International Journal of Innovative Research in Computer Science & Technology (IJIRCST)
ISSN: 2347-5552, Volume-10, Issue-2, March 2022
https://doi.org/10.55524/ijircst.2022.10.2.110
Article ID IRPV1049, Pages 581-587
www.ijircst.org

Age Estimation Through Radiographs

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ABSTRACT: The skeleton is an important part of the human body. It provides a definite shape and definesthe stature of the human body along with it also plays an important role in forensic science. It aids forensic anthropologists in determining the age, sex and post mortem interval of the deceased person, if only the skeletal remains are found. This article reviews the techniques used for age estimation from different bones of human body. Forensic anthropologyis study of human skeletal remains to help determine the identity of the missing persons andto estimate time since death and age. There are various bones which help to determine the age range of the deceased like skull, clavicle and the pelvis region. Radiographic methods arehelpful in examining these bones. There are around 300 bones present in a new born and as a person grows these bones start to fuse. At the age of 40 years all the bones fuse to make atotal of 206 bones. Bones start to ossify as the person ages and hence by studying the ossification of bones we can determine an age range for a person.

KEYWORDS: Age Estimation, Forensic Anthropologists, Forensic, Radiographic Methods.

I. INTRODUCTION

The application of science to civil and criminal law is known as forensic science. By providing crucial information, forensic scientists assist police officers in solving crimes. They give information such as the post mortem interval, the cause of death, and an estimate of the deceased's age, among other things. Forensic anthropologists assist in determining the dead person's age. Real humanities (the study of people's natural or physiological characteristics) may also be defined as the application of actual human science (the study of people's organic or physiological characteristics) to criminal and civil law, with a focus on human contexts. Forensic anthropologists are experts at studying bones, and they also have experience digging buried remains and documenting the data thanks to their archaeological expertise. They utilize radiographs to analyze a person's bones in order to identify their age or gender. Radiographs are pictures created by X-rays on a sensitive film, and radiography is the imaging technology used to create them [1]–[4].

Age estimate has a long history, dating back to the 19th century when it was mostly done by dentists. When Edwing Saunders wrote " The Teeth as an Age Test " in 1837, the British Parliament claimed that teeth ejection was an accurate technique of determining a child's age. In 1895, Rontgen discovered X-beams, that opened up a new way of determining the time of living people. His discovery was soon used to legal medicine, and the age gauge in living persons was swiftly updated to include new radiograph-based procedures. The primary definitive techniques of age determination based on radiographic study of the carpus or dental maturation were established during the decades of the 1950s and 1980s. Estimating a person's age is crucial for biological identification in a variety of crimes. It may be used to determine the age of both living and deceased persons. It may assist in crimes including age fraud, human trafficking, including child pornography when used on live persons [5], [6]. Also, it is helpful in determiningthe age of perpetrators which will further determine their punishment for criminal liability especially in younger criminals. It can be helpful in mass disaster cases to help investigatorsto correctly identify a person among large number of people, as shown in Figure 1.

