




Non-medical Human Imaging in Sport and Age Assessment




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Category 1 non-medical human imaging: Specific Safety Guide SSG-55 <https://www.iaea.org/publications/12352/radiation-safety-of-x-ray-generators-and-other-radiation-sources-used-for-inspection-purposes-and-for-non-medical-human-imaging>

- usually takes place in a **medical radiation facility** that performs radiological procedures for the primary purpose of medical diagnosis; uses medical radiological equipment to obtain the image; is performed by medical personnel, typically radiology personnel; and produces images that are **assessed by a radiological medical practitioner**.
 - for occupational and employment related purposes, such as assessment of fitness for employment, and **assessment of physiological suitability for a career or a sport, including assessment of athletes before a selection or transfer**;
 - Imaging for legal purposes, including obtaining legal evidence, **age determination**, immigration or emigration purposes, and detection of drugs within a person;
- 




Non-medical human imaging for sport and age assessment

1. What is known;
 - A. Assessment of physiological status for:
 1. Chronic injuries in athlete (for selection),
 2. Screening (pre-signing of contract),
 3. Precautionary imaging, and
 4. sports regulatory imaging (annual licensing).
 - B. Age of individual may influence-
 - eligibility to participate in sport / performing arts
 - asylum decision,
 - criminal justice,
 - eligibility for benefits or
2. Examples of good practices;
3. Further work needed.

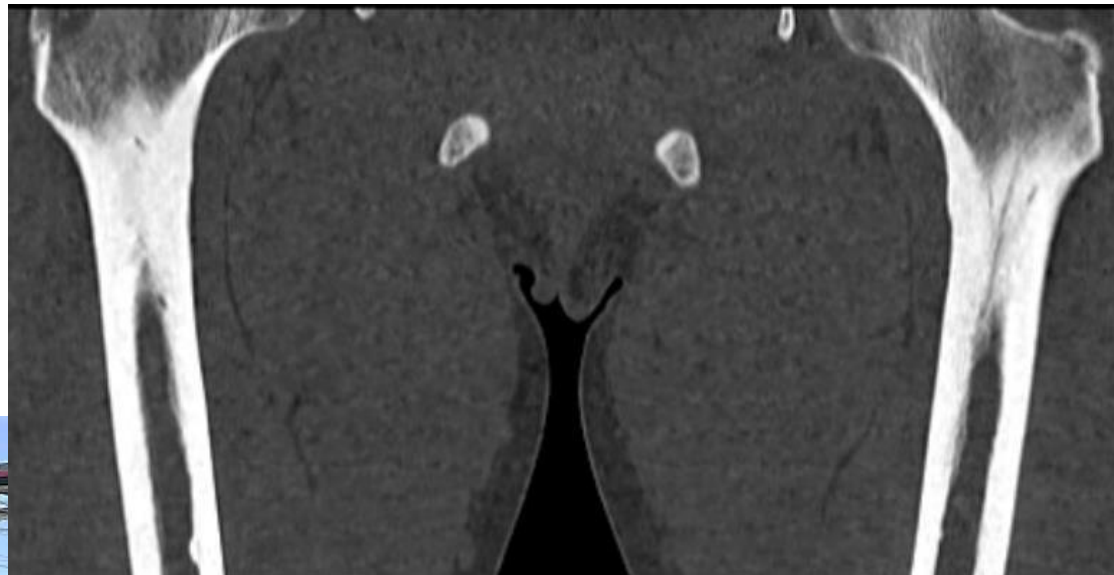
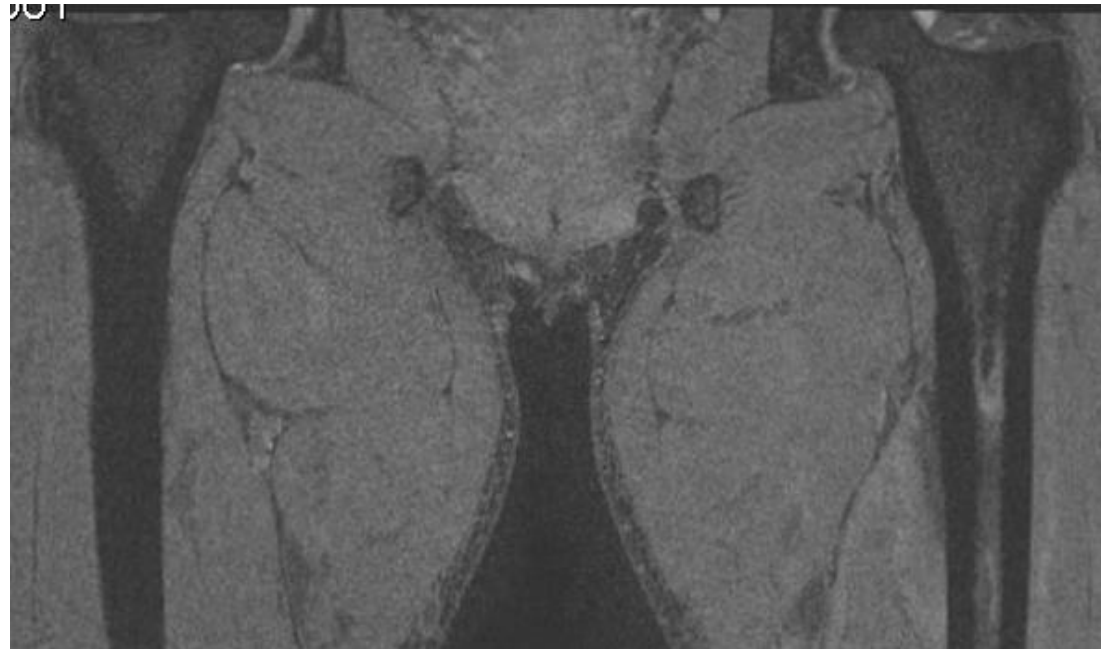
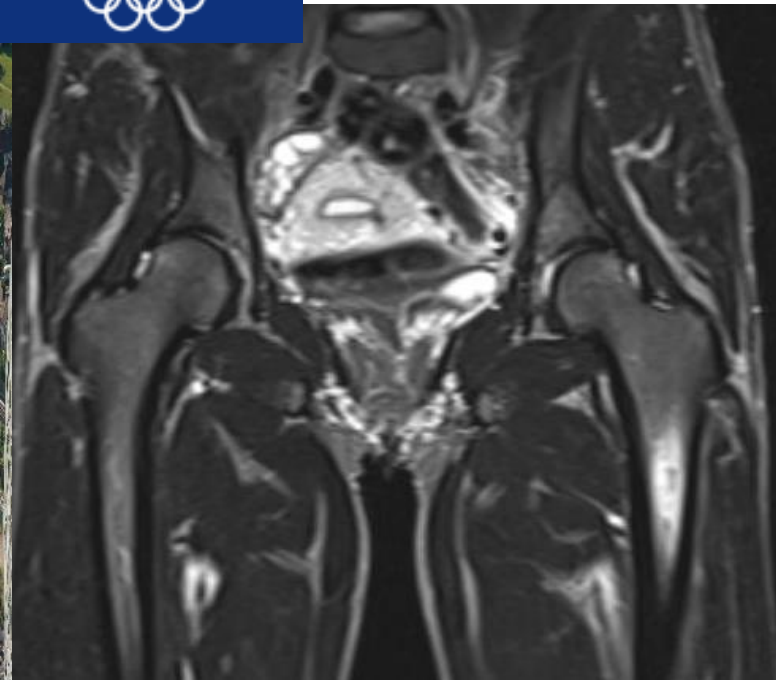




1. Chronic overuse injury: selection

- Medically indicated when essential to prevent further injury through competition or for nutritional decisions
 - **Non-medical** Imaging to aid **selection** for competition and return to **sport** (but not for diagnosis)... Grey area
 - **MRI and US** should be used more whenever possible, rather than CT
 - Avoid unnecessary repeat imaging
 - Optimisation should be as for medical imaging, ALARA, appropriate collimation, **diagnostic quality images**
- 

Female endurance athlete: MRI & CT



2. Contractual non-medical imaging: Pre-signing scan

- Now usually **MRI not CT** / x-ray
- CT not effective for low grade bone stress injury or soft tissue injury and should not be used
- Potential problems with incidental findings which may be seen in up to 25% of subjects (ethical issue)



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"Excellent same day service. The appointment and report is just what athletes need."

