IOF WORLDWIDE CONFERENCE OF PATIENT SOCIETIES

Helsinki FINLAND 2013

LAURA MASI

Paediatric bone health

www.iofbonehealth.org/iof-wwc-2013-helsinki
Pediatric Bone Health

Bone is a living tissue which remains metabolically active throughout life: the skeleton provides support for muscles and locomotion, acts for minerals and offers a protective environment to bone marrow.
Bone is a complex tissue

There are 2 types of bone tissue in the human skeleton: cortical (compact) bone and trabecular (spongy or cancellous) bone.

Bones formed using:

- intramembranous ossification
- endochondral ossification which replaces cartilage with bony tissue
Children are the key to get to the problem

In recent years, the issue of low bone mass/low bone density in children and adolescents has attracted much attention.

On the one hand, there is a growing knowledge that the bone mineral mass acquired at the end of growth and development is a major determinant of the future risk of osteoporosis; on the other hand, the problem of osteoporosis is increasing also in young patients.

Bone Growth

During childhood and adolescent years, the skeleton accumulates bone mass and generally arrives at a peak level of bone strength in late adolescence.

Adolescence is a period of rapid development and a critical step toward building adult skeletal strength.
Up to 25% of PBM is acquired during the 2 years of peak height velocity.

By age 18, at least 90% of PBM has been acquired, while the remaining 10% will be added later in the skeletal consolidation phase.
The achievement of optimal peak bone mass is important for the prevention of osteoporosis in later life. Fracture risk approximately doubles with each standard deviation of bone lost from mean PBM. (Rizzoli R. et al. “Maximizing bone mineral mass gain during growth for the prevention of fractures in the adolescents and the elderly” Bone 2010)

If factors prevent a teenager’s skeleton from growing and fortifying during this time, his or her adult skeleton will not reach an adequate level of bone mass and the risk for adult osteoporosis and fracture increases.
Prepubertal Bone Development

Bone strength increases both in boys and girls with a similar developmental pattern.
PUBERTY

Girls:
- Increases in $E_2$ inhibit periostal bone formation
- Promoting bone formation at endocortical surface

Boys:
- Increases in A increase in perisotal apposition

During aging …

- Progressive endocortical resorption is equivalent in women and men.
- Men have a greater degree of periostal apposition during aging than women.
Bone Mass

Bone Mass construction is influenced by

Genetic factors
- Gender
- Family History
- Ethnicity
accounting for up 75%
However ..... DXA

Bone mineral mass is the only surrogate of *bone strength* accessible to measurement
(Rizzoli R. et al. “Maximizing bone mineral mass gain during growth for the prevention of fractures in the adolescents and the elderly” Bone 2010)

Several studies examining the patterns of bone mineral accretion during growth in healthy children were performed by DXA

DXA-based measures of BMD and BMC are influenced by numerous factors during growth and development
Indeed…..

Bone Mass construction is influenced by Genetic factors
- Gender
- Family History
- Ethnicity
accounting for up 75%

Environmental factors
- Nutrition (calcium and protein intake)
- Exercise
- Endocrine Status (Vitamin D, IGF-I, GH)
- Body mass/habitus
- Illnesses
accounting for up 25%
The origin of osteoporosis, traditionally considered a disease of the old age, had to be focused in the pediatric age.
Physical activity
Space Flight and Physiological Effects

- Space motion sickness
- Neurovestibular dysfunction
- Fluid redistribution to upper body and head
  - Negative Ca++ balance
  - Renal stone risk
- Blood plasma
  - Muscle strength
- Cardiovascular efficiency
  - Radiation doses
- Bone density
Physical Activity and Hip Bone Mass

Physical activities that impose high forces on the skeleton, i.e. gymnastics
Associated with Higher Hip Bone Mass

Physical activities that impose low forces on the skeleton, i.e. swimming
Associated with Lower Hip Bone Mass

Welten CM J Bone Min Res 1999
Nutrition plays a critical role in the achievement of the optimal genetically programmed PBM. One of the main focuses of lifestyle modification for peak bone mass is dietary calcium intake. Optimizing calcium intake is particularly important during adolescence. Peak calcium-accretion rate is realized at an average of 12.5 years of age in girls and 14.0 years of age in boys (Greer FR. et al. 2006).
Effect of calcium supplements on bone – randomized placebo-controlled trials

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Pregnant</th>
<th>Lactating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–6 months*</td>
<td>200 mg</td>
<td>200 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7–12 months*</td>
<td>260 mg</td>
<td>260 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3 years</td>
<td>700 mg</td>
<td>700 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–8 years</td>
<td>1,000 mg</td>
<td>1,000 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9–13 years</td>
<td>1,300 mg</td>
<td>1,300 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14–18 years</td>
<td>1,300 mg</td>
<td>1,300 mg</td>
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<tr>
<td>19–50 years</td>
<td>1,000 mg</td>
<td>1,000 mg</td>
<td>1,000 mg</td>
<td>1,000 mg</td>
</tr>
<tr>
<td>51–70 years</td>
<td>1,000 mg</td>
<td>1,200 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>71+ years</td>
<td>1,200 mg</td>
<td>1,200 mg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Effect of calcium supplements on bone mineral mass accrual (randomized controlled trials).

