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Age estimation in Egyptian children by measurements of carpals and epiphyses of the ulna and radius

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ABSTRACT

One of the most frequently used area for age estimation, in children and adolescents, is hand–wrist. This retrospective study of 257 Egyptian children and adolescents (142 boys and 115 girls), aged 4–18 years, used the ratio between the total area of carpal bones and epiphyses of the ulna and radius (Bo) and carpals (Ca) as age indicators. Age calculated, using a formula reported earlier for an Italian sample, resulted in a standard error of estimate of 1.96 years. The new regression model for the Egyptian population, describing age as a linear function of gender (g) and the ratio between carpal bones area and carpal area (Bo/Ca), yielded the following equation: Age = −0.998 + 18.708 (Bo/Ca) + 1.724 g (Bo/Ca). This model explained 71% of total variance. The median of the absolute values of residuals (observed − predicted age) was −1.67 years, with a standard error of estimate of 1.85 years. It can be concluded that the Cameriere's method is not completely suitable for the Egyptian sample and a new modified formula was proposed.

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1. Introduction

Forensic age assessment in living children and adolescents is an established research sector in the field of forensic human identification [1]. The main importance in age estimation lies in the assessment of criminal liability and protection of unaccompanied minor immigrants, when they have no identification documents providing their correct birth dates [2,3]. Within clinical medicine, age assessment assists in diagnosis and treatment planning. It is also an important clinical tool in the area of pediatrics, especially in relation to endocrinological problems and growth disorders [2,4].

In Egypt, the juvenile justice system operates with a specific set of rules and procedures intended to reflect the child's limited responsibility, with the recently reformed child law now setting the minimum age of criminal responsibility at 12 years. In addition, the child law stipulates that children aged between 7 and 12 years who commit a crime shall have their case considered by the child court. Thus, although the age of criminal responsibility is 12 years, according to the law, children can be tried at the age of seven already [5]. It is therefore very important to assess age with accurate and reliable methods, in order to determine whether juvenile penal systems or penal systems in force for adults are to be applied [1,6].

Among the updated recommendations of the Study Group on Forensic Age Diagnostic of the German Association of Forensic Medicine (AGFAD), X-ray examination of the hand–wrist bones is one of the fundamental steps for assessing age in children and adolescents [7,8]. Examination is facilitated by the absence of other hard tissues, the low level of radiation exposure, and the large number of bones, making this area preferential for age evaluation [9,10].

Many methods exist to evaluate the growth advancement of the hand–wrist region [2]. The quickest and sufficiently accurate technique for this purpose is the Greulich and Pyle atlas [11]. This method has the advantages of simplicity and availability of multiple ossification centers for the evaluation of maturity [12–14].

In the last few years, the increasing number of auxological and forensic questions has encouraged new studies of bone mineralization and maturation as an age indicator. One of the most recent is a quantitative method published by Cameriere at al. [9] which analyzed the mineralization of carpal bones and distal

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epiphyses of ulna and radius. In 2007, the technique was tested in a large sample of Slovenian children and adolescents aged between 6 and 16 years [15]. More recently, Cameriere and Ferrante [16] and Cameriere et al. [17] used a combination of both teeth and hand–wrist bones for age estimation in children. The results obtained were interesting and highlighted better accuracy compared with results achieved with teeth or hand–wrist bones separately.

Although the assessment of age according to carpal bones development is one of the most commonly used method, there are well-known factors which affect these criteria such as gender, human variability, socio-economic status, systemic diseases, nutritional disorders, constitutional growth retardation, congenital and endocrinal disorders (hypothyroidism, congenital adrenal hypoplasia, precocious puberty, etc.) [18,19]. It is therefore necessary to check the accuracy and reliability of this technique in order to verify whether the regional background, gender, chronological age distribution of the sample, and statistical procedure represent major factors controlling accuracy and reliability in sub-adult age assessment.

The present study aimed to analyze the possible applications of the proportion of carpal area maturation as a criterion of age estimation and to verify the accuracy of the Cameriere's method [9] for assessing chronological age in a sample of Egyptian children and adolescents. Last but not least, if this formula turns out to be unsuitable, it aimed to study a specific formula for this population. In fact, fundamental to all comparative work in skeletal biology is the question as to whether age changes are uniform across populations and researchers have urged testing of these methods in print.

