

Evaluation of the pelvic apophysis with multi-detector computed tomography for legal age estimation in living individuals

Mehdi Karami, Meisam Rabiei, Maryam Riahinezhad

Department of Radiology, Alzahra Hospital, Isfahan University of Medical Sciences, Isfahan, Iran

Background: Legal age estimations of living individuals are gaining increasing importance for radiologists involved in delivering expert opinions. The present study aimed to assess the correlation between chronological age and apophyseal centers distance from pelvic bone. **Materials and Methods:** This was a cross-sectional study carried out on 2013. Subjects were chosen from 15 to 25 years old people who had previous pelvic multi-detector computed tomography for any reason. The distance of iliac crest apophysis to iliac bone, and pubic apophysis to pubic bone were assessed. **Results:** There was a reverse linear correlation between chronological age and distance of iliac crest apophysis ($P < 0.001$, $r = 0.899$) and pubic apophysis to pelvic bone ($P < 0.001$, $r = 0.898$). Pubic apophysis was not appeared in subjects before 16 years old and it was appeared in all of the subjects with 18 years old and more. Subjects with age of 21 had near ossification of iliac or pubic apophysis and subjects with age of 24 had full ossification of iliac or pubic apophysis. **Conclusion:** skeletal age can be estimated by assessing the apophyseal centers distance from the pelvic bone in adolescents 15-25 years old.

Key words: Age estimation, iliac crest apophysis, multi-detector computed tomography, pubic apophysis

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INTRODUCTION

Estimation of age in living individuals represents a legal challenge with important social and legal implications, which legal regulations and principles of medical ethics have to be considered in. The increase of children and adolescents with no valid proof of their chronological age is a legal concern to many countries, especially in situations of illegal immigration, sub adult delinquency, and juvenile work.^[1,2]

When there is a doubt about the age of a person who is suspected of a criminal offense, legal estimation of age is motivated by the need to verify whether the person concerned has reached the age of criminal responsibility and whether criminal law in force which is for older juveniles or adults must be applied.^[3]

Different biological ages, such as, dental age and morphological, skeletal and secondary sexual characteristics, have been proposed for this goal.^[1] Because any method of evaluation should be not invasive, accurate, reproducible and easily exploitable, radiological investigation for age dependent features are the most suitable method for this purpose. Since there are correlations among skeletal

maturity and chronologic age, in childhood and adolescence morphological methods, which are based on the radiological examination of skeletal development are to be suggested.^[4,5]

The conventional method of skeletal age assessment by radiological examination is based on radiographic appearance of the maturity in the hand-wrist radiographs by comparison with a reference atlas: Either the Greulich and Pyle or the Tanner and Whitehouse (TW2) method.^[6] However, a meta-analysis and systematic review concluded that age in living individuals cannot be estimated accurately when only X-ray methods on the hand-wrist are used.^[7]

Other methods include determination of the ossification stage of the medial clavicular epiphysis and Sauvegrain method, which uses four anatomical landmarks of the elbow: The trochlea, lateral condyle, proximal radial epiphysis and olecranon apophysis.^[8-10] Also, recent studies have shown that subjects might benefit more by assessing X-rays of the cervical vertebrae than the hand and wrist.^[11,12]

In order to improve reliability, previous studies have recommended that these methods should

Address for correspondence: Dr. Meisam Rabiei, Department of Radiology, Alzahra Hospital, Isfahan University of Medical Sciences, Isfahan, Iran. E-mail: drmeisamrabiei@yahoo.com

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be used in combination, ensuring that each part is performed by experienced experts of the relevant disciplines.^[3]

On the other hand, completion of body growth is best shown by development of epiphyses and apophyses, which are the bone growth centers. These centers have a rather long time development and are more useful for age determination in adolescents 15-25 years old. One of the last ossification centers to appear and develop is the iliac crest apophysis, which is plainly visible and appears laterally and anteriorly on the crest of the ilium as an ossification center.^[13] The pubic apophysis is also a component of the anterior pubic facet, located along the anterior corner of the symphysis and shown most clearly on corresponding axial computed tomography (CT) sections.^[14]

Recently, ossification of apophysis of the iliac crest has been assessed by pelvic radiographs and sonography for correlation with chronological age.^[15,16] They suggested that for the establishment of the apophysis in routine diagnostics, further studies are needed with focusing on the comparison of different radiological techniques and grading systems.

In this study, we assessed the correlation between chronological age and distance of iliac crest apophysis and pubic apophysis to the pelvic bone.

MATERIALS AND METHODS

Study design and participants

This was a cross-sectional study carried out in 2013. The study followed the Declaration of Helsinki on Biomedical Research Involving Human Subjects and was approved by the Ethics Committee from the Isfahan University of Medical Sciences. All participants provided written informed consent.

