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Forensic Anthropology Population Data

Age estimation methods using hand and wrist radiographs in a group of contemporary Thais

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ABSTRACT

Objectives: The aim of this study was to evaluate the accuracy and reliability of three commonly used age estimation methods in Thailand: Greulich–Pyle, Tanner–Whitehouse and Fishman.
Materials and methods: Three hundred and sixty-five hand and wrist radiographs of 8–20 years old Thai patients were retrospectively collected. The radiographs were taken between 2011–2016. Greulich–Pyle, Tanner–Whitehouse 3 radius, ulna and selected short bones (RUS), and Fishman method were applied for each radiograph. Comparisons between the estimated age from each method and the chronological age were done using Wilcoxon signed ranks test with Bonferroni correction. Sensitivity, specificity and accuracy tests were performed on the important legal age thresholds in Thailand (10, 13, 15 and 18 years old). Intra- and inter-observer reliability were evaluated by weighted kappa analysis.
Results: The estimated ages from the three methods were significantly different from the chronological age, except for Tanner–Whitehouse 3 RUS in males. Regarding the legal age thresholds, Greulich–Pyle showed the best accuracy (83.2% for females and 79.63% for males) for legal age threshold of 10 years old. Fishman method showed the best accuracy for legal age threshold of 13 (77.5% for females and 74.31% for males) and 15 years old (83.08% for females and 73.77% for males). For age threshold of 18 years old, Greulich–Pyle showed an accuracy of 53.85% for females and 54.44% for males. The reliability tests showed substantial to almost perfect agreement.
Conclusions: This study showed no significant difference between Tanner–Whitehouse 3 RUS age and chronological age for male subjects of contemporary Thai children and adolescents. However, Greulich–Pyle and Fishman method were superior regarding the accuracy of prediction based on Thai legal age thresholds. Due to the possible effects from ethnical difference and secular changes, adaptation of age estimation methods specifically for contemporary Thai population should be further studied.

1. Introduction

Age estimation is an essential method applied in a variety of situations, such as growth observation, immigrant registration, legal penalty judgment and body identification. The accuracy of age estimation is very important to the legal system. In Thailand, the critical legal ages are 10, 13, 15, 18 and 20 years old. Whether the age of an individual is younger or older than the legal age, the outcome may affect not only the degree of penalty, but also the appropriate care for minors [1,2].

Hand and wrist radiography is useful for age estimation since it is straightforward, inexpensive and non-invasive. The commonly used hand and wrist skeletal age estimation methods in Thailand are Greulich–Pyle (GP), Tanner–Whitehouse (TW) and Fishman [3–11].

The GP method is based on a visual comparison of the whole hand. The reference population comprises children from Cleveland, Ohio, and the data was collected till 1942 [3]. The TW method is based on a visual comparison of each single bone, using a numerical system that underwent a series of revisions to improve accuracy. The most recent version is Tanner–Whitehouse 3 (TW3), published in 2001. The reference data was collected from various countries, including Japan, but mostly from Europe and USA. The latest dataset for Tanner–Whitehouse 3 was collected in the 1990s [6,7]. The Fishman method is particularly well-known in the orthodontic field [10–13]. This method is based on data collected from American children and was first proposed in 1982. This method uses the dichotomous tracing concept on a systematic observation scheme [10,11]. The observation scheme starts from the first skeletal maturity indicator (SMI); its presence or absence will divert to another SMI, and so on. The SMIs are then matched

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with norm ages for males and females. The last positive SMI indicates the final estimated age [10,11].

The validity of the estimated age in ethnic groups that are different from the reference population is still questionable. Commonly used age estimation methods are based on United States and European populations [3,7,9–12,14–22]. Therefore, the deviation between the estimated age and the chronological age may be significantly higher when these methods are applied to other populations [4,23]. Moreover, these methods are based on old data from former generations. Some studies have shown a trend of changes in growth and development between generations [8,19,24–27]. In contrast, some studies found no significant effect regarding these factors [28,29].

The general ethnicity in Thailand is different from Europe and the United States. The contemporary Thai population is an admixture of native Thais and people with Chinese and other Southeast Asian ancestry. No age estimation studies using different methods of hand and wrist radiographs on the contemporary Thai population have been published. Therefore, the aims of this study were to evaluate the accuracy, reliability and comparability of commonly used age estimation methods on a Thai population.

2. Materials and methods

The study protocol was approved by the ethical committee, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (No. 022/2017).

