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Towards Automated Athletic Bone Age Determination by Wrist MRI: Correlation of Quantitative Growth Plate Features with FIFA Grading System

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Purpose

Complying fair play in U17 football matches is not limited to doping tests and ethical issues during the match but also includes age limits because over-aged players can cause sport injuries and may change the result of the match by stronger bodies and higher expertise. Although birth certificate is the major legal document to define chronological age of the players but unreliable birth certificates have resulted in medical investigations to assure compliance with age limits in U17 teams particularly in Asian and African countries. According to physiological studies, bone age has the highest correlation with chronological age.

In order to avoid unnecessary x-ray exposure in healthy young athletes, MRI has replaced conventional wrist and hand x-ray in this particular group. FIFA has adopted a grading system based on closure of epiphyseal plates in distal radius.

Segmentation and 3D shape modeling of the epiphyseal plate has already been reported by our group. Dealing with the epiphyseal plate as a discrete 3D object and extracting quantitative features of this object has been considered a promising approach to understand bone age determination using MRI.

The purpose of this project was to explore correlations between quantitative features extracted facilitate development of a fully automated CAD system for MRI bone age determination.

Methods and Materials

Thirty football players of our national U17 team were examined using Siemens 1.5 Tesla scanner, Magnetom Avanto 18-channel. All players aged between 14 -18. The FIFA protocol results in 9 coronal slices of wrist.

Then the studies were graded by a radiologist according to FIFA scoring.

grade I: Completely unfused
grade II: Early fusion.
grade III: a Trabecular fusion of less than 50% of the radial cross-sectional area.
grade IV: a Trabecular fusion of more than 50% of the radial cross-sectional area.
grade V: Residual Physis, less than 5 mm on any one section.
grade VI: Completely fused
The image processing of the MR images followed these steps:

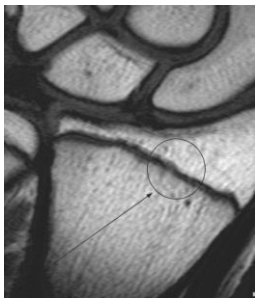
First, radius was segmented in all coronal slices automatically using a 3D level set method [2], then its growth plates was segmented [2]. Subsequently, the segmented growth plates were set together to build a 3D object [3].

The following features were extracted from the 3D object:

1) Thickness estimated by calculating the ratio of total volume to the surface
2) Volume density of growth plate
3) Mean of intensity
4)Variance of intensity

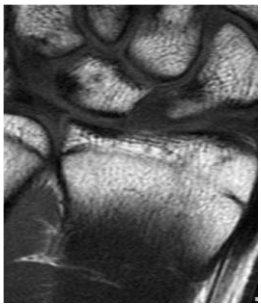
At the moment, the thickness of the coronal slices is the most important feature that FIFA uses for age estimation. In this article 3D volumetric features are used instead of 2D features.

