



Forensic Anthropology Population Data

Identification of age and sex based on knee radiography

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ABSTRACT

The identification of age and sex constitutes the cornerstone in biological profile determination. Identification of age and sex depends mainly on ossification of bones and sexual dimorphism respectively. The knee is an ideal site for assessment of 3 epiphyseal unions at the same time. Moreover, patella is a compact bone that could display sexual dimorphic characters. A total of 479 anteroposterior and lateral radiographs of the knee were reviewed retrospectively in subjects aged between 10 and 20 years old; 255 males and 224 females. Epiphyseal union was scored as stage 0 (non-union), stage 1 (beginning union), stage 2 (active union), stage 3 (recent union) or stage 4 (complete union). Three measurements on patella (maximum height, width, and thickness) were used to determine sex by univariate and multivariate discriminant analysis. Intra- and inter-observer variability were excellent. Mean age increases with each stage of union and also varies between sexes. The relationship between the three knee epiphyses and chronological age was strong for both sexes. It has been noted that union occurs at an earlier age in the Chinese population. As expected, epiphyseal union in females occurred earlier than males. Interestingly, the present study exhibited that stage 2 of the three knee epiphyses occurs in males earlier than their female counterparts by 6 months. Compared with previous published data, the patella in this study was small and wide. The best discriminant functions for sex determination were 73% which is obtained by the combination of 2 measurements only; height/thickness and height/width. Thus, the patella is of limited value as sex indicator. Further studies on different areas within China are recommended in order to verify not only the accuracy of the used methods but also to enable evaluation of different ethnic groups. Further studies based on different anatomical regions for assessment of sex are also encouraged.

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1. Introduction

Forensic anthropology is concerned with gaining an insight into the characteristics of either the human skeleton or living individual to develop methods helping in biological profile construction [1,2]. The determination of sex and age are often fundamental pieces in biological profiles [3].

Evaluation of an individual's age using various methods is required for medicolegal (ML) and medical purposes. Regarding ML purposes, it could be for civil and criminal matters. Regarding medical purposes, it could be used by pediatricians to compare the bone age with chronological age of the children for diagnosing several disorders. Most chronic disorders that impair growth as the consequence of metabolic and endocrinal causes will result in a

bone age retardation. In contrast, certain conditions can accelerate bone growth so that it exceeds chronological age [4].

Skeletal maturation is restricted to early life and thus provides an ideal mechanism for age identification [1]. The epiphyseal union can be used to estimate age between 10 and 20 years [1]. Different bones begin and complete their ossification at different but almost fixed periods of life [4]. These changes can be studied by X-rays. The knee is an ideal anatomical locus for assessment of epiphyseal union. It is easily positioned so that anteroposterior (AP) radiographs can be taken and yields information for three epiphyses; the distal femur, proximal tibia and proximal fibula [1].

Pyle method is used to compare the radiographs of various joints, and once the X-rays are exactly matched, the ages are read off directly from the atlas. Before an attempt is made to use such method in estimation of age, it must be considered that the data for that method was derived from children taken from a particular nation, so the data may not work well for other nations, or even within different areas of the same nation [4,5].

In humans, most differences between the sexes do not become apparent until puberty [6]. Therefore, assigning sex in the adult is

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more straightforward than assigning it in a prepubertal juvenile because of the difference within the skeletal system that occurs [7]. Sex identification depends on the degree of sexual dimorphism [8]. The observation of sexual traits on bones by using discriminant function analysis (metrical method) proved to be a more reliable approach than the morphological (non-metrical) method [8,9]. The pelvis and skull exhibiting prominent sexually dimorphic characters can predict sex with fairly high accuracy [9,10]. But in their absence the task of the ML expert becomes quite difficult especially in cases where isolated or fragmentary bones are recovered. Meanwhile, the patella seems to be the bone most omitted in forensic anthropology despite having features such as being a small compact bone, very resistant to postmortem changes, easily found as complete in good condition, and differentially affected in males and females as a result of biomechanical forces through the joints [8,10–12].