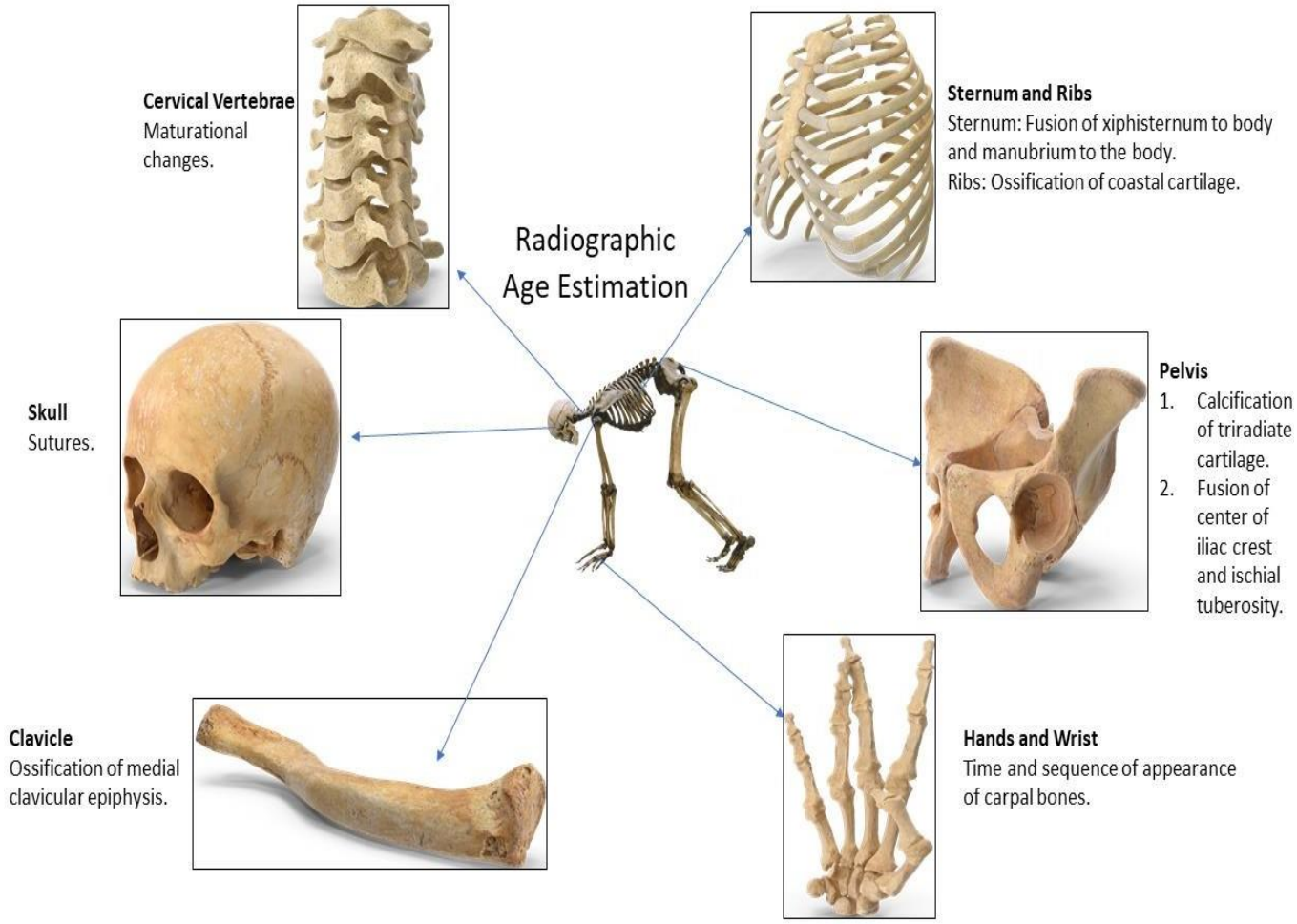


Figure 1: Illustrate the Radiographic Age Estimation, like as cervical Vertebrae, Sternum and Ribs, Pelvis etc.

Bones and bodily fluids such as urine, blood, saliva, and sperm may be used to estimate age. The topic of radiographic age estimate from bones is explored in this review study. Radiographic pictures are required for a live person since it is dependent on measuring length and form of different bones, ossification stages, or developmental processes of teeth and bones. The clavicle, skull bones, elbow or knee joints, bones in the foot, cervical vertebrae, hands, and wrists, or sacrum, pelvic, or coccyx bones may all aid in age assessment. Radiographic pictures may help determine the age of a deceased person, particularly in decayed and skeletonized remains when skeleton manipulation is impossible or if the whole bone is not accessible. The length of longitudinal bones and the developmental state of the epiphysis are assessed to estimate age in childhood or adolescent mineralization status of teeth. There are three options available for adults. The first is aspartic acid racemization in dentin. Individual aspects of teeth are investigated in the second procedure. The third way is Nemeskeri's combination method, which involves assessing the pelvic symphysis or even the clavicle's medial extremity.

