# DOSE RELATED ASSOCIATION OF IMPACT ACTIVITY AND BONE MINERAL DENSITY IN PRE-PUBERTAL GIRLS

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*Introduction*: Attainment of optimal peak bone mass is critical in the prevention of osteoporosis. Women approach peak bone mass by approximately 16 years of age, and acquire nearly 40% of total body bone mineral content during four peri-menarcheal years. Impact activity is an important modifiable factor contributing to bone accrual. Children who engage in large amounts of impact activity have been shown to have 10-15% greater bone mineral density (BMD) than controls. This study was designed to evaluate pre-pubertal girls participating in varying amounts of impact activity, in order to determine whether BMD and impact activity are related in a dose-dependent fashion.

*Methods*: In this cross-sectional study, 49 7-11 year old pre-pubertal, Caucasian, female gymnasts, participating at 3 different frequency levels based on hours per week (hrs/wk) of gymnastics practice [low, 2 to <5 hrs/wk (n=11); mid, 5 to <10 hrs/wk (n=20); and high, ≥10 hrs/wk (n=18)] were compared to 23 sedentary controls, matched for height, weight, age, and Tanner stage. Institutional review board approval and informed consent were obtained prior to study onset. Hip, spine, arm, and total body BMD and fat free mass (FFM) were determined by dual energy X-ray absorptiometry (DXA) (Hologic QDR4500). Anthropometrics, pubertal stage, strength by one repetition maximum testing, and body composition by skinfold and bioelectric impedance analysis were measured to coincide with DXA scanning. Calcium intake was measured with multiple administrations of a semi-quantitative food frequency questionnaire. Physical activity was quantitated with the Godin-Shepard questionnaire, multiple administrations of the Physical Activity Checklist Inventory, and use of the Caltrac activity monitor for two weekdays and one weekend day. Statistical analysis was performed using Statview. ANOVA determined differences between groups for the outcome variables. BMD at all sites was adjusted for FFM, height, weight, age, strength, calcium intake and activity measures using ANCOVA. Correlation analysis and stepwise regression analysis examined the relationship between BMD and the other variables.

*Results*: There was no significant difference between the groups for age, height, weight, Tanner stage, or calcium intake ($p>0.05$). Percent fat was less in mid and high groups than controls ($p<0.05$), however, FFM did not vary significantly between groups (Table 1).

Table 1. GROUP CHARACTERISTICS

| | Control (N=23) | Low (N=11) | Mid (N=20) | High (N=18) |
|---|---|---|---|---|
| Age (yrs) | 9.9 ± 0.8 | 9.6 ± 1.3 | 10.4 ± 1.3 | 10.4 ± 1.3 |
| Height (cms) | 137.4 ± 7.4 | 132.4 ± 8.3 | 137.3 ± 7.0 | 136.2 ± 7.9 |
| Weight (kgs) | 32.2 ± 5.4 | 30.3 ± 5.5 | 31.9 ± 5.3 | 31.4 ± 5.8 |
| Tanner stage | 2.3 ± 0.7 | 2.1 ± 0.7 | 2.3 ± 0.7 | 2.2 ± 0.7 |
| Calcium intake (mg/day) | 1085 ± 389 | 1075 ± 384 | 937 ± 503 | 1044 ± 408 |
| % fat | 24.3 ± 6.5 | 21.5 ± 5.8 | 20.0 ± 3.1* | 18.5 ± 4.5* |
| Fat free mass (kg) | 23.2 ± 3.2 | 22.4 ± 3.6 | 24.1 ± 3.7 | 24.1 ± 3.8 |
| Gymnastics activity (hrs/wk) | 0.1 ± 0.5 | 3.4 ± 0.9 | 7.3 + 1.6 | 12.9 ± 3.2 |

Mean values ± SD are shown for controls and low (2 to <5 hrs/wk), mid (5 to <10 hrs/wk), and high (≥ 10 hrs/wk) gymnastics groups.
* statistically significant difference from controls ($p<0.05$).

Both total and regional BMD increased incrementally as hours of gymnastics increased (Figure 1). BMD was significantly greater in the mid and high groups for all sites compared to controls ($p<0.05$). Furthermore, BMD was significantly greater in the high versus low group for all sites except lumbar spine, and in the mid versus low group for hip and forearm ($p<0.05$). These relationships were independent of age, height, weight, Tanner stage, calcium intake, and physical activity. In addition, total BMD was greater in the mid versus low group when adjusting for either FFM or the combination of elbow flexion and extension strength ($p<0.05$). Lumbar BMD was higher in the mid versus low group when adjusting for any of the covariants ($p<0.05$).

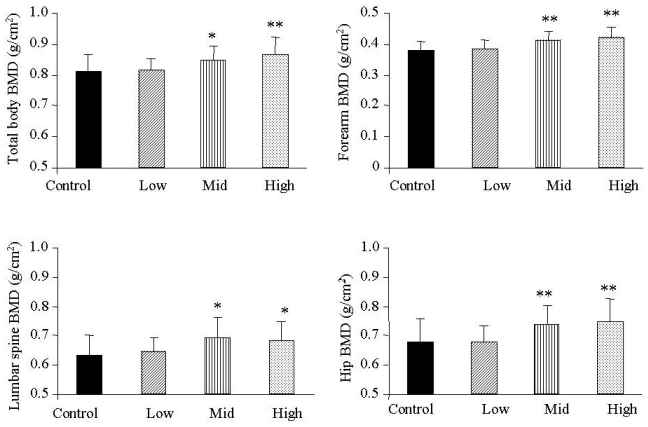


Figure 1. BONE MINERAL DENSITY PER GROUP
Mean values ± SD are depicted for total body, forearm, lumbar spine and hip bone mineral density (BMD) for controls and low (2 to <5 hrs/wk), mid (5 to <10 hrs/wk), and high (≥ 10 hrs/wk) gymnastics groups.
* statistically significant difference from controls ($p<0.05$).
** statistically significant difference from both controls and low group ($p<0.05$).

Strength increased incrementally from controls through the high group. Upper body strength measures were the variables most highly correlated with both regional and total BMD (elbow flexion, r=0.60; elbow extension, r=0.58; grip, r=0.53 for total BMD, $p<0.0001$). Significant correlations ($p<0.001$) between total BMD and FFM (r=0.58), situps (r=0.45), standing height (r=0.45), and hrs/wk of gymnastics (r=0.43) were also found. Similar significant correlations ($p<0.01$) were found for forearm, lumbar, and hip BMD (r=0.35 to 0.70). Stepwise regression analyses established upper body strength measures as the most significant predictors of regional and total BMD. Elbow flexion and elbow extension strength accounted for 43 to 50% of variability in both total, lumbar spine, and forearm BMD ($p<0.0001$). Elbow flexion strength and FFM were the only significant contributors to hip BMD ($R2=0.47$, $p<0.0001$).

*Discussion*: Consistent with the literature, we observed higher total and regional BMD in pre-pubertal female gymnasts than in controls. More importantly, we found that as little as 5 hrs/wk of gymnastics resulted in a 5-9% increase in BMD, a lower threshold of activity than previously identified. Furthermore, girls participating in the highest amount of gymnastics activity (≥10hrs/wk) had an additional non-significant increase in BMD of 2-3% at all sites except the lumbar spine. Although cross-sectional in nature, our data suggests that even modest amounts of impact loading activity are beneficial in the accrual of BMD in pre-pubertal girls. Longitudinal study is necessary to determine whether this apparent benefit will persist beyond puberty, increasing the ultimate peak bone mass. Further research is necessary to determine whether these results, using gymnastics as a model, can be generalized to other impact loading activities.

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