English Institute of Sport Athletes
(January 2007)

Pre-signing Scans

Fit for Purpose for the 2009-2010 Season?

Time to focus on a new season and signing new playing staff for your Club.

Time to fully assess the musculoskeletal health of potential new signings or existing players with niggling and reoccurring injuries.

New club professionals and existing staff need to be fully fit and ready to face the physical challenges ahead.

Our 3 Tesla clinical MRI diagnostic service for elite sports professionals offers the highest resolution MRI service available in the UK for key staff assessment.

find out how

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3. Regulatory non-medical imaging: Licensing of athletes in fighting sports

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Women's boxing gains Olympic spot



Popularity boost predicted for women's boxing

Women boxers will have the chance to fight for gold at the 2012 Olympics.

International Olympic Committee chiefs voted on Thursday to lift the barrier to the last all-male summer sport.

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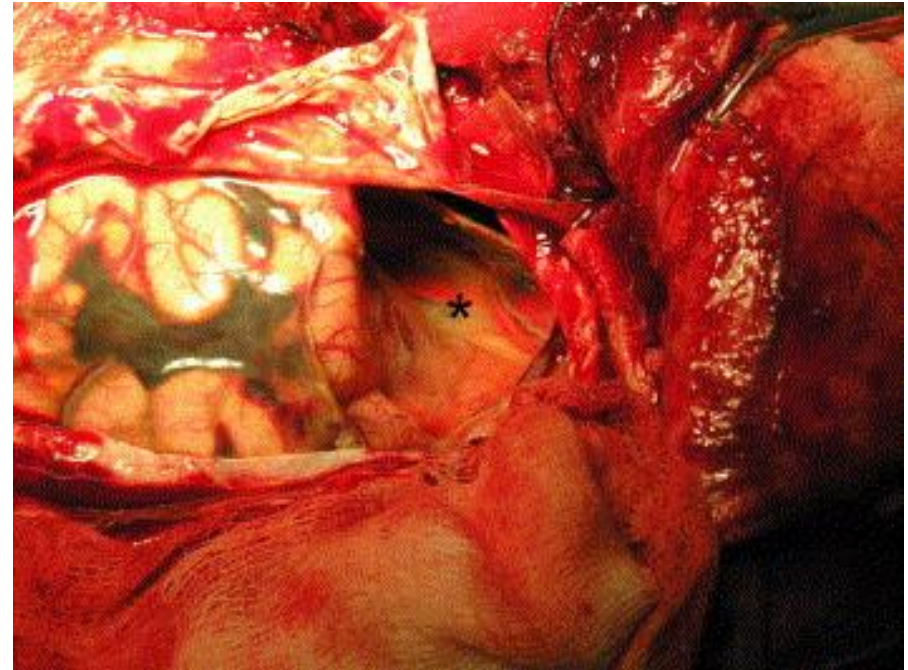
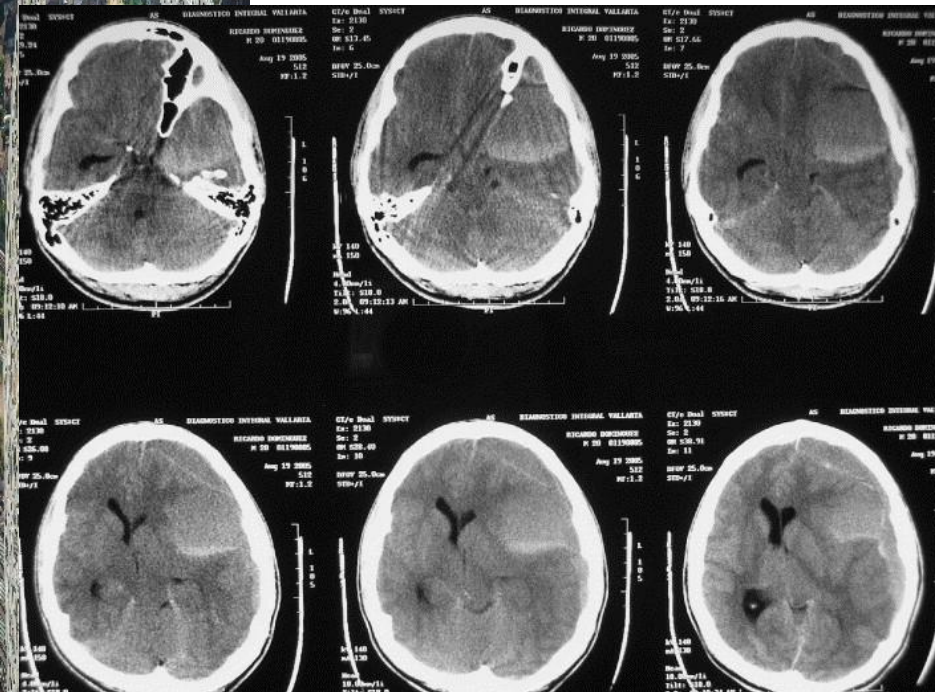
RELATED BBC LINKS:

- ▶ [Matt Slater on women's boxing's 2012 bid](#)
- ▶ [BBC London's 2012 coverage](#)

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4. Precaution: eg. TKO arachnoid cyst & subdural bleed in a boxer [Robles, Hernandez. 2006. Injury Extra; 37:375](#)



>650 boxers have died, most in USA


Chronic traumatic encephalopathy (dementia pugilistica)
common





Regulatory licensing of athletes in combat sports: variation in requirements

Jurisdiction	CT	MRI	CT/MRI	No scan
Alberta: boxing, muay thai, kickboxing, mixed martial arts				✓
British Columbia: boxing, mixed martial arts, wrestling, kickboxing	✓			
New Brunswick: Professional boxing	✓			
Ohio: need doctor's report			✓	
UK: British Board of Boxing Control		✓		
South Australia: combat sports		✓		





Bone age for U-17 football: MRI not x-ray*

In some countries, birth certificates are inaccurate or even not available, without that necessarily being the fault of the player or the association.

Dr Yacine Zerguini, member of the FIFA and CAF Medical Committees

To tackle this potential problem, FIFA has decided to conduct magnetic resonance imaging (MRI) of the wrist at the FIFA U-17 World Cup, with randomly selected players being tested in Nigeria under the supervision of FIFA's medical experts.

The research behind the decision actually began in 2003 when, in response to numerous requests by member associations, FIFA's Medical Assessment and Research Centre (F-MARC) started to investigate the use of biological markers for age determination.

X-ray images of the growth plate of the left wrist have been used in court and paediatrics to determine age for decades. The growth plates of the bones of the human skeleton are open during growth, and close at different times with increasing age and maturity. However, for ethical reasons, the exposure to radiation prohibits the use of X-ray in the age screening of football players.

Prof. Jiří Dvorák, the chairman of F-MARC who also works in a large orthopaedic hospital, came up with the idea of using MRI instead, since MRI does not expose players to any radiation and also provides detailed images and better contrast between different body tissues than any other imaging systems in radiology. Consequently, F-MARC developed a



Ballet x-ray and skeletal maturity: pointe in question

<http://www.pointeshoefitting.co.uk/styled-3/styled-4/>



"that there was no reason to get a young dancer up on full pointe if she could not do anything when she got up there!