Subjects were chosen from whom referred to the Alzahra Hospital (Isfahan, Iran). All subjects met the following inclusion criteria:

1. Men and women aged 15-25 years;
2. Having previous pelvic multi-detector computed tomography (MDCT) for any reason;
3. Willing and able to provide written informed consent.

Subjects also met none of the following exclusion criteria:

1. History of pelvic fracture or trauma;
2. History of metabolic disease, hypo or hyper thyroidism, acromegaly and mal-absorption;
3. Any chronic medical condition that may cause poor nutrition or delay in growth.

Procedures and variables assessment

Demographic data included chronological age and sex. After exclusion, we were left with 152 subjects who included in the study.

We assessed the distance of iliac crest apophysis to the iliac bone, and pubic apophysis to the pubic bone in pelvic MDCTs (64 slice MDCT) as below.

The shortest vertical distance between apophysial center of iliac crest and cortex of underlying iliac bone was measured. Also, the shortest distance between apophysial center of the pubic bone and adjacent pubic bone was determined.

All MDCTs were analyzed by the same observer.

Statistical analysis

The data were analyzed by independent sample *t*-test, Pearson correlation, and regression analysis. All analyses were performed using Statistical Package for the Social Sciences version 20.0 (SPSS Inc., Chicago, Illinois, USA) and a $P < 0.05$ was considered as statistically significant for all analyses.

RESULTS

Overall 152 subjects were assessed. There were 109 (71.7%) male and 43 (28.3%) female. In legal principles, the age is measured by years, so we considered subjects from 15 years and 1-day to 15 years and 11 months and 30 days, as 15 years old. The mean standard deviation (SD) age was 20.9 (2.9) and 21.2 (3) years for male and female respectively. It was not different significantly ($P = 5.12$). The frequency of different ages is shown in Table 1.

The mean (SD) of iliac crest apophysis distance to iliac bone was 0.962 (0.865) mm for men and 0.969 (0.899) mm for women. It was not different significantly ($P = 0.96$).

The mean (SD) of pubic apophysis distance to the pubic bone was 0.785 (0.790) mm for men and 0.781

Table 1: Frequency of different ages in the sample (n = 152)

Age (years)	Frequency	Percentage
15.00	6	3.9
16.00	9	5.9
17.00	7	4.6
18.00	15	9.9
19.00	12	7.9
20.00	11	7.2
21.00	16	10.5
22.00	24	15.8
23.00	15	9.9
24.00	19	12.5
25.00	18	11.8

(0.843) mm for women. It was not different significantly ($P = 0.98$).

The mean (SD) of distance to the pelvic bone (iliac or pubic) was 0.964 (0.872) mm and 0.784 (0.802) mm for iliac crest apophysis and pubic apophysis, respectively.

The Pierson correlation test showed that there is a reverse linear correlation between chronological age and distance of iliac crest apophysis to the iliac bone ($P < 0.001$, $r = 0.899$), [Figure 1]. According to iliac crest apophyseal distance, age can be estimated by following equation:

$$Y = 23.87 - 3.03x.$$

When Y is age and x is apophyseal distance.

The analysis also showed that there is reverse linear correlation between chronological age and distance of pubic apophysis to pubic bone ($P < 0.001$, $r = 0.898$), [Figure 2]. According to pubic apophyseal distance, age can be estimated by following equation:

$$Y = 23.75 - 2.77x.$$

When Y is age and x is apophyseal distance.

With considering both of iliac crest and pubic apophysis, regression analysis resulted the following equation for age estimation:

$$Y = 23.86 - 1.69X^1 - 1.1X^2$$

When $Y =$ age, $X^1 =$ iliac crest apophyseal distance, $X^2 =$ pubic apophyseal distance.

Pubic apophysis was not appeared in subjects before 16 years old and it was appeared in all of subjects with

18-years-old and more. Iliac apophysis was appeared in all of subjects with 15-years-old and more.

Subjects with age of 21 had near ossification of both iliac and pubic apophysis (distance = 0.2 mm) and subjects with age of 24 had full ossification of both iliac and pubic apophysis (distance = 0 mm).

DISCUSSION

Age estimation is an important and sometimes challenging task, especially for legal issues. In this study we assessed 152, 15-25 years men and women for apophyseal distance to pelvic bone as a method for age estimation.

