



Sonographic examination of the apophysis of the iliac crest for forensic age estimation in living persons



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ABSTRACT

The present study examines the applicability of ultrasound diagnostics in assessing the ossification processes of the apophysis of the Crista iliaca of the pelvis for the purposes of forensic age diagnostics in living persons. To this end, the apophyseal ossification stages were determined in 307 female and 309 male study participants aged between 10 and 25 years.

In females, ossification stage I was identifiable at an age of 10.1 years at the earliest ($\bar{x} = 11.8$), ossification stage II at 11.2 years at the earliest ($\bar{x} = 14.6$), ossification stage III at 14.7 years at the earliest ($\bar{x} = 18.6$), and ossification stage IV at 17.9 years at the earliest ($\bar{x} = 22.7$). In males, ossification stage I was observable from an age of 10.0 years ($\bar{x} = 11.8$), ossification stage II from 10.5 years ($\bar{x} = 14.9$), ossification stage III from 15.6 years ($\bar{x} = 18.9$), and ossification stage IV from 17.4 years ($\bar{x} = 22.6$).

In forensic age estimation procedures in living persons, sonographic examination of the iliac crest apophysis makes it possible to minimise exposure of the individual to radiation in accordance with the existing legal basis for the use of X-rays on humans. In application areas with no legal basis to justify X-ray examinations, the accuracy of an age diagnosis can be improved by integrating skeletal maturity as a criterion.

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1. Introduction

According to an estimate by the International Organisation for Migration (IOM), the number of migrants worldwide in 2010 is amounted to 214 million people [1]. For many years, a large number of persons whose exact birth dates are unknown or obviously contradict their apparent age have been observed in many countries of the world, particularly within this group. Depending on the legal parameters applicable in each case, a variety of legal problems arise which make detection of the true chronological age of a person procedurally significant [2]. This is the context in which criminal age estimation procedures have gained their greatest significance to date. They serve both to safeguard legal certainty within the state as well as to protect the individual interests of a defendant. According to the current recommendations of the international Study Group on Forensic Age Diagnostics (AGFAD) of the German Association of Forensic Medicine [3], examination methods which help to gather characteristics of physical maturity and characteristics of dental and skeletal developments should be combined for the purposes of forensic age estimation in the area of criminal law.

With the intensification of cross-border migration movements, forensic age estimation procedures today also play an ever greater role in areas of the law which have to examine any claims made by

the persons concerned to receive benefits from social security systems. In such cases, the investigation of age-relevant developmental characteristics is to a much greater degree depending upon the cooperation of the claimant. What is particularly problematic in this context is the establishment of criteria of skeletal maturity, as the use of ionising radiation on human beings is in many cases strictly regulated by law so that there is frequently no state legitimation for an examination. For this reason, in the case of age estimation in adolescents and young adults outside criminal proceedings, AGFAD recommendations are limited to a physical examination and a dental inspection of the oral cavity [4]. However, this limitation of the range of examinations available in the relevant sectors of the law considerably restricts the safety of age diagnoses. One of the aims of current research efforts is, therefore, to establish examination methods with which the characteristics of skeletal maturity can be surveyed without the use of ionising radiation, thus improving the accuracy of an overall age diagnosis.

Radiological examination of the apophysis of the iliac crest has long proved its applicability in estimating the status of an individual's skeletal maturity, especially in the clinical orthopaedic field. In order to be able to utilise the process of ossification of this skeletal element for forensic age estimation purposes, it was recently analysed from this point of view too [5,6], on the one hand based on the projection radiography stages of Risser [7], on the other hand based on the projection radiography stage classification for clavicular ossification put forward by Jit & Kulkarni [8], as well as the modification for

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computer tomography based on this which was proposed by Kellinghaus et al. [9]. A pilot study finally provided evidence that sonographic examination of the iliac crest apophysis is an efficient and valid method of making use of a characteristic of skeletal maturity in forensic age estimation even outside the area of criminal law [10].

The present study examines the value of skeletal sonography in assessing the age-dependent process of ossification of the apophysis of the Crista iliaca in a more extensive population.

2. Test persons and methods

The basis of the present study is the prospective sonographic determination of the stage of ossification of the iliac crest apophysis which was carried out in a group of volunteer test participants. The research project was preceded by a positive vote in the responsible ethics commission.

A total of 307 female and 309 male individuals aged between 10 and 25 years were examined. Fig. 1 shows the figures relating to all the case groups that are studied and arranged by sex and chronological age.

The study collectively reflected the average composition of the population of the Federal Republic of Germany. In none of the cases studied were there any indications of diseases which could potentially influence skeletal maturation.

