

# Reliable Bone Source in Forensic Investigations to Determine the Age by X-Ray Radiography of Pakistani Population

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## ABSTRACT

**Objective:** To know the reliable bone source in forensic investigations to determine the age by x-ray radiography of Pakistani population.

**Study Design:** Cross sectional study

**Place and Duration of Study:** This study was conducted at the Forensic Medicine Department, Government Khawaja Muhammad Safdar Medical College, Sialkot and UHS, Lahore from July 2019 to June 2020.

**Materials and Methods:** For age assessment at hand-wrist joint 60 subjects aged between 5-19 years and posteroanterior radiographs of chest were examined to determine age at sternal end of the clavicle of 62 subjects aged between 17 to 27 years were selected for this cross-section study. Chronological and skeletal age of each participant was observed.

**Results:** The age range from 5-19 years with mean chronological age for male was  $9.96 \pm 3.04$  while mean skeletal age for male subjects was found  $9.30 \pm 3.21$ . Mean chronological age for female subjects was  $9.13 \pm 2.68$  while mean skeletal age for female subjects was  $8.65 \pm 3.06$ . Results of G&P method were found to be statistically significant for both males and females. The mean with interquartile range for stages 2-5 by gender. Stage 2 was first found in both genders at the age of 17.

**Conclusion:** For age assessment at hand and wrist joint Greulich & Pyle method proved to be reliable for use in Pakistani population. When compared to other populations, Pakistani population followed a delayed and narrow time frame for development of medial epiphysis of clavicle. At stage 5 of ossification minimum age estimated was 25 years for both genders.

**Key Words:** Bone, Forensic, X-ray, Chronological, Skeletal, Age, Gender

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## INTRODUCTION

Forensic age evaluation of anonymous cadavers and their skeletons for recognition purposes has remained custom in legal science. In forensic research age evaluation of living individuals experiencing criminal lawsuits has created a generally new zone that is progressively becoming imperative.<sup>1-3</sup> In case of living individuals such age evaluations are carried out to confirm whether the accused of doubtful age has

achieved culpable age for crime and if universal criminal statute of adults can be practiced.<sup>4</sup> Particularly in case of non-nationals, with no valid identification records, such difficulties are faced when it comes to differentiate between juvenile and adult offenders. For criminal responsibility various age limits of confinement are given by different laws. In numerous states, the age threshold of legal applicability ranges between 14-21 years of age.<sup>5</sup> On government level and in many countries this age threshold is set at 18 years.

In the year 2000, "Study Group on Forensic Age Diagnostics" (AGFAD) distributed its ground rules for the assessment of the historical age of alive persons forensically, for criminal proceedings. The rules elaborated the performance of the relevant tests to decide the age of majority or minority (18-years); a) Physical examination: anthropometrical estimations including, stature, weight, physique and assessment of signs of sexual development (clinical examination is first and foremost imperative to interpret any disease, syndrome or hindrance which could impact the assessment of skeletal and dental development); b) roentgenographic left hand's examination is the second mainstay of criminological age diagnostics with the end

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goal of criminal execution; c) teeth external examination and dental x rays, d) Radiographic clavicular examination, to affirm if the authentic age is greater or lesser than 21.<sup>6</sup>

Keeping in mind the end goal to figure bone age different approaches have been created utilizing diverse skeletal components and different visualization methods. The ossification pattern in the hand and wrist bone is in a quite certain manner with varying epiphysis shapes that are age particular till end of puberty. In crime scene investigations globally utilized method for age determination by hand and wrist radiographs is the atlas method of Greulich and Pyle. Along with its clinical applicability this method has forensic applications as well.<sup>7</sup>

Purpose of the present study is to determine juvenile age at left wrist and adult age at medial end of clavicle to be used as a forensic tool in differentiating juvenile and adult delinquent, to support to the criminal justice system of Pakistan and NADRA in cases of falsifying age representatives.

