Short report

Measurements of developing teeth, and carpals and epiphyses of the ulna and radius for assessing new cut-offs at the age thresholds of 10, 11, 12, 13 and 14 years

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A B S T R A C T

The minimum age of criminal responsibility is the youngest age at which children may be held liable for infringements of penal laws. New cut-offs at the age thresholds of 10, 11, 12, 13 and 14 years were determined by applying three different methods: measurement of open apices in tooth roots (T); the ratio between the total area of carpal bones and epiphyses of the ulna and radius (HW); and the combined method (THW). The sample consisted of 291 Italian children (152 boys, 139 girls), aged between 5 and 15 years. The sensitivity and specificity were established. As regards THW, specificity reached the maximum of 95% in boys aged 10, and the minimum of 87% in boys aged 11. The best score of the Positive Predictive Value (PPV) was obtained in boys at 10 years with the THW method and the worst in girls of 12 with the HW method.

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1. Introduction

One of the most complex and controversial questions confronting modern juvenile/youth justice systems is the Minimum Age of Criminal Responsibility (MACR). This is the age at which children are considered to be capable of committing crimes and accepting responsibility for their actions, thus rendering them liable for prosecution and formal sanctions. The MACR also indicates the lowest age at which a state or an international community is willing to hold children liable for their alleged criminal acts in a court of law.[1–3]

The practical outcomes for children without proof of age are often deplorable. Most often, judges simply guess children's ages by appearance, a fast route to discrimination in judicial processes.[1] Almost as frequently, courts ask medical professionals, who are not always available and/or competent in this specific field, to provide age estimates, and children languish in pre-trial detention. Conversely, in many countries, prosecutors and police officers regularly overstate children's ages, even registering children younger than MACR as adults, as retribution against alleged young offenders and to boost arrest and prosecution rates. They may target street children and poor children in particular, who are often less likely to have proof of age, and judges readily accept inflated age claims.[1]

A careful review of juvenile justice systems around the world was carried out by Cipriani in 2009,[1] and indicated that the MACR set by various countries ranged hugely, from as low as six years of age up to 18, with a median value of 12. Of the 192 countries members of the United Nations, 81 set the MACR at an age between 10 and 14 years (Table 1).

Some countries have varying age limits, according to the nature or severity of the offence. In others, the MACR depends on the relative maturity of the child within certain defined ages, according to the principle of *doli incapax*, i.e., the concept that, at certain ages, children are incapable of distinguishing between right and wrong and, more importantly evil.[1] The *doli incapax* individual is contrasted with the *doli capax* individual, as one who can discern between good and evil at the time when the offence is committed.

In the 28 countries of the European Community (EU), the MACR also varies hugely, from as low as 7 up to 15 years of age, with a median value of 14 (age established in 12 of the 28 EU countries).

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Table 1
Worldwide MACR (minimum age of criminal responsibility) provisions by country.

10	11	12	13	14
Australia	Barbados	Bolivia	Algeria	Bosnia and Herzegovina
Cameroon	Turkey	Brazil	Benin	Bulgaria
Cook Islands		Canada	Burkina Faso	Central African Republic
Côte d'Ivoire		Colombia	Burundi	Croatia
England		Costa Rica	Comoros	Democratic People's Republic of Korea
Fiji		Dominica	Djibouti	Germany
Guyana		Dominican Republic	France	Hungary
Kiribati		East Timor	Gabon	Italy
Malaysia		Ecuador	Guinea	Japan
Nepal		El Salvador	Haiti	Libyan Arab Jamahiriya
Niue		Eritrea	Madagascar	Liechtenstein
Palau		Ghana	Mali	Macedonia
Sierra Leone		Greece	Monaco	Marshall Islands
Suriname		Honduras	Nicaragua	Mauritania
Tuvalu		Ireland	Niger	New Zealand
Vanuatu		Israel	Togo	Panama
Wales		Jamaica	Tunisia	Paragauy
		Netherlands		Republic of Korea
		Perú		Romania
		San Marino		Rwanda
		Uganda		Slovenia
		Venezuela		Somalia
				Spain

Twenty-three of the EU countries apply an MACR of between 10 and 14 years.

In Italy, the age at which an individual becomes legally responsible is 14 years. Actual accountability between 14 and 18 years must be established case by case, mainly on the basis of assessment of psychological maturity (*doli incapax test*). At 18 years of age, a person is considered to be an adult, and would therefore be tried according to general criminal laws.

There are many practical challenges in implementing the MACR: in many countries children are not registered at birth and do not have documentation proving their age; judges and prosecutors may not take time to ascertain a child's age properly, and often simply rely on a subjective assessment of the age of the defendant in front of them. There are also problems regarding how children below the MACR are treated when they come into conflict with the law.[1,2]

In view of this reality, when governments or other agencies need to know the age of a child without documents, attempts are often made to estimate that child's age with a combination of assessment methods. The main aim of pooling age estimation methods is to report obtained age results and interpret them as a conclusive age outcome with narrowed prediction intervals.

Since 2000, researchers at the Institute of Legal Medicine, University of Macerata (Italy) have been extensively studying new methods for age estimation in both living and deceased subadults.[4] They have developed regression formulae for age estimation according to measurements of teeth (T), hand-wrist bones (HW) and/ or both areas (THW).[5—7]

The aim of the present study is to assess new cut-offs at the age thresholds of 10, 11, 12, 13 and 14 years by analysing dental mineralization patterns and the development of hand-wrist bones.

2. Materials and methods

2.1. Sample

This work is a retrospective cross-sectional study of radiographs. X-rays of hand-wrist bones and orthopantomograms (OPGs), taken from 291 native Italian children (152 boys, 139 girls) between the ages of 5 and 15, were analysed (Table 2). All were orthodontic patients and did not display any growth disorders. The X-rays were taken as part of routine treatment between 2008 and 2012.

For each radiograph, the subject's identification number, gender, date of birth, and date of X-rays were recorded. The chronological age for each case was calculated from the date of birth to the date of the X-rays, and was also recorded in a Microsoft Excel® file.

The OPGs of patients with hypodontia, hyperdontia or bilaterally extracted lower first molars were excluded from the study, since it was impossible to obtain complete data from them. Additional exclusion criteria were systemic diseases, premature birth, congenital anomalies, tooth agenesia, endodontic treatments, large carious lesions involving the dental pulp, gross mandibular pathologies, and poor-quality X-rays.

The nomenclature to classify teeth was that proposed by the F.D.I. (Fédération Dentaire Internationale) or a two-digit numbering system.

2.2. Measurements

Following Cameriere and Ferrante[6,7] for hand-wrist bones, X-rays of the left hand were taken in the postero-anterior projection, with fingers slightly splayed. X-ray images were processed by computer-aided drafting (Adobe® Photoshop® CS4). The

Table 2
Age and gender distribution of Italian sample.

Age (years)	Females	Males	Total
5	4	6	10
6	8	5	13
7	7	6	13
8	13	12	25
9	14	12	26
10	24	14	38
11	17	20	37
12	14	12	26
13	15	24	39
14	14	27	41
15	9	14	23
Total	**139**	**152**	**291**