



**Saint Paul's Hospital Millennium Medical College Department of
Forensic Medicine and Toxicology**

**Evaluation of the pattern of skeletal maturity of hand and wrist
bone among 8 to 19 years old children and adolescents from schools
with known chronological age using X-rays, Addis Ababa, Ethiopia,
2024 G.C**

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Addis Ababa, Ethiopia

April 2024 G.C



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ABSTRACT

Introduction: Skeletal maturation, articulated as bone age; has been recognized as significant criterion for assessing growth and development. Wrist hand bones influence in age and gender determination. Radiographic methods are customarily used for bone age determination. For age determination purpose, hand-wrist radiographs taken from patients are commonly ideal techniques.

Objective: To evaluate the pattern of skeletal maturity of hand and wrist bone among 8 to 19 years old children and adolescents with known chronological age using X-rays. The degree of appearance and/or fusion of epiphyseal centers of hand wrist bones at certain age is assessed and then compare the findings of present study with other similar studies.

Methods: Community based, cross-sectional study design was conducted in schools found in Gullele sub city. Convenience sampling method was used to select study participants until 150 study subjects are found. Ordinal logistics regression test used to identify the association between age and skeletal maturity of the bone. p-value <0.05 is considered statistically significant. All the data analysis is done by using SPSS 26.0 version.

Results: Complete fusion of the epiphyseal end of radius in 94.5% of cases is at the age of 18 -19 years old and complete fusion of epiphyseal end of ulna at 18 -19 years only in 83% of cases. Complete fusion of the head of 2nd to 5th metacarpal bones is in 100% cases at age 16-17 years. Complete fusion of base of first metacarpal in 100% of cases 17-18 years in males and 16-17 in females. Pisiform appeared in female at the age of 9 years and at 8 years in males and 100% appearance of pisiform at 11 years in females and 14 years in males.

Conclusion and Recommendations: Complete fusion of the distal end of radius and ulna is at the age of 18-19 years. Complete fusion of head of first metacarpal is at the age of 16-17 years in females and 17-18 years in males. Complete fusion of head of 2nd to 5th metacarpals is 16-17 years. Pisiform appears at the age of 8-9 years in males and at 9-10 years in females it appears one year earlier in males.

Keywords: Radiography, Bone, X-Ray, Age, Adolescents, Hand, Wrist, Ethiopia

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ACRONYMS AND ABBREVIATION

AaBET	Addis Ababa Burn, Emergency and Trauma center
BFM	Base of First Metacarpal bone
CT	Computed Tomography
FM	Forensic Medicine
MCH	Meta-carpal head
mSV	milliSieVert
OPD	Outpatient Department
PU	Pediatric Unit
ROI	Region of Interest
RU	Radiology Unit
SM	Skeletal Maturity
SPHMMC	Saint Paul's Hospital Millennium Medical College
SPSS	Statistical package for Social Science
X Ray	Radiography

1. INTRODUCTION

1.1. Background

In day today medical life, age is vital for assessing the overall development of a patient. The chronological age, although easiest to determine if the child's date of birth is known, often does not accurately reflect a patient's development(1). "Chronological age is a key variable that has been misrepresented by demographers since a link between mortality and age was first established. Its use as a variable of choice for the analysis of all demographic phenomena which suggested that chronological age is the determinant of all demographic behaviors (2)." However, while the notion of age as the time that elapses between a person's birth and the phenomenon under study appears obvious to us today, it may encompass a number of different realities, depending on the individual, the time and the place concerned(3-5).

Because of many different factors like genetic and social or other, growth and development, and chronological age could be different among children's or people of the same age. Due to this discrepancy skeletal maturation, articulated as bone age; has been recognized as significant criterion for assessing growth and development (6,7).

The assessment of an individual's development by investigating the skeletal maturity is a very common current medical practice. There are too many methods that precisely reveal the different developmental stages. These methods work by determining the dental age and skeletal age(8). Skeletal maturity can be estimated by evaluating the morphology of the cervical vertebrae. Hand wrist radiographs have been used to estimate bone maturity, even though skeletal age determination technique is far better technique (9).

Radiographic methods are customarily used for bone age determination. For age determination purpose, hand-wrist radiographs taken from patients are commonly ideal techniques(7,9,10). Due to the possible side effects and damages of X-rays, radiation-free diagnostic methods are highly preferable. Age variation of human can be identified based on growth plates in the palms from an x ray image of hand. Initially growth plates will be thinner as the child grows to adulthood, the plates will disappear. Hand wrist x ray images are commonly used for estimation of bone age since hand can be easily exposed for minimal x-ray radiation with any position and direction, it also include many bones in single view (11).

1.2. Statement of the problem

The assessment of skeletal maturity is useful in many fields, such as pediatrics, endocrinology, pediatric dentistry, and orthodontics. In orthodontics, the degree of skeletal maturity influences the treatment planning and the optimal choice of treatment (6,12). Bone age is used for diagnosis and treatment in anthropology, cadavers, and dentistry, pediatric, orthopedic, and forensic cases in the decision-making process, and in the assessment of criminal and legal responsibility(13–16). In dentistry, especially in orthodontic treatment-planned patients, the timing of treatment and selection of the treatment method are gaining importance(17).

An increasing number of unidentified cadavers and human remains, a rise in cases requiring age determination in live individual with no valid proof of date of birth, make age assessment an important and vital tool to undertake for accurate estimation of age (3,15,16). The current educational and medical technology advancement in our continent Africa ease up the empirical age determination discrepancy during migration, law suits or medico-legal and computational sports where bone age can provide nearly accurate age information(18).

In Ethiopia people has pseudo age because of many reasons, while most children have variable physical status, developmental growth due to either nutritional, social or genetic factors. For this reason, age estimation using radiological method is vital to get the most accurate age of individuals(19–21).

Radiological examination of various ossification centers of bones form the backbone of various age determining diagnostic methodologies in the health sector(22). The hand wrist radiograph is considered to be the most standardized method of skeletal assessment. In hand wrist radiographs, the right hand is more likely to be exposed to trauma than the left hand, resulting in more reliable values using the left hand(23–26).

And therefore, the current study merely be used as a baseline to show the discrepancies between ours and other population groups using hand wrist X-ray for age determination

1.3. Significance of the study

The estimation of age is very important in medico-legal issues. Hence, it is very important, for the forensic authorities, that the age estimates are as accurate as possible. The solution of this problem is important as it is concerned to the right of legal defense of individuals.

Determining the true age of individuals is critical in medicine, ethico-legal issues, social and cultural practices as well as monitoring children's developmental status. Therefore, this study will contribute significant importance to all sectors of the society using X-ray methods of age determination technique.

Currently in Ethiopia, enough research has not been done on determination of age using radiographic study of bone. In the experience of clinical age determination being practiced in SPHMMC, it has been evident that those age determination methods notably derived from India have shown some gaps when it comes to interpreting the X-ray findings from Ethiopian descent. Therefore, this research will put a founding stone and it will pave a way to understand the patterns of appearance and fusion of the ossification centers of hand and wrist bone.

Additionally, conducting this study is believed to provide valuable information on the deliverance of justice, besides to its pioneer nature of the study, it will also provide baseline findings to upcoming studies.

Furthermore, X-ray technique is not the sole means of age assessment methods rather, MRI and CT-scan have also been used for determination of age. Strong correlation between MR skeletal age and chronological age was observed for both investigators, Pearson correlation $R^2 \geq 0.9$ for each, But X-ray is preferred in this study as it has quick and easy access, very low cost, and most importantly it's routinely used in any ordinary hospital settings.