It is **VERY** important that you are at least 12 years or older. Why?

Children's bones are extremely immature and soft. While we grow and develop, our bones go through the same process. If you were able to look at a young person's bones, you would see that there is cartilage and not bone at each of the ends, these are called the growth plates. These growth plates will not finish growing until much later in your life, usually around 21 years old.

As you reach 12-13 years, the foot growth will start to slow down, and the hardening process will begin. This normally coincides with the onset of menstruation or your second growth spurt. When periods begin the hormone oestrogen is secreted by your body, it is this hormone that will keep your bones healthy, strong and solid.

Are you also emotionally ready to start?

Starting pointe work will be very demanding on your feet & body. Pointe work is very hard work, so you need to be prepared for your feet and body to ache during and after class.

There is no one calendar age that's right, but there is a skeletal development age, which according to the late Celia Sparger, was 11.5 years. This amount of development is reached when the ends of the toes are completely ossified. The rest of the structures are still in flux until about age 25, but safety starts at 11.5. Now, Sparger was gathering her data through the thirties and forties, and the calendar age at which this point is reached may have decreased over time, but on the whole, only the pediatrician knows for sure! mcr's doctor is right. Whatever the reason, it's better to wait, and there are all sorts of criteria for readiness for pointe besides skeletal development age.

Swedish justification for DXA in sport*

- Sport involves increased risk of injury / musculoskeletal overload in the skeleton, muscles and tendons.
- [DXA] measures the body composition, partly to identify any asymmetry in muscle mass and partly for bone density, in order to prevent overload damage and stress fractures during sports and partly to detect precursors to osteoporosis at an early stage. In case of deviations from the reference values, the patient will be referred for medical consultation with orthopedic surgeons for investigation and possible treatment.
- Clinical indications for DXA in athletes are:
 - (1) Athletes with repeated injury problems,
 - (2) Athletes with abnormal BMI and
 - (3) Female athletes with longer (> 6 months) menstrual loss



Female endurance athlete: MRI & DEXA

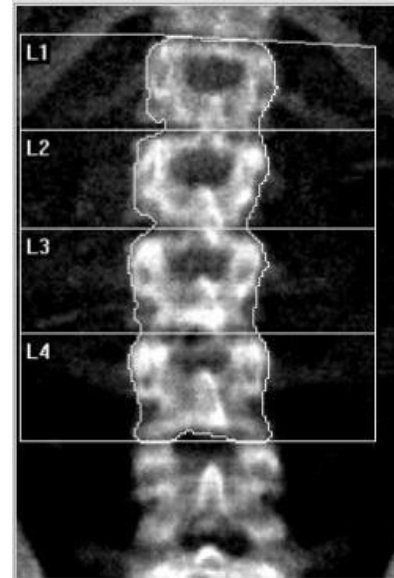
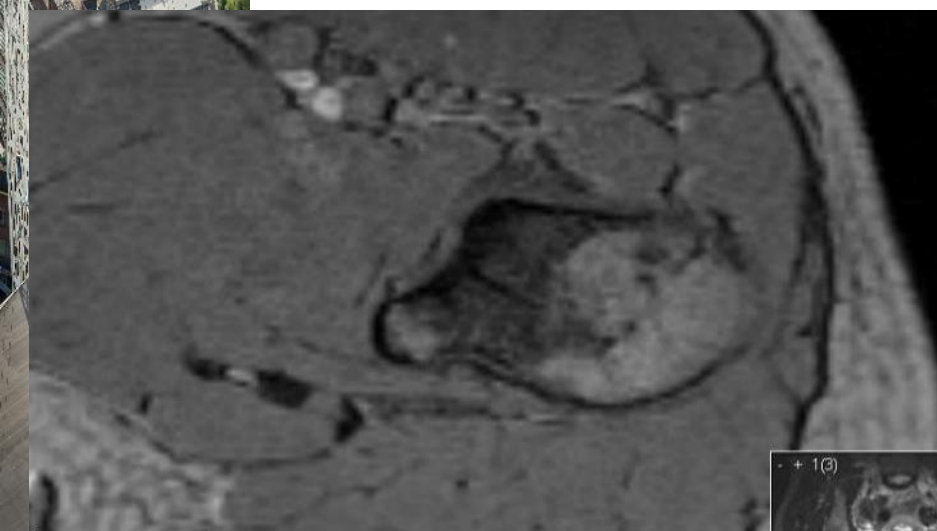
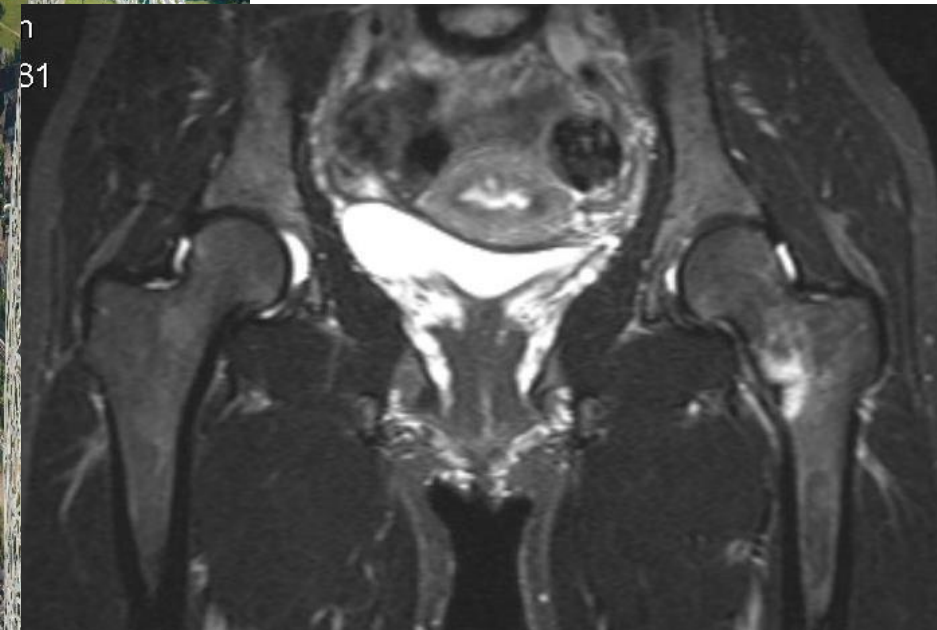
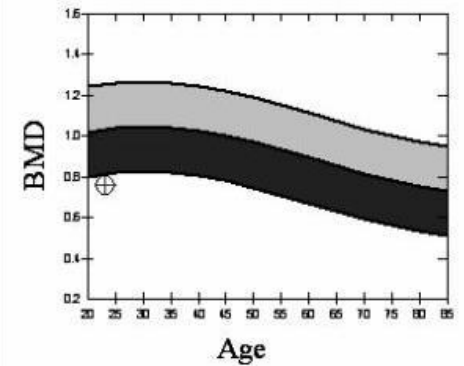


Image not for diagnostic use

116 x 133

L1-L4



T-score vs. White Female; Z-score vs. White Female. Source: Hologic

Results Summary:

Region	Area[cm ²]	BMC[(g)]	BMD[g/cm ²]	T-score	PR (Peak Reference)	Z-score
L1	11.33	7.12	0.629	-2.7	68	-2.6
L2	12.57	9.80	0.779	-2.3	76	-2.1
L3	13.73	11.16	0.813	-2.5	75	-2.3
L4	14.86	11.76	0.792	-2.9	71	-2.8
Total	52.49	39.84	0.759	-2.6	72	-2.5

