

ORIGINAL ARTICLE**ACCURACY OF AGE ESTIMATION USING MAGNETIC RESONANCE IMAGING AMONG 12-19 YEARS- OLD ADOLESCENTS AT SAINT PAUL'S HOSPITAL**Etenesh Tewolde Tesfahunegn, MD^{1*}, Fikre Enkusilassie, PHD²**ABSTRACT**

Introduction: In forensic practice as well as among football players, there is a growing need for accurate methods of age estimation. Age estimation has been done by using x-rays, which exposes the client for radiation. However, with the recent introduction of magnetic resonance imaging in Ethiopia, age estimation can be done by using this technique, which is free of ionizing radiation.

Objective: The aim of the study is to evaluate accuracy of skeletal age estimation using Tomei's magnetic resonance imaging.

Methods: Magnetic Resonance Imaging (MRI) images of the left wrist of 90 female and 86 male adolescents who were 12 to 19 years of age and had no chronic disease or developmental disorder were analyzed.

We used a 1.5Tesla MRI scanner for the study. Coronal T1 Weighted Images with a slice thickness of 1.3mm were acquired. Skeletal maturation was determined by the principal Investigator (PI) in a blinded fashion to the chronological age using Tomei's MRI atlas. Bland-Altman plots were used to determine mean differences between skeletal and chronological age.

Results: Bland-Altman analysis demonstrated that the differences between chronological and skeletal ages were not significant. Spearman's correlation coefficient showed good correlation between skeletal and chronological age both in females (spearman's rho = 0.952) and in males (spearman's rho = 0.955). Pearson's coefficient also showed a good linear correlation for (females=0.955 and for males=0.951).

Conclusions: Our result showed that magnetic resonance imaging skeletal age has good correlation with chronological age and the Tomei's magnetic resonance imaging atlas method may assume an important role in forensic age estimation. magnetic resonance imaging does not use ionizing radiation and is fundamentally more accurate than X-ray due to its high contrast resolution.

Keywords:-Age estimation, magnetic resonance imaging, forensic.

INTRODUCTION

According to the latest United Nations Children's Fund (UNICEF) estimation, about 51million births go unregistered in developing countries each year (1). As a result of these circumstances, age determination of living individuals has become an essential part of the forensic practice (2-4).

Age can be estimated through somatic features that are universally considered associated with chronological age. Unfortunately, these features do not always coincide with real chronological age for these reasons that age estimation is often very difficult and controversial. There are many variables that may result in discrepancies between biological development and chronological age, like ethnicity, low socio-economic status and hormonal imbalances (5,6).

Regarding skeletal age determination, many anatomical districts have been investigated through radiological approaches: left hand-wrist, clavicle, pelvis, and knee. Among these, the most commonly performed technique is the x-ray of the left hand-wrist using Greulich and Pyle (GP) and Tanner Whitehouse (TW) methods (7), However in order not to expose patients to ionizing radiation our study was performed by an MRI method.

Age estimation with the x-ray techniques have a described margin of error of 2-3 years, which is too inaccurate to confirm if an individual is over or under 14 or 18 years, which are ages of judicial importance in many countries. Age estimation is also needed for football players to determine whether they are under 17 or under 20 in order to have fair play.

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The International Atomic Energy Agency (IAEA) regulates the use and possible abuse of X-rays under the title "International Basic Safety Standards for Protection against Ionizing Radiation and for Safety of Radiation Sources" (CD-ROM, edition 2003, Geneva, Switzerland). Thus, in sports the use of X-rays (a radiation exposure) to determine players of over age is not allowed. For these reason, age estimation should be done by using MRI which do not expose the players to ionizing radiation which is why this study also was conducted by using MRI rather than X-ray.

Currently, MRI is used in Saint Paul Hospital Millennium Medical College (SPHMMC) for football players, mostly, to determine their ages. However, there is no study done in Ethiopia about the accuracy of MRI age estimation compared to the chronological age. Therefore, we are using the western studies to interpret the MRI imaging findings.