The results showed that with increasing of age the apophyseal distance to pelvic bone will be reduced and the age can be estimated based on this distance. In previous studies which has used hand-wrist radiographs, correlation of skeletal age determined with the Greulich and Pyle or the TW2 methods, requires to relate the published "norm" which is from US or European population back to the local population and that is not always reliable because of ethnic differences.^[6,7,17] However assessing of apophyseal ossification, may be used with more validly for legal age determination.^[18]

On the other hand, hand-wrist radiographs are more useful for age estimation before puberty (before 13-15 years);^[7] and assessment of elbow radiographs is a reliable tool to assess skeletal age during puberty;^[10] but apophyseal methods like our study, as well as assessing of the medial clavicular epiphysis for ossification, are more useful for adolescents after puberty.^[8,13,19]

Our results is consistent with recent studies of Schmidt *et al.* and Wittschieber *et al.* on ossification of iliac

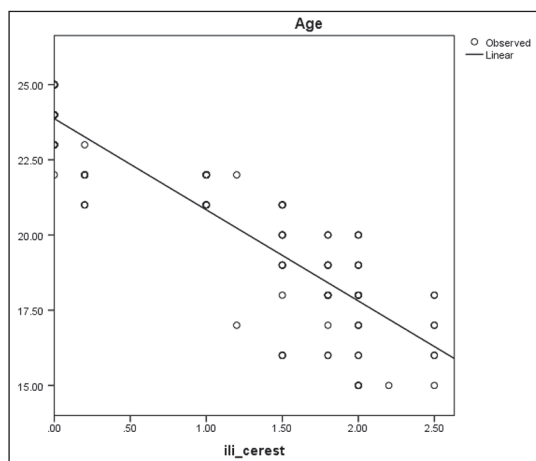


Figure 1: Scattered diagram and linear regression of age by distance of iliac crest apophysis from iliac bone

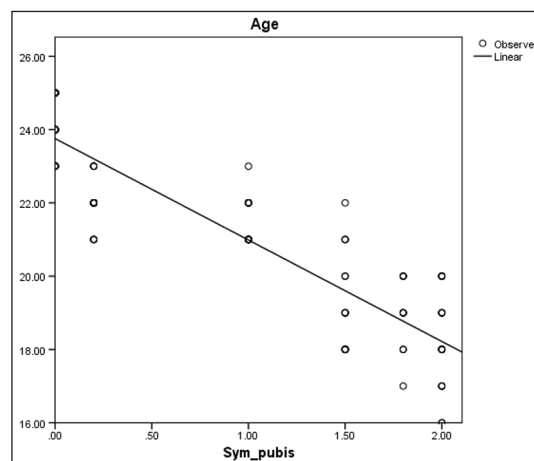


Figure 2: Scattered diagram and linear regression of age by distance of pubic apophysis from pubic bone

crest apophysis.^[15,16,20,21] Schmidt used sonography and Wittschieber used pelvic radiographs for assessment of apophysis ossification; but this study used MDCT which is more precise and sensitive in detecting and grading of ossification.

In previous studies apophysis ossification grading has been used for age estimation, which estimates the age according to 4-5 grade of ossification of apophysis based on different methods;^[15,16,18] but in this study we assessed the apophyseal distance to pelvic bone. By this method, age can be estimated by an equation, which is possibly more accurate.

Pubic apophysis was not appeared in subjects before 16 years old and it was appeared in all of the subjects with 18 years old and more. This shows that when pubic apophysis appears in the CT, there is a possibility for an accurate diagnosis of age more than 15; and when it is not appeared in the CT, the age is <18. This range of age (15-18) is considered as legally relevant ages thresholds for criminal responsibility in different settings in most of the countries.

Subjects with age of 21 had near ossification of both iliac and pubic apophysis and subjects with age of 24 had full ossification of both iliac and pubic apophysis. This shows that when there is full ossification of apophysis, the age of subject is possibly 24 years old and more, and more accurately is more than 21 years old at least.

Studies in US population has reported that the average chronologic age, when the iliac apophysis is completed, is 14-16 years, which may occur as late as 18-20 years.^[13] However in our population, this is as late as 21-24 years. This may be because of ethnic differences and also we used CT for assessing the ossification and we assessed the exact apophyseal distance to the pelvic instead of using grading system which is possibly more sensitive.

CONCLUSION

Skeletal age can be estimated by assessing the apophyseal distance to the pelvic bone in adolescents 15-25 years old accurately. Therefore, the pelvic apophysis (iliac crest and pubic apophysis) seem suitable as possible criterion for legal age estimation in the living. However, further studies with higher case numbers are needed in order to decide whether these apophysis might be appropriate for routine age estimation according to local ethnic backgrounds.

Using of CT in general population, maybe considered not suitable because of ionizing radiation; but if these apophysis would be considered reliable enough for legal age estimation in researches protocols, the measurement can be done by other less harmful modalities such as ultrasound.

On the other hand, in some specific situations which the most of precise and sensitivity is vital for age estimation, CT can be considered as a reliable choice.

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AUTHOR'S CONTRIBUTION

MK designed the study. MR collected the data and wrote the article. MR wrote and revised the article.

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