2. LITRATURE REVIEW

2.1. Overview of hand and wrist bone

Wrist hand bones influence in age and gender determination. The wrist hand bones play crucial part because it has more exceptional features than any other part in human anatomy. Ossifications of carpal bones and growth plates in between phalanges can be easily identified if digital image or x-ray of hand wrist is accessible(27).

Normal adult human anatomy includes 206 bones, on the same way hand of human body contribute more than 25% of bones. Hand bone contains 27 small bones including 8 carpals, 5 distal phalanges, 5 proximal phalanges, 4 middle phalanges and 5 metacarpals bone and therefore, identification of gender with age estimation from a hand wrist digital image is not easily accessible task(28–31).

The process of growth can be evaluated from these bones that appearance from calcification point to epiphyseal growth plates closure occurrence throughout their growth period, hence wrist bones provide a valuable means of skeleton maturity. Some of the prominent features of wrist are very important to identify gender and age at different developmental milestones(30).

Over decades, evaluation of bone growth was based on visual method for hand and wrist bone is commonly done using two standard method: i) Greulich and Pyle atlas method and ii) Tanner Whitehouse method. These two methods take left hand digital images as input for prediction which is totally dependent on professional expert who checks input radiograph with standardized atlases to identify any differences if exists, later they assign evaluated score to radiograph. On an average a trained expert radiologist may take around 15 minutes for prediction of gender and age of an input image. These manual prediction techniques consume more time and they are subject to produce differences in prediction based on the observers. Literally, the accuracy and robustness of this technique is low because of the bias in intra and inter observers, since the laboratory experience plays vital role for reporting the correct estimation.

Predictions based on atlas methods need great labor effort to judge and compare radiograph for references from atlas images [1]. This process is also subjective that different evaluators judge in different approach based on their training and expertise level in this field. With the advancement in digital technology and digital imaging, many attempts were done to deploy a standard image processing method that will automatically explore key features from bone ossification that provides more efficient and effective approach in assessment of bone maturity. To the best of our knowledge, there are no standard parameters and tools reported yet that will identify gender with age by the input of hand wrist radiographs. The changes occur commonly in human bone that particularly greater during growth period. Hand bone is closely joined to the lower arm through radius and ulna bones. It

is made up of metacarpal and phalange bones, 8 carpal bones all together 27 small bones. These arrangements of wrist hand bones or anatomy of bones are depicted in figure 1.

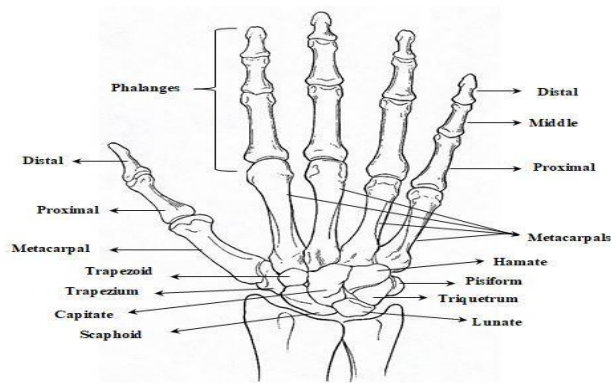


Fig 1. Anterior view of hand wrist bone

2.1.1. **CARPAL BONE:** Carpal bones are primary examples to view. “Appearance of carpal bone from an infant to adulthood is a good indicator for age estimation with a difference of 4-5 months.” Figure 1 and figure 2 illustrates the age of difference from an image based on carpal bone of wrist.



Fig 2: Appearance of carpal bones at age 9 years

2.1.1. EPIPHYSEAL PLATE FUSION: Epiphyseal plates also known growth plates is a good indicator of maturity. Growth plate at the proximal end of metacarpal stops growing at certain age, in between 14 to 16 years old. Figure 3 and 4 depicts fusion of growth plates at different stages.



Fig 3; Epiphyseal plate fusion at age 13 years

The appearance of eight carpal wrist bones in human hand in chronological order with respect to age along with gender is depicted in table 1 below. Hamate and Capitate are the two carpal bones of the wrist that appears in newborn baby, Triquetrum bone can be visible first in a girl infant baby. Appearances of carpal bones are delayed in boys compared to girls.

Table 1: Appearance of carpal bones

Bone appeared	Carpal bone	Male	Female
First	Capitate	2.0 months	4.0 months
Second	Hamate	2.0 months	4.0 months
Third	Triquetrum	2 yrs	3 yrs
Fourth	Lunate	3 yrs	4 yrs
Fifth	Trapezium	3 yrs	4 yrs
Sixth	Trapezoid	4 yrs	6 yrs
Seventh	Scaphoid	4 yrs	6 yrs
Eighth	Pisiform	9 yrs	12 yrs

2.2. Pattern of skeletal maturity of hand and wrist bone

A study conducted in Thailand to evaluate the accuracy and reliability of Greulich–Pyle, Tanner–Whitehouse and Fishman age estimation methods (8) revealed that, 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 (8) 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”(8).

According to a critical literature review study on bone age assessment methods revealed that there is no standard method for bone age assessment. Whereas the most commonly used and extensively developed methods use Hand & Wrist radiographs in children under 18 years and computed tomography (CT) images of medial end of clavicle in individuals aged 18-22 years. Also, some methods are considered applicable to children of certain populations whereas they do not conform to the growth pattern of children in other geographic locations. The study also suggested that due to great variations in results from various bone age estimation methods, pilot studies should be carried out using various modalities, on normal healthy children and these results should be compared in order to select and/or develop the best methodology that accurately represents the growth pattern and correlates best with chronological age in Pakistani children. Subsequently, large scale researches should be planned to develop national guidelines of bone age assessment for our children (9).

According to a study conducted in India, there is insignificant difference in dental development in males and females. In this study a highly significant correlation ($P < 0.01$) was obtained between MP3 and hand-wrist in all age groups of males and females. MP3 can substitute hand-wrist radiographs for skeletal maturity evaluation. MP3 radiographs are taken on standard IOPA X-ray film. The technique has the advantages of being simple, using low patient radiation dose and exhibiting high degree of clarity of the radiographs. The equipment required is available in most dental clinics. Canine maturation shows close association with MP3 and hand-wrist in the age group 12-14 years (17).

On the other hand, the study reflected skeletal age (from MP3 and hand-wrist) and dental age do not show high correlation regardless of the sex of the participant with chronological age in all the age groups which indicates that chronological age has no sufficient correlation with individual maturational development. The findings in this study reveal that there is highly significant correlation of MP3 stages with hand-wrist; however, an inconsistent relationship was observed with dental age and chronological age. This suggests that MP3 radiographs can be used for assessment of skeletal age

as hand-wrist radiographs. Dental and chronological ages are poor indicators of development status (17).

Another study that assessed skeletal age using hand-wrist radiographs following Bjork system showed that hand and wrist radiographic examination can give accurate bone age (skeletal age) picture and details of the hand and wrist method introduced by Bjork which is simple and easy to use with minimal radiographs. The hand and wrist were used because it is easy to locate the different developmental stages and ossification centers which will give accurate skeletal age compared to chronological age as it is frequently accelerated or decelerated, and it is technically simple to make radiograph. The study also elaborated that every method mentioned above has its own advantages, disadvantages, and limitation over the other methods. It also concludes more research is needed to find the best method to assess the maturity of subjects seeking orthodontic treatment (32).

In a study conducted in Nigeria 224 subjects in age group of 1-21 years old complete fusion was first observed at 17-18 years in males and 16-17 years in females. Majority (>50%) of the subjects had complete epiphyseal union by 18-19 years and 17-18 years in males and females respectively(45) which is consistent with present study.