## MATERIALS AND METHODS

This cross sectional study was conducted at the Forensic Medicine Department, Government Khawaja Muhammad Safdar Medical College, Sialkot and UHS, Lahore from 1<sup>st</sup> July 2019 to 30<sup>th</sup> June 2020. For age assessment at hand-wrist joint 60 subjects (25 female, 35 male) aged between 5-19 years were selected for this cross-section study. The local citizen of Pakistan, mentally and physically sound, who have negative history of any chronic diseases, predominant right hand with no history of injury or damage to left hand and wrist were included. The cases were selected to rule out any hormonal, nutritional and developmental abnormality. On the basis of positive history of any chronic disease, any medication intake within previous six months, like vitamin and food supplements and calcium, participants were excluded. The completed information for each child to record their historical age was recorded. Age was confirmed from history, B-Form or birth certificate and by CNIC in case of adults. The left hand-wrist region was exposed in poster-anterior (PA) position without using Bucky.<sup>8</sup> Examinations were performed on computerized radiography (CR) system and images were processed digitally on green sensitive, 14x14 films (Kodak), with exposure factors selected between 40-50 KVp, 3-6 MAs. X-ray images were compared against G&P method based on "The Radiographic Atlas of Skeletal Development of Hand & Wrist" by Dr. William Greulich & Dr. Sarah Idell Pyle containing reference images of male & female standards of the left wrist & hand from birth till 19 years of age.<sup>9</sup> Radiographs with known chronological age of each subject were compared by radiologist. The cases with inter-observer differences were reevaluated and bone age was defined

with consensus. Posteroanterior radiographs of chest were examined to determine age at sternal end of the clavicle of 62 living individuals (26 females, and 36 male) falling in the age group of 17-27 years. X-ray examination was performed on imaging plate of computerized radiography (CR) system and images were processed digitally on green sensitive, 14x14 or 14x17 films (Kodak), with exposure factors selected between 65-70 KVp, 3-6 MAs depending on patient anatomy. The ossification status of medial end of clavicle was defined according to 5 staging system suggested by Schmeling.<sup>10</sup> The radiographs were interpreted for staging by radiologist. While interpreting the stage of ossification we all were known with the age and sex of each candidate.

To perform statistical analysis of data collected SPSS 21.0 software was used. Skeletal age (SA) and chronological age (CA) of each participant was observed. The mean value and standard deviation of chronological and skeletal age were calculated for each gender. Paired t-test was performed and p-value was computed to determine the significance for each gender.

## RESULTS

In the study population of 5-19 years, mean chronological age for male subjects was  $9.96 \pm 3.04$ . While mean skeletal age for male subjects was found  $9.30 \pm 3.21$ . Results of G&P method were found to be statistically significant for males ( $P=0.015$ ). Mean chronological age for female subjects was  $9.13 \pm 2.68$  while mean skeletal age for female subjects was  $8.65 \pm 3.06$ . Results of G&P method were found to be statistically significant for females ( $P=0.04$ ) (Table-1). A positive correlation ( $r=0.89$ ) was found between calculated and chronological age (Fig. 2). Majority of the male participants presented complete ossification of hand & wrist bones at 19 years of age while female participants presented closure of all epiphysis at 18 years of age.

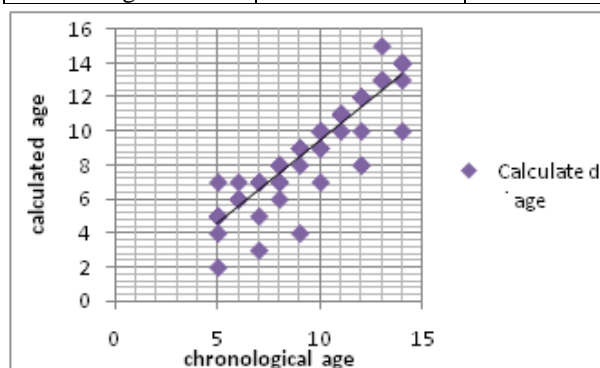
Table 2 presents the mean  $\pm$  standard deviation (SD) with interquartile range for stages 2-5 by gender. In the age spectrum that was selected for sample analysis (17-27 years old) for both genders, stage 1 did not appear. So no calculations were made for stage 1. Stage 2 was first found in both genders at the age of 17. Differences produced in gender comparison at Stage 4 with female participants reaching at this stage one year prior to their male counterparts. Stage 4 was first noted in female subjects at the 22 years of age and in male participants earliest observation of stage 4 was at age 23. Whereas in each gender lowest age for stage 5 was observed at 25 years of age. Sexual differences were analyzed. On analysis, there were statistically significant differences between genders calculated for the stages 2 to 5, assessed P value was 0.399.



