SDS is adjusted for age and sex.

Dual-energy radiograph absorptiometry was used to measure bone mineral content. Its safety, reliability, and accuracy in the pediatric population are well studied.35–36 Dual-energy radiograph absorptiometry measurements were made by a scanner (DPX model, IQ 2025; Lunar Radiation Corporation, Madison, WI) equipped with Pediatric Software, Version 4.7 (Lunar Radiation Corporation) for lumbar spines (Ls). BMD (g/cm2) of L2 to L4 was assessed.

During measurement of the L, the participant was supine, and the physiologic lumbar lordosis was flattened by elevation of the knees. All measurements were performed and analyzed by the same person. The pediatric software supplied by Lunar Radiation Corporation, which contains gender- and age-specific norms, provided a z score for the L2 to L4 BMD for each participant.

Because BMD may be influenced by bone size, we calculated bone mineral apparent density (BMDA; g/cm2). Spine L2 to L4 BMDA was derived using the formula: L2 to L4 BMDA = L2 to L4 BMD ÷ (area)2/3, as previously described.3,30,40

Venous blood samples were collected and centrifuged immediately for measurement of serum levels of calcium, intact para-

ABBREVIATIONS. BMD, bone mineral density; SD, standard deviation; BMI, body mass index; SDS, standard deviation score; L, lumbar spine; BMD, bone mineral apparent density; PTH, parathyroid hormone; 25(OH)D, 25 hydroxyvitamin D; 1,25(OH)2D, 1,25 dihydroxyvitamin D.
thyroid hormone (PTH), total protein, 25 hydroxyvitamin D (25(OH)D), and 1,25 dihydroxyvitamin D (1,25(OH)2D). Intact PTH levels were measured by a highly sensitive 2-site chemiluminescent assay. Endocrine Sciences Laboratory (Calabasas Hills, CA) performed all serum measurements.

**Statistical Methods**

All statistical tests were performed with SPSS, Version 9.0 (SPSS, Chicago, IL). One-sample t tests were used to compare our participants’ BMD z scores with standard controls from the Lunar pediatric software package. Independent samples t test was used to compare sex differences. Stepwise multiple regression analysis was used to determine predictors of BMD.

**RESULTS**

**General Characteristics**

Table 1 provides a general description of our data. Mean age for boys and girls was comparable, as was their dietary intake of calcium, phosphorus, protein, and vitamin D. Five boys (10%) had a BMI-SDS > 2.

Mean consumption of calcium by the participants under 19 years old was 908 ± 506 mg/day (n = 46), which is lower than the adequate intake of 1300 mg/day for this age.18,41 Serum calcium levels were normal, serum 25(OH)D levels were in the low normal range, and serum 1,25(OH)2D levels were in the high normal range. Boys had significantly higher serum levels of 1,25(OH)2D than did girls (P = .03).

Significantly, L2 to L4 BMD z scores for all adolescents were reduced compared with the age- and sex-matched normative data supplied by Lunar Radiation Corporation. We ran 1-sample t tests to perform this comparison. Mean L2 to L4 BMD z score (± SD) was −1.25 ± 1.25 (n = 50; P < .001). Figure 1 shows z score distribution for the entire cohort.

Mean L2 to L4 BMD z score for boys was −1.71 ± 1.18 (P < .001) and for girls −0.58 ± 1.04 (P < .001). Significantly, boys had lower L2 to L4 BMD z scores than did girls (P = .001). Eight boys (27%) had L2 to L4 z scores < −2.5, which defines osteoporosis in adulthood. Twenty-seven adolescents (54%), 16 boys and 11 girls, had Tanner stage V. One boy had Tanner stage II. Two boys had delayed development of Tanner stage V. Table 2 stratifies z scores by Tanner stage.

Sixteen adolescents (32%), 11 boys and 5 girls, had a history of trauma-induced fracture. We compared mean z scores for adolescents who had trauma-induced fracture with adolescents who did not. This comparison resulted in no significant difference.