It has been shown by many anthropologists that these characteristics (epiphyseal union, sexual dimorphism) display population specific variation and therefore need to be studied for major populations around the world [10]. In the absence of large collections of contemporary skeletal collections of immature human remains, radiographs provide an alternative avenue of analysis [1]. Recently, MRI studies of the knee were conducted to evaluate the reliability of that technique in age identification. Although MRI showed a new safe alternative to X-ray, certain places with limited facilities and that cannot afford to perform MRI, are still using plain radiographs [13,14]. Thus, radiographs are indispensable tools that can be used in forensic anthropological research [10].

To our knowledge, there is no available data about identification of age and sex based on the knee joint from the modern Chinese population. So the extracted data from this study could provide a detailed picture of the range of variation in epiphyseal union at the knee in the Chinese population. It aimed to examine the age of Chinese population in relation to defined stages belong to McKern & Stewart method. It also aimed to examine sex in relation to metric radiographic measurements of patella that could be deemed admissible for forensic purposes.

2. Material and methods

A longitudinal study of epiphyseal union would give the most accurate results. However, it is not ethically possible due to the

expected health risks from repeated radiological examinations. In spite of longitudinal data is not equivalent to that extracted from other type of study, a cross-sectional study that examines larger numbers of individuals in each age group was the best compromise in this situation.

2.1. Data collection

We retrospectively reviewed (AP and lateral) knee X-rays of living subjects aged between 10 and 20 years, performed at the department of Radiology, the third Xiangya Hospital of Central South University (Changsha, Hunan, China) using a picture archiving and communication system (Lanwon PACS System, China). The data of X-rays equipment and settings were as follows: FFD: 110 cm, no grid, kV: 55 kV, mA: 100 mA, ms: 50 ms, GE Definium 6000 DR, Selected Protocols: Extremities: Lower/Knee. The chronological age of each subject was calculated using information provided by the date of birth and the date of registration for X-ray, therefore allowing calculation of exact age (years) at the time of X-ray.

Data were acquired from 479 subjects (age, 10–20 years; 255 male/224 female) after getting approval by Ethics Committee of The Third Xiangya Hospital of Central South University, Changsha, China (number: 14017). Subjects were included if they had a good-quality X-ray. Most of the subjects were referred by specialists of orthopedics with chief complaints of existing knee pain. Subjects were excluded if they were not originally Chinese, they had knee fracture, or they had known bone, endocrine, metabolic or nutritional disorders. Bilateral symmetry has been reported in the previous studies [15,16]. Thus, where both sides were available, only one side was included to avoid duplication of results.

2.2. The assessment of radiographs

Both AP and lateral radiographs were used together and not separately scored while assessing the stage of epiphyseal union. The assessment of X-ray was based on using McKern & Stewart stages' definitions which sub-divided epiphyseal union at the knee into five stages; non-union (stage 0), beginning union (stage 1), active union (stage 2), recent union (stage 3) and complete union (stage 4) [17]. The details of criteria for assignment of different stages of union have been shown in Table 1 and Fig. 1. Lastly, the composite score was done by summation of the three scores of the

Table 1
Criteria for assignment of stage of union.

Stage	Criteria
Stage 0 (non-union)	<ul style="list-style-type: none"> The diaphyseal and epiphyseal bones are adjacent to each other. The epiphysis remains separate from the diaphysis due to the presence of the cartilaginous growth plate.
Stage 1 (beginning union)	<ul style="list-style-type: none"> The radiolucent strip between adjacent surfaces of the epiphysis and diaphysis has become narrowed. The radiolucent gap is not continuous from anterior to posterior or medial to lateral. Towards the central region of the growth plate there is a definite breaking up of the adjacent outlines of the epiphyseal and metaphyseal margins. This is a consequence of the extension of bone across the intervening gap between shaft and epiphysis.
Stage 2 (active union)	<ul style="list-style-type: none"> The terminal plate of the epiphysis is no longer distinguishable. A fusion line or zone of greater density than the adjacent bone replaces the epiphyseal cartilage.
Stage 3 (recent union)	<ul style="list-style-type: none"> A fine line of fusion of greater density may remain between the epiphysis and diaphysis. There is discontinuity of trabeculae between the former epiphysis and diaphysis.
Stage 4 (complete union)	<ul style="list-style-type: none"> The epiphysis and diaphysis are united as a single unit of bone. Remodelling has taken place and there is continuity of trabeculae from shaft to former epiphysis.

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