<table>
<thead>
<tr>
<th>Study</th>
<th>Calcium supplement</th>
<th>Dose (mg/day)</th>
<th>Duration (months)</th>
<th>Mean age (years)</th>
<th>Sex</th>
<th>Skeletal site*</th>
<th>Difference (%) between Ca-supplemented and placebo groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonjour et al. [61]</td>
<td>Milk extract</td>
<td>850</td>
<td>12</td>
<td>7–9</td>
<td>F</td>
<td>Radius/femoral shaft</td>
<td>1.7/1.2</td>
</tr>
<tr>
<td>Cameron et al. [149]</td>
<td>CaCO₃</td>
<td>1200</td>
<td>24</td>
<td>10.3</td>
<td>F</td>
<td>Whole body*</td>
<td>3.7</td>
</tr>
<tr>
<td>Chevalley et al. [43]</td>
<td>Milk extract</td>
<td>850</td>
<td>12</td>
<td>7.4</td>
<td>M</td>
<td>Femoral shaft</td>
<td>1.3</td>
</tr>
<tr>
<td>Dibba et al. [150]</td>
<td>CaCO₃</td>
<td>1000</td>
<td>12</td>
<td>10.3</td>
<td>F/M</td>
<td>Radius</td>
<td>3.9</td>
</tr>
<tr>
<td>Iuliano-Burns et al. [151]</td>
<td>Milk mineral/CaCO₃</td>
<td>600–800</td>
<td>10</td>
<td>8.9</td>
<td>F/M</td>
<td>Whole body</td>
<td>NS</td>
</tr>
<tr>
<td>Johnston et al. [62]</td>
<td>Ca citrate-malate</td>
<td>1000</td>
<td>36</td>
<td>10.0</td>
<td>F/M</td>
<td>Radius/spine</td>
<td>5.1/2.8**</td>
</tr>
<tr>
<td>Lee et al. [152]</td>
<td>CaCO₃</td>
<td>300</td>
<td>18</td>
<td>7.2</td>
<td>F/M</td>
<td>Radius</td>
<td>2.5</td>
</tr>
<tr>
<td>Lee et al. [153]</td>
<td>CaCO₃</td>
<td>300</td>
<td>18</td>
<td>7.0</td>
<td>F/M</td>
<td>Radius/spine</td>
<td>1.7/4.6</td>
</tr>
<tr>
<td>Lloyd et al. [63]</td>
<td>Ca citrate-malate</td>
<td>500</td>
<td>24</td>
<td>11.9</td>
<td>F</td>
<td>Whole body</td>
<td>2.2</td>
</tr>
<tr>
<td>Matkovic et al. [59]</td>
<td>Ca citrate-malate</td>
<td>1000</td>
<td>24</td>
<td>14</td>
<td>F</td>
<td>Radius</td>
<td>NS</td>
</tr>
<tr>
<td>Matkovic et al. [88]</td>
<td>Ca citrate-malate</td>
<td>1000</td>
<td>48</td>
<td>10.8</td>
<td>F</td>
<td>Trochanter</td>
<td>3.0</td>
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<tr>
<td>Moyer-Mileur et al. [154]</td>
<td>CaCO₃</td>
<td>800</td>
<td>12</td>
<td>12</td>
<td>F</td>
<td>Distal tibia</td>
<td>5.7</td>
</tr>
<tr>
<td>Nowson et al. [155]</td>
<td>CaCO₃/Ca citrate-malate</td>
<td>1000</td>
<td>18</td>
<td>14</td>
<td>F</td>
<td>Spine</td>
<td>1.6</td>
</tr>
<tr>
<td>Prentice et al. [156]</td>
<td>CaCO₃</td>
<td>1000</td>
<td>13</td>
<td>16.8</td>
<td>M</td>
<td>Whole body/spine/hip</td>
<td>1.3/2.5/2.3</td>
</tr>
<tr>
<td>Rozen et al. [157]</td>
<td>CaCO₃</td>
<td>1000</td>
<td>12</td>
<td>14.8</td>
<td>F</td>
<td>Whole body/spine</td>
<td>0.73/0.66</td>
</tr>
<tr>
<td>Stear et al. [158]</td>
<td>CaCO₃</td>
<td>1000</td>
<td>15</td>
<td>17.3</td>
<td>F</td>
<td>Femoral neck</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* BMD or BMC, assessed by SPA, DXA or pQCT.
# A significant difference was detected at lumbar spine and total hip after 12 months.
** Only in those remaining prepubertal throughout the study.
Calcium-enriched Foods and Bone Mass Growth in Prepubertal Girls: A Randomized, Double-blind, Placebo-controlled Trial

