Journal of Pediatric Nursing (2014) **29**, e3–e14

Identification, Prevention, and Treatment of Children With Decreased Bone Mineral Density

Laura Lee Szadek DNP*, Kathleen Scharer PhD

University of South Carolina Columbia, SC

Key words:
Osteoporosis;
Osteopenia;
Decreased bone density;
Densitometry;
DXA;
Calcium;
Vitamin D;
Weight bearing;
Bisphosphonates

Osteoporosis in children is the presence of decreased bone mineral density in association with a significant fracture history. The amount of bone accretion in childhood and early adulthood is predictive of the risk of osteoporosis and fracture in later adulthood. A myriad of disorders and medications are associated with decreased bone mineral density in childhood. In addition, lifestyle factors including poor dietary habits and minimal physical activity are associated with low bone mass. Because of the limited attention given to childhood osteoporosis, this review was undertaken to examine the diagnostic criteria, etiologies, prevention of and treatment strategies for osteoporosis in children and adolescents.

Bone Health in the Pediatric Population

BONE HEALTH IS an increasingly important health concern in the pediatric population with ramifications that extend into adulthood. Although osteoporosis is primarily considered an adult disorder, there is evidence to suggest that its roots may actually lie in childhood (Leonard & Zemel, 2002). Adolescence represents a significant time period in bone formation and is described as the "bone bank" of the future. Approximately 40% of bone mass is accumulated in adolescence and peak bone mass occurs into early adulthood (Greer & Krebs, 2006). Future bone health and the risk of osteoporosis in adulthood is significantly related to the amount of bone mass that accumulates in adolescence through early adulthood (DeFranco, Carl, Goodwin, Bergfeld, & Iannotti, 2009; Steelman & Zeitler, 2001).

The burden of osteoporosis includes both monetary and nonmonetary costs to society. According to the Surgeon General of the United States (2004), by the year 2020 half of Americans age 50 and older will have or be at risk for osteoporosis with potentially significant economic consequences. The economic burden of fractures related to osteoporosis in 2005 exceeded $19 billion in the United States, with costs expected to double or triple in future decades (DeFranco et al., 2009, National Osteoporosis Foundation, 2008). The monetary costs include direct medical costs such as acute and rehabilitative care. The nonmonetary costs include quality of life issues for the patient such as functional deficits, pain, depression, school and work absenteeism, and caregiver burden. The total costs to both individual patients and to society are significant, especially for a disease which can often be prevented by identifying patients at risk early and initiating lifestyle changes.

Multiple factors play a role in bone health such as genetics, family history, nutrition, calcium intake, vitamin D synthesis, and physical activity. In addition hormones, such as parathyroid hormone, calcitonin, insulin, steroids, estrogen, testosterone, thyroid hormone, growth hormone, are critical to bone metabolism (Castells, 1996; Henwood & Binkovitz, 2009). Decreased bone mass and fracture are potential

* Corresponding author: Laura Lee Szadek DNP.
E-mail addresses: lszadek@aol.com, kmschar@mailbox.sc.edu.

http://dx.doi.org/10.1016/j.pedn.2013.11.002
0882-5963/

complications of chronic disease, genetic disorders and unhealthy lifestyle. A 35 to 65% increase in pediatric fractures over the past four decades has been documented in the literature. Although the exact cause of this increase in fractures is unknown, decreased bone density is implicated as one possible cause, although increased participation in sports may be another. (Khosla et al., 2003). Early education is essential to prevent osteoporosis, preserve quality of life into adulthood, and decrease the economic burden of this disease.

Defining Osteoporosis

According to the World Health Organization (WHO), osteoporosis is a skeletal disorder characterized by decreased bone mass and micro-architectural deterioration that leads to fragile bones and susceptibility to fracture. The definition of osteoporosis is based on bone mineral density measurements, primarily through dual energy X-ray absorptiometry (DXA). A measurement that falls 2.5 standard deviations (SD) or more below the average value of a young healthy adult defines osteoporosis. Osteopenia is defined as a bone mineral density (BMD) falling between 1.0 and 2.5 SD below the average value of a young healthy adult (Uziel, Zifman, & Hashkes, 2009; [WHO], 2004).

