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Forensic Anthropology Population Data

Age assessment using the Greulich and Pyle method on a heterogeneous sample of 300 Italian healthy and pathologic subjects

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ABSTRACT

The exponential growth of the illegal immigration phenomenon, the requests for asylum, and the increasing number of migrant settlements on Italian territory have strong repercussions on the legal system. One important aspect of this problem is age assessment. In the case of living individuals, identification may be focused on ascertaining their age, more directly if they can attest their age but are not registered (foreigners who claim to be minors or under 14 years of age). These have entered our country as illegal immigrants and have an interest in declaring a younger age (as a minor or under 14) rather than their true age because they can obtain the benefits specifically provided by Italian law for such categories. Since the most frequently used method in age assessment is the Greulich and Pyle Atlas, the objective of this study was to evaluate the consistency and accuracy of the method on a sample of Italian teenagers, in order to ascertain whether or not the Atlas is suitable for the purpose, especially in the critical threshold between 14 and 18 years of age. A total of 300 radiographs of the left wrist and hand of individuals between 10 and 20 years of age were obtained from the outpatient Pediatric Radiology Department of the Papa Giovanni XXIII Hospital in Bari. The results showed that the Greulich and Pyle Atlas, used on the Italian population, provide a good match with the chronological age, showing no statistically significant differences. The Greulich and Pyle Atlas is usable on the Italian population since there were no significant differences in skeletal age determination with this method as compared to the chronological age; however, one must allow for a possible standard deviation equal to more or less 13 months.

In recent years, the exponential growth of the illegal immigration phenomenon and the presence of ever more numerous migrant settlements in the Italian territory have had strong repercussions on the legal system. One important problem is age assessment, also for the purposes of determining criminal liability of individuals with no identity documents or unreliable papers. Moreover, the practice of not registering the birthplace of the refugee in their country of origin means that often such individuals will not even possess an identity document [1,2]. The issue is particularly important when determining the age of individuals between 14 and 18 years of age.

In general there is a close relationship between the notion of liability for delinquent or criminal behaviour and other social rights and responsibilities (such as marital status, civil majority, etc.). For example, in most States in the US the age of criminal liability is 16 or 18, the age at which young offenders are dealt with in the adult criminal justice and penal systems where the legal consequences for adult offenders apply.

In Council of Europe countries the age of criminal liability ranges from the end of infancy (7– 10 years) – for UK countries, Ireland, Greece, Cyprus, Malta, Liechtenstein and Switzerland – to the onset of adolescence (12–14) – for France, Germany, Italy, the Netherlands, Austria, Portugal and some of the countries of central and eastern Europe. Finally, there are countries which stipulate the end of adolescence (15–18) like the Scandinavian countries, Spain, Belgium, Luxembourg and some eastern European countries [3].

In Italy, article 97 of the Criminal Code states that the grounds for liability are full awareness that an action is wrong, and of the consequences of such an action; therefore anyone under 14 is not liable by law as they are not considered to be in full possession of this awareness.

On the other hand, for individuals between the ages of 14 and 18, it is necessary to investigate each case on its own merits. On this basis, in any case of doubt about the age of the individual the judge must commission forensic tests (as per Art. 220 Criminal Code), which are considered the only effective means in the

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absence of official or reliable data with legal value. If doubt persists even after an expert opinion, on the principle of "favor rei", the individual will be assumed to be less than 14 years old. Therefore, the need for more in-depth studies is evident, using other techniques in order to reliably determine the age of the person. These should seek to obtain more accurate results for the fundamental requirements of application to both civil and criminal law cases [4,5].

The determination of age in living individuals requires a multidisciplinary approach involving physicians with knowledge of auxology, radiology, dentistry and forensic medicine [6]. The indicators most commonly used in age assessment are those related to somatic, gender, bone and dental maturity [7]. X-rays for the study of bone growth help to enable the determination of chronological age; this technique has been used since the beginning of the 20th century (Rotch). Bone age determined by the observation of ossification corresponds to the age of individuals with normal growth. We know for a fact that females grow earlier: 3 weeks earlier during the embryonic period, 4–6 weeks at birth and up to 2 years during puberty.

The observation of ossification is mainly based on hand X-rays, palm up and down, shown to be one of the most reliable methods for chronological age assessment (qualitative methods). This is based on observing the growth of the nuclei, as well as on comparison with reference tables and images. It includes morphological comparison between X-rays taken at intervals of 6 months or 1 year, thus establishing age within defined temporary intervals. The most important exponents of these qualitative types of studies were Greulich and Pyle, authors of the famous Atlas published in 1959 [8].

Recently [9] the Forensic Anthropology Society of Europe proposed a review of the field of age estimation, highlighting the advantages and limits of each method, and deemed that the Greulich and Pyle method was quicker and easier to use to determine the skeletal age of living individuals [9]. In fact, the use of X-rays of the wrist and hand in determining bone age is rapid, objective and involves minimal radiation exposure.

