Original Article

Age determination using ultrasonography in young football players

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Abstract

Background: Increasing of age cheating in sports makes problems to athletes comparable to taking illegal substances. Current method used by AFC and FIFA is applying MRI of growth plate of distal of radius to determine the bone age. This study was designed to evaluate the diagnostic accuracy of ultrasonography in bone age determination by measuring the width of growth plate in distal of radius, and comparing it with identity documents.

Materials and Methods: The study was conducted from September to December 2009 in the Department of Radiology at Al-Zahra University Hospital, Isfahan, Iran. Ultrasonography was done for 82 (15-20 years old) young professional football players and results were compared with identity documents (such as National ID card). Young football players were divided into three age categories: <16 and >16 years old, <17 and >17 years old, and <18 and >18 years old. Receiver Operator Characteristics (ROC) curves for discriminant values and sensitivity and specificity were analyzed.

Results: Cut-off point was set for each group, based on the width of the growth plate, and negative test was defined as subjects <cut-off point, showing subjects over the defined age in each group. ROC curve analysis demonstrates consistently acceptable diagnostic sensitivity and specificity values in age determination of each group.

Conclusions: The overall predictive accuracy of ultrasonography, as described by the area under the ROC curve, was high for determination of bone age. It has an acceptable sensitivity and specificity to use for determination of age in sport competitions, and has the capability to become the screening test for age determination, especially because it is inexpensive and without any risk of radiation. It seems to be comparable with MRI in age determination.

Key Words: Accuracy, age determination, sport medicine, ultrasound

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INTRODUCTION

Increase in age cheating in sports causes problems with athletes comparable to taking illegal substances.[1,2] Age cheating occurs in several tournaments such as International Four Nations Tournament for underprivileged children in 1998, in which more than half of the South African under-14 National soccer squads were over the age limit.[3-5] Therefore, several

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players were excluded from tournaments for ostensibly being over-age, causing a reaction from many of the parents of these players who claimed that their children had been disqualified unfairly.

Skeletal maturity or bone age describes the degree of biological maturation.[6] The most common method of skeletal maturity assessment is using a radiograph of the left hand and wrist to determine the different stages in bone maturation.[7] Two traditional techniques, namely the Tanner and Whitehouse II (TW_2)[8] and Greulich and Pyle (GandP)[9] methods, are used for assessment of the bone age. However, estimation of skeletal age using the GandP or the TW_2 systems necessitates usage of ionizing radiation. Thus, non-ionizing, radiation-based techniques have been developed for the estimation of skeletal age.[10-12] Shimura and colleagues measured bone age ultrasonically with Sunlight Bone Age (SBA) and compared the results with radiographs. They showed that good correlation existed with SBA results and TW_2 and CASMAS methods.[13] In the international U-17 soccer competition, FIFA uses wrist MRI for assessment of skeletal age to determining degrees of fusion of the distal radius growth plate.[14,15] In this method, the degree of fusion of the distal radius was graded independently into six classes in which grade I means completely infused and grade VI means fused growth plate. They concluded that complete fusion (grade VI) occurs at the age of 17-18 years. But the disadvantages such as costly and unavailability limit the use of MRI for predicting bone age, especially in underdeveloped countries. However, little evidences exist in radiation-free methods for assessment of bone age, especially in athletes. With regard to the fusion occurring from central to the peripheral of growth plate between 16 to 18 years, and the costly benefits and availability of ultrasonography, this method may be useful to determine the bone age according to the width of distal radius growth plate by measuring the thickness of hypoechoic cartilaginous band between metaphysis and epiphysis. Therefore, this study was designed to evaluate the diagnostic accuracy (with the focus on sensitivity) of the ultrasonography in bone age determination with measuring the thickness of growth plate (hypoechoic band between epiphysis and metaphysic) in distal of radius. The goal was to identify subjects who had the growth plate width ≤ defined cut-off (positive test) and are actually over the determined age in each category according to the identity documents.

MATERIALS AND METHODS

This diagnostic accuracy study was conducted from September to December 2009 in the Department of Radiology at Al-Zahra University Hospital (Isfahan University of Medical Sciences), Isfahan, Iran. The 15- to 20-year-old football players with the history of two or more years of professionally playing football and the verified age by official identity documents derived from original birth certificates participated in study. Exclusion criteria included wrist fracture or surgery, systemic disease, cartilaginous, or metabolic disorders. The Ethics Committee of Isfahan University of Medical Sciences approved the study protocol. Informed consent from the subjects, according to the guidelines stated in the Helsinki declaration, was obtained.