The terms osteopenia and osteoporosis that are used to describe decreased bone mass in the adult population should not be used or applied to the pediatric population arbitrarily. The Pediatric Position Development Conference (PDC) of the International Society of Clinical Densitometry's (2007) guidelines and recommendations are based on evidence and expert opinion for ordering and interpreting bone densitometry in the pediatric population. The PDC recommends using the term osteoporosis in children only if bone mass is low (less than 2 SD) and there is a significant fracture history. A significant fracture history is described as a fracture that occurs from little or no trauma and a fracture that occurs from standing height or less (Bachrach & Sills, 2011).

The International Society for Clinical Densitometry (ISCD) (2007) discusses the definition of osteoporosis in children and adolescents, which is based on the recent literature on bone density studies and fracture risk. The ISCD's position on the diagnosis of osteoporosis in children is in agreement with the PDC recommendations that the diagnosis should not be based on densitometry alone. The ISCD's definition of osteoporosis in children is "a significant fracture such as long bone fracture of the lower extremities, vertebral compression fracture, two or more long bone fractures of the upper extremities, and a low bone mineral content (BMC) or BMD."

Skeletal Development and Bone Formation

Bone is a dynamic organ that undergoes resorption and formation throughout the lifespan (Hadjidakis & Androulakis, 2006; Hahn, 2009). The process of bone modeling and remodeling maintains the shape and strength of bone (Roth, Ward, Chan, & Sarafoglou, 2009). The process is regulated by external regulatory mechanisms, such as hormones, vitamins, minerals, growth, weight bearing, stress on the skeleton, and nutrition. In addition, local regulators of bone metabolism include prostaglandins, cytokines, and growth factors. Disruption of any of these mechanisms leads to interference in bone metabolism (Castells, 1996).

Skeletal development begins early in fetal life. Embryonic development begins with a few cells that eventually differentiate into three layers; the ectoderm, endoderm and mesoderm. The mesoderm layer gives rise to the skeleton. By 3 months gestation, the fetus has a framework of the skeleton. The fetal skeleton is composed of cartilage and connective tissue which eventually matures into bone. Adequate calcium and minerals are necessary for growth and mineralization of the fetal skeleton (Land & Schoenau, 2008).

In childhood, bone modeling and remodeling work in response to bone growth and function (Robling, Castillo, & Turner, 2006). As a child grows, muscle mass increases and body weight increases. These changes affect the skeleton and the bones must adjust to meet the demands of the growing skeleton. Bone is, therefore, added or reabsorbed to alter the shape or increase the strength of the bone (Robling et al., 2006).

Bone growth occurs at the physis. During infancy and childhood, activity at the physis is stimulated by growth hormone. Testosterone and estrogen promote adolescent growth and eventually induce epiphyseal closure. Once a child reaches skeletal maturity, modeling and remodeling processes are slowed (Robling et al., 2006).

Bone Modeling and Remodeling

During childhood, bone mass accrual is influenced by growth, modeling and subsequently increased bone size (Gafni & Baron, 2007). Modeling is the formation of bone at one site and removal of bone at another site within the same bone. The process of modeling allows for increase in bone size and change in bone shape (United States Department of Health and Services, 2004).

Bone remodeling is the replacement and formation of bone at the same site (United States Department of Health and Services, 2004). After peak bone mass is attained, remodeling is the dominant process throughout life. During adolescence, bone formation is greater than bone resorption thus leading to increased bone mass. Twenty five percent of peak bone mass is attained during the peak height velocity or growth spurt during adolescence. Gains in bone mass continue after linear growth is complete (Bachrach & Sills, 2011).

Bone remodeling occurs in five stages in; quiescence, activation, resorption, reversal and formation (International Osteoporosis Foundation, n.d.; United States Department of