**Figure No.1:** Male children's x-ray images of CA 5, 13 and 18 years (SA 5, 13, 18 years respectively) with examination points while evaluating skeletal age: (1) Size, appearance and shape of distal radial epiphysis (2) Presence of epiphyseal fusion line of distal radius (3) Size of epiphysis of distal ulna (4) Number of carpals, their size and shape (5) First metacarpal's proximal end epiphysis size (6) Size of distal epiphysis (head) of 2nd to 5th metacarpal (7) Appearance, size, shape and union of epiphyseal plate of phalanges. 8) Metacarpha's proximal end cupping.

**Table No.1: Presenting mean skeletal and chronological age of participants according to gender**

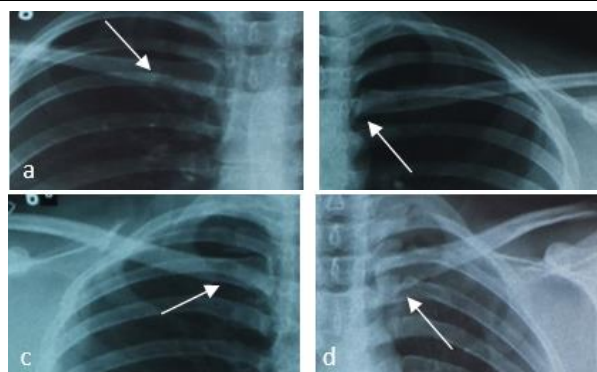
Age of participants according to gender		
Gender	Mean±SD	P value
Male		
Chronological age	9.96±3.04	0.015
Skeletal age	9.30±3.21	
Female		
Chronological age	9.13±2.68	0.04
Skeletal age	8.65±3.06	



**Figure No.2:** Correlation between chronological age and calculated age

**Table No.2: Comparison of mean age in different gender with respect to stages 2-5**

Stage	Gender	Mean±SD	IQ (range)
2	Male	17.50±0.70	10.50-11.50
	Female	17.00±0.73	10.42-11.47
3	Male	20.28±1.60	0.94-2.18
	Female	19.66±1.32	1.02-2.25
4	Male	23.61±1.64	0.47-2.19
	Female	22.75±1.16	0.32-2.04
5	Male	25.88±0.78	0.44-1.72
	Female	25.25±1.28	0.50-1.78



**Figure No.3:** (a) Stage 2: 17 years old male, right clavicle from PA chest radiograph, showing the non-ossified epiphyseal cartilage. (b) Stage 3: 19 years old female, presenting left clavicle, PA chest radiograph, indicating the partially ossified epiphyseal cartilage. (c) Stage 4: 23 years male, right clavicle PA chest radiograph, showing complete ossification with discernible scar. (d) 25 years male, depiction of clavicle from chest radiograph, indicating that epiphyseal scar has vanished.