Jean-Philippe Bonjour, Anne-Lise Carrie, Serge Ferrari, Helene Clavien, Daniel Slosman, Gerald Theintz, and Rene Rizzoli

**Placebo : n = 67**

**Calcium Fortified Foods : n = 77**

- **Δ BMD**
  - **low**
  - **high**

- **Δ BMC**
  - **low**
  - **high**

- **Δ Area**
  - **low**
  - **high**

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J Clin Invest 1997
High-Protein Intake Enhances the Positive Impact of Physical Activity on BMC in Prepubertal Boys

Thierry Chevalley, Jean-Philippe Bonjour, Serge Ferrari, and René Rizzoli

**Protein Intake**
- Recommended intake: 1 gr/kg/day
- Above intake: ≈ 1.7 gr/kg/day

It is possible that the positive association of physical activity and protein intake on BMC is mediated in part by the stimulation of IGF-I, which in turn would impact on both skeletal muscle and bone.
High-Protein Intake Enhances the Positive Impact of Physical Activity on BMC in Prepubertal Boys

Thierry Chevalley, Jean-Philippe Bonjour, Serge Ferrari, and René Rizzoli

Calcium Intake
Vitamin D

- Critical for normal calcium absorption from diet

- Risk factors for deficiency:
  - Inadequate diet
  - Inadequate sunlight
  - Obesity
  - Anticonvulsant therapy
  - Malabsorption
Current research indicates that calcium intake in school-age children and in young men and women is below the recommended adequate intake.

In the United States: Between 44% and 87% of school-aged boys and girls do not meet their recommended intake for calcium (Caine-Bish N, Gordon KL. J Nutr Educ Behav. 2006;38(3):199-200).

National survey data indicate only about half (53%) of young men and 21% of young women (19 to 30 years) consume the recommended amount of Ca.

Furthermore, 39% of men and 43% of women (20 to 29 years) consume less than even 1 daily serving of dairy products (Nicole I. Larson, et al. J Calcium and Dairy Intake: Longitudinal Trends during the Transition to Young Adulthood and Correlates of Calcium Intake. Nutr Educ Behav. 2009;41:254-260.)
In Italy: In a recent study in 773 Italian adolescents aged 11-13 years showed that the daily calcium intake (815 mg/day) is under the recommended quantity for this population (Martone D. et al. (2010) Food consumption and energy and nutrient intakes in a group of roman adolescents. Minerva Pediatr. 62, 139-146).

As the recommended adequate calcium intake for children between the ages of 9-11 years is about 1100-1300 mg/day (LARN 2012), altogether the available information indicates that calcium intake in Italian primary school-age children is below the recommended adequate intake.
There is broad and consistent evidence that long-term milk avoidance is associated with smaller body height as well as lower BMC, aBMD and/or vBMD in growing children.

Furthermore, pre-pubertal children with low milk intake were shown to be more prone to fractures, mainly of the distal radius, generally occurring after a low energy trauma such as a fall from standing height. In those children who had avoided drinking cows' milk for prolonged periods, fracture risk was 2.7-fold higher than in a matched birth cohort (Goulding A. et al. “Children who avoid drinking cow's milk are at increased risk for prepuberteral bone fractures” J Am Diet Assoc 2004;104:250–3; Konstantynowicz J. Et al. “Fractures during growth: potential role of a milk-free Diet” Osteoporos Int 2007;18:1601–7).
In adults

Osteoporosis-Prevention Interventions

141 Chinese-American women (35-55 years old) were recruited from six weekend in the Philadelphia, PA. This intervention consisted of one heel scan and six interactive lessons.

- Knowledge of osteoporosis and calcium-rich foods
- Intention of consuming calcium-rich foods when compared to the control group
- Retention of the increase in both calcium and vitamin D intake at 3-month follow-up is also notable.

In adults

Other osteoporosis-prevention interventions have targeted calcium intake as the main outcome variable and resulted in no substantial increase in calcium intake


Substantial higher in calcium intake


Compared to the interventions that did not produce changes in calcium intake, effective interventions used repeated contact (eg, eight weekly lessons, 5-month biweekly lessons, 18-month intervention), visual demonstrations and hands-on activities.
In children

A number of school-based interventions have been developed to modify the dietary habits of school-age children, however they are few educational programs designed to increase the intake of calcium.

