Non-medical Human Imaging in Sport and Age Assessment

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Northwick Park Hospital, UK
Category 1 non-medical human imaging: Specific Safety Guide SSG-55  

- 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)
3. Regulatory non-medical imaging: Licensing of athletes in fighting sports
4. **Precaution:** eg. TKO arachnoid cyst & subdural bleed in a boxer  

>650 boxers have died, most in USA  
Chronic traumatic encephalopathy (dementia pugilistica) common
### Regulatory licensing of athletes in combat sports: variation in requirements

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>CT</th>
<th>MRI</th>
<th>CT/MRI</th>
<th>No scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta: boxing, muay thai, kickboxing, mixed martial arts</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>British Columbia: boxing, mixed martial arts, wrestling, kickboxing</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Brunswick: Professional boxing</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohio: need doctor’s report</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>UK: British Board of Boxing Control</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Australia: combat sports</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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. Jiri Dvorak, 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! mcrm’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.

Mr. Johnson
Ballet Talk for Dancers Ballet Master.
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

Results Summary:

<table>
<thead>
<tr>
<th>Region</th>
<th>Area [cm²]</th>
<th>BMC [g]</th>
<th>BMD [g/cm²]</th>
<th>T-score</th>
<th>PR (Peak Reference)</th>
<th>Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>11.33</td>
<td>7.12</td>
<td>0.629</td>
<td>-2.7</td>
<td>68</td>
<td>-2.6</td>
</tr>
<tr>
<td>L2</td>
<td>12.57</td>
<td>9.80</td>
<td>0.779</td>
<td>-2.3</td>
<td>76</td>
<td>-2.1</td>
</tr>
<tr>
<td>L3</td>
<td>13.73</td>
<td>11.16</td>
<td>0.813</td>
<td>-2.5</td>
<td>75</td>
<td>-2.3</td>
</tr>
<tr>
<td>L4</td>
<td>14.86</td>
<td>11.76</td>
<td>0.792</td>
<td>-2.9</td>
<td>71</td>
<td>-2.8</td>
</tr>
<tr>
<td>Total</td>
<td>52.49</td>
<td>39.84</td>
<td>0.759</td>
<td>-2.6</td>
<td>72</td>
<td>-2.5</td>
</tr>
</tbody>
</table>
Need for age determination

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

Immigrant and migrant crisis: in whether off its coasts, on its or 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 of more than 10,000 children.
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 (15-18 yrs)
Tanner Whitehouse estimation: Wrist, Radius-Ulna Score, 20 Bone estimation
Dental Radiological Age Estimation: simple and sophisticated methods (Horner)


Fewer teeth to assess in older children

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

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Non-ossified ossification centre.</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Ossified ossification centre with non-ossified epiphyseal cartilage.</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Partially ossified epiphyseal cartilage.</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Fully ossified epiphyseal cartilage with a discernable epiphyseal scar.</td>
</tr>
<tr>
<td>Stage 5</td>
<td>Fully ossified epiphyseal cartilage with no discernable epiphyseal scar.</td>
</tr>
</tbody>
</table>

Medial clavicular ossification for age: evidence

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

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

a no documentation of X-ray findings
b no differentiation between partial and complete fusion
n.d. no data available

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


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.

<table>
<thead>
<tr>
<th>Country</th>
<th>Wrist XR</th>
<th>Hand XR</th>
<th>Clavicle XR</th>
<th>Dental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Netherlands</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>France</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK*</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

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

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.
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?
An age assessment is a procedure organised by a public body to determine the chronological age of an individual lacking legal documents.

23 countries made use of carpal X-ray
17 countries made use of dental X-ray
15 countries use clavicle X-ray
14 countries use of dental observation
8 countries undertook sexual maturation observation

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


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

*Mansour H¹, Fuhrmann A², Paradowski I², van Well EJ², Püschel K².*

**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

**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)

<table>
<thead>
<tr>
<th>X-ray examination</th>
<th>Effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand X-ray</td>
<td>0.0001</td>
</tr>
<tr>
<td>Orthopantomogram</td>
<td>0.026</td>
</tr>
<tr>
<td>Computed tomography of medial clavicular epiphysis</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Forensic age estimation in living adolescents with CT imaging of the clavicle—impact of low-dose scanning on readers’ confidence, 2020*
https://doi.org/10.1007/s00330-020-07079-y

<table>
<thead>
<tr>
<th></th>
<th>Low-dose imaging</th>
<th>Standard-dose imaging</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLP (mGy*cm)</td>
<td>8.3 (IQR: 7.0)</td>
<td>226.8 (IQR: 68.5)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>CTDI&lt;sub&gt;vol&lt;/sub&gt; (mGy)</td>
<td>0.3 (IQR: 0.2)</td>
<td>6.7 (IQR: 1.8)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Effective dose (mSv)</td>
<td>0.2 (IQR: 0.1)</td>
<td>4.6 (2.2)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Simulated effective dose&lt;sup&gt;1&lt;/sup&gt; (mSv)</td>
<td>0.1 (IQR: 0.0)</td>
<td>0.9 (IQR: 0.6)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

<sup>1</sup>Analysis of 55 low-dose and 50 standard-dose cases
<sup>2</sup>DLP dose length product, CTDI<sub>vol</sub> 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