A. Approaches

The skull, clavicle, bone of the hands and forearms, elbow or knee joints, bones of the foot, cervical vertebrae, bone of the pelvis, sacrum, or coccyx are among the bone of the human body. Teeth, too, may be useful in determining age. Let's have a look at some of the approaches for estimating age from these bones.

a. Skull

Sutures are different fissures in the skull that are known as sutures. These sutures are used as a means of determining a person's age. One of the oldest ways for determining age is to evaluate cranial sutures. Sutures close at different ages, and studying them may help determine the age. The bones of the skull are divided into two layers: tabula internal and tabula externa, with diploe, a vascular supple bone area between them. These bones are separated by sutures that are similar to the epiphyses-diaphyseal planes, which are the two development foci but have a time but also association grouping. The stitch conclusion begins endocranially or progresses ectocranial, similar to how the epiphyses-diaphyseal relationship begins in the middle and progresses haphazardly. Little tongues of hardened tissue extend out across the gap between the stitches but also connect securely all the way along the length of both threads until the connection is complete. Despite the fact that there is variation in the conclusion rates or instances, cranial stitches often merge as people become older [7]–[10].

b. The Fredric Rating Scale for estimating age from the skull is as follows

CT scans of the pivotal, coronal, but also sagittal sections of the skull's sutures were obtained. Sagittal, coronal,

lambdoidal, or temporo-parietal sutures were evaluated ectocranial using the Fredric grading scale. The same scoring methodology was used for endocranial as well. Endocranially or ectocranial, stitch demolitions were detected. Three portions of the coronal stitch, four sections of the sagittal stitch, three pieces of the lambdoidal stitch, but one section of the temporo-parietal stitch were considered [11].

Scale for closure

- Patent
- Only about a third of the way closed Half closed
- More than half closed
- Completely shut

Endocranial suture fusions is stable, speedy, uniform and complete and hence it is a better parameter for age estimation than ectocranial union.

c. Cervical Vertebrae

Our vertebral column is divided into 5 groups, lumbar, thoracic, cervical, sacrum or coccyx. The first seven vertebrae are called as cervical vertebrae. The first two of it arecalled as atlas and axis are quite unique and 3 to 7 are very much similar, as shown in Figure 2 and Figure 3. These cervicalvertebrae show maturational changes from birth to death. The changes are divided into six categories:

- Initiation:

Teenage development starts at this period, so 80 percent to 100 percent of adolescent growth is projected.

- Acceleration:

At this age, development accelerates, and teenage growth is estimated to range from 6% to 85%.

- Transition:

In this stage, teenage development continues to increase in order to achieve peak velocity, with 25 percent to 65 percent of adolescent growth projected.

- Deceleration:

In this period, teenage development starts to slow drastically, but only 10percent in terms to 25percent of total adolescent growth is projected.

- Maturation:

Vertebrae develops at this time, with adolescent growth of 5% to 10% predicted.

- Completion:

This period of development is believed to be complete, with little to no teenage growth.