Total BMD CV 1.0% ACF = 1.018 BCF = 0.999

Need for age determination

- Asylum seekers
- Human trafficking victims
- Eligibility for benefits
- Criminal proceedings



Refugee and migrant crisis in
whether off its coasts, on its
r along its roadsides – is a
children. One in every four
seekers in Europe so far this
been a child. A total of
children sought asylum
January and July – an



Hand/Wrist Radiological Age Estimation: limitations

- Greulich & Pyle **reference data** from Caucasians, 1930s, upper socio-economic class
- Tanner & Whitehouse (1975) system more reliable
- Radiographic positioning problems
- Intra- and inter-observer **variability**
- Influence of **socio-economic status and ethnicity/race**
- **Less accurate with older children** (15-18yrs)

26 Nigerians Fail Age Test

BY DAN MCAULIFFE 5 MONTHS AGO ❤️ 0

INTERNATIONAL SOCCER

Nigeria's chances of winning the U-17 Africa Cup of Nations took a big hit when 26 of their 60 their national team players **failed a mandatory MRI screening** before a home qualifier against Niger. The Confederation of African Football (CAF) just moved last week to have an independent doctor administer MRI scans to various countries in an effort to combat age cheats.

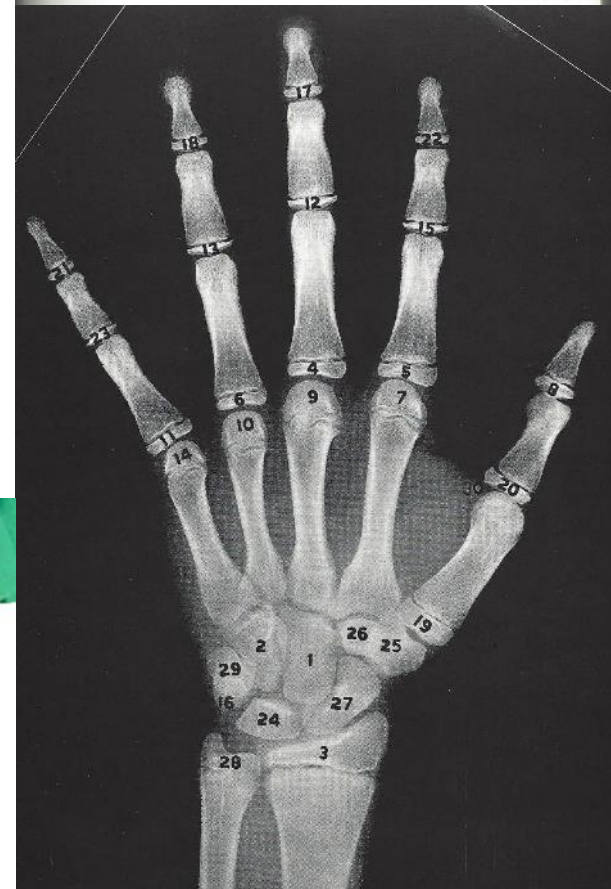
X-RAY DEPT.
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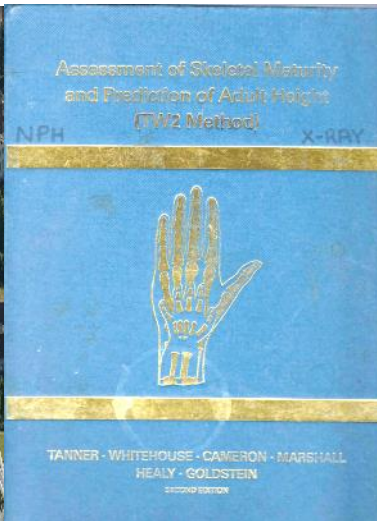
RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE HAND AND WRIST

SECOND EDITION

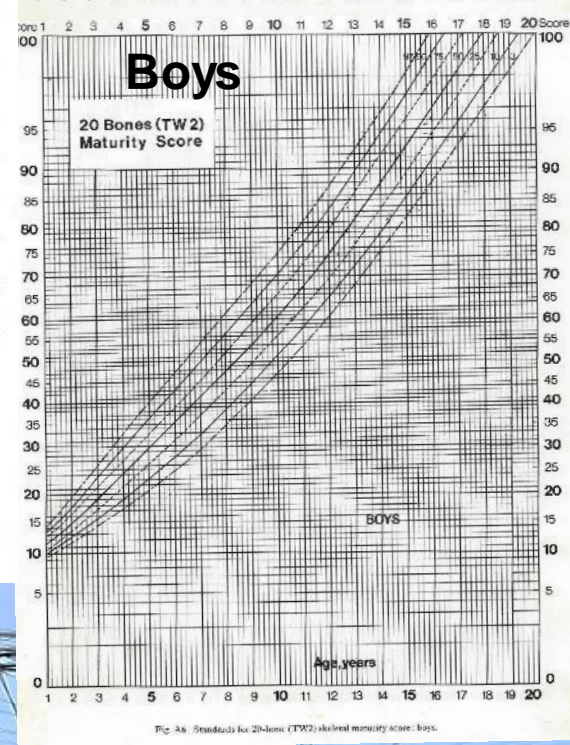
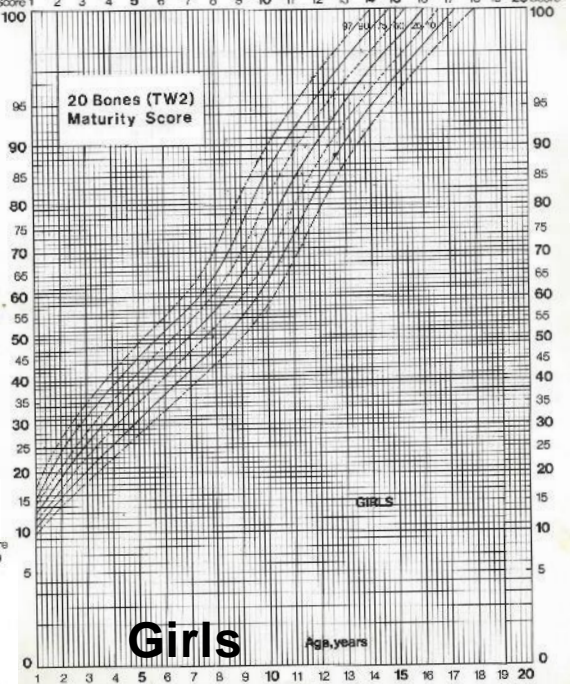
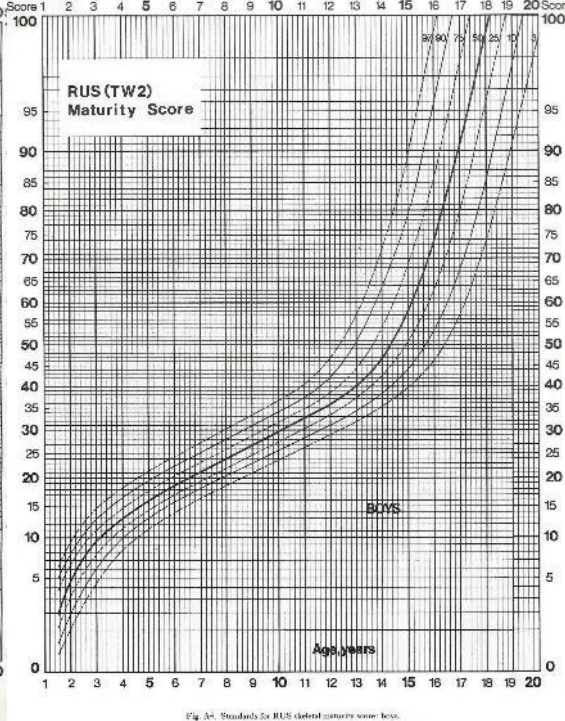
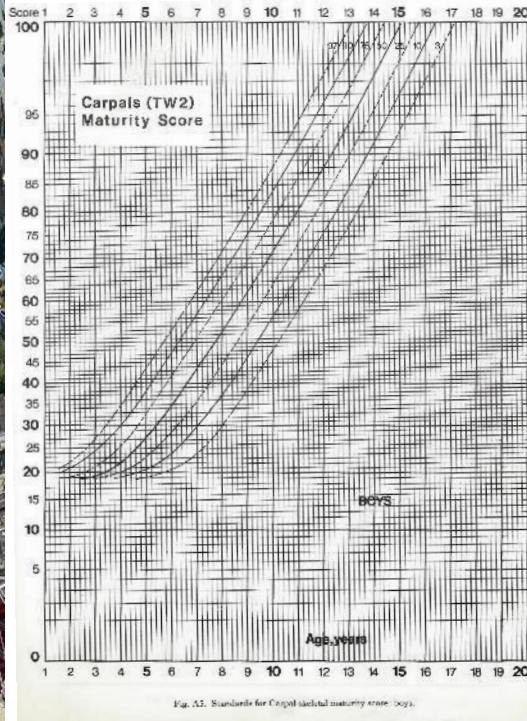
WILLIAM WALTER GREULICH
Professor of Anatomy, Stanford University School of Medicine