Education in primary schools

The school setting is known to influence students’ eating patterns, and presents an effective vehicle through which to intervene with children


Schools are a crucial social environment for children and adolescents, and many attempts have been made to utilise this environment to promote healthy behaviour in youth, including healthy eating habits


We need to talk about prevention
Milk, cheese and yogurt contribute important nutrients to the school meal programs. In fact, milk is the number one food source of calcium, vitamin D and potassium in children’s diets. National Dairy Council offers resources, such as sample menus and analysis that meet nutrition guidelines, to support School Nutrition Professionals in efforts to provide healthy meals to students. These sample menus utilized USDA Recipes or products currently in the marketplace and feature Offer verses Serve options overall (not with each food station).

(http://www.nationaldairycouncil.org/ChildNutrition/Pages/NutritioninSchools.aspx)
Dairy foods provide critical nutrients that help improve children’s overall diet and health. **National Dairy Council offers valuable information and resources** designed to help health care professionals, school nutrition professionals, and teachers ensure that children 9 years of age and older get the **Dietary Guidelines for Americans’** recommended three servings of low-fat and fat-free dairy foods every day.*

(http://www.nationaldairycouncil.org/ChildNutrition/Pages/ChildNutritionHealthEducationKit.aspx)

**Learning Connection**

**The Wellness Impact:**
**Enhancing Academic Success Through Healthy School Environments – Full report**

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This report addresses why schools play a more important role than ever in helping forge the nation’s future. It illuminates the vital importance of improved nutrition and increased physical activity in creating an environment that enriches students’ readiness to learn.
Scientific results of pilot study

Objective: The purpose of our study was to monitor and to promote the intake of calcium and vitamin D in children to achieve the goal of an optimal peak bone mass, and to safeguard bone health later in life. The modifications of nutritional behavior in schoolchildren were evaluated as the result of a nutritional program designed to increase calcium intake.

Design: Nutritional habits in children were evaluated, through a food frequency questionnaire (FFQ) specifically validated for assessment of calcium and important nutrients for bone health in children (Pampaloni B. et al. 2013), at baseline and after 7 months of exposure to a unique educational program especially designed.

Setting: Central Italy (Florence), between November and May of the school year.

Subjects: 176 schoolchildren (48 % male and 52 % female) attending 4th and 5th grades of two selected primary schools.
Growing strong and healthy with Mister Bone: an educational program to have strong bones later in life

“Growing strong and healthy with Mister Bone” is a campaign to promote optimal bone health in 9-11 years old children, thus reducing their risk of osteoporosis later in life. The goal is to educate and encourage children to establish lifelong healthy habits, especially increased calcium consumption and physical activity, to build and maintain strong and healthy bones.

Collaboration with publisher Giunti specialized in school books for children
The first step was devoted to nutrition education with particularly emphasis of dairy nutrition and importance of adequate intake of calcium and nutrients necessary to maintain bone health.

A 60 minutes lecture and discussion with children was performed by nutritionists.
The educational supports

A fun website (www.misterbone.it) was constructed to help children to

+ build robust bones
+ give information on the project’s contents
+ offer the possibility to play with “on line” games improved to teaching the correct way of life to have a strong and healthy skeleton.
**WEBSITE**

**QUIZZES:** Game with questions regarding the lessons that nutrizionists have done

**FIND THE WRONG BEHAVIOR:** The family Bone history. It is the story of a children (Baby Bone) that makes many errors during the day in the nutrition. The children have to find the errors and at the end of the game the computer indicate the score realized.

**MISTER BONE CROSSWORD:** that contains the most important words of the project
“Mister Bone Calendar” allows children to track their calcium intake and physical activity by the stickers

Brochure describing the contents of the initiative

CD with all project contents, including games
**Results:** The FFQ, administered before and after the educational program, revealed in children a significant increase ($p < 0.05$) of calcium (from $870 \pm 190$ to $1100 \pm 200$ mg/day), and vitamin D (from $3.6 \pm 1.53$ to $4.1 \pm 2 \mu g/day$) intake.

The percentage of children eating cheese increased from 84% to 91% and the percentage of those eating vegetables varied from 89% to 96%, with milk consumption going from 92% to 96%.
Conclusions
Our educational program appears to be significantly effective in modifying calcium intakes in children. Analysis of data from questionnaire that showed a significant increased in the dairy products and vegetables children consumption, without significant changes in the total caloric intakes, revealed an important change in nutritional children habits.
Behavior modifications are the result of progressive nutritional education obtained through lessons, brochures, calendar, games, quizzes and crosswords.

These findings may encourage school policies to promote educational strategies for the skeletal health of young students.