In a study carried out in 296 subjects age group from 11-21 years old in Khmmam region observes complete fusion of distal end of ulna with its shaft was seen in the age group of 16-17 years in males and 15-16 years in females and 100% complete epiphyseal fusion at wrist joint was noticed at the age of 18-19 years in males and 17-18 years in females. Ages of bilateral complete union of epiphysis around wrist joint i.e. for lower end of radius and ulna both, it is found to be 17-18 years for girls & 18-19 years for boys in Khammam region(48).

In a study conducted Jordanian population in age group of 12-21 years old observes the youngest age group showing complete union of radius epiphyses is 16-17 years in males and 15-16 years in females. In case of lower end of ulna earliest age showing complete union in 100% of the cases is 20-21 years and 18-19 years for males and females, respectively. On the other hand, the earliest age group showing complete union is 17-18 years in case of males and 15-16 years in case of females. Therefore, females showed earlier epiphyseal fusion at lower end of radius and ulna compared to males with a difference of two years(49).

A study carried out between the age group of 10 to 20 years in Kavrepalanchok district of Nepal found the epiphyseal fusion at the distal end of radius and ulna to be hundred percent at the age of 18-19 years in males and 17-18 years in females. At wrist, the complete union of epiphysis is seen by 18-19 years in males and 16-17 years in females (46). A study in Addis Ababa observes the complete fusion of the epiphyses of radio-ulnar was observed 80% at the age interval of 18-19 years old students(44)

The metacarpal heads appear as circular undifferentiated ossified centers until approximately 5 or 6 years of age, at which stage they begin to develop distal articular surfaces and complete fusion of the metacarpals occurs between 14 and 16 years of age (35).

A study on Bengalis observed that the ossification center of pisiform appears by 9-12 years in females and 12-17 years in males, studied the appearance of pisiform in Uttar Pradesh population on both male and female subjects and observed that it appears by 11 years in females and by 13 years in males (36).

Studied the appearance of wrist ossification centers in Australians and concluded that pisiform appears by the age of 9 years in females and by 11 years in males (37). a study on North Karnataka observed that the ossification center of Pisiform appears by 6.-15 years in females and 12-15 years in males(51).

A retrospective radiological study done in Saudi Arabia in 2020 with 279 children shows that the pisiform bone in females starts to ossify at 7 years old but only at age group 9 in boys and it was the last bone to ossify in both gender (39).

According to a study conducted in Shaheed Hassan Khan Mewati Government Medical College, Haryana showed that skeletal age assessment is one of the most reliable methods for assessing developmental age. The correct estimation of developmental age is required by pediatric endocrinologist and pediatric orthopedic surgeon for choosing the effective treatment procedure in a child patient. The study also added that the accurate age assessment has its importance in forensics. The study identified various bone age assessment methods and emphasized the hand wrist radiography is a boon for medical science. Various methods of hand –wrist assessment has been devised, the latest being the automated systems. The study also conclude that no method of hand wrist radiography is flawless and lot of research is required in this direction to obtain a desired hand wrist radiographic technique for skeletal age assessment (40).

Another study conducted in India among a total of 240 subjects aged between 12-21 years showed that, the Risser's scores evaluated in X ray and USG findings show predominance in X-ray (68.3%) as compared to USG (38.3%) findings. Among the X-ray findings the highest score was found in the age group of 20-21 years (4.93 ± 0.34) and lowest was in 12-13 years (1.11 ± 0.33). In case of USG findings, the highest score was found in the age group of 20-21 years (4.11 ± 1.02) and lowest was in 12-13 years (1.66 ± 0.86). The regression equations for predicting the age by X-ray and USG was calculated. Among the regression equations, X-ray has higher coefficient of determination ($R^2=0.84$) than USG ($R^2=0.44$) among all the subjects irrespective of gender. The coefficient of determination was higher

for females on both X-ray ($R^2=0.92$) and USG ($R^2=0.55$). The males have coefficient of regression in X-ray ($R^2=0.76$) and USG ($R^2=0.29$). The predicted mean age was observed to be close to actual age on X-ray among all the subjects. However, the predicted mean age was observed to be distant from actual age on USG among all the subjects (41).

3. OBJECTIVES

3.1. General objective

Evaluation of the pattern of skeletal maturity of hand and wrist among 8 to 19 years old children and adolescents from schools with known chronological age using X-rays, Addis Ababa, Ethiopia, 2023 G.C.

3.2. Specific objective

1. To find the degree of fusion of epiphyseal centers of distal end of ulna and radius among school children, Addis Ababa, Ethiopia, 2023 G.C.
2. To find the degree of fusion of base of 1st metacarpal bones and head of the rest metacarpal bone among school children, Addis Ababa, Ethiopia, 2023 G.C.
3. To find the appearance or not appearance of the pisiform bone among school children and, Addis Ababa, Ethiopia, 2023 G.C.
4. Compare and contrast the degree of skeletal maturity observed between male and females at different chronological age among school children, Addis Ababa, Ethiopia, 2023 G.C.

4. METHODOLOGY

4.1. Study area and period

This study is conducted at Gullele sub-city which is among the 11 sub cities in Addis Ababa city administration between May 2023 and August 2023. The site of the study, Gulele sub city, Ediget ber elementary school and Abissiniya secondary and preparatory school selected as study area. This is because of resource constraint related to radiation cost and its proximity to Saint Paul's hospital millennium medical college, where the radiography diagnosis will take place.

4.2. Study Design

Analytical, community based, cross-sectional study is conducted whereby data collected from the study subjects using radiology (X-Ray) of the non-dominant hand.

4.3. Source and study population

4.3.1 SOURCE POPULATION

All healthy children and adolescents aged 8-19 years old students enrolled to schools, in Gullele sub city, Addis Ababa.

4.3.2 STUDY POPULATION

All healthy children aged 8-19 years old students enrolled in elementary classes in Ediget ber elementary school and Abissiniya secondary and preparatory school classes in Gullele sub city, Addis Ababa, and who fulfill the inclusion criteria.

4.4. Sample Size Determination: The sample size is determined by using Single population

proportion formula $\left(\frac{(z_{\alpha/2})^2 p(1-p)}{d^2} \right)$ with the following assumption of 50% for no former study is conducted in the country. A 95% level of confidence, 5% margin of error and 5% non-respondent rate will be used.

$$n = \frac{(z_{\alpha/2})^2 p(1-p)}{d^2}$$

Where n = the desired sample size.

$Z_{\alpha/2}$ = critical value at 95% confidence level of certainty = 1.96.

P = is the proportion of radiography and ultrasonography mean value measurement = 50%.

d = marginal error of between the sample and population = 5%

$$n = \frac{(1.96)^2 0.5(1-0.5)}{0.05^2} = \frac{0.9604}{0.0025} = 384$$

Then using correction formula as the total population is below 10,000

Therefore, based on the total average number of students enrolled in single classroom at Abyssinia secondary and preparatory school and Ediget Ber primary school is 40 in each class. So, taking 3 class from each school would bring a total of about 240 students. Since, the source population is less than 10,000 the sample size was adjusted with the following correction formula.

n = the desired sample size?

N_0 = Initial total sample size (384).

N = Total population (240)

$$n = \frac{n_0}{1 + (n_0/N)} = \frac{384}{1 + (384/240)} = \frac{384}{2.6} = 147$$

$$1 + (n_0/N) = 1 + (384/240) = 2.6$$

Using 5% non-respondent rate, the total sample size will become = 154

4.5. Eligibility criteria

4.5.1 INCLUSION CRITERIA

- ✓ Both the males and females between the age group of 8 to 19 years
- ✓ Subjects having proof of age (in the form of birth certificate, school records, ration card and immunization card) will be included.