Following a preliminary interview during which information was imparted in a manner appropriate to the age of the person concerned, each study participant or legal guardian gave his/her consent for the performance of the sonographic pelvic diagnostic procedure.

The ultrasound examinations were carried out with a digital DP-6600 system (Mindray, Shenzhen, PR China), using a 7.5 MHz linear array transducer. The left apophysis of the iliac crest of each test person, lying in abdominal position, was explored following adjustment of the longitudinal sectional planes by means of parallel shift of the transducer in its entire anterolateral–posteromedial spread.

A physician with experience in imaging procedures used in forensic age estimation and certified in compliance with the guidelines of the Study Group on “Musculoskeletal Organs” of the German Society for Ultrasound in Medicine (DEGUM) undertook the sonographic ossification stage determination in the entire study population. In 61 cases, the examinations were repeated by a similarly qualified second physician to investigate interobserver agreement. Neither examiner was previously aware of the chronological age of any of the test participants.

The assignment of each ossification stage of the apophysis of the Crista iliaca was based on the somomorphological classification

already used in the pilot study [10]. These, for their part, rested upon the stage definitions of clavicle development formulated for skeletal sonography by Schulz et al. [11]:

- Stage I: (no ossification of the apophyseal ossification centre)
The upper edge of the iliac crest displays an acute-angled configuration. A secondary ossification centre (apophysis) cannot be represented anywhere in the entire area examined.
- Stage II: (ossification of the apophyseal ossification centre; no ossification of the apophyseal plate)
The upper edge of the iliac crest is divided by a sound gap from a secondary ossification centre (apophysis) throughout the entire area examined.
- Stage III: (partial ossification of the apophyseal plate)
In the area examined, both sectional planes with a sound gap between the upper edge of the iliac crest and the secondary ossification centre (apophysis) as well as sectional planes with a convexly curved upper edge of the iliac crest with no separate ossification centre (apophysis) can be detected.
- Stage IV: (complete ossification of the apophyseal plate)
The upper edge of the iliac crest displays a convex curve throughout the entire area examined. A separate ossification centre (apophysis) cannot be defined.

Fig. 2 gives a schematic overview of the somomorphological characteristics of each of the ossification stages of the iliac crest apophysis. Figs. 3 to 5 present examples of sonograms showing the characteristic features of stages I, II and IV.

IBM SPSS software (release 20.0.0) was used for the statistical evaluation of the data. To describe the individual ossification stages, divided by sex, a number of statistical parameters were calculated (minimum age, maximum age, mean value with standard deviation, median with lower and upper quartile). Potential significant differences between the sexes in relation to distributions of the individual ossification stages were analysed with the aid of the Mann–Whitney test ($p < 0.05$; exact two-sided). As a statistical measure for interpreting the correlation of the stages diagnosed by the two examiners, we selected the weighted kappa coefficient.

3. Results

In a total of 613 cases, it was possible to determine the sonographic ossification stage of the iliac crest apophysis. In three cases, no stage classification was possible due to limitations placed on

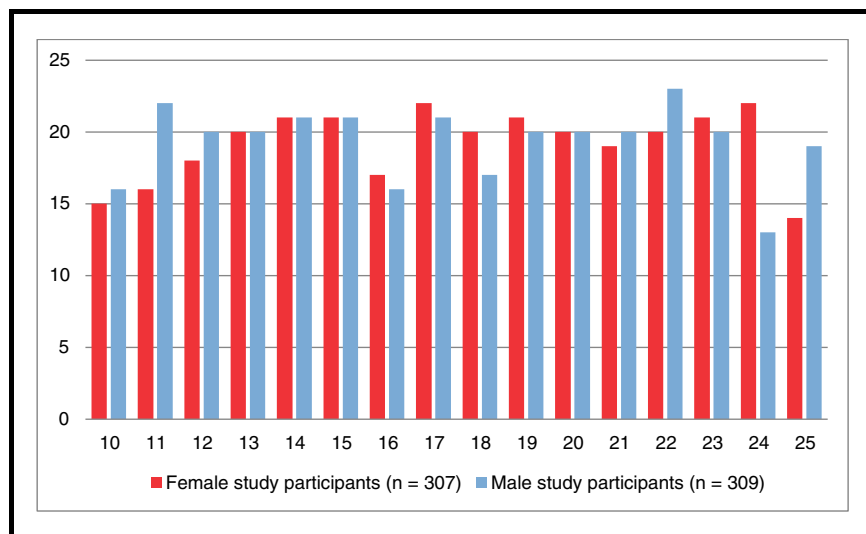


Fig. 1. Number of cases by age and sex ($n = 616$).

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