## DISCUSSION

The study was carried out to determine the age of Pakistani population by hand wrist radiographs. To assess age, radiographs were compared with G&P Atlas<sup>9</sup>, a holistic method accepted worldwide to determine age. Similar study was carried out by Patil et al<sup>11</sup> regarding applicability of the GP atlas in Indian population between age group 1 to 19 years. Study showed delay in skeletal growth of 0.5 years for the group who were in range of 4-15 years for males and between the age group 4-7 years and 9-10 years for the female group. Study found that GP atlas method is not definitive method, especially in middle and late childhood, for the Indian population for both genders. In our study, results were statistically significant for females ( $P=0.04$ ) and males ( $0.015$ ). Result of our study is strongly supported by a research conducted by van Rijn et al<sup>12</sup> on Dutch Caucasian population by X-ray imaging of hand and wrist and the observed significance was ( $P<0.001$ ) for both genders. A similar study conducted by Büken et al<sup>13</sup> in Turkish population revealed statically significant results for females ( $P<0.001$ ), but insignificant results for males ( $P>0.05$ ). A study performed by Groell et al<sup>14</sup> reported a difference of about 1 year between actual age and skeletal, and according to researchers, bone age estimation by G&P is reliable to use for Central European children. Based on data of our study, radiography of hand-wrist region is a reliable indicator to determine skeletal age and G&P method proved to be statistically significant for Pakistani population. To study correlation between sequential age and ossification status of medial extremity of clavicle several studies have been conducted, to be used as a

forensic tool in several medico-legal cases as well as in the field of anthropology. In view of forensic practice, our concern is to determine the minimum chronological age of Pakistani individuals at which ossification of the medial clavicle epiphysis completed. Recent studies defined complete ossification as 4<sup>th</sup> stage proposed by Schmeling et al<sup>10</sup> with full ossification of medial clavicular epiphysis while epiphyseal scar still discernible. In our study stage 4 was observed in females at 22 years of age while in males at 23 years of age. These results are similar to a study conducted by Flecker<sup>15</sup> in which 655 individuals were analyzed aged <30 years by X-ray examination and found a complete fusion of epiphysis at age of 22 in majority of individuals. Appearance of stage 4 has been reported at younger age by a number of researches. As in our case stage 4 was seen at 22 years in females and 23 in males but it does not reveal conformity with radiographic study conducted on German population by Schmeling et al<sup>10</sup> in which he demonstrated minimum age of epiphyseal fusion at 20 years of age, likewise Schulz et al<sup>16</sup> observed 21.2 years by CT examination of German population and Schaefer<sup>17</sup> and Black<sup>18</sup> noted minimum age of 21 years in population of Bosnia by osteological examination. In the same way Richel<sup>19</sup> and Schultze et al<sup>20</sup> observed minimum age of 19.14 years at stage 4 in German population by CT examination. Stevenson<sup>21</sup> reported complete fusion of medial clavicular epiphysis at 18 years of age. Comparative to these reference studies, our study revealed delayed observation of stage 4 in Pakistani population. During study we also find out results for stage 5 proposed by Schmeling et al<sup>10</sup> and defined as complete ossification but scar of epiphysis no longer visible. According to results minimum age observed for stage 5 was 26. Contrary to this, our study reported an early appearance of stage 5 at 25 years of age for both genders. So in case of an individual who is undergoing criminal prosecution if an X-ray examination reveals stage 5 it means that individual has attained age of 23 years at least 2 years before this examination or has attained 20 years of age at least 6 years before X-ray examination. Now the question related to practical use of this study in forensics arises, whether the results of this study can be applied to different socioeconomic status populations. In case of criminal prosecutions, it is not justified to underestimate the age of individual who is in charge of a serious crime. This condition demands a reference data based on bone age of Pakistani population. As per criminal acts, an adult criminal and juvenile offender is tried and punished differently depending upon their age, which essentially requires age estimation to spare innocents from culprits. So this research study provides a reference data to be used as forensic tool in criminal justice system of Pakistan, to provide fair justice system to the juveniles and adults in this society. Immigration rules are very clear regarding age determination so this

study is legally applicable to immigrants along with criminal justice system.

## CONCLUSION

To conclude for age determination, the reference values established on Pakistani population can be applied in forensic practice to support to the justice system.

### Author's Contribution:

Concept & Design of Study:	Iqra Kanwal
Drafting:	Muhammad Faheem Ashraf, Samina Kanwal
Data Analysis:	Shahid Nazir Paracha, Muhammad Farhan Khan
Revisiting Critically:	Iqra Kanwal, Muhammad Faheem Ashraf
Final Approval of version:	Iqra Kanwal

**Conflict of Interest:** The study has no conflict of interest to declare by any author.

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