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Forensic Anthropology Population Data

Radiographic fetal osteometry: Approach on age estimation for the portuguese population

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ABSTRACT

The estimation of gestational age (GA) on fetal remains can be an important forensic issue. Forensic specialists usually use reference tables and regression equations derived from reference collections, which are quite rare in what fetuses are concerned. Since these tools are mostly grounded on ultrasonographic measurements, which are known to differ from real bones measurements or are based on ancient literature, this study aimed the construction of tables and regression equations for the Portuguese population on the basis of diaphyseal bone length measurements (femur, tibia and humerus) of 100 fetuses of known GA, using post-mortem radiographs.

There is a strong correlation between the longitudinal length of studied bones and GA; the femur exhibits the strongest correlation ($r = 0.969$; $p = 0.000$), followed by the tibia ($r = 0.966$; $p = 0.000$) and the humerus ($r = 0.963$; $p = 0.000$). Therefore it was possible to obtain regression equations and to build tables with reference values for each of the diaphysis analyzed.

1. Introduction

Fetal age estimation is still a difficult task, especially since this kind of remains is unusually found, making it hard for the anthropologist to become comfortable when studying it [1,2]. However, it can be of important forensic value, particularly when it is necessary to determine the fetus viability, or in other words, if the fetus could have been born alive [3–7], even knowing that the skeleton alone will not convey the information about whether the fetus was born alive or dead, unless it is regarding neonate's remains [1–3].

The two main criteria used for fetal age estimation are dental mineralization and skeletal data, such as long bone diaphyseal length [1,3,6], which is highly correlated with gestational age [8–13] and quite resistant to decomposition when comparing with other fetal structures [2,3,5,8]. Although dental age is recognized as more reliable than skeletal age, in many forensic instances the human remains do not include dentition. It is thus of upper-most importance to test the reliability of diaphyseal length for the purpose of age evaluation. Furthermore, recent studies advocate that the derived regression equations used for this estimation are, in some way, specific for each population and should be based on recent well-documented samples. As shown by various studies, size at birth is affected by secular trends which affect fetal length and depends on factors such as environmental improvements and socio-economical status [14–16]. Considering the size of fetal bones, even small differences may cause a big impact in age determination and, therefore, affect the outcome of forensic cases.

When estimating skeletal age, forensic specialists typically use reference tables and specific regression equations that are derived from reference samples such as osteological collections. Yet, the lack of large identified skeletal collections including fetuses precludes the existence of appropriate formulae [8]. Consequently, these tables are mostly based on ultrasonographic measurements [9–12] that might differ from actual measurements on dry bone [17,18]. Moreover, formulae applicable on dry bones have two-steps and are mostly supported by outdated literature [8,13]. Until now, the most used reference to estimate fetuses' age at death has

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been Fazekas e Kósa's data, which dates back to the 1970s and was derived from historical and not identified samples [8]. The need to develop new standards and to evaluate their specificity in relation to the population on the basis of which they were developed has become obvious. Recent studies, as is the case of Adalian et al. [4,17], who validated a methodology using measurements made on radiographies, which are more reliable than ultrasound measurements, used an identified sample, obtained from a hospital database.

As such, the main goal of the present study was to update fetal radiographic data for the Portuguese population, using a validated method [17]. The authors also sought to identify which of the three studied bones (femur, tibia and humerus) was more accurate to estimate gestational age. Also, it was intended to assemble reference tables for each bone to simplify gestational age comparisons. The final purpose of this study was to compare the obtained equation for the femur with the formulas developed by other authors with the same aim, namely those from Fazekas and Kósa, Adalian et al. and Scheuer and Black [8,17,19].

2. Materials and methods

The present study was based on a validated method, using plain radiographs (XR) from fetuses of known gestational age. The decision of employing XR measurements was due to the fact that they are more reliable than ultrasound measurements and can easily be used when the subject of study (in forensic context, for instance) retains soft tissues [4,17,18].

This was a retrospective cohort study. Anonymous fetopathological autopsy records from spontaneous and therapeutic abortions (meaning that none of the fetuses was born alive), performed at Hospital Garcia de Orta, E.P.E. (Almada, Portugal) were collected. All abortions occurred between 2000 and 2011. There were no ethical issues involved since there was authorization to perform plain radiographs and autopsies following the hospital's protocol, as well as to use these data in further investigations; on the other hand, there was no additional manipulation of the fetuses.

The sample used in the present study consists of 100 fetuses (55 males; 45 females) with an age range between 13 and 40 weeks of gestational age (GA). The mean age at death is 26.11 weeks (SD = 7.74). The selection of the fetuses was made according to the following criteria:

- GA between 13 and 40 weeks;
- Absence of external limb malformation;
- Absence of pathological alterations which could compromise normal skeletal growth (e.g. Intra Uterine Growth Restriction);
- Lack of maternal pathology;
- Time elapsed between intrauterine death and fetal expulsion inferior to a week;
- Twin pregnancies were included only when there were no signs of discordant growth.

Diaphyseal bone length measurements of the femur, the tibia and the humerus were performed using post-mortem radiography (XR), taken with Siemens Mobilett II equipment (Global Siemens Healthcare Headquarters – Siemens AG, Healthcare Sector, Henkestrasse 127, D-91052 Erlangen, Germany); XR were then stored in a software application called *Centricity® Radiology*, developed by General Electric Company© (GE Healthcare Global Headquarters, Pollards Wood, Nightingales Lane, Chalfont St. Giles HP8 4SP, United Kingdom).

Considering that XR records are collected form a hospital background, the fetuses belong to an identified sample, which is of great empirical value to develop formulas for each population [4,17].

Measurements of the larger dimension of the three long bones chosen for this study were taken with a 0.5 mm graduated metal ruler. Whenever it was necessary, the obtained value was converted to scale (included in the XR). As a rule, the measurements were performed on the left side, with the fetus placed anteroposteriorly (Fig. 1), otherwise the measurements were taken with the fetus placed laterally (Fig. 2).

The calculation of GA was made in weeks, following the standard terminology used in obstetrics [9–11] and forensic sciences [7]. Classical formulae calculate GA in lunar months [8,13].

Statistical analysis was performed with SPSS® (Statistical Package for the Social Sciences) 17.0. Gestational age and the longitudinal dimensions of the long bones were treated as continuous variables. The normal distribution of the variables was assessed through the skewness and kurtosis of the distributions [20] and the *Q–Q* plots. The equality of variances was evaluated with a Levene's test. All the variables are modeled by a normal distribution. The reliability of the method was evaluated with the relative Technical Error of Measurement (rTEM) [21]. A Student's *t*-test for independent sampled was used to evaluate if gender affected the length of the long bones. A linear inverse calibration model was used to predict gestational age at death, with gestational age as the response variable. 95% CI formulae were also included to encompass a range within which the parameter "gestational age" is estimated to be located.

Fig. 1. Typical radiograph – anteroposterior position.

In order to construct easy access reference tables, the sample was divided in six groups comprising five gestational weeks.

Fig. 2. Typical radiograph – lateral position.