S. IDELL PYLE
*Research Assistant, Departments of Anatomy, Western Reserve University
and Stanford University School of Medicine*





Tanner Whitehouse estimation: Wrist, Radius-Ulna Score, 20 Bone estimation



Dental Radiological Age Estimation: simple and sophisticated methods (Horner)

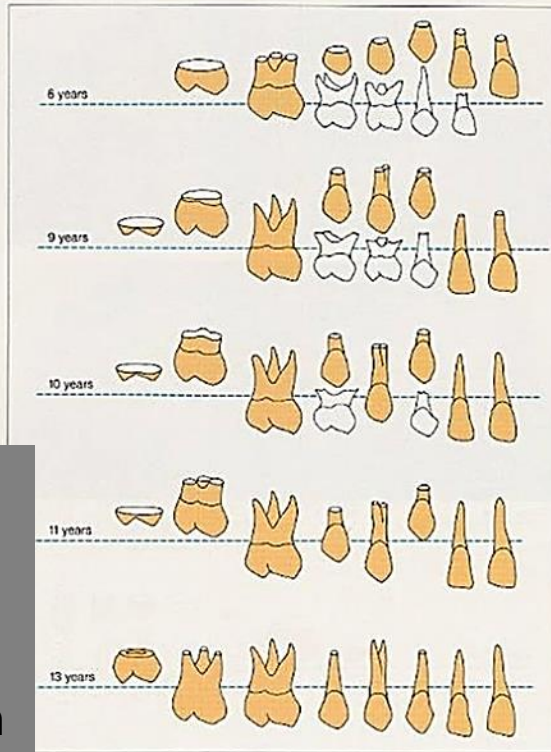
Diagram of the Formation and Eruption of the Permanent Teeth

The eruption of the permanent teeth usually occurs according to the following time sequence:

Central incisors	6 - 8 years
Lateral incisors	6 - 8 years
Canines	10 - 14 years
First premolars	9 - 12 years
Second premolars	10 - 13 years
First permanent molars	6 - 7 years
Second permanent molars	10 - 13 years
Third permanent molars	16 - 30 years

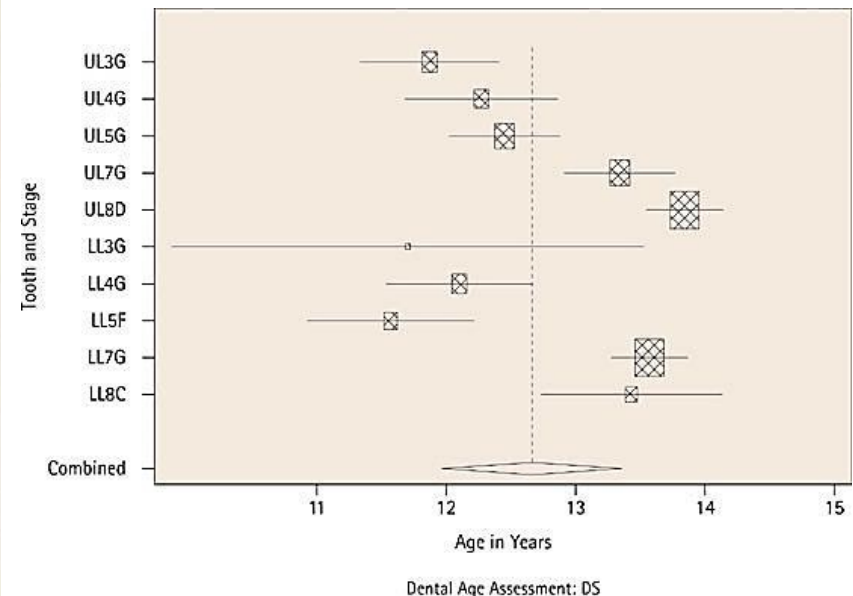
86 Formation and eruption of the permanent teeth of the maxilla

The eruption times of the mandibular permanent teeth are similar to their maxillary analogues.



Fewer teeth to assess in older children

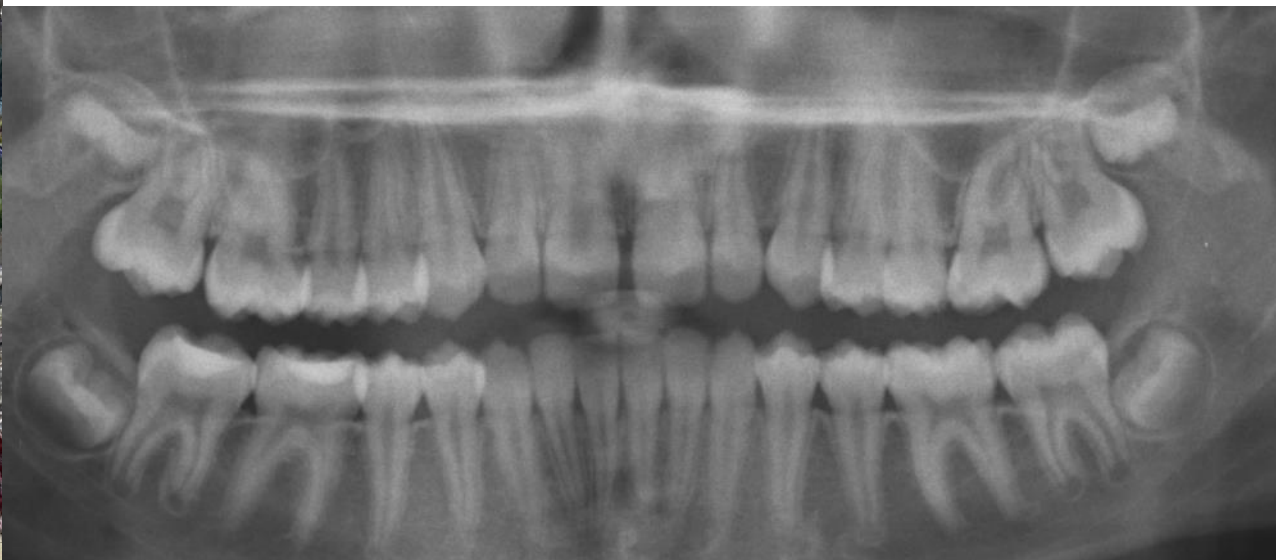
Roberts et al (2008) Dental age assessment (DAA): a simple method for children and emerging adults. Br Dent J, 204: E07