2. Materials and methods

2.1. Study design

This is a retrospective cross-sectional radiographic study of patients treated at the Orthodontics Department (between 2007 and 2009), Faculty of Dentistry, Mansoura University. Children from the outpatient clinic of University Pediatric Hospital (2011–2012), Faculty of Medicine, Mansoura University were also included in the study.

This study followed the ethical guidelines of the Mansoura University's Research Ethics Committee. Pre-existing radiographs were used and patients' information was kept anonymous.

2.2. Sample

Radiographs of hand–wrist bones from 257 Egyptian children and adolescents (142 boys and 115 girls), aged between 4 and 18 years, were analyzed. X-ray films in the postero–anterior projection were taken of the left hand, with fingers slightly splayed. Subjects included in this study fulfilled normal findings on the radiograph of the left hand with neither bone (including fracture) nor soft tissue abnormalities and no medical record of congenital disorder or developmental disturbances.

With regard to the hand–wrist bones, mineralization of this area begins at birth and lasts until approximately 13 years for girls and 15 for boys for carpals, and 16–17 years for epiphyses of the ulna and radius.

All radiographs were performed by an X-ray experienced technician. Radiographs were in digital form and they were recorded on computer files, which were processed with a computer-aided drafting program (Image Tool program for digitalized images (UTHSCSA, Texas, USA).

2.3. Skeletal age estimation

Chronological age (CA) was calculated by subtracting the date of the radiograph from the date of birth after having converted both to a decimal age.

Skeletal age (SA) estimation was performed according to the method of Cameriere et al. [9]. The mathematical areas of carpal bones and the epiphyses of ulna and radius were identified (Fig. 1A) and added together to yield the global values of bone areas (Bo). The mathematical area of each carpal bone was selected and the pixel areas were calculated and added together to yield the global values of carpal area (Ca). If two bones overlapped, the common area was calculated only once (Fig. 1B). Lastly, to normalize measurements, the Bo/Ca ratio between total area of bones and carpal area was calculated. With the Bo/Ca ratio, the age was estimated as follows:

Age HW (hand–wrist) $= -3.253 + 0.719g + 20.610$ (Bo/Ca) (formula 1).

where g is the variable equal to 1 for boys and 0 for girls.

This is the linear regression formula, also available as an MS Excel template at the website of the Istituto di Medicina Legale, Universitá degli Studi di Macerata (Italy), AgEstimation project: http://agestimation.unimc.it.

The CA of each individual together with his/her gender and Bo/Ca ratio were entered in an EXCEL® file for use in the subsequent statistical analysis.

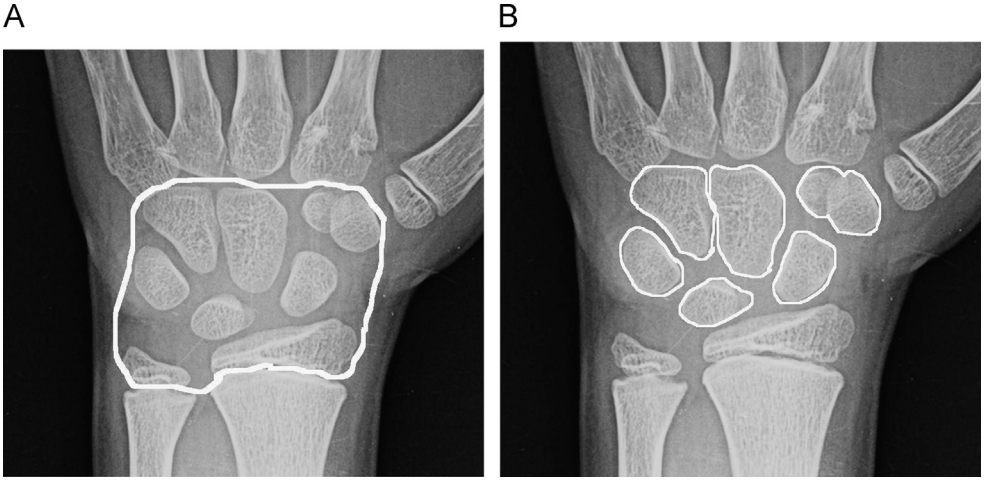

Fig. 1. (A) an example of the bone area (carpal bones and the epiphyses of ulna and radius) selected; (B) an example of correct selection of carpal bones. Note that, overlapping area between trapezium and trapezoid is calculated only once.

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