4.5.2. EXCLUSION CRITERIA

- ✓ Subjects displaying any sign of disease (thyroid dis-function, rickets etc) affecting skeletal maturation.
- ✓ Subjects with history or any stigmata of previous fractures of bones (of hand wrist) and subjects who are severely malnourished will not be included in this study.
- ✓ Female subjects who are pregnant will be excluded.

4.6. Sampling technique and Sampling procedure

All healthy children and adolescents aged 8-19 years old who are enrolled in Ediget ber elementary school and Abissiniya high school and preparatory school in Gullele sub-city is included. For the purpose of convenience with regard to limited resource, convenient sampling will be used as all study participants might not have birth certificates and all study participant with birth certificates might not give consent to participate in the study because of the concern of radiation exposure. When a study subject is found to be eligible for this study but, did not gave a consent, those subjects will be automatically excluded and baseline characteristic of those consenting and not consenting subjects will be assessed to avoid sampling bias. Eligible and willing participants will be assigned for the X-ray until I get 150 study subjects with X-ray of the hand wrist.

4.7. Data collection, quality, and analysis

The subjects has given an explanation in their understandable language about the procedure and written informed consent taken. The consent and written informed sheet is translated to Amharic and Oromiffa for the study subject and parents to read and sign upon consenting. Regarding children from school consent will be taken from the principal of the respective school. The data regarding students' particulars like age, sex, clinical history etc. has taken on predesigned proforma.

Detailed physical examination has done. The radiography in the form of X-rays was done. Visualization by hand & wrist plain film radiographs using standard posteroanterior (PA) view of the hand and wrist was taken. The effective radiation received during each exposure is between 0.0001-0.1 mSV (43). Typically, left-hand radiographs is utilized (as most individuals are right dominant and

the left hand has less chance of being deformed). The subjects was asked to lie down their left-hand prone position for X-ray. Adequate precautions has taken to avoid unnecessary X-ray exposure of subjects and as well for the working staffs.

The radiographic staging of X-rays scan of individual subject has evaluated with respect to the stage of epiphyseal ossification by two seniors from forensic physician . Each of assessors has blindly (without knowing the chronological age of the study subjects) evaluate the age of the study subjects by comparing with the given standard of Greulich–Pyle method. When there is a disagreement between those assessors regarding on assessed age, a third assessors from forensic senior will make an assessment on the final age. The X-rays will be assessed as appearance and not-appearance of epiphysis and different phases of skeletal maturity will be graded according to McKern and Stewart (1957) (43). Classification on epiphyseal union (stage of fusion) which subdivides the continuum of epiphyseal union into five stages is shown on Table below:

Table 1: Classification on epiphyseal union

Stage	Description
Stage 1	Nonunion – when the epiphyseal cartilage did not begin to decrease in thickness
Stage 2	Commence of union – when the thickness of epiphysial cartilage was found to be reduced appreciably (1/4th united)
Stage 3	Incomplete union – when the epiphysis has begun to fuse with shaft and complete union was well underway (1/2 united)
Stage 4	Complete union – when the epiphyseal cartilage was bony in architecture and its density indistinguishable from the epiphysis and diaphysis in its neighborhood but an epiphysial line called epiphysial scar could still be distinguished. (3/4 united)
Stage 5	Complete union – with absence of epiphyseal scar

Zero (0) will be designated for the appearance of bone and not appearing will indicate when the epiphyseal end has not appeared at all.

Operational definitions

1. Appearance: If the ossification center has appeared and visible on plain radiography.
2. Non-appearance: If the ossification center of interest doesn't appear or exist on viewing plain radiography.

3. Non fusion: Includes all ossification centers where the epiphysis has appeared but does not yet start fusing or fused completely. It includes stage 1 to stage 2 of epiphyseal union.
4. Partial fusion: Where the epiphysis of the bone has started fusion but not into phase of completed fusion. Epiphyseal scar can be present and includes stage 3 and 4 of epiphyseal union.
5. Completed fusion: where the epiphysis of the bone has completely fused, and no epiphyseal scar is visible, and it includes stage 5.

4.8. Statistical analysis

Results is presented in tables, graphs, scatter plot and narrations.ordinary logistic regression test is used to identify association between skeletal maturity of wrist and hand bone with age and sex of the participants.p-value <0.05 will be considered to be statistically significant. Inter-observer difference and the percentage will be calculated and assessed regarding reading of the X-rays and for that Kappa statistics will be calculated to know the agreement and disagreement between the two assessors. The data will be entered, cleaned, and coded in Microsoft Excel and transferred and analyzed through Statistical Package for the Social Sciences (SPSS) Statistics for Windows, version 26.0.

4.9. Ethical consideration

Ethical clearance was obtained from institutional review board of SPHMMC, Research Internal Review Board (IRB) committee. Support letter from department of forensic medicine was written to SPHMMC radiology and pediatric units. Informed written consent was obtained from all study participants from their parents or legal guardian. Participants and/or parents has informed about the objective of the study, the possible risks and benefits of participating in the study.

After information is provided about purpose of the study, non- invasiveness of the data collection procedure, confidentiality of the information and respondents has reassured that they would be anonymous (unnamed). Then respondents was given a chance to ask anything about the study and to be free to refuse or stop at any moment they want if their choice.

4.10. Dissemination and utilization of result

Since the primary objective of this thesis is for partial fulfillment of specialty training in Forensic Medicine and Toxicology; it will be presented and submitted to SPHMMC department of Forensic Medicine and Toxicology. In addition, copies of the result will be given to SPHMMC pediatrics and radiology unit to utilize the information for further development of strategic and educational plan promotion. Presentations at professional, local, national and international meetings and publication in peer reviewed national or international journals will be attempted.

5. RESULTS

5.1. Characteristics of the study participants

In the present study a total of 150 participants from Abyssinia secondary & preparatory school and Edigetber elementary school in the age group of 8-19years is included and more than half 94(62.7%) of the students are males while the remaining 56(37.3%) are females. The mean age of study participants was 13.65years old(min=8,max=19,SD 3.135)

as shown in table 5.1 below highest number of participants is observed 17 in the age group of 15-16 years old followed by 16 at age 17-18 years old and the lowest number of participants are 8 and 6 in the age 8-9 and 19-20 years old respectively.

			Sex		Total
			Male	Female	
Age	8-9	Count	5	3	8
	9-10	Count	5	4	9
	10-11	Count	8	5	13
	11-12	Count	11	4	15
	12-13	Count	11	4	15
	13-14	Count	5	5	10
	14-15	Count	9	6	15
	15-16	Count	12	5	17
	16-17	Count	8	6	14
	17-18	Count	10	6	16
	18-19	Count	8	4	12
	19-20	Count	2	4	6
	Total	Count	94	56	150
		%	62.7%	37.3%	100.0%

Table 5.1 Distribution of age and sex

5.2. Pattern of dentition with age

Regarding the dentition of subjects a total of 24 teeth count (mixed dentition) was observed between the age group of 8-12years old.all of the study participants in the age group of 13-18years have permanent teeth,and 63% of them have a more than 28 teeth.in the age group of 16-19years old in 97% of cases have a total of 32 teeth.106(70%)(64-(42%) male ,42(27%)female participants have permanent and 45(30%)(31-(20.5%)male,14(9.5%)female have mixed dentition.