The weighted-combined estimated, mean dental age for this subject is indicated by the dotted line and the 99% confidence interval by the horizontal limits of the diamond

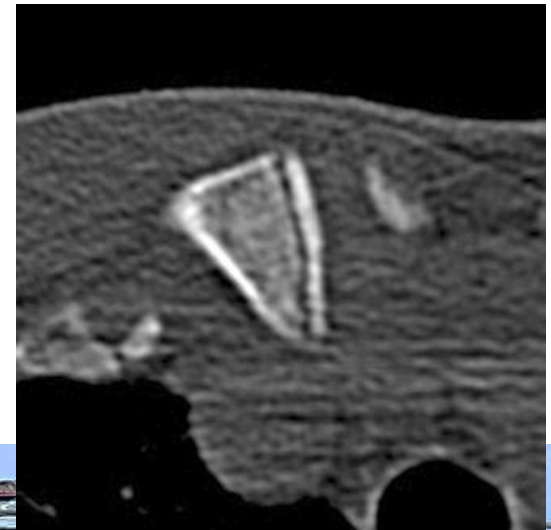
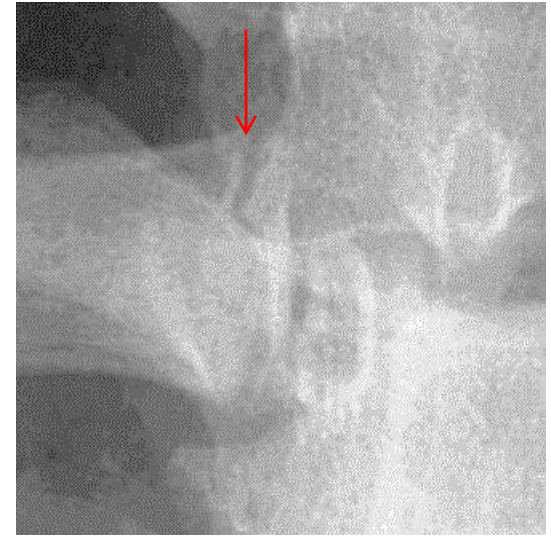


Dilemma:
Both aged
11 years



Clavicle Radiological Age Estimation

- Stage 1 Non-ossified ossification centre.
- Stage 2 Ossified ossification centre with non-ossified epiphyseal cartilage.
- Stage 3 Partially ossified epiphyseal cartilage.
- Stage 4 Fully ossified epiphyseal cartilage with a discernable epiphyseal scar.
- Stage 5 Fully ossified epiphyseal cartilage with no discernable epiphyseal scar.



Images and table from: Schulz et al (2008)
Radiographic staging of ossification of the medial clavicular epiphysis. Int J Legal Med
122: 55-58

Medial clavicular ossification for age: evidence

K.-F. Kreitner et al.: Bone age determination

1121

Table 2. Survey of the most comprehensive studies dealing with the development of the medial clavicular epiphysis

Study group (year)	Sample size	Males	Females	Age (years)	Ethnic group	Method	Ossification of medial epiphysis (age in years)	Partial union (age in years)	Complete union onset (age in years)	Complete union in 100% of the sample (age in years)
Todd, D'Errico (1928)	166	130	36	17–29	White, Black, USA	Anatomic preparation	n. d.	19–27	22	28
Flecker (1933)	437	206	231	11–26	Australasians	Chest X-rays ^a	11–26	n. d.	22	26
Galstaun (1937)	654	446	209	12–25	Bengalis	Chest X-rays ^a	12–19	n. d.	19 ^b	25 ^b
McKern, Stewart (1957)	374	374	–	17–31	White, USA, death during Korean war	Anatomical section	n. d.	18–30	23	31
Jit, Kulkarni (1976)	684	391	193	11–30	North Indians	Chest X-rays	11–19	18–24	22	25
Owings Webb, Myers Suchey (1985)	859	605	254	11–40	White, Black, Latin Americans, USA	Anatomical section	16–21	17–33	21	34
Present study (1997)	380	229	151	0–29	White, Europe	Thoracic CT	11–22	16–26	22	27

^a no documentation of X-ray findings

^b no differentiation between partial and complete fusion

n. d. no data available

Ultrasound: Schulz et al (2008) *Ultrasound studies on the time course of clavicular ossification*. Int J Legal Med 122: 163-7

MR studies: Schmidt et al (2007) *Magnetic resonance imaging of the clavicular ossification*. Int J Legal Med 121: 321-4



Age Determination of Unaccompanied Asylum Seeking Minors in the European Union: A Health Law Perspective

Roscam Abbing. European Journal of Health Law 18 (2011) 11-25

Abstract

In the European Union, unaccompanied asylum seekers below 18 years of age are entitled to specific treatment. Age assessment practices to verify the age-statement by the asylum seeker differ between EU Member States. Medical methods in use raise questions about accuracy, reliability and safety. The medical, legal and ethical acceptability of invasive methods (notably X-rays) in particular is controversial. Human rights are at stake. The lack of common practices results in different levels of protection (discrimination). The absence of standardisation is an obstacle for the functioning of the Common European Asylum System. EU Best Practice Guidelines should remedy the situation; such guidelines should reflect the best interest of the child.

Country	Wrist XR	Hand XR	Clavicle XR	Dental
Belgium	✓		✓	✓
Netherlands	✓		✓	
France	✓	✓		
UK*	✗	✗	✗	✗

6. Age Determination: The Challenges Ahead

A harmonised system of the methods used to determine the age of unaccompanied minor asylum seekers, as well as of the procedural rights must be in compliance with the human rights involved. Only then, are the respective asylum seekers given equal chances and a fair treatment. Due account ought to be given to the fact that age determination is an inexact science. So far, few studies only have





Medical, statistical, ethical and human rights considerations in the assessment of age in children and young people subject to immigration control

Aynsley-Green et al 2012 British Medical Bulletin 2012; 102: 17–42

<https://academic.oup.com/bmb/article/102/1/17/312555/Medical-statistical-ethical-and-human-rights>


Background: Unprecedented changes in both the scale and the complexity of international migration have led to international concern and controversy over the assessment of age in children and young people subject to immigration control or seeking asylum who say they are children yet have no documents to prove their stated age.

Sources of data: The article reviews the existing evidence on the reliability of medical and non-medical techniques for the assessment of chronological age.

Areas of agreement: There is evidence that **radiography (X-rays) of bones and teeth, which is increasingly relied upon by immigration authorities, is imprecise, unethical and potentially unlawful, and should not be used for age assessment.**

Areas of controversy: Medical techniques including **X-rays continue to be relied upon in the absence of an alternative approach resulting in legal challenges and uncertainty for children and young people.**

Areas timely for developing research: Further work is needed to establish a process for **age assessment based on a 'holistic' multi-disciplinary approach** which focuses not on chronological age exclusively but rather on the needs of children and young people subject to immigration control.






UN Children's Fund (UNICEF), *Age Assessment:*

A Technical Note, 2013 <https://www.refworld.org/docid/5130659f2.html>

Assessments of age usually consider :

- Presentation and demeanour at interview
- Account of their past history
- Growth, physical or sexual development
- Mental and cognitive development
- Emotional and 'abstract' thought development.

Before imaging ask:

1. Is the procedure really **necessary**?
 2. Is a physical examination the **only method** of assessing age?
 3. Has the child given **informed consent** to a physical examination?
 4. Is a **range of approaches** being used in the age assessment?
 5. Are the professionals engaged in the assessment **independent**?
 6. Is the assessment sensitive to **cultural and gender** needs?
- 

EU28, Norway, New Zealand, Australia,
Canada and the United States

Doctors of the Word – Médecins du monde International Network



European Asylum Support Office: Practical Guide on age assessment, 2018

<https://www.easo.europa.eu/sites/default/files/easo-practical-guide-on-age-assesment-v3-2018.pdf>

MRI-

hand (FIFA),
knee (SE), or clavicle. Slightly lower age assess.