In compliance with Italian law, a minor does not begin to be liable for a crime until the age of 14. The liability of a minor between the ages of 14 and 18 is at the discretion of the juvenile court; such liability must be examined on a case-by-case basis, assessing whether the minor under 18 was of sound mind while committing the crime. As from the 18th birthday, the individual is considered liable. The purpose of our research was to provide a further contribution to determining skeletal age. We focused particularly on X-rays of the left hand and wrist.

1. Materials and methods

Since the Greulich and Pyle method is the most frequently used in age assessment, the objective of this study was to evaluate the consistency and accuracy of the method on a large sample of Italian teenagers, in order to ascertain whether or not the Atlas is suitable for the purpose, especially for the critical growth period between 14 and 18 years of age. Since the 1959 G–P Atlas was compiled using data on American children, our study was carried out mainly on Italian individuals, especially from the Puglia region, with the ultimate goal of assessing the validity of the method for the Italian population as well.

A total of 300 X-rays of the left wrist and hand were obtained from individuals between the ages of 10 and 20 from the outpatient paediatric radiology department of the Papa Giovanni XXIII Hospital in Bari. The data recorded were:

- full name
- gender (154 males and 146 females)
- date of birth
- department of origin: 224 from the paediatric endocrinology department; 9 from paediatric internal medicine; 9 from paediatric nephrology; 20 from the emergency department, 20 from healthcare, 17 from primary healthcare, 1 from the department of paediatric orthopaedics,
- working diagnosis (GH deficiency, short stature, obesity, early and delayed puberty, adrenogenital syndrome, trauma, thyroiditis, phenylketonuria, nephrotic syndrome, hypothyroidism, rectal ulcerative colitis, Noonan syndrome)
- height and weight
- chronological age

The tables were then given to four operators with different levels of experience, assigned the task of estimating the skeletal age of single X-rays according to the Greulich and Pyle method. The 4 operators (1 radiologist, 2 forensic experts, 1 house physician) used the same reference tables and an average time per evaluation of about 1 min.

In this blinded study, an external operator converted the data into tables by assigning a numerical code to the single elements of the sample; the known chronological age was omitted from the tables.

Subsequently, the data pertaining to gender, to chronological age and to bone age assessed by the 4 operators conducting the blinded study were recorded on special cards and inserted in a database created with File Maker Pro 9 software. The data were analyzed by Epi-Info 3.3 (public domain software-CDC Atlanta, Georgia; WHO Geneva, Switzerland). Quantitative variables were expressed as mean, standard deviation and range; qualitative variables were expressed as proportions and 95% confidence intervals.

The ANOVA test was carried out to evaluate differences between the mean bone ages assigned by the single operators. To evaluate the differences between the mean bone age assigned by the single operators and the chronological age, Student t test for paired samples was applied.

In addition, the correlation between the bone age assigned by the operators and the chronological age was verified by calculating the value of the gradient coefficient and the coefficient of determination. For all tests, significance was set at a value of $p < 0.05$.

2. Results

The results obtained were first distinguished in relation to gender; the pie charts below report:

(1) skeletal age deviation calculated with respect to the chronological age estimated by each of the 4 operators in males (Fig. 1);
(2) skeletal age deviation calculated with respect to the estimated chronological age in females (Fig. 2).

Of the 300 X-rays evaluated, 154 (51.3%; 95% CI = 45.4–57.1) were of males and 146 (48.7%; 95% CI = 42.9–54.5) of females. The mean chronological age of the individuals evaluated was 12.3 years (SD = 2.0; range 9–19), being 12.4 (SD = 2.1; range = 9–19) years for males and 12.3 (SD = 1.9; range = 9–17) years for females ($t = 0.57$, $p = 0.56$).

The mean bone age attributed by the single operators to the X-rays evaluated was 12.09 years (SD = 2.33; range = 5–19), with no significant difference as compared to their chronological mean age ($t = 1.43$, $p = 0.15$).

Overall, no significant differences in the mean bone age assigned by the four different operators were observed ($F = 1.05$, $p = 0.38$; Table 1).

The mean bone age measured by operator 1 and by operator 2 did not differ from the mean chronological age (operator 1: $t = 0.72$, $p = 0.46$ – operator 2: $t = 1.39$, $p = 0.16$), whereas there were significant differences between the chronological age and bone age calculated by operator 3 ($t = 2.67$, $p = 0.007$) and operator 4 ($t = 2.01$, $p = 0.04$). Analysis of the correlation between chronological age and estimated bone age showed statistically significant differences for all four operators taken together ($R^2 = 0.51$, $p = 0.0001$; Fig. 3), as well as for each operator (Figs. 4–7). However, it should be noted that the coefficient of determination is quite low for operators 3 and 4. The mean difference between the bone age and the true chronological age amounts to 0.005 (SD = 1.63); this difference is not statistically significant ($t = 0.59$, $p = 0.27$). The mean difference between the bone age estimated by individual operators and the master data is 0.27 for operator 1 (SD = 0.271, $t = 2.85$, $p = 0.02$), 0.16 for operator 2 (SD = 1.46, $t = 1.93$, $p = 0.03$) 0.09 for operator 3 (SD = 2.12,