Table 5.2. distribution of age, sex and type of dentition

Dental Type			Male	Female	Total
Mixed	Age of correspondant	8-9	5	3	8
		9-10	5	3	8
		10-11	9	4	14
		11-12	10	4	14
		12-13	2	0	2
	Total		31	14	45
Permanent		11-12	1	0	0
		12-13	9	4	13
		13-14	4	7	11
		14-15	8	7	15
		15-16	10	7	17
		16-17	8	6	14
		17-18	12	4	16
		18-19	12	7	19
	Total		64	42	106

5.3. Pattern of age at menarche

Regarding to age of menarche in female participants all participants in the age group of 8-11years(33.9%) have not started to see menses.in most of females (32.1%) menarche started at the age of 12years and in 25% of at the age 13years.the maximum age of participants to see menarche is 15year and the least is 12year.

Table 5.3 distribution of age at menarche

		Menarche		
		Frequency	Percent	Total
Age at menarche	Not started	19	33.3	19
	13	14	25	14
	14	3	5.3	3
	15	2	3.5	2
	12	18	32.1	18
Total				56

5.4 Pattern of skeletal maturity of hand wrist bone

The bone fusion pattern was assessed by 2 readers (raters) and there were no potential inter-observer differences concerning the evaluation of the fusion where Cohen's kappa score being $k=0.78$) that implies there was a substantial agreement between the two assessors.

5.4.1 Degree of fusion of lower end of radial bone

The maturity of epiphyseal lower end of radial bone among age of 8-9years old participants in 75% at stage 2 fusion and 25% at stage 3 fusion .stage 5 fusion seen in subjects at age of 16-17 years old in 14.3% cases and 42.9% cases at stage 3 and stage 4 fusion.among participants of age of 18-19 years old in 50% of cases and 19-20 years in 66.7% in stage 5 fusion.

age * lower end of radius

			Lower end of radius					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
age	8-9	Count	0(0.05)	6(75%)	2(25%)	0	0	8(10%)
	9-10	Count	3(33.3%)	2(22.2)	4(44.4)	0	0	9(100%)
	10-11	Count	0	7(53.8%)	6(46.2%)	0	0	13(100%)
	11-12	Count	0	5(33.3%)	10(66.7%)	0	0	15(100%)
	12-13	Count	0	3(20%)	12(80%)	0	0	15(100%)
	13-14	Count	0	1(10%)	9(90%)	0	0	10(100%)
	14-15	Count	0	0	13(86.7%)	2(13.3%)	0	15(100%)
	15-16	Count	0	2(11.8%)	9(52.9%)	6(35.3%)	0	17(100%)
	16-17	Count	0	0	6(42.9%)	6(42.9%)	2(14.3%)	14(100%)
	17-18	Count	0	0	5(31.3%)	7(43.8%)	4(25%)	16(100%)
	18-19	Count	0	0		6(50%)	6(50%)	12(100%)
	19-20	Count	0	0	1(16.7%)	1(16.7%)	4(66.7%)	6(100%)

Table 5.4.1fusion of distal end of radius with age

5.4.2 Pattern of lower end of ulnar bone maturity

In the lower end of ulnar bone maturity appearance observed in 100% of the participants and among the age of 8-9years old in 37.5% cases was in stage 1 fusion and 62.5% cases was at the stage 2 fusion. stage 5 fusion occurs in 11.8% of participants aged group of 15-16years old. the greater percent of stage 5 fusion observed in participants age of 19-20 years old in 66.7% cases followed by in 41.7% cases in age of 18-19years old.

age * lower end of ulna

			lower end of ulna					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
age	8-9	Count	3(37.5%)	5(62.5%)	0	0	0	8(100%)
	9-10	Count	7(77.8%)	2(22.2%)	0	0	0	9(100%)
	10-11	Count	9(69.2%)	3(23.1%)	1(7.7%)	0	0	13(100%)
	11-12	Count	10(66.7%)	5(33.3%)	0	0	0	15(100%)
	12-13	Count	5(33.3%)	7(46.7%)	3(20%)	0	0	15(100%)
	13-14	Count	3(30%)	4(40%)	3(30%)	0	0	10(100%)
	14-15	Count	2(13.3%)	6(40%)	6(40%)	1(6.7%)	0	15(100%)
	15-16	Count	2(11.8%)	2(11.8%)	9(52.9%)	2(11.8%)	2(11.8%)	17(100%)
	16-17	Count	0	0	7(50%)	5(35.7%)	2(14.3%)	14(100%)
	17-18	Count	0	1(6.3%)	7(43.8%)	4(25%)	4(25%)	16(100%)
	18-19	Count	0	0	2(16.7%)	5(41.7%)	5(41.7%)	12(100%)
	19-20				1(16.7%)	1(16.7%)	4(66.7%)	6(100%)

Table 5.4.2 fusion of distal end of ulna with age

5.4.3 Patterns of base of 1st metacarpal bone maturity

On the pattern of base of 1st metacarpal bone maturity of participants in 100% cases appearance of ossification center observed and among participants age of 8-9 years old in 37.5% cases was at stage 3 and 4 fusion and the rest 12.5% at the stage 1 and 2 fusion . stage 5 fusion begins to be seen in participants age of 14-15 years old in 6.7% of cases and greatest percent of stage 5 fusion observed in 100% of cases in age of 19-20 years old followed 75% in 18-19 years old .with in the age of 17-18 years old in half (50%) of cases was at stage 5 fusion and the rest 50% of cases was at stage 4 fusion.

age * base of first metacarpal

			base of first metacarpal					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
age	8-9	Count	1(12.5%)	1(12.5%)	3(37.5%)	3(37.5%)	0	8(100%)
	9-10	Count	0	6(66.7%)	3(33.3%)	0	0	9(100%)
	10-11	Count	1(7.7%)	4(30.8%)	7(53.8%)	1(7.7%)	0	13(100%)
	11-12	Count	1(6.7%)	5(33.3%)	9(60%)	0	0	15(100%)
	12-13	Count	1(6.7%)	5(33.3%)	7(46.7%)	2(13.3%)	0	15(100%)
	13-14	Count	0	4(40%)	2(20%)	4(40%)	0	10(100%)
	14-15	Count	0	2(13.3%)	5(33.3%)	7(46.7%)	1(6.7%)	15(100%)
	15-16	Count	1(5.9%)	1(5.9%)	4(23.5%)	9(52.9%)	2(11.8%)	17(100%)
	16-17	Count	0	0	1(7.1%)	4(28.6%)	9(64.3%)	14(100%)
	17-18	Count	0	0	0	8(50%)	8(50%)	16(100%)
	18-19	Count	0	0	0	3(25%)	9(75%)	12(100%)
	19-20	Count	0	0	0	0	6(100%)	6(100%)

Table 5.4.3 fusion of base of 1st metacarpal with age

5.4.4 Patterns of heads of 2nd to 5th metacarpal bone maturity

In all participants (100%) appearance of ossification centers for heads of 2nd to 5th metacarpals was observed. among participants age group of 8-9 years old 37.5% cases was at stage of 3 and stage 4 and in age group of 9-10 years old in 88.9% cases was at stage 4. the least age group stage 5 fusion occurs at the age group of 12-13 years old in 6.7% and 10% and 20% of cases in the age group of 13-14 years old and 14-15 years old respectively. the highest percent of stage 5 fusion which is 100% of cases observed in the age of 18-19 years old followed by 87.5 and 71.4% of cases in the age group of 17-18 years old and 16-17 years old respectively. among the age group of 15-16 years old both stage 4 and 5 fusion in 29.4% cases and 41.2% of cases at stage 3 fusion.