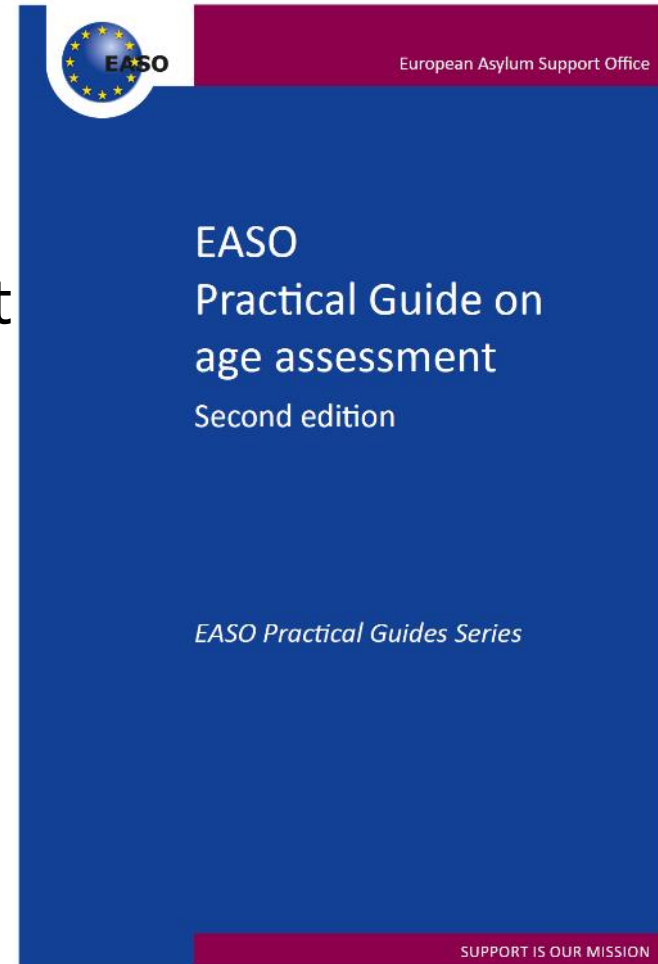
(Ultrasound)- hand, clavicle, iliac crest but not reliable.

Radiograph-

hand, fusion at 17/18, EU 23/28;
clavicle, fusion at 20/21, EU 12/28;
pelvis, EU 3/28

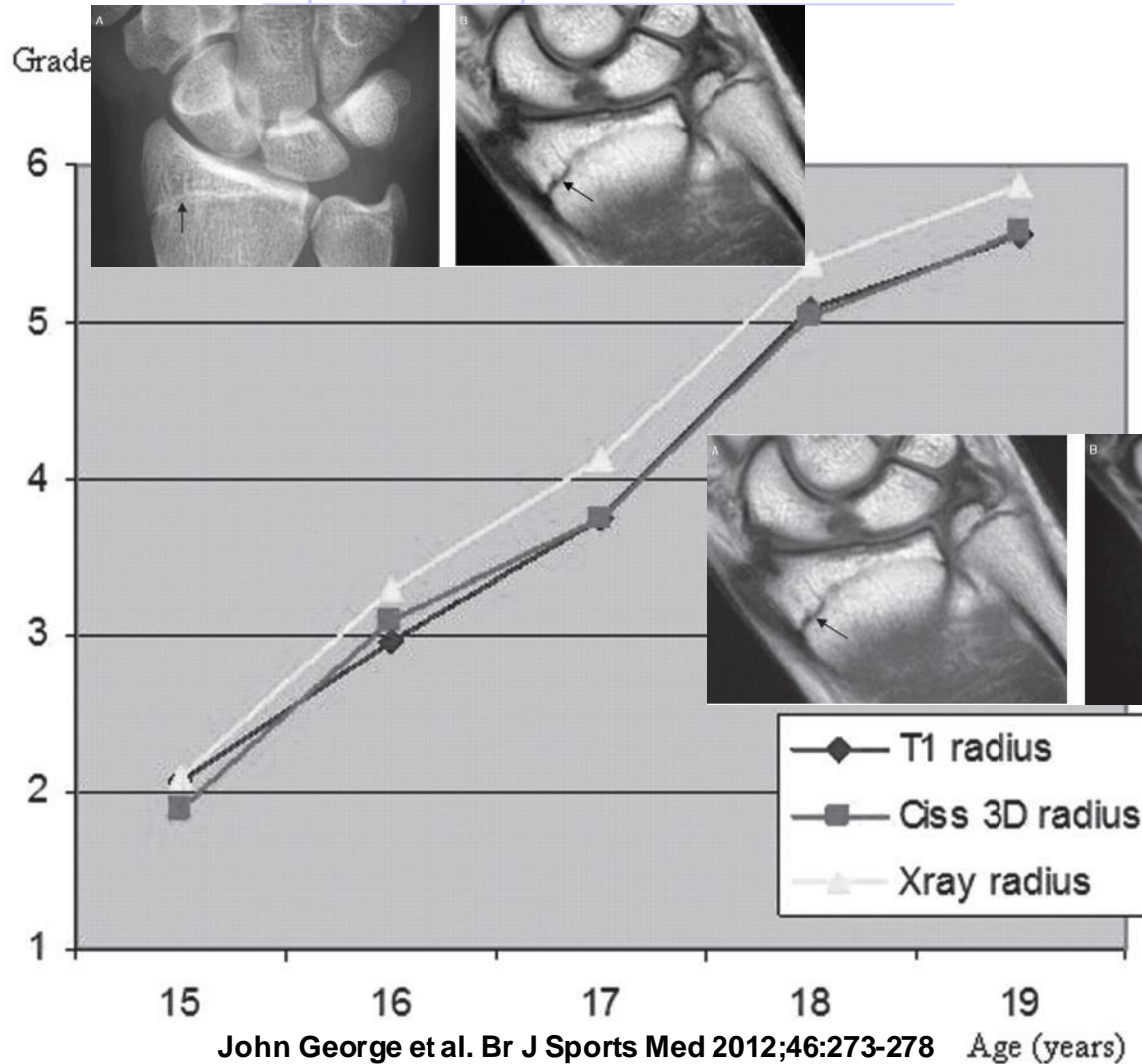
Dental x-ray- All but wisdom teeth at 16-20. EU 19/28

CT- clavicle (DE)



Grades of fusion of the distal radius for age groups 15–19 years comparing T1 MRI and plain radiographs*

<https://bjsm.bmj.com/content/46/4/273.full>





Age determination in Germany, 2016:

More **clinical examination and OPT**; fewer **hand** and **clavicle** x-rays

<https://www.ncbi.nlm.nih.gov/pubmed/28032243>

Int J Legal Med. 2016 Dec 28. doi: 10.1007/s00414-016-1517-y. [Epub ahead of print]

The role of forensic medicine and forensic dentistry in estimating the chronological age of living individuals in Hamburg, Germany.

Mansour H¹, Fuhrmann A², Paradowski J², van Well EJ², Püschel K².