Eighty-two male football players met the inclusion criteria and volunteered for the study. Ultrasonography was done with the instrument medison V10 ultrasonography machine and the 7-10 MHz linear trasducer. For correct positioning, the investigator has to mark the position of the distal tip of the ulnar styloid process [Figure 1]. The technique utilizes the width of the growth plate as a hypoechoic area to determine the width of epiphysis of distal of radius [Figure 2], in three views: Anterior, posterior, and lateral. Ultrasonic waves with a frequency of 7-10 MHz are used. The Radiologist performed measurement, without knowledge of the age of subjects (blindly).

Standard ROC curve analysis was used to (1) generate sensitivity and specificity results and (2) to determine the optimal differentiating cutoff normal values. Optimal normal cutoff values were determined on the basis of maximum sensitivity × specificity with equal importance assigned to both sensitivity and specificity. The positive test defined the persons over the cut-off point in each category, and the negative test defined the persons who are below the cut-off point in each category (which shows the persons over the determined age of

Figure 1: Site of insertion of the transducer

each category). The main goal was to identify the subjects ≥ determined age, so we set the cut-off point in the maximal sensitivity. All data were analyzed with SPSS software version 16.

RESULTS

Eighty-two football players with the age of 15 to 20 years underwent sonographic evaluation. The sensitivity and specificity are showed in Tables 1-3. The goal was to find the cut-off point to identify subjects over the determined age. So, we needed to access to a cut-off point with high sensitivity rather than specificity. It's obvious that to identify the persons under each determined age, we should set the cut-off point with high specificity.

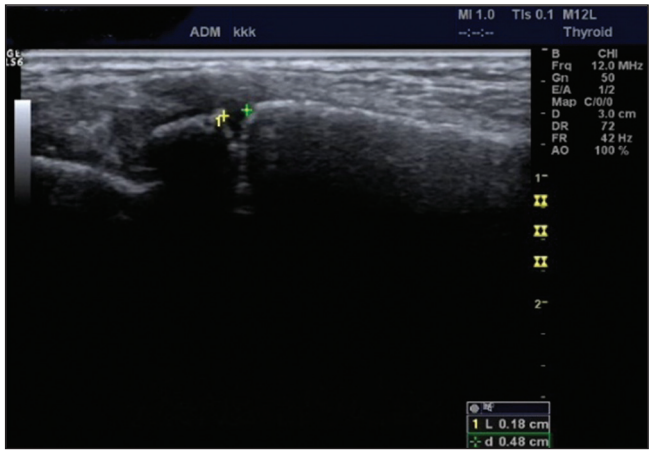

Figure 2: Sonographic hypoechoic growth plate and the method of its measurement

Table 1: Diagnostic sensitivity and specificity of ultrasonography in subjects over 16 years old

	Cut-off point (mm)	Sensitivity (%)	Specificity (%)
Anterior	1.05	86	71.6
Posterior	1.05	86.7	73.1
Lateral	1.05	93	64.2

Table 2: Diagnostic sensitivity and specificity of ultrasonography in subjects over 17 years old

	Cut-off point (mm)	Sensitivity (%)	Specificity (%)
Anterior	0.95	89	68
Posterior	0.95	100	75
Lateral	0.95	100	57

Table 3: Diagnostic sensitivity and specificity of ultrasonography in subjects over 18 years old

	Cut-off point (mm)	Sensitivity (%)	Specificity (%)
Anterior	0.75	97.7	67
Posterior	0.75	95.3	70
Lateral	0.85	100	70

According to the ROC [Figure 3], for the first category (<16 and >16 years old), the optimal sensitivity and specificity (86.7% and 73.1%) for posterior view is achieved with the cut-off point of 1.05 mm, which means 86.7% of persons with width of epiphyseal plate <1.05 mm are above 16 years old.

For anterior view, the cut-off point of 1.05 mm shows the optimal sensitivity (86.7%) and specificity (71.6%), which means 86.7% of subjects with the width of epiphyseal plate <1.05 mm are over 16 years old. For the lateral view, optimal sensitivity (93.3%) and specificity (64.2%) are achieved with cut-off point 1.15 mm.

In second category (>17 and <17), according to ROC [Figure 4] for posterior view, the cut-off point of 0.95 mm showed the highest sensitivity (100%) for subjects over 17 years old, which means all person with ≤0.95 mm width are above 17 years old, the specificity for this cut-off point was about 70%. We could raise the specificity by setting the cut-off point at 1.05 mm (83%), but it would result in lower sensitivity (78%).