2.1. Subjects

Digital hand and wrist radiographs were retrospectively collected from the hospital database, Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. All patients were referred to have these radiographs taken as part of growth evaluation for orthodontic treatment. The subjects were defined as 'contemporary Thai' by complying with the selection criteria:

- Thai nationality must be indicated in the dental chart. Subjects with foreign surnames and/or foreign nationalities were excluded.
- Radiographs were taken between 1 January 2011 and 31 December 2016.
- The chronological age of the subjects must be 8–20 years old when the radiographs were taken. The chronological age was calculated by subtracting the X-ray date with the birthdate recorded in the dental charts.

Patients with history of diseases affecting skeletal development were excluded.

Three hundred sixty-five subjects, consisting of 193 females and 172 males, were included in this study. The subjects were categorized into 13 age groups, with a distribution as shown in Table 1.

The hand and wrist radiographs were taken by Carestream™ CS 8000c and CS 9000c radiographic units (Carestream Health, Inc., Rochester, NY, USA). The standard exposure parameters were set according to the patients' size. The images were stored in the hospital picture archiving and communication system (PACS).

2.2. Age estimation methods

The GP method compares the features from the radiographs of the subjects with standard radiographs in an atlas. The age from the most similar standard will be the estimated age [3].

Table 1
Distribution of subjects in each age group.

Age (years)	Female	Male	Total samples
8–8.99	11	11	22
9–9.99	22	20	42
10–10.99	27	21	48
11–11.99	29	33	62
12–12.99	36	23	59
13–13.99	31	34	65
14–14.99	12	10	22
15–15.99	12	9	21
16–16.99	7	5	12
17–17.99	3	3	6
18–18.99	1	1	2
19–19.99	1	2	3
20–20.99	1	0	1
Total	193	172	365

TW3 method are normally separated into 2 scoring systems; 'radius, ulna and selected short bones (RUS)' score and 'carpal bones (CAR)' score (Fig. 1). Only the RUS score was selected in this study because the CAR score should not be used when subjects are between 8–20 years old [6,30]. Fig. 1 shows thirteen short bones observed in RUS scoring system: 1, radius; 2, ulna; 3, 1st metacarpus; 4, 3rd metacarpus; 5, 5th metacarpus; 6, 1st proximal phalange; 7, 3rd proximal phalange; 8, 5th proximal phalange; 9, 3rd middle phalange; 10, 5th middle phalange; 11, 1st distal phalange; 12, 3rd distal phalange; 13, 5th distal phalange. A score was given to represent the developmental stage of each bone. The scores from every bone were summed together and compared with the sum–score table to find the estimated age [6,7].

For the Fishman method, the skeletons were observed in an order as illustrated in the observation scheme and matched with the skeletal maturity indicator (SMI) (Fig. 2). A positive result from the first SMI (SMI 4) led to a higher SMI (SMI 8), while a negative result led to a lower SMI (SMI 1). The highest positive SMI indicated the final estimated age [10,11].

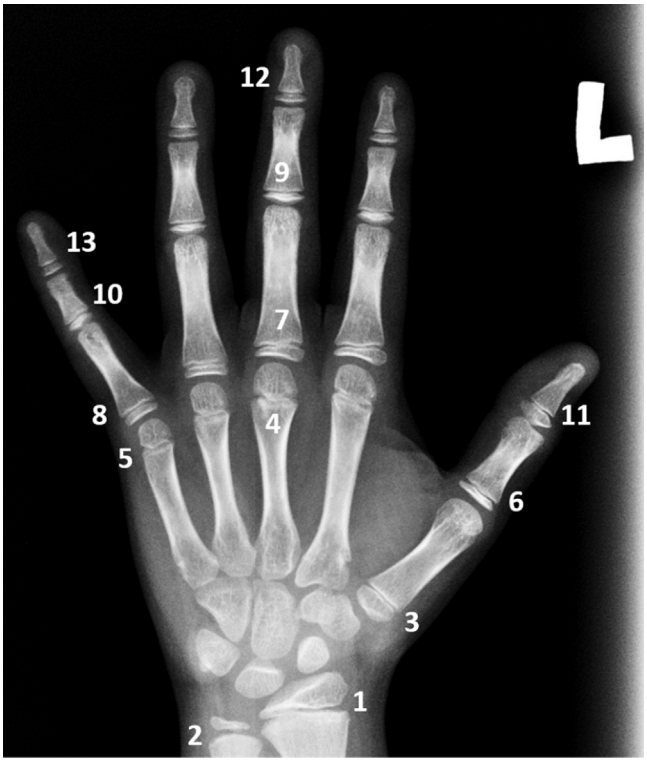

Fig. 1. Hand and wrist bones observed in RUS scoring system [6,7].