age * head of 2nd to 5th MC

			head of 2 nd to 5 th MC					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
age	8-9	Count	1(12.5%)	1(12.5%)	3(37.5%)	3(37.5)	0	8(100%)
	9-10	Count	0	1(11.1%)	8(88.9%)	0	0	9(100%)
	10-11	Count	1(7.7%)	0	11(84.6%)	1(7.7%)	0	13(100%)
	11-12	Count	0	0	15(100%)	0	0	15(100%)
	12-13	Count	0	0	12(80%)	2(13.3)	1(6.7%)	15(100%)
	13-14	Count	0	1(10%)	6(60%)	2(20%)	1(10%)	10(100%)
	14-15	Count	0	1(6.7%)	7(46.7%)	4(26.7)	3(20%)	15(100%)
	15-16	Count	0	0	7(41.2%)	5(29.4)	5(29.4%)	17(100%)
	16-17	Count	0	0	0	4(28.6)	10(71.4)	14(100%)
	17-18	Count	0	0	0	2(12.5)	14(87.5)	16(100%)
	18-19	Count	0	0	0	0	12(100)	12(100%)
	19-20	Count	0	0	0	0	6(100%)	6(100%)

Table 5.4.4 fusion of head of 2nd-5 metacarpal with age

5.4.5 Pattern of appearance or non-appearance of pisiform bone

Pisiform appeared in 129 (86%) and not appeared in 21(14%)cases.among participants age group of 8-9 years old in 50% of them appeared and in the rest 50% not-appeared.the highest percent of appearance of psiform observed in the age group 14-19 years old in 100% of cases followed by 90%and 86.7% in the age group of 13-14 years old and 12-13yerar old respectively.in both participants age group of 9-10yerar old and 11-12 years pisiform appeared in 66.7% and not appeared in 33.3% cases.in the age group of 10-11yerar old in 53.8% cases pisiform has appeared.

age * pisiform

			Pisiform		Total
			not appeared	appeared	
age	8-9	Count	4(50%)	4(50%)	8(100%)
	9-10	Count	3(33.3%)	6(66.7%)	9(100%)
	10-11	Count	6(46.2%)	7(53.8%)	13(100%)
	11-12	Count	5(33.3%)	10(66.7%)	15(100%)
	12-13	Count	2(13.3%)	13(86.7%)	15(100%)
	13-14	Count	1(10%)	9(90%)	10(100%)
	14-15	Count	0	15(100%)	15(100%)
	15-16	Count	0	17(100%)	17(100%)
	16-17	Count	0	14(100%)	14(100%)
	17-18	Count	0	16(100%)	16(100%)
	18-19	Count	0	12(100%)	12(100%)
	19-20	Count	0	6(100%)	6(100%)

Table 5.4.5 appearance of pisiform with age

5.5 Skeletal maturity of hand and wrist bone observed between male and female

5.5.1 Degree of fusion of epiphyses of lower end of radial bone among male and female

In the age of 9-10 years old in females 50% and males 20% of cases was at stage 1 fusion. stage 5 fusion starts to be seen at the age group of 16-17 years old in males 12.5% and in females 16.6%. highest percent of stage 5 fusion observed in males at the age of 19-20 years in 100% of cases and in females at the age of 18-19 years old in 75%. stage 4 fusion begins at the age of 14-15 years old both on male (11.1%) and female (16.6%).

Count

age			Lower end of radius					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
8-9	sex	male		3(60%)	2(40%)			5
		female		3(100%)	0			3
9-10	sex	male	1(20%)	2(40%)	2(40%)			5
		female	2(50%)	0	2(50%)			4
10-11	sex	male		5(62.5%)	3(37.5%)			8
		female		2(40%)	3(60%)			5
11-12	sex	male		3(27.2%)	8(72.7%)			11
		female		2(50%)	2(50%)			4
12-13	sex	male		3(27.3%)	8(72.7%)			11
		female		0	4(100%)			4
13-14	sex	male		1(20%)	4(80%)			5
		female		0	5(100%)			5

14-15	sex	male			8(88.8%)	1(11.1%)		9
		female			5(83.3%)	1(16.6%)		6
15-16	sex	male		2(16.6%)	7(58.3%)	3(25%)		12
		female		0	2(40%)	3(60%)		5
16-17	sex	male			4(50%)	3(37.5%)	1(12.5%)	8
		female			2(33.3%)	3(50%)	1(16.6%)	6
17-18	sex	male			4(40%)	4(40%)	2(20%)	10
		female			1(16.6%)	3(50%)	2(33.3%)	6
18-19	sex	male				5(62.5%)	3(37.5%)	9
		female				1(25%)	3(75%)	8
19-20	sex	male					2(100%)	2
		female			1(25%)	1(25%)	2(50%)	4

Table 5.5.1 Maturity of lower end of radius with age and sex

5.5.2 Degree of fusion of epiphyses of lower end of ulna bone among male and female

In male participants the highest percent of stage 1 fusion observed at the age group of 9-10 years in 100% of case and in females at the age group of 10-11 years old in 60% of cases. stage 5 fusion seen at the age group of 15-16 years old in 16.6% of cases in males and at 16-17 years old in 16.7% in females. the highest percent of stage 5 fusion observed in both males and females at the age group of 18-19 years old in 50% of cases in females and 100% in males at the age of 19-20 years..

sex * lower end of ulna * age

Count

			lower end of ulna					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
8-9	sex	male	3(60%)	2(40%)				5

		female	0	3(100%)				3
9-10	sex	male	5(100%)	0				5
		female	2(50%)	2(50%)				4
10-11	sex	male	6(75%)	2(25%)	0			8
		female	3(60%)	1(20%)	1(20%)			5
11-12	sex	male	8(72.7%)	3(27.3%)				11
		female	2(50%)	2(50%)				4
12-13	Sex	male	5(45.5%)	4(36.4%)	2(18.2)			11
		female	0	3(75%)	1(25%)			4
13-14	sex	male	2(40%)	3(60%)	0			5
		female	1(20%)	1(20%)	3(60%)			5
14-15	sex	male	2(22.2%)	5(55.6%)	2(22.2%)	0		9
		female	0	1(15%)	4(60%)	1(15%)		6
15-16	sex	male	2(16.6)	2(16.6)	6(50%)	2(16.6%)		12
		female	0	0	3(60%)	2(40%)		5
16-17	sex	male			5(62.5%)	2(25%)	1(12.5%)	8
		female			2(33.3%)	3(50%)	1(16.7%)	6
17-18	sex	male		1(10%)	6(60%)	1(10%)	2(20%)	10
		female		0	1(16.7%)	3(50%)	2(33.3%)	6
18-19	sex	male			2(25%)	3(37.5%)	3(37.5%)	8
		female				2(50%)	2(50%)	4

19-20	sex	male				2(100%)	2
		female		1(25%)	1(25%)	2(50%)	4

Table 5.5.2 maturity of lower end of ulna with age and sex

5.5.3 Degree of fusion of base of 1st metacarpal bone among males and females

In female participants aged 8-9 years old 100% in stage 4 fusion where as in males with in the same age in 60% at stage 3 and 20% in stage 1 and stage 2. stage 5 fusion of observed in female participants at the age of 12-13 years old in 25% cases and in males stage 5 fusion seen at the age of 16-17 years old in 62.5% of cases. 80% of female participants with in the age of 16-17 years old was in stage 5 fusion. both male and female participants aged 17-18 years old 50% of cases at the stage 4 and 50% at the stage 5 fusion. stage 5 fusion in 100% female participants observed in the age of 18-19 years old where as in males with in the age of 19-20 years old.

