Review of Bone Age

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#SAMSON19

Day 3; Wednesday 13th

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Overview

• Pubertal Delay

• Skeletal Development

• Definition of Bone Age

• Methods for assessing Bone Age

• Causes of delayed and accelerated Bone Age
Development of the musculoskeletal system with age

• 642 Swedish men aged 18-20 years

• Older age at peak height velocity (indicative of pubertal timing) predicted:
  • Lower cortical vBMD (pQCT) (explained 14% of variance)
  • Lower trabecular vBMD (pQCT)
  • Lower aBMD at all sites (DXA) (i.e. lower peak bone mass)
  • Greater odds of upper limb fracture (OR 1.35 [1.04, 1.75])
• Sex-specific polygenic risk scores for pubertal timing in Mendelian Randomisation Analyses

• Later puberty (menarche and voice breaking) associated with lower aBMD at LS and FN in males & females
Skeletal Development

X-ray of a newborn. Gaps between bones indicate cartilage
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Adult
Skeletal Development

Skeletal mineralization begins in 3rd trimester
Calcium: 25g at birth – 1000g as adult
When growth plates (Epiphyseal plates) fuse, longitudinal growth ceases

Long bones grow in length by Endochondral Ossification at the growth plate
Paediatric Growth Curves

Impaired linear growth
Growth curves

Boys: 2 to 20 years
Boys: 2 to 20 years

Determinants of childhood growth

**Infantile** (15% of adult height)
- Nutrition
- Good health and happiness
- Thyroid hormones

**Childhood** (40% of adult height)
- Growth hormone
- Thyroid hormones
- Genes
- Good health and happiness

**Pubertal** (15% of adult height)
- Testosterone and oestrogen
- Growth hormone

**Fetal** (30% of adult height)
- Uterine environment
Growth modeling with SITAR methods

Superimposition by Translation And Rotation (SITAR) Cole, et al. (2010) IJE.
Tanner Staging
Definition of Bone Age

• The degree of skeletal maturity during childhood

• Different from chronological age (calculated from date of birth)

• If bone age ≠ chronological age by more than 10%, can indicate endocrine/genetic disease

• Most frequently defined from plain hand & wrist radiographs (PA)

  (radiation: 0.0001-0.1 mSV)
Left hand radiograph

The order in which carpal bones ossify

Carpals
1: Capitate, 2: Hamate
3: Triquetal, 4: Lunate
5: Scaphoid, 6: Trapezium
7: Trapezoid

Radius
Ulna
Methods for assessing Bone Age on Hand/Wrist Radiographs

**Atlas-based methods**

1. Greulich and Pyle (GP) (1959) — Compares vs. atlas of hand radiographs of American Caucasian males and females (quick)


3. Tanner Whitehouse (TW) — Scoring approach, generates an age range, British ref popn (not as quick as GP)


**Automated Skeletal Bone Age assessment**

5. Bone Xpert (uses TW and GP)

- Bones used in all include distal radius and ulna, the carpals, metacarpals and phalanges
Bone age

**Infancy**
- Females: Birth to 10 months
- Males: Birth to 14 months

**Toddlers**
- Females: 10 months to 2 years
- Males: 14 months to 3 years

**Pre-Puberty**
- Females: 2 to 7 years
- Males: 3 to 9 years
Bone age

**Early & Mid-Puberty**
- Females: 7 to 13 years
- Males: 9 to 14 years

**Late Puberty**
- Females: 13 to 15 years
- Males: 14 to 16 years

**Post-Puberty**
- Females: 15 to 17 years
- Males: 17 to 19 years
Bone age

Early & Mid-Puberty
- Females: 7 to 13 years
- Males: 9 to 14 years

Late Puberty
- Females: 13 to 15 years
- Males: 14 to 16 years

Post-Puberty
- Females: 15 to 17 years
- Males: 17 to 19 years
Assessing bone age using other skeletal sites

Iliac Bone, Femoral Head, Cranial Sutures, Cervical Vertebrae

Infant | Child | Adult
Causes of accelerated skeletal maturation *i.e.* bone age > chronological age

Early puberty
Obesity
Endocrine disorders of precocious Puberty
  *e.g.* Thyrotoxicosis
  Cushing’s Syndrome
Congenital disorders of precocious puberty
  *e.g.* McCune-Albright syndrome
  Pseudohypoparathyroidism
Causes of delayed skeletal maturation
\textit{i.e.} chronological age > bone age

Delayed puberty

Chronic illness
\hspace{1cm} \textit{e.g.} Perinatal HIV
\hspace{1cm} Malnutrition
\hspace{1cm} Rickets

Endocrine disorders
\hspace{1cm} \textit{e.g.} Hypothyroidism

Congenital disorders
\hspace{1cm} \textit{e.g.} Down Syndrome
\hspace{1cm} Skeletal Dysplasia's
BoneXpert Software
Bone age and DXA

• DXA Z-scores are usually calculated based on chronological age using reference population data

• Reference data should be sex and ethnicity specific

• In children with delayed maturation, the applicability of chronological age to derive Z-scores is debated

• Adjusting DXA Z-scores for bone age helps to take account of skeletal maturation

• Bone age reference data are needed for Zimbabwe
Summary

• Bone age is seldom exactly the same as chronological age

• Bone age reflects (accurately) the degree of pubertal maturation

• Bone age is measured on a plain PA radiograph of the left hand

• Bone age can be automated using Bone Xpert (at a cost) provided population reference data are available

• In musculoskeletal research studies involving children and adolescents, measurement of bone age is recommended
Thank you