⊕ Author information

Abstract

Age estimation represents one of the primary responsibilities of forensic medicine and forensic dentistry. It is an integral procedure aiming to estimate the chronological age of an individual, whose age is either unknown or doubtful, by means of assessing the stage of dental, skeletal, and physical development. The present publication reviews the methods and procedures used in estimating the age of young living individuals as well as the experiences of the Institute of Legal Medicine in Hamburg-Eppendorf, Germany, during the last 25 years. From 1990 to 2015, 4223 age estimations were carried out in Hamburg. During this time, forensic age estimation was requested by different concerned authorities including courts, the foreigners' registration office (Zentrale Ausländerbehörde), and the state office of education and consultation (Landesbetrieb Erziehung und Beratung). In the context of judicial proceedings, orthopantomograms, as well as X-ray examinations of both the left hand and the medial clavicular epiphyses were carried out in accordance with AGFAD recommendations. For investigations not associated with judicial proceedings, orthopantomogram examinations play a key role in the process of age estimation, due to their high diagnostic value and low radiation exposure. Since 2009, mainly unaccompanied young refugees were examined for age estimation. Orthopantomograms and clinical-physical examinations have been used as essential steps in this context to determine whether an individual is 18 years or less. Additional X-ray examinations of the left hand and the medial clavicular epiphyses have been used less frequently.

KEYWORDS: AGFAD recommendations; Forensic age assessment; Hamburg model; Institute of Legal Medicine Hamburg- Eppendorf

PMID: 28032243 DOI: [10.1007/s00414-016-1517-y](https://doi.org/10.1007/s00414-016-1517-y)



Forensic Age Estimation: Methods, Certainty, and the Law 2016

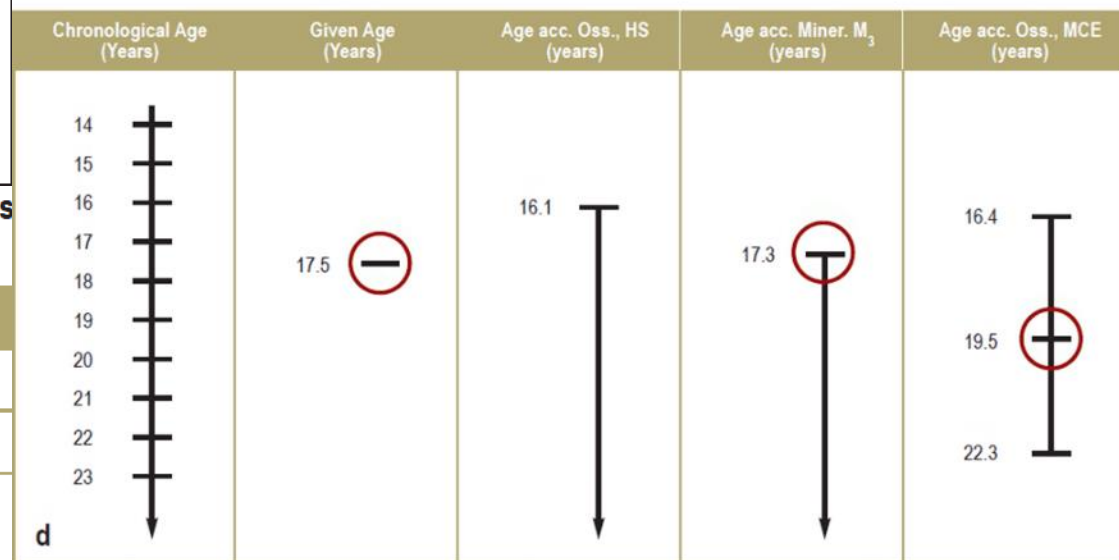
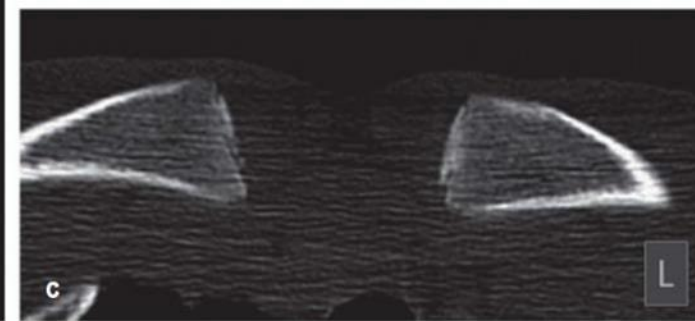
Schmeling, et al Dtsch Arztebl Int 2016; 113(4): 44-50;
<https://www.aerzteblatt.de/int/archive/article/173619/Forensic-age-estimation-methods-certainty-and-the-law>

KEY MESSAGES

- Forensic age assessment is carried out by medical experts on behalf of courts or authorities, to allow age-dependent legal procedures to be correctly carried out for undocumented young people.
- The methodology used for forensic age assessment depends on whether or not a legal basis for X-ray examinations without medical indication is present.
- The confidence level of age estimates without a legal basis for X-ray examinations is likely to be increased by the use of non-X-ray imaging methods.
- Age assessment reports should indicate variations and spread of age-related parameters.
- The minimum age concept allows statements about whether an age is under or over the legally relevant limits to be made with the highest standard of proof.

Effective radiation doses of X-rays used for age assessment (10, e19, e20)

X-ray examination	Effective dose (mSv)
Hand X-ray	0.0001
Orthopantomogram	0.026
Computed tomography of medial clavicular epiphysis	0.4



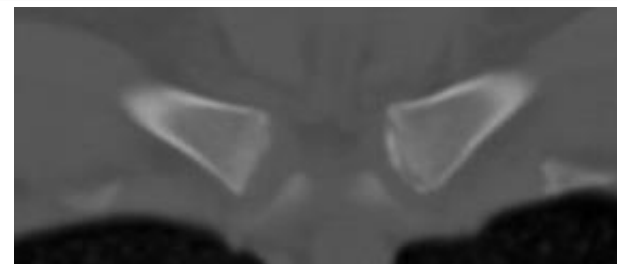
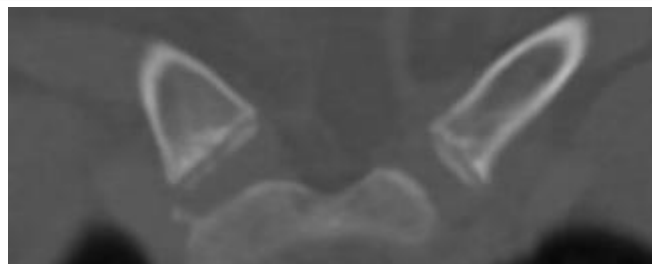
Forensic age estimation in living adolescents with CT imaging of the clavicle—impact of low-dose scanning on readers' confidence, 2020*

Gassenmaier S *et al. Eur Radiol* **30**, 6645–6652 (2020).

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	Low-dose imaging	Standard-dose imaging	<i>p</i> value
DLP (mGy*cm)	8.3 (IQR: 7.0)	226.8 (IQR: 68.5)	< 0.001
CTDI _{vol} (mGy)	0.3 (IQR: 0.2)	6.7 (IQR: 1.8)	< 0.001
Effective dose (mSv)	0.2 (IQR: 0.1)	4.6 (2.2)	< 0.001
Simulated effective dose ¹ (mSv)	0.1 (IQR: 0.0)	0.9 (IQR: 0.6)	< 0.001

¹: Analysis of 55 low-dose and 50 standard-dose cases
²: DLP dose length product, CTDI_{vol} computed tomography dose index



Low-dose CT imaging of the clavicle for age estimation in living adolescents is possible without loss of readers' confidence.



Non-medical human imaging in Sport and Age Assessment

- Optimise Cat 1 imaging for **diagnostic quality**
 - Age assessment now with a **holistic and evidence-based approach** for a uniform, robust and acceptable system to make important decisions with legal or asylum implications
 - Must take into account **gender, geographical, and ethnic** differences with consideration of normal distribution
 - Need for **consent** + **legally & ethically** acceptable solution
 - **Justification** by **specialist doctors, governing bodies and regulators** needed to balance benefit & **avoid financial bias**
 - **Sports precautionary and screening imaging needs guidance** to encourage uniformity promoting MRI and US where relevant
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