sex * base of first metacarpal * age

Count

age			base of first metacarpal					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
8-9	sex	male	1(20%)	1(20%)	3(60%)	0		5
		female	0	0	0	3(100%)		3
9-10	Sex	male		3(60%)	2(40%)			5
		female		3(75%)	1(25%)			4
10-11	sex	male	1(12.5%)	2(25%)	5(62.5%)	0		8
		female	0	2(40%)	2(40%)	1(20%)		5
11-12	sex	male	1(9%)	4(36.3)	6(54.5)			11
		female	0	1(25%)	3(75%)			4
12-13	sex	male		5(45.5%)	5(45.4%)	1(9%)	0	11
		female		0	2(50%)	1(25%)	1(25%)	4

13-14	sex	male		4(80%)	1(20%)	0		5
		female		0	1(20%)	4(80%)		5
14-15	sex	male		2	5	2	0	9
		female		0	0	5(93.3%)	1(6.7%)	6
15-16	sex	male	1(5%)	1(5%)	4(40%)	6(50%)	0	12
		female	0	0	0	3(60%)	2(40%)	5
16-17	sex	male			1(12.5%)	2(25%)	5(62.5%)	8
		female			0	2(20%)	4(80%)	6
17-18	sex	male				5(50%)	5(50%)	10
		female				3(50%)	3(50%)	6
18-19	sex	male				3(37.5%)	5(62.5%)	10
		female				0	4(100%)	4
19-20	sex	male					2(100%)	2
		female					4(100%)	4

Table 5.5.3 maturity of base of 1st metacarpal

5.5.4 Degree of fusion of epiphyses of 2nd to 5th metacarpals among males and females

In female participants age group of 8-9 years old 100% of was on stage 4 fusion and in males 60% were on stage 3 and 20% in stage 1 and stage 2. stage 5 fusion seen in 25% of cases in age group of 12-13 years old in females and 15-16 years old in males. 100% of cases are in stage 5 fusion at the age group of 17-18 years in females and 18-19 years old in males.

sex * head of 2nd to 5th MC * age

Count

age			head of 2nd to 5th MC					Total
			stage 1	stage 2	stage 3	stage 4	stage 5	
8-9	sex	male	1(20%)	1(20%)	3(60%)	0		5
		female	0	0	0	3(100%)		3
9-10	sex	male		1(20%)	4(80%)			5
		female		0	4(100%)			4
10-11	sex	male	1(12.5%)		7(87.5%)	0		8
		female	0		4(80%)	1(20%)		5
11-12	sex	male			11(100%)			11
		female			4(100%)			4
12-13	sex	male			10(90.9%)	1(9.1%)	0	11
		female			2(50%)	1(25%)	1(25%)	4
13-14	sex	male		1(20%)	4(80%)	0	0	5
		female		0	2(40%)	2(40%)	1(20%)	5
14-15	sex	male		1(11.1%)	7(77.1%)	1(11.1%)	0	9
		female		0	0	3(50%)	3(50%)	6
15-16	sex	male			7(58.3%)	2(16.7%)	3(25%)	12
		female			0	3(60%)	2(40%)	5
16-17	sex	male				3(37.5%)	5(62.5%)	8
		female				1(16.7%)	5(83.3%)	6

17-18	sex	male				2(20%)	8(80%)	10
		female				0	6(100%)	6
18-19	sex	male					8(100%)	8
		female					4(100%)	4
19-20	sex	male					2(100%)	2
		female					4(100%)	4

Table 5.5.4 maturity of head 2nd -5th metacarpal

5.5.5 Appearance and non-appearance of pisiform bone in males and females

The appearance and non appearance pattern observed among participants age group of 8-9 years old females in 100% of cases pisiform not appeared and in the same age group in males in 20% of cases pisiform has appeared. In age group of 9-10 years old in males pisiform has appeared in 80% cases and in females only in 50% cases pisiform has appeared. 100% of cases shows appearance of pisiform in males at the age group of 14-19 years old and in females at the age of 11-19 years old.

sex * pisiform * age

Count

age			Pisiform		Total
			not appeared	appeared	
8-9	sex	male	4(80%)	1(20%)	5
		female	3(100)	0	3
9-10	sex	male	1(20%)	4(80%)	5
		female	2(50%)	2(50%)	4
10-11	sex	male	4(50%)	4(50%)	8
		female	2(40%)	3(60%)	5
11-12	sex	male	5(45.5%)	6(54.5%)	11

		female	0	4(100%)	4
12-13	sex	male	2(18.2%)	9(81.8%)	11
		female	0	4(100%)	4
13-14	sex	male	1(20%)	4(80%)	5
		female	0	5(100%)	5
14-15	sex	male		9(100%)	9
		female		6(100%)	6
15-16	sex	male		12(100%)	12
		female		5(100%)	5
16-17	sex	male		8(100%)	8
		female		6(100%)	6
17-18	sex	male		10(100%)	10
		female		6(100%)	6
18-19	sex	male		8(100%)	8
		female		4(100%)	4
19-20	sex	male		2(100%)	2
		female		4(100%)	4

Table 5.5.5 maturity of pisiform with age and sex

5.6 Analytical study

Ordinal logistic regression test was used to identify association between age of the study subjects, skeletal maturity of hand and wrist joint and sexes.

I. Distal end of radius: in ordinal logistic regression analysis, the overall model is fit with statistically significant value ($p < .001$) with parameter estimates (age = 0.658, sex1 = -4.86, sex2 = 0, p value = .000, df = 1) and McFadden's pseudo R-Square of 34.7%. This indicates that for each unit increase in age there is increase likelihood of being in a higher stage of fusion when the independent variable (sex) is kept constant and being male is associated with decrease likelihood of being in a higher state of fusion when compare with the female sex when other independent variables (age) is kept constant.

II. Distal end of ulna: in ordinal logistic regression analysis, the overall model is fit with statistically significant value ($p < .001$) with parameter estimates (age = +0.804, sex1 = -1.44, sex2 = 0, p value = .000, df = 1) and McFadden's pseudo R-Square of 32.2%. This indicates that for each unit increase in age there is increase likelihood of being in a higher stage of fusion when the independent variable (sex) is kept constant and being male is associated with decrease likelihood of being in a higher state of fusion when compare with the female sex when other independent variables (age) is kept constant.

III. Base of first metacarpal: in ordinal logistic regression analysis, the overall model is fit with statistically significant value ($p < .001$) with parameter estimates (age = +0.658, sex1 = -1.585, sex2 = 0, p value = .000, df = 1) and McFadden's pseudo R-Square of 28.6%. This indicates that for each unit increase in age there is increase likelihood of being in a higher stage of fusion when the independent variable (sex) is kept constant and being male is associated with decrease likelihood of being in a higher state of fusion when compare with the female sex when other independent variables (age) is kept constant.

IV. Head of 2nd -5th metacarpal: in ordinal logistic regression analysis, the overall model is fit with statistically significant value ($p < .001$) with parameter estimates (age = +0.883, sex1 = -2.266, sex2 = 0, p value = .000, df = 1) and McFadden's pseudo R-Square of 41.6%. This indicates that for each unit increase in age there is increase likelihood of being in a higher stage of fusion when the independent variable (sex) is kept constant and being male is associated with decrease likelihood of

being in a higher state of fusion when compare with the female sex when other independent variables(age) is kept constant.

V. Pisiform bone: in ordinal logistic regression analysis,the overall model is fit with statistically significant value ($p < .001$)with parameter estimates (age=+0.672,sex1=-1.428,sex2=0,p value=.000,df=1) and McFadden's pseudo R-Square of 34.9%.This indicates that for each unit increase in age there is increase likelihood of being in a higher stage of appearance when the independent variable(sex) is kept constant and being male is associated with decrease likelihood of being in a higher state of appearance when compare with the female sex when other independent variables(age) is kept constant.