For anterior view, the highest sensitivity (100%) was obtained with cut-off point of 0.75 mm but with the specificity about 50%. Therefore, we used the cut-off point of 0.95 mm with sensitivity and specificity about 89% and 67%, respectively. As explained above about the posterior view, it showed that 89% of the subjects with ≤0.95 mm width were truly more than 17 years old.

For lateral view, the cut-off point of 0.95 mm had the highest sensitivity (100%), which means all subjects with ≤0.95 mm width are about 17 years old; the specificity was about 57%. Cut-off point of 1.05 mm showed sensitivity and specificity about 82% and 63%, respectively. Therefore, because of our emphasis on the sensitivity, we used 0.95 mm as the cut-off point for lateral view.

Finally, according to the ROC [Figure 5] in third category (<18 and >18) and for the posterior view, the cut-off point of 0.75 mm shows the optimal sensitivity (95.3%) and specificity (70%). For the anterior view, optimal sensitivity (97.7%) and specificity (67%) is achieved with cut-off point of 0.75 mm. And finally for the lateral view, the cut-off point of 0.85 mm shows the sensitivity of 100% and specificity of 70%.

Figures 3 to 5 confirm the high diagnostic capacity of the ultrasonography for predicting age to identification of subjects with ≥ determined age in each group. The overall predictive accuracy of ultrasonography, as described by the area under the ROC curve, was high for bone age determining.

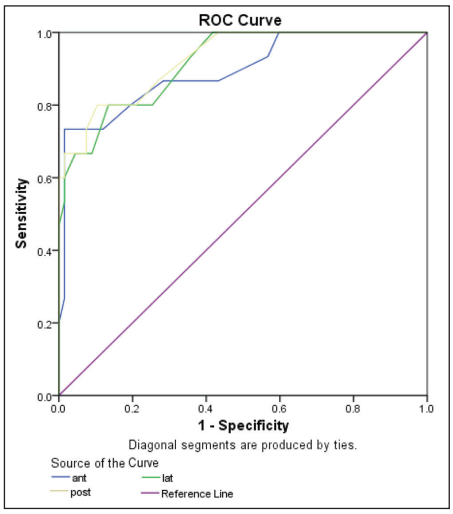

Figure 3: ROC curve for ultrasonography, results of first category (subjects below and over 16 years old)

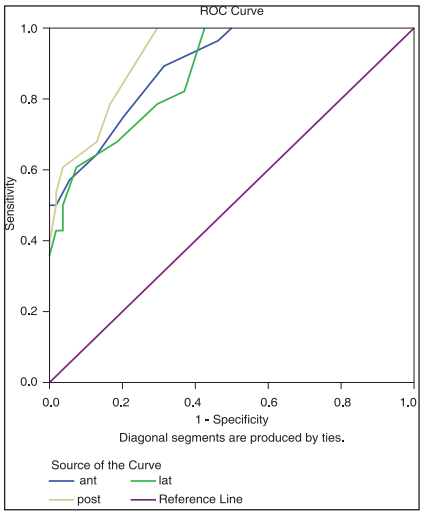

Figure 4: ROC curve for ultrasonography, results of second category in subjects below and over 17 years old

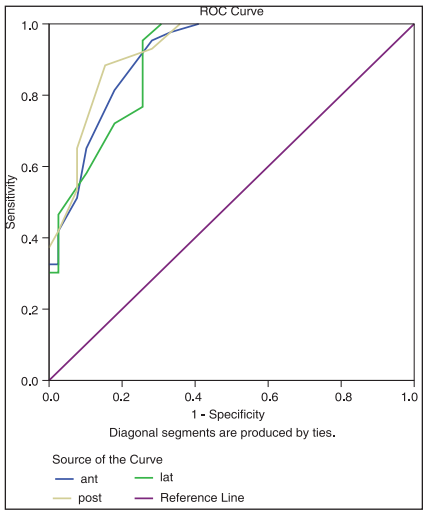

Figure 5: ROC curve for ultrasonography, results of third category in patients below and over 18 years old

DISCUSSION

Our goal was to identify subjects with the age over the determined age in each category. Therefore, we focused on the sensitivity to rule out subjects with negative test. Our main findings showed that ultrasonography of distal radius had optimal sensitivity (and also specificity) in the determination of bone age. Therefore, with the help of ultrasonography and use of determined cut-off in each category, we can truly find the objects over determined age (negative test = width of growth plate < cut-off point) with an acceptable sensitivity.

