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Role of Physical Activity on Bone Mineral Content in Young Children

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Previous studies identifying factors that influence peak bone mass have typically focused on older children, although it has been suggested that environmental factors early in life also may be important in optimizing the genetic potential for bone gain[1]. Physical activity and calcium intake are considered major environmental factors influencing bone mass accretion.

Longitudinal studies beginning in childhood show that high activity early in life is associated with high adult bone density[2,3]. The long-term effect between bone mass accretion and early calcium intake is less clear, with most trials finding that the beneficial bone effect of high calcium intake does not persist once the supplementation is withdrawn[4]. Results of several studies related to bone changes and physical activity that we conducted in young children are reviewed below.

We previously reported results of a randomized trial of gross motor vs. fine motor activity in infants and found that the response in total body bone mass accretion to activity was dependent upon the infant's calcium intake[5]. Infants consuming a low to moderate calcium intake who were randomized to receive daily bone loading activities had a lower total body bone mass accretion than infants randomized to fine motor activities. There was no difference in bone accretion between the two activity groups consuming moderately-high to high calcium intakes. A summary of adult exercise studies also showed that calcium intake may modify the bone response to activity[6]. In order to formally test the hypothesis that calcium intake modifies the bone response to activity we conducted a randomized 2-by-2 factorial trial in 3- to 5-year-old children[7]. A total of 239 children were randomized to a calcium or placebo group and to a gross motor or fine motor activity group; 178 of these children completed at least 38 weeks (mean=50 weeks) of intervention and were present in the center at least 50% of the total days. We found a significant interaction between activity and supplement group in leg BMC gain: the difference in BMC gain between gross motor and fine motor groups was more pronounced in children receiving calcium versus placebo. Among children receiving placebo, leg BMC gain was similar in the gross motor and fine motor groups. However, among children receiving calcium, those in the gross motor group had 9.7% greater increase in leg BMC than those in the fine motor group. Change in leg BMC per change in bone area was not correlated with calcium intake among children in the fine motor group ($r=-0.09$, $p=0.42$), but was correlated with intake among children in the gross motor group ($r=0.30$, $p=0.005$). Measurements of bone size were made using pQCT of the 20% distal tibia. After the intervention, children in the gross motor group had greater periosteal and endosteal circumferences than children in the fine motor group (Figure 1). Neither circumferences differed by calcium group. The interaction between activity and supplement groups was significant for both cortical area and thickness. These results indicate that physical activity stimulates bone growth in diameter, but the amount of mineralized bone is dependent upon both physical activity and calcium intake.

Results of the six activity trials in either infants or children reported to date have been inconsistent[5,8-12]. The majority of studies that measured predominantly trabecular bone sites, such as the spine, find a greater increase in bone density with activity compared with controls. These findings are compatible with animal studies showing that mechanical stimulation increases both trabeculae number and size[13]. Reports on activity effects at predominantly cortical bone sites are not seen in all studies. Although we did not measure a trabecular bone site, we did find that gross motor activity alters bone shape at the 20% distal tibia shaft.

Bone responds locally to loading by increasing modeling and remodeling to give a stronger structure[14]. Expanded periosteal circumference and cortical thickness with increased activity indicate that skeletal loading increases

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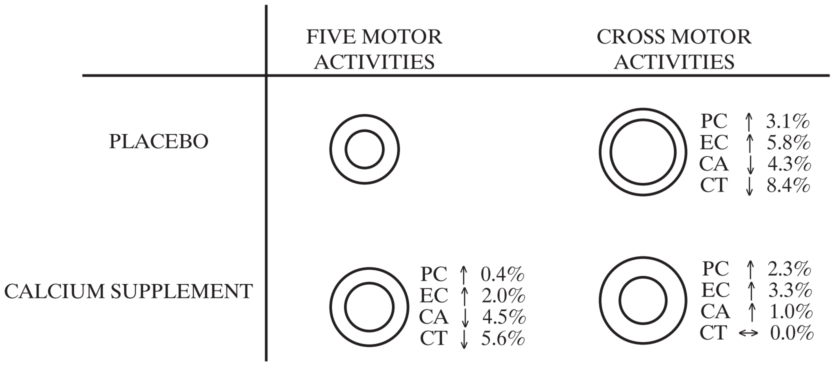