6. DISCUSSION

In the present study a total of 150 students from Aabissiniya secondary and preparatory school and Ediget ber primary school which are in the age of 8-19 years old of both males 94(62.7%) and females 56(32.3 %) was participated.

In the present study complete fusion of lower end of radius begins in the age group of 14 to 15 years old in both female and male participants which is consistent in a study done in Ethiopia addis ababa complete fusion of lower end of radius seen at the age of 14-15 years old on both sexes(44).in another study conducted in Nigeria complete fusion was first observed at 17-18 years in males and 16-17 years in females .

Complete fusion by the age of 18-19 years old is in 94% of cases which is consistent with a study conducted in Ethiopia addis ababa complete fusion by the age of 18-19 years old in 80% of cases observed(44).in a study conducted in Nigeria population majority (>50%) of the subjects had complete epiphyseal union by 18-19 years and 17-18 years in males and females respectively(45).in a study carried out with in age group of 6 to 20 years in Nepal found the epiphyseal fusion at the distal end of radius hundred percent at the age of 18 to 19years old in males and 16 to 17 years old in females(46).

The complete fusion of lower end of ulna starts to see at 14-15 years old in females and at 15-16years old in males this is consistent with a study done in Khammam region (48),and a study done in Jordanian population (49) but different with a study carried ou in Nigeria complete fusion occurred as early as 17-18 years in females compared with 18-19 years in males(45).

Complete fusion observed in 83% and 50% cases in age of 18-19 years and 17-18years old respectively which is consistent with a study conducted in addis ababa observed 80% complete fusion at the age of 18-19 years old and 52% at the age of 17-18 years old. Study in North East Madhya Pradesh India 100% complete epiphyseal fusion was noticed at the age of 17-18 years old (50).

Complete fusion of base of the first metacarpal seen at the age 14-15 years old and in 100 % of cases in the age of 16 -17 years old female participants and 100% in the age of 17-18 years old in male participants.comparing to the study conducted in addis ababa complete fusion starts at the age of 14-15 years consistent to the present study.in female participants aged 16-17 years old complete fusion observed in 80% of cases and in males complete fusion observed in 62.5% of cases which is consistent compared to a study conducted (46) by Galstaun for Bengal for both the sexes, M.J.S Pillia for South India,Ramji.

Complete fusion of 2nd -5th head of metacarpal seen at the age of 12-13years old in 6.7% of subjects and in 100% of the cases at the age of 14-15 years old females and 16-17years old in males .

In the present study in female subjects pisiform bone has not appeared in the age 8-9years but in 20% male subjects pisiform bone appeared which is consistent with study conducted in Nepale observed minimum age for the appearance of pisiform was 9year in females(51) and almost consistent with study conducted in addis ababa observed pisiform had not appeared in 100% at the age 8-9years old. In a study conducted in pediatric age group Maharashtra india observed appearance at 10 to 13 years and 100% at 13-14 years in males while in females it appeared at 9 to 12 years and 100% at 12-13 years(52) inconsistent with our present study.

In the present study appearance of pisiform bone in 100% subjects observed early in females at the age 11 to 12 years comparing to males which appears at the age 14-15years consistent with a study conducted Vijaypur India observed all the girls of age 11 to 12 years and all the boys of age 12 to 13 years had appearance of Pisiform(53). Inconsistent with a study carried out in addis ababa observes 100% of study population pisiform had appeared in age greater than 12 years old which is different with present study(44).

7. CONCLUSION and RECOMMENDATION

7.1 Conclusion

From the findings based on present study we conclude complete fusion of the distal end of radius and ulna is at the age of 18-19 years .complete fusion of head of first metacarpal is at the age of 16-17 years in females and 17-18years in males.complete fusion of head of 2nd to 5th metacarpals is 16-17 years.pisiform appears at the age of 8-9years in males and at 9-10 years in females it appears one year earlier in males.

There is significant association between skeletal maturity of wrist and hand bones and age,sex .

From these findings,we concluded radiography analysis of skeletal maturity of hand and wrist bones is valuable for age estimation in forensic medicine and other filed of studies.

7.2 Recommendation

This study is conducted in a limited set up where resources were a constraint factor so it will be better to be done with enough resources in large sample size.

8. STRENGTH AND LIMITATION

Our research has tried to observe both the appearance and fusion of epiphyseal of hand wrist bone with greater age range where it's the medicolegally significant age groups.

There was no reported injuries or side effects following the procedure of taking x-rays. The X-rays were read by well acknowledged forensic seniors and it was cross checked for similarities and differences. Most of the X-ray film's quality were good.

The limitation of this study is that the number of cases examined, and sex distribution were not equal in each of age groups. This has impaired to perfectly compare results among different age groups and sexes.

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10.ANNEXES

10.1. Proforma - 1

The following proforma is used for collection of information obtained from the study participants, birth certificate or vaccination card and from parents or legal guardians of study subject. Thus, data including the degree of appearance and fusion of the ossification centers of the bone are filled by myself after conduction of complete reading of the X-ray results by two forensic physicians.

Study subject's preliminary particulars (to be collected from study subject and/or parents or legal guardian of the study subject).								
Study subject No. ____								
Age (retrieved from documents showing proof of age e.g. birth certificate)								
Sex:		If female; pregnant or not						
Height:		Weight:						
Place of residency:								
Radiological examination								
X-ray identification number								
Date and time of X-ray taken								
Joint/bone (Left/Right)								
Different stage of epiphysial fusion								
Age (in years)		Fusion stages						
		0	1	2	3	4	5	Not appeared

10.2. Proforma 2: Information sheet

Hello, my name is _____, I am one of the participants who is working on a X-ray study of hand and wrist bone for evaluation of skeletal maturity on clients visiting St. Paul's Hospital Millennium Medical College and on students in Addis Ababa.

Purpose of the study – To assess the possible age at which the bones of hand and wrist will appear and fuse so as to determine the chronological age of the study subject that will be selected randomly from clients visiting St. Paul's Hospital Millennium Medical College and students in Addis Ababa, Addis Ababa, Ethiopia.

Risk and benefits – The effective radiation received during each exposure will be between 0.0001-0.1 mSV.[1] Adequate precautions will be taken to avoid unnecessary X-ray exposure of subjects and as well for the working staffs by covering the non-study body regions with a protective shield. And most importantly, having a radiography of non-dominant hand, which is by nature away from the main trunk of your body will fortunately reduce the possible radiation exposure to the rest of the body significantly. You will be benefited from participating in this study by having you a screening result given by a radiologist expert for

any of the bone diseases like tumors, infections and joint abnormalities. And most importantly, this study will benefit the society when the information deduced finally shades light in providing justice for the victims. The transportation and other costs that could be expended during the study will be covered by me. Voucher cards for mobile credit will be given for encouragement purpose.

I only need a few moments of your precious time to take part in this study.

Payments for participating – You will not receive any payment for participating in this study.

Confidentiality – The information collected from this study will be kept confidential and it will only be used for research purposes. The information will be stored in a file without any personal identifiers, but a code number will be assigned to it.

Right to refusal or withdrawal – You have a full right to refuse and/or withdraw from the study at any time.

Do you have any questions? May I begin?

10.3. Consent form

I am willing and/or allow my child (for parents/legal guardians) to participate in the study, after it has been explained to me thoroughly in a language that I understand.

Signature: _____

Name of investigator: _____ Signature: _____ Date: _____

Identifiers: - Study subject No. _____