MRI is free of ionizing radiation with better sensitivity, it is vital to study the accuracy of MRI skeletal age estimation versus the chronological age in healthy individuals 12-19 years as previously mentioned. Thus, this study was conducted to assess the accuracy of MRI in skeletal age estimation using Tomie's MRI atlas method (8).

PARTICIPANTS AND METHODS

Study setting and examination protocol:

A Cross sectional study was conducted at SPHMMC, Department of Radiology, using a 1.5-T magnet and wrist coil. The wrist was positioned at the side of the body. The third metacarpal was placed as close as possible to the same axis as the radius. Coronal sequences was planned parallel to the distal volar radial surface. The following parameters were applied: T1-weighted spin echo, TR 350-500, TE 12-20ms, slice thickness 3mm, interslice gap 0.2mm,

Study Population and study area: The study populations include students with age range of 12-19 years from government institutions around saint Paul's hospital selected mainly for the proximity to the hospital. There are two kifle ketema's included in the study i.e Gulele kifle Ketema Wereda 9, where five government schools are included in this wereda, including Medhanealem elementary and high school, Kelem amba elementary school, Addis ababa number 1 and 2 elementary schools, and the rest of the schools are found under Addis ketema kifle ketema woreda 5 where Abbisynia secondary school, Haleluya primary school, Ediget primary school and Hibret Belijinet primary schools are found in this kifle ketema, finally, SPHMMC students were also involved in the study.

Inclusion and Exclusion Criteria:

Inclusion criteria

- Students in the age range from 12-19 years with birth certificate at hand.

Exclusion criteria

- Those cases with previous history of fracture to the left hand,
- Those cases with known hormonal imbalances like adreno-genital syndrome, precocious puberty, hyperthyroidism will be excluded from the study group.
- Those cases with known physical deformities and mental retardations will not be included in the study.

Sample size determination and sampling procedure: As the outcome of interest is a continuous variable, the sample size was calculated using the following formula:

$$N = Z^2 * S^2 / D^2$$

Z is the critical value corresponding to 95% confidence interval (CI).

S is the standard deviation.

D is the mean difference taken from previous study

$$N = (1.96 * 1/0.2)^2 = 96$$

$$\text{Female sex} = 96$$

$$\text{Male sex} = 96$$

Consecutive sampling techniques were used during the study.

Variables of the study: Dependent variable

Estimated MRI radiological age.

Independent variables

Socio demographic variables

Age

Sex

Operational Definition: All assessments were performed in accordance with a recent skeletal MRI atlas method using sex and age-matched MRI, the Tomei et al. method (8). We say MRI is accurate if the:

Standard deviation is between 0.1 and 0.9 years,

- Mean difference is between -0.8 and +0.2 years.

At skeletal age of 18:-

- The difference between skeletal age and the mean value of the chronological age were between -0.5 years and -0.2 years.

Males and females have different maturation stages and different atlases were used, respectively. Tomie's MRI age assessment methods have also assessed morphological features of the bones.

Data Collection Procedures, instruments, processing and analysis: SPSS Version 20 was used for data analysis. Scattered plots were used to determine the mean difference between the chronological and the skeletal age group. A structured questionnaire was used to collect the data on socio-demographic characteristics like age and sex, which was filled out by data collectors. The estimated radiological age was filled out by the principal investigator in a blinded fashion, to the chronological age. In order to interpret the MRI scanning, principal investigator used Tomei's MRI atlas as reference. All questionnaires were checked for completeness and consistency of responses manually. All data were entered in to EPI data then exported to SPSS versions 20 for analysis.