Bone age assessment plays an important role for the purpose of screening players at age-group tournaments where a player 1 day older than the defined age is regarded as 'too old' for the competition. Among the many methods proposed for assessing skeletal maturity, the x-ray based methods (GandP[9] and TW_2[8]) are most commonly used in clinical practice. Being subjective, time-consuming and difficult to perform and facing to ionize x-ray, the scientists are encouraged to achieve a more simple and safe method.

MRI as a safety modality was identified as a novel method of determining the bone age. In international U-17 soccer competition, FIFA uses wrist MRI for assessment of skeletal age to determine degrees of fusion of the distal growth plate of radial bone.[14,15] In this method, the degree of fusion of the distal radius was graded independently into six classes, in which grade I is completely unfused, grade II is early fusion; minimal hyperintensity within physis, grade III is trabecular fusion of less than 50% of radial cross-sectional area, grade IV is trabecular fusion of more than 50% of radial cross-sectional area, grade V is residual physis less than 5 mm on any section, and grade VI is completely fused of growth plate. But disadvantages such as cost and unavailability limit the use of MRI for predicting bone age, especially in underdeveloped countries. Also, spatial resolution of ultrasonography probe is 0.1 mm, which is more diagnostic than MRI, with 1 mm spatial resolution. So, the study on ultrasonography method in determining bone age is necessary.

Sonographic evaluation is based on the maturation of an epiphysis, by virtue of enchondral ossification, which is strongly related to the systemic bone development. In the distal radius, as in other long bones, the developmental process begins with the appearance of ossification center of the diaphysis, followed by ossification centers in the epiphyses and the formation of the physeal growth plates. The end of bone growth is marked by fusion of the growth plates. Between 16 to 18 years old, the fusion occurs from central to peripheral, so the width of growth plat can be determined as a hypoechoic area with ultrasonography.

There are some studies which are designed to assess the validity of ultrasonography with the mechanism of speed difference in tissues and comparing it with the traditional methods. However, according to our knowledge, there is no study to evaluate the accuracy of ultrasonic measurements of width of the growth plate in the distal of radius, and this is the first report.

Zadik *et al.*[16] assessed the ability of the Sunlight Medical ultrasonic system to accurately predict bone-age obtained by the GP method and showed that the bone age device measurements were found to be highly reproducible and highly correlated with conventional bone age readings using the GandP method. Bilgili and colleagues showed that the ultrasonographic version of the GandP atlas can be used to estimate bone age even in ultrasonography departments. They reported that the ultrasonographic method is highly correlated and a valid alternative to plain radiography for bone age estimation. In addition, they suggested the estimation of skeletal age in ultrasonography departments easily without exposing the patient to radiation.[12] In contrast, Khan *et al.* suggested that ultrasonic assessment should not yet be considered a valid replacement for radiographic bone-age determination.[17]

The data on ultrasonographic use for bone age estimation are limited. Ultrasonography of the iliac crest has been found to be sensitive and specific compared with radiography in individuals with scoliosis[18] and a GandP atlas based on US has been proposed.[12] An alternative approach to evaluation of ossification is US of the overlying cartilage, with the thickness of the anterior femoral head cartilage being shown to be inversely related to chronological age.[10]

Recently, an application was introduced using a fixed transducer device (BonAge®, Sunlight Medical Ltd, Nashville, TN, USA), which measures a conductive velocity forage determination in the growth plate. So far, ultrasound as a method to assess skeletal maturity has been studied by Mentzel *et al.*,[19] followed by diverging evidence to its validity value when compared with Greulich — Pyle and TW_3 methods.[17]

The low sample size and not determining the factors such as height, weight, and race, and also the nature of ultrasonography which is operator-dependent, were the limitations of our study.

CONCLUSIONS

In summary, this study was a pilot study which showed that the overall predictive accuracy of ultrasonography, as described by the area under the ROC curve, was high for determination of bone age. It has an acceptable sensitivity and specificity to use for determination of age in sport competitions, and has the capability to become the screening test for age determination, especially because it is inexpensive and without any risk of radiation. It seems to be comparable with MRI in age determination. Further studies with more samples, including determination of the factors such as height, weight, and race, and also studies comparing the accuracy of ultrasonography to MRI are warranted.

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