(a) Grade I



(b) Grade II

(c) Grade III

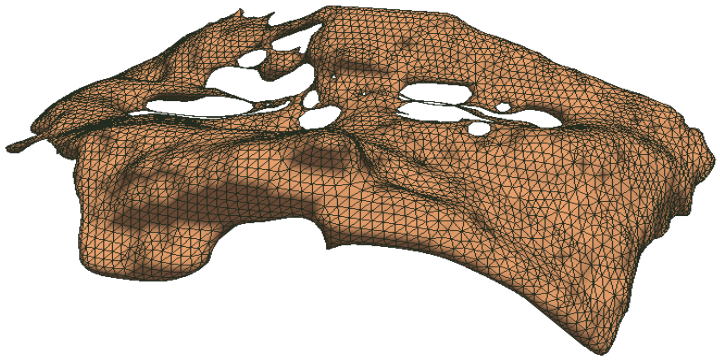


(d) Grade IV

(e) Grade V

(f) Grade IV

(g) Radius bone with its growth plate segmentation



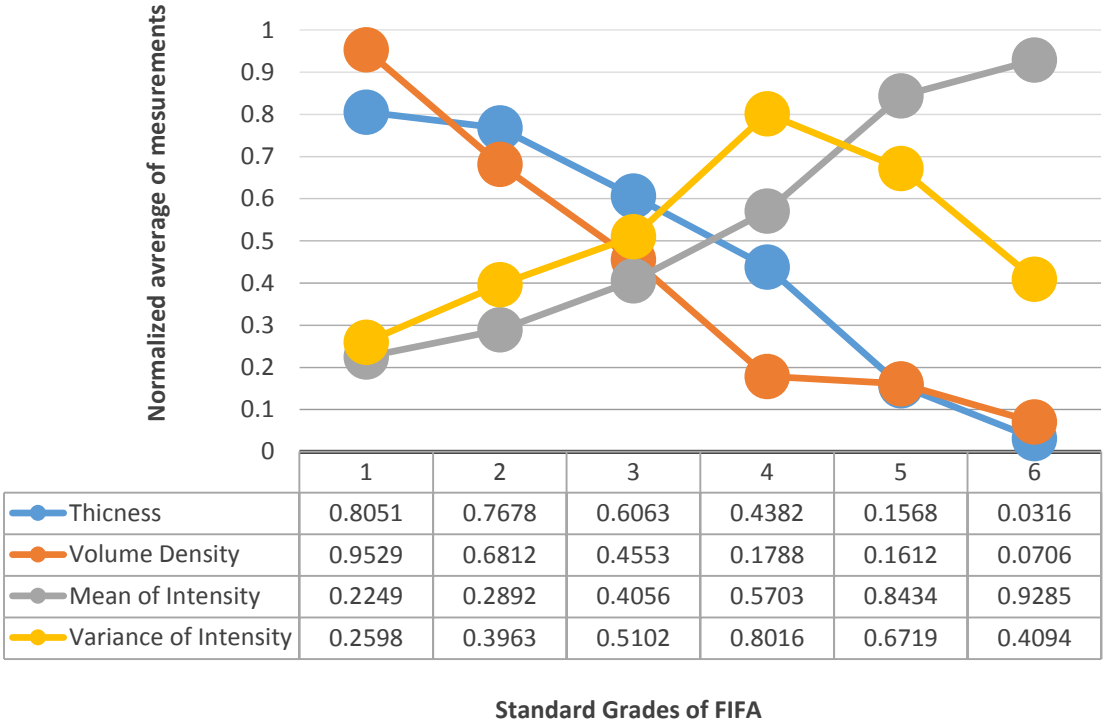
(h) Magnified growth plate

Fig 1. (a), (b), (c), (d), (e) (f) The mandatory use of MRI was introduced by FIFA in 2009. (g), (h) Results of growth plate segmentation and 3D visualization.

Results

The extracted features were correlated with FIFA grade of each player interpreted by a member of AFC panel of radiologists. The thinner the thickness of growth plate, the older the bone, and also the smaller the volume. This criterion works to determine the grade of FIFA. On the other hand, this criterion can be evaluated in any data set. Furthermore, the ratio of volume to the surface as a single feature is capable of classifying FIFA grades with an accuracy of 88.31%. which is of course unreliable for automatic bone age determination purpose. Hence, three other features are also taken into account including "volume density", "average intensity" and also "intensity variance" which is related to the beginning of ossification. The ossification pattern with aging is completely correlated with our results. In grade, I and II, because of a large amount of Physis which is darker rather than bone in MRI images, the intensity is completely low in contrast of grade V or VI. Furthermore, by developing of the ossification in grade III and IV, the middle part of the growth plates would be brighter than the corners. Hence, the higher variety in intensity will be expected in these grades in comparison to grade I and II and grade V or VI in which the dark material of Physis completely disappears (Table-1). There is a correlation between intensity and thickness with ossification. The measurements are the average amounts in each grade and also are normalized between 0 to 1.

Table 1. 3D feature extracted related to grades of FIFA



	1	2	3	4	5	6
Thicness	0.8051	0.7678	0.6063	0.4382	0.1568	0.0316
Volume Density	0.9529	0.6812	0.4553	0.1788	0.1612	0.0706
Mean of Intensity	0.2249	0.2892	0.4056	0.5703	0.8434	0.9285
Variance of Intensity	0.2598	0.3963	0.5102	0.8016	0.6719	0.4094

Conclusion

In proposed method 3D visualization and feature extraction from the distal radial growth plate will provide new criterions for player's age estimation. Combined use of 4 separate quantitative features result in high accuracy and reproducibility.