Ethical considerations

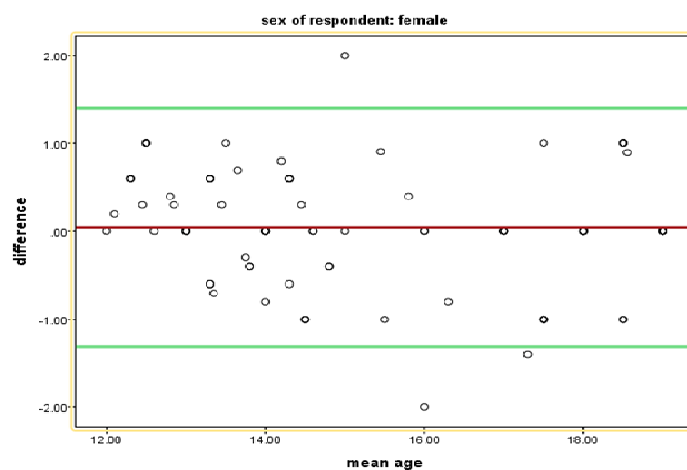
Ethical clearance was obtained from ethical review board of SPHMMC. After thoroughly discussing, the ultimate purpose and method of the study, a written consent was sought from SPHMMC and informed verbal consent was obtained from each respondent. The respondents were informed that their inclusion in the study is voluntary and they are free to withdraw from the study if they are not willing to participate.

If there was any question they did not want to answer they had the right to withdraw. To ensure confidentiality of respondents, their names were left out on the questionnaire. All interviews were done individually to keep confidentiality.

RESULTS

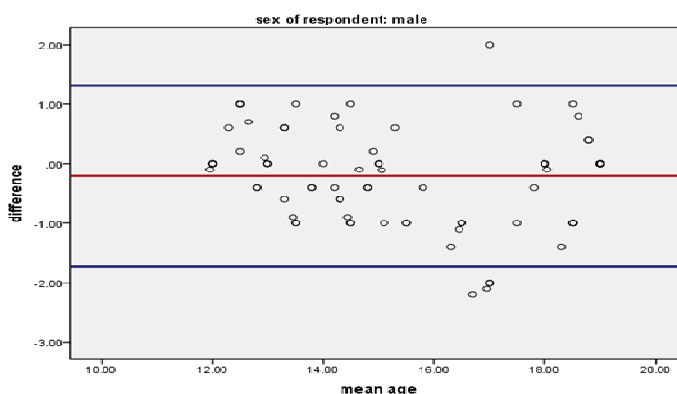
A total of 176 healthy subjects were involved in the study, MRI was done for 90 females and 86 males and a statistical analysis involved a comparison of skeletal age and chronological age. The results are presented on a scatter graph plot with Bland-Altman analysis (Figure 1a & 1b). It shows that differences between the chronological age and the MRI skeletal age are clinically not significant.

Means, Standard deviations (SD), minima and maxima of skeletal age in chronological age cohorts are shown in Table 1.



Mean=0.039

Figure 1a: Bland-Altman graph showing the differences between chronological and skeletal age for female groups.



Mean=-0.2

Figure 1b: Bland-Altman graph showing the differences between chronological and skeletal age for male groups.

Spearman's correlation coefficient(r) showed good correlation between the skeletal age and the chronological age in both females and males (Spearman's rho in females=0.952 and in males= 0.955).

Pearson's correlation coefficient also showed a good correlation in both females and male groups, respectively 0.955 and 0.951.

Table 1: Means, standard deviations, minima and maxima of skeletal age in chronological age cohorts in subjects 12-19years.

Chronological Age (Years)	Skeletal Age (Years)					
			Mean \pm SD		Min-Max	
	Males	Females	Males	Females	Males	Females
12-12.9yrs	13	14	12.4 \pm 0.4	12.7 \pm 0.3	11.9-13	12.0-13.0
13-13.9yrs	10	15	13.3 \pm 0.6	13.4 \pm 0.4	12.6-14.6	13.0-14.6
14-14.9yrs	13	17	14 \pm 0.6	14.3 \pm 0.7	13.0-15.0	13.6-16.0
15-15.9yrs	9	7	14.7 \pm 0.5	14.6 \pm 0.7	14.0-15.6	14.0-16.0
16-16.9yrs	5	4	15.2 \pm 1.4	15.6 \pm 0.6	14.0-17.6	14.6-16.0
17-17.9yrs	7	6	16.0 \pm 0.9	17.1 \pm 0.4	15.0-18.0	17.0-18.0
18-19yrs	29	27	18.3 \pm 0.8	17.9 \pm 0.9	16.0-19.0	16.0-19.0

DISCUSSION

X-ray analysis of the left hand and wrist have been used for decades to estimate age and maturation in children. However, the "bone age" determined with X-rays have some limitations to be used for forensic purposes, such as the exposure to ionizing radiation and the lack of accuracy.