Figure 1. Schematic representation of effect of activity and calcium intake on the 20% distal tibia in young children (not to scale). Percentages are differences compared to fine motor, placebo group. PC = periosteal circumference; EC = endosteal circumference; CA = cortical area; CT = cortical thickness.

bone size[6,15]. Our finding of greater periosteal circumference at the 20% distal tibia site in children in the gross motor vs. fine motor group is consistent with animal studies, but is not consistent with two other reports on structural bone changes resulting from physical activity in older children[10,16]. Some investigators have found that periosteal expansion with skeletal loading is greater at distal vs. proximal sites[17,18] and this may explain why our results at the 20% distal tibia site differ from studies that measured more proximal bone sites. These studies, which used DXA scans to estimate femoral shaft periosteal and endosteal diameters, reported no activity effect on periosteal expansion but did report a decrease in endosteal diameter in children assigned to physical activity.

The type of force applied to bone also may determine the bone response to increased activity. Petit and co-workers suggested that the reason an endosteal circumference decrease, and not a periosteal increase, was observed in their study was due to the higher axial compression forces resulting from jumping[16]. Axial compression forces are considered to be more likely to induce bone formation on the endosteal surface, while torsion or bending forces are more likely to induce bone formation on the periosteal surface. Our study provided a wide range in daily gross motor activities that would lead to a greater combination of compression, torsion and bending forces among children randomized to gross motor vs. fine motor activities. Whether the dissimilar finding on periosteal adaptation to bone loading between us and other investigators is due to age differences of the children studied, measurement methods, bone sites measured, or in the types of bone loading forces that were applied is not known.

Preliminary analyses of data obtained one year after cessation of the intervention in these children indicate that some of the changes resulting from loading may have a persistent effect. However, activity levels 6 months after the intervention stopped were still higher among those children randomized to gross motor activity vs. fine motor activity. Whether bone differences 12 months post-intervention are due to greater activity levels following the intervention or delayed bone response to exercise is not known.

Pubertal stage or growth velocity also may affect the bone response to physical activity. Although some trials report beneficial bone effects of activity in prepubertal children[8,10,12], others find beneficial effects in pubertal, but not prepubertal children[9]. It is speculated that estrogen augments the bone response to activity[19] and the positive findings in pubertal, but not prepubertal children would support this hypothesis. However, others have speculated that increased activity may enhance bone formation during the prepubertal years by acting synergistically with growth hormone[20]. Based on the studies completed to date, and the lack of preponderance of positive findings in one pubertal group vs. the other, it is not clear whether pubertal status modifies the bone response to physical activity.

We conducted a trial in 54 children to determine whether the bone response to bone loading differed depending upon pubertal status (26 prepubertal, 12 peripubertal, 16 pubertal)[21]. Children were randomized either to a jumping program (25 jumps/d for 12 weeks) or to no jumping. Overall, jumpers showed greater gains in total body and leg BMC compared with non-jumpers, but no difference was observed in bone size. Jumping had a more beneficial effect on bone at predominantly trabecular sites (spine, 4% tibia BMC) among pubertal children than prepubertal children; jumping was actually detrimental in peripubertal children (non-jumpers had greater bone gain than jumpers in the peripubertal period). We are unaware of other studies that have looked specifically at the effect of loading at trabecular bone sites during different pubertal stages.

In summary, the effect of physical activity on bone in children is modified by calcium intake and may also be modified by pubertal status, especially at bone sites that are predominantly trabecular bone.

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