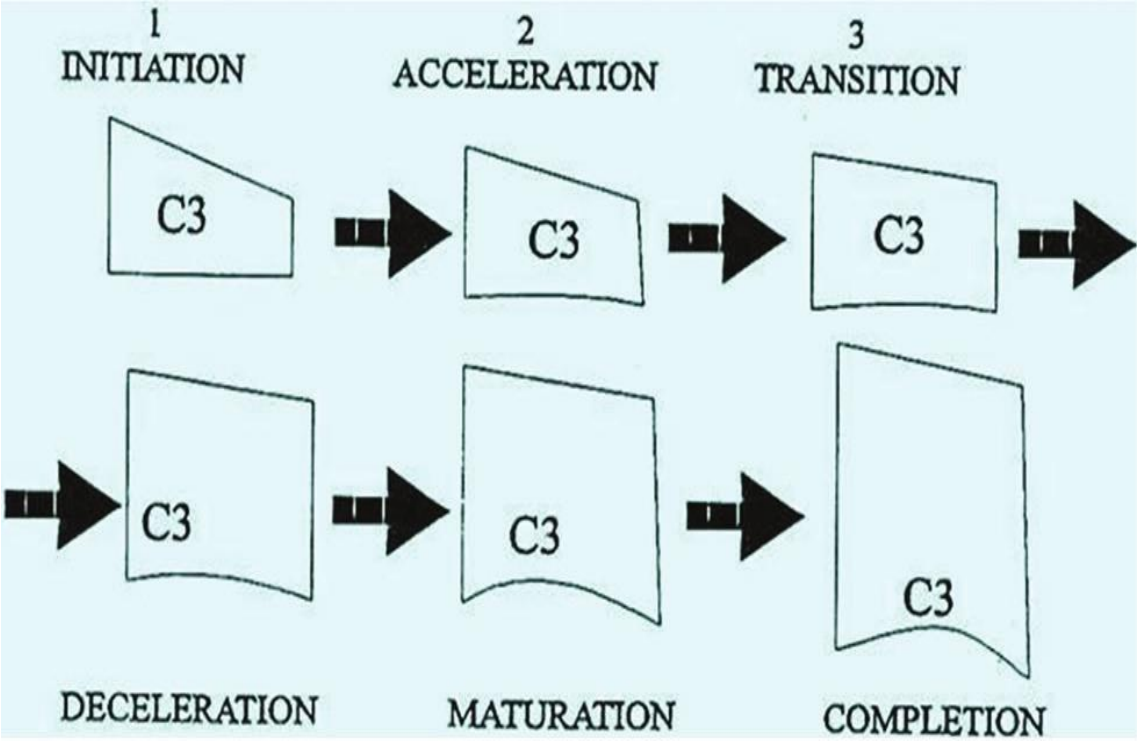
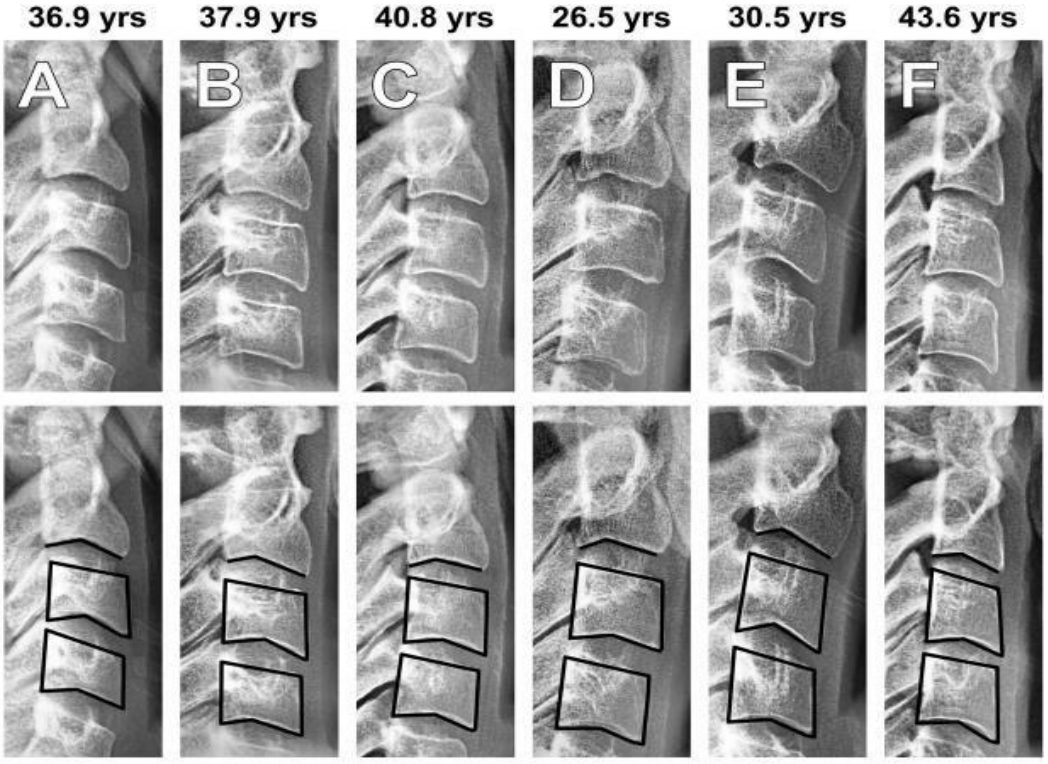