European commission in its basic safety standards of the EURATOM declared that "alternative techniques which do not involve exposure to ionizing radiation must be available" (9).

Tomei et al. method shows an excellent inter-rater agreement, and the differences between chronological age and MRI skeletal age are not significant. However, these authors considered some morphological features that may have played a role in their forensic age assessment.

Our results are good in relation to the literature by Serenella Serinelli et al. (10). Their results on the scattered graph Bland -Altman analysis showed that the difference between chronological age and MRI skeletal age are not clinically significant, which is similar to our results of the Bland -Altman analysis, furthermore our study also included and observed outliers. Spearman's correlation coefficient also showed a good linear correlation between the skeletal age and chronological age in both females (Spearman's rho=0.952) and in males(Spearman's rho=0.955) which is comparable with previous studies with Spearman's rho for females of 0.96 and for males of 0.94 (11).

Schmidt et al (12) tested Greulich and Pyle's method on hand radiographs of healthy subjects and found that the standard deviation for the age range 13-16 years old varied from 0.3 to 1.7 years. Schmidt et al, (13) also tested TW2 and TW3 methods on hand x-rays and in this case the standard deviation for the age range 13-16 years old varied from 0.4 to 1.1 years with TW2 and from 0.4 to 1.2 years with TW3. Tomie's MRI method in the same age range showed standard deviations between 0.1 and 0.9 years, and our results using Tomie's method for the age range from 13 to 15.9years showed standard deviation between 0.4 and 0.7 years, so our study showed better accuracy for age estimation using Tomei's MRI atlas method.

Schmidt et al (13) also tested TW2 and TW3 method in the legally relevant skeletal age group, 14 -16 years and found that there was a serious risk of over estimation for TW2 method. The difference between the skeletal age and the mean value of the chronological age were between -0.1 and +1.4 years, in the same age range from 14-15.9 years we found the mean difference between -0.4 to +0.16 years which is comparable with other studies done by Serenelli Serene et al, whose study showed difference between -0.8 and +0.2 years. Therefore, it's clear that the Tomei's MRI method seems to provide a reduced risk of overestimation in this age range. We observed a wide range of standard deviation for the age range between 16-16.9 years. It was between \pm 1.4 years as the outliers lie in this age group and the sample size was smaller for this age range but the mean difference is comparable with the other results, which lies between -0.45 and -0.08 years.

Even if our results were good, the current recommendation of a combination of methods (physical, dental and skeletal examination of hand-wrist and clavicles) should always be taken into account especially for medico-legal purposes. In fact none of the existing methods is absolutely precise, as they present a margin of error (over/under estimation). This over/under estimation is due to two important factors: the first one is the variability of skeletal maturation, which changes among individuals of the same chronological age depending on genetic characteristics and environmental conditions, the second one being the error made by the operator, which depends mostly on his/her experience.

From the above discussion, a reasonable conclusion is that, Tomei et al. method can provide a good accuracy for age estimation. In fact, in comparison with x-ray, MRI can be proposed for age assessment as it leads to evaluate not only bone segments but also the cartilage changes occurring during the maturation process (14,15).

The lack of ionizing radiation and relative lack of operator dependence are additional advantages of MRI comparing to x-rays, computed tomography and ultrasound. The limitations of this study were few, first, there is only one MRI (1.5T) scanner at SPHMMC, which serves for the whole hospital and for other government and private hospitals which don't have their own MRI.

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Due to this fact it was difficult to find free time to study more cases. Secondly due to the possibility of artifacts, it was difficult to interpret the images and last but not least due to the presence of metallic devices MRI could not be executed.

Conclusion:

MRI does not use ionizing radiation and is fundamentally more accurate than x-ray due to its high contrast resolution. It may assume an important role in forensic age determination and foot ball players.

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Declaration of Conflict of interest: None

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