Pediatric Dual-Energy X-Ray Absorptiometry In Clinical Practice: how to report it

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Aims and objectives

Pediatric age is characterized by growth and maturation of all body systems, including skeleton. Bone development starts during fetal life, but it is during adolescence that remodelling reaches the highest level. Bone accrual occurring during growth and pubertal development, indeed, achieves peak bone mass (PBM), the amount of bone present in the skeleton at the end of its maturation process, which is a key determinant of current and future fracture risk (1, 2).

Although more than 60% of PBM variability is genetically determined, the rest is influenced by environmental factors, such as adequate dietary intake of calcium and vitamin D, and a regular weight-bearing physical activity. As a result, optimizing PBM acquisition through dietary and physical exercise measures may represent an important primary intervention for fracture prevention.

This primary goal is often difficult to accomplish due to children's and adolescent's lifestyle, resulting in an increase in childhood fracture rate (3). DXA has become the gold standard method in bone quantity measurement, and recently it also allows to obtain qualitative informations with microarchitecture and geometric parameters by the means of the introduction of TBS and HSA.

This paper focuses on all the essential informations that an exhaustive pediatric DXA report should contain, with particular regard to what the clinicians need to know, which is quite different from the adult setting.
Methods and materials

In clinical practice, the evaluation of bone status in children requires identification of notable changes in bone mineral density (BMD) and bone mineral content (BMC), that can provide an accurate diagnosis of low bone mass and an early fracture risk assessment in growing children and adolescents. Moreover, it provides the best monitoring of pharmacological treatments.

Three methods for quantifying BMC and BMD have been developed and translated from adults to children and adolescents: quantitative ultrasound, peripheral computed tomography and dual-energy X-ray absorptiometry (DXA) (4).

DXA has been recognized as the gold standard method for bone mass measurement (5) both for adults and children and it is the most used technique for the assessment of BMD, because it is a feasible, wide available, low cost, safe and accurate method (6, 7). Moreover DXA allows vertebral fracture assessment and morphometric analysis in order to identify even asymptomatic vertebral compressions (crush fractures).

A precise and complete DXA report should contain the following informations, summarized in Table 1.

Recommended sites for pediatric DXA examination are:

- lumbar spine (LS): considered a mainly trabecular bone skeletal site, evaluated between L1 and L4. It can provide a highly reproducible measure of BMC and BMD for children aged 0 to 5 years;
- total body less head: derived from the whole body scan, provides information on cortical department. It should be performed in infants older than 3 years. It provides a measure of total bone mass and allows an evaluation of body composition, as a lean body mass (LBM);
- others: proximal femur scan, lateral distal femur (LDF), distal forearm.

DXA provides several informations about bone status in children, with the identification of

- BMC: the total bone mineral content (expressed in grams). In children over 5 years old, it should be corrected for height;
- BMD: the amount of mineral in bone projected area (g/cm²). It contributes for 60 to 80% of bone mechanical resistance (8) and is the easiest parameter to quantify bone strenght in clinical practice. It allows to define a "fracture threshold"(9), and it is a potential prognostic tool to determine the probability of fragility fractures. BMD values should be expressed in terms of Z-score, which represents the number of SD above or below the age-, sex- and
ethnicity-matched mean BMD (10). The term "osteopenia" is inappropriate and should not appear in pediatric reports. On the contrary, the diagnosis of osteoporosis is fundamentally clinical and requires a clear evidence of fragility fracture history regardless of BMD (11), which has been defined by the Pediatric Position Development Conference as two or more fractures of long-bone before ten years of age, or three or more long-bone fractures before 19 years of age (10).

- Bone Mineral Apparent Density (BMAD): the mineralized tissue mass per total tissue volume (g/cm3).
- Trabecular Bone Score (TBS): a texture parameter obtained from pixel grey-level variations in DXA lumbar spine images, considered to be a trabecular micro-architectural index (12). A score equal or more than 1.310 is associated with a reduction in fracture risk, while a value of 1.230 or less means an increased fracture risk (13). TBS normally increases with growth in both genders, and it is correlated positively with muscle strength and lean mass, spine BMD, subtotal body BMD and lean mass in both genders.

Errors in interpretation are pitfalls that radiologists should avoid, such as the use of T-score, instead of Z-score, which is the SD score compared with adult, the use of a pediatric database that does not differentiate between boys and girls or that does not consider ethnical variation.
Table 1: What to include in a DXA report. BMI: body mass index; LSC: least significant change; LS: lumbar spine; FN: femoral neck; TBLH: total body less head; BMD: bone mineral density; BMAD: bone mineral apparent density.

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Results

The International Society for Clinical Densitometry (ISCD) states that the presence of a DXA BMD Z-score # -2.0 indicates a reduced bone mass in children and adolescents and is associated with increased fracture risk (14). Moreover, the presence of one or more fragility VF, regardless of BMD, allows to make diagnosis of osteoporosis (15, Table 2).

Healthy Children and Adolescents

When considering a DXA scan for healthy children or adolescents, the clinician has to take into account family, personal and fracture history, which consists of two or more fractures of long bones under ten years of age, or three or more long-bone fractures before 19 years of age (16). The presence of a non-traumatic vertebral compression fracture is sufficient for the diagnosis of osteoporosis in children regardless BMD Z-score.

Bone Diseases

In pediatric primary bone diseases DXA measurement is used for monitoring the disease progression and the effect of treatment (17). A baseline DXA scan is recommended at the beginning of any treatment, and periodically every 6-12 months for OI and every 12 months for IJO.

Chronic diseases (Table 3) can interfere with bone mineralization, but impaired statural growth, delayed puberty, reduced weight-bearing physical activity or poor nutrition, and glucocorticoid therapies, can negatively influence bone health. TBLH BMC and areal BMD by DXA should be obtained at baseline and, in case of suboptimal mineralization, after one or two years (10).

Malnutrition and malabsorption could explain the important decrease in bone mineral content and the low bone mass during chronic diseases or in restrictive eating disorders.

Cerebral palsy and particularly Duchenne muscular dystrophy (DMD) are associated with low BMD and increased fracture risk due to progressive muscle weakness and functional bone-muscle unit impairment, chronic inflammation, reduced weight-bearing activity(18).

The follow-up scan is indicated to monitor the bone changes related to the disease, ongoing or recovery, and/or the efficacy of a treatment between six and twelve months, depending on clinical status (3).
**Table 2:** Diagnosis criteria of osteoporosis or low bone mass or mineral density in children and adolescents. BMC: bone mineral content. BMD: bone mineral density. SD: standard deviation

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<table>
<thead>
<tr>
<th>Osteoporosis</th>
<th>Low bone mass or bone mineral density</th>
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<tr>
<td><em>One or more vertebral fractures in absence of local diseases or trauma history</em></td>
<td><em>BMC or BMD Z-score ≤ 2.0 SD</em></td>
</tr>
<tr>
<td><em>BMD Z-score ≤ 2.0 SD and fracture history (at least one of these):</em></td>
<td></td>
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<tr>
<td>• Two or more long bone fractures before age 10</td>
<td></td>
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<tr>
<td>• Three or more long bone fractures at any age up to age 19</td>
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Table 3: Diseases with indication for a pediatric DXA examination.

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Conclusion

The need of bone status assessment in pediatric age has gained relevance in many pathologic conditions and in monitoring treatment for bone mass impairment. DXA is the preferred tool, which provides informations about bone quantity and quality. An exhaustive and precise DXA report by the radiologist is necessary for the clinician to obtain all possible notions to prevent current and/or future fragility fractures.
Personal information

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References