Figure 2: Illustrate the Cervical Vertebrae Maturation Indicators Using C3 as a Guide

d. Clavicle

Choosing the phase of solidification of the average clavicular epiphysis is an important aspect of determining the length of time individuals spend throughout criminal proceedings with completed hand hardening. It is recommended that minimal cut CT filters be used to get the highest level of accuracy in determining age. The following is how the situation with the advancement of the average clavicular epiphyseal ligament is appraised using Schmeling et a classification .'s of stages:

Stage 1: The core of ossification is not ossified.
Stage 2: The epiphyseal cartilage has not ossified, but the ossification center has.
Stage 3: Partially ossified epiphyseal cartilages.
Stage 4: An epiphyseal scar may be visible if the epiphyseal cartilage has entirely ossified.
Stage 5: The scar on the epiphysis has faded and is no longer visible.



CVM code	CCC-HT	CCC-HH	CCC-SH	CCC-SS	CCC-VS	CCC-VV
CVM stage	4	4	5	5	6	6
CVM score	4	5	6	7	8	9

Figure 3: Illustrate a stage classification is used to measure the growth of both the medial clavicular epiphyseal cartilages

The second phase was first seen in boys when they were 14 years old, and in girls when they were 13 years old. The third stage was achieved by males at the age of seventeen and females at the aged of 16. At the age of 21, both sexes had reached Stage 4. When both sexes were 26 years old, they were first diagnosed with Stage 5.

e. Sternum and Ribs

The sternum is often used to assess age in adults above the age of 25. In middle and old adults, the fusion of the xiphisternum to the body of the sternum and the manubrium to the body of the sternum function as radiological tools for measuring age. The state of fusion of the xiphisternum or manubrium with the body of a sternum was taken and analyzed using radiological changes and X-rays. The patients were graded based on whether they had complete fusion or not. The following scale was used to assess the degree of the manubrio-sternal joint:

- Absent Fusion: In the joint, a dark black radiolucent line may be visible. There is no fusion and the bone components are completely separated.
- Partial/Equivocal Fusion: The gap between the joints narrows. Fusion is apparent on less than or more than half of the connecting surface, and a white dense line indicates partial fusion.
- Complete Fusion: The bone parts are completely fused together. There is no white dense line, homogeneous radio opacity, or total fusion seen.
- Absent Fusion: In the joint, a dark black radiolucent line may be visible. There is no fusion and the bone components are completely separated.
- Complete Fusion: The bone parts are completely fused together. There is homogeneous radio opacity and fusion.

f. Rib

Ernst described the process of ossification of coastal cartilage and Michelson in 1934applied it for the first time on the first rib. The various stages in this systems are:
Stage 0: The first rib's coastline cartilage shows no signs of ossification.
Stage 1: The cartilage shows signs of beginning ossification.
Stage 2: There is ossification of 50percent of the cartilage.
Stage 3: The first rib's coastline cartilage has ossified completely or almost completely.
At the age of 14, head centers and tubercles arise (there are no tubercles in the 11th or 12th ribs) then fuse at the age of 25. The process of ossification starts in the top and bottom ribs and continues to the middle ribs. As a result, the 4th to 9th ribs are the last to completely ossify. This happens 2-3 years sooner in females.

g. Hand and Wrist

The hands wrist radiograph is indeed the most often used type of skeletal examination. Many researchers have accounted for bone growth using radiographs as an indicator based on the timing and order of emergence of carpal bones and specific ossification processes. Using two kinds of hand wrist radiographs, several approaches for assessing skeletal maturity have been presented:

- Atlas method
- Scoring method

The most often used approaches are:

- Greulich and Pyle's Atlas Method; and

- Biork, Grave, or Brown's