**Correlations of L2 to L4 BMD z Score**

Table 3 shows Pearson correlation of L2 to L4 BMD z scores. L2 to L4 BMD z score had positive correlation with walking hours. The correlation between L2 to L4 BMD z score and weight-bearing activity was close to significance.

We could not find correlation among L2 to L4 BMD z scores for the entire cohort and any of calcium, vitamin D, or protein intake. However, boys L2 to L4 BMD z scores had positive correlation with calcium and protein intake. Also, L2 to L4 BMD z scores for boys correlated significantly to Tanner stage (r = 0.41; P = .025).

After adjustment for Tanner stage, boys who had Tanner stage V (n = 16) had stronger positive correlation between L2 to L4 BMD z scores and calcium and protein intake, as was the correlation between L2 to L4 BMD z score and weight-bearing activity and walking hours.

Interestingly, boys at Tanner V had a positive correlation between L2 to L4 BMD z scores and vitamin D intake, which we could not find before adjustment for Tanner stage.

The entire cohort had negative correlation between serum level of 1,25(OH)2D and L2 to L4 BMD z score (r = −0.33; P = .018).

**Predictors of L2 to L4 BMD z Scores**

We ran multiple regression analysis using stepwise selection method for L2 to L4 BMD z score as the dependent variable. The significant predictors were sex (B = −1.7; t = −5.7; P < .001), walking hours (B = 0.24; t = 3.8; P < .001), weight-SDS (B = 0.32; t = 6.3; P < .001), and calcium level (B = 0.07; t = 2.9; P = .004). Intact PTH level did not have a significant effect on L2 to L4 BMD z score.

**TABLE 1. Description of the Cohort, Dietary Intake, and Serum Measurements**

<table>
<thead>
<tr>
<th>Females (n = 20)</th>
<th>Males (n = 30)</th>
<th>Significance P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Age (y)</td>
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<tr>
<td>BMI-SDS</td>
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<td>Weight-SDS</td>
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<td>0.6</td>
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<tr>
<td>Height-SDS</td>
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<tr>
<td>Calorie (kcal)</td>
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<tr>
<td>Protein (g/d)</td>
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</tr>
<tr>
<td>Calcium (mg/d)t</td>
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</tr>
<tr>
<td>Vitamin D (IU/d)</td>
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<td>155</td>
</tr>
<tr>
<td>Phosphorus (mg/d)</td>
<td>1195</td>
<td>496</td>
</tr>
<tr>
<td>Weight-bearing activity (h/ wk)</td>
<td>4.1</td>
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</tr>
<tr>
<td>Walking (h/ wk)</td>
<td>2.71</td>
<td>1.73</td>
</tr>
<tr>
<td>Intact PTH level (pg/mL)</td>
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<tr>
<td>Calcium level (mg/dL)</td>
<td>9.68</td>
<td>0.98</td>
</tr>
<tr>
<td>Total protein (g/dL)</td>
<td>7.73</td>
<td>0.72</td>
</tr>
<tr>
<td>25(OH)D (ng/mL)</td>
<td>19.25</td>
<td>8</td>
</tr>
<tr>
<td>1,25(OH)2D (pg/mL)</td>
<td>65.25</td>
<td>12.8</td>
</tr>
</tbody>
</table>

NS indicates not significant.

* Independent samples t test was used to compare between means for boys and girls.

† Participants’ ages ≤18 years, n = 20 for girls, n = 26 for boys.
A primary goal of this study was to determine the BMD status of adolescents of the ultra-Orthodox Jewish community. Our results indicate that the lumbar BMD was significantly reduced in male and female adolescents of this community with 27% of boys actually having very low values. This reduction could be attributable to lifestyle factors, ie, observance of religious customs, eating habits, and studying for many hours hunched over books, although we were unsuccessful in finding significant dietary predictors by our study design. The poor BMD can also be attributable to genetic factors, which have been shown to account for 46% to 62% of the variance in a study of parents and their children.\(^4\)

We took into account the regulators of bone mass.\(^4\)\(^3\)\(^4\) Medical histories and laboratory measurements did not point to abnormal regulation of bone in any of these adolescents. It is unclear whether the high normal levels of 1,25(OH)\(_2\)D represent a compensatory mechanism to absorb more calcium from the intestine and whether the low normal 25(OH)D levels represent relatively poor total body stores of vitamin D in this group of adolescents. Although 1,25(OH)\(_2\)D levels were normal by our reference laboratory values, other studies would consider these levels to represent vitamin D deficiency.\(^4\)^\(^5\)

When compared with similar bone health studies of a comparable sample and method, the mean calcium intake for our participants was similar.\(^4\)\(^6\) Calcium intake was excluded as a predictor of L2 to L4 BMD \(z\) score for the entire cohort; however, it was correlated to L2 to L4 BMD \(z\) score only in boys. Boot et al\(^4\)^\(^7\) also reported that the intake of calcium is not associated with bone mineral status in girls. Welten et al\(^4\)^\(^8\) as well excluded calcium intake as a predictor of lumbar BMD in adolescents.

Girls had higher L2 to L4 BMD \(z\) scores than did boys, who had near osteoporotic values. Previous studies have introduced estrogen as a critical factor in bone mineralization; however, the role of estrogen is still controversial. Our investigation of the significant determinants of BMD\(^4\)^\(^7\)\(^1\)\(^0\)\(^5\)\(^0\) proved that sex is an important predictor of \(z\) score in this group, which may indicate the importance of sex hormones.
Walking activity comprised a major part of their weight-bearing activity. Walking activity was positively associated with \( z \) score in boys and was a significant predictor of \( z \) score in our linear regression model. Our study singles out walking as a principal activity, which is not a surprise, because walking is primarily an outdoor activity, which, in turn, increases the chance of concomitant sunlight exposure. In contrast, our study does not prove that walking activity is lacking and it is not a causal factor of low BMD.

Our study identifies a group at great risk for the morbidities of poor bone health if no bone mineral recovery happens later in their life. We recommend an increase in calcium intake to reach the adequate intake. We also recommend an increase in weight-bearing activity, particularly walking. However, our study provides no evidence that following these recommendations will improve the BMD of this particular population. We encourage additional longitudinal studies to evaluate the bone mineral status of the older generation of this community and possible interventions that will lead to improved BMD.

ACKNOWLEDGMENTS

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REFERENCES


TABLE 3. Pearson Correlation of Lumbar L2 to L4 BMD \( z \) Scores

<table>
<thead>
<tr>
<th></th>
<th>Entire cohort</th>
<th>Females</th>
<th>Males</th>
<th>Males at Tanner V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( z ) scores</td>
<td>( z ) scores</td>
<td>( z ) scores</td>
<td>( z ) scores</td>
</tr>
<tr>
<td></td>
<td>((n = 50))</td>
<td>((n = 20))</td>
<td>((n = 30))</td>
<td>((n = 16))</td>
</tr>
<tr>
<td>Weight-SDS</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height-SDS</td>
<td>0.56*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (g/d)</td>
<td>NS</td>
<td>NS</td>
<td>0.42*</td>
<td>0.35*</td>
</tr>
<tr>
<td>Protein (g/d)</td>
<td>NS</td>
<td>NS</td>
<td>0.43*</td>
<td>0.52*</td>
</tr>
<tr>
<td>Vitamin D (IU/d)</td>
<td>NS</td>
<td>NS</td>
<td>0.59**</td>
<td>0.77**</td>
</tr>
<tr>
<td>Weight-bearing (h/wk)</td>
<td>0.42 (P = .059)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking (h/wk)</td>
<td>0.63**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NS indicates not significant.

\* \( P < .05 \); \** \( P < .005 \).

\† Calorie, calcium, protein, and vitamin D represent daily intakes; \( r \) value always represents correlation among parameters of the same group of participants, ie, females BMD \( z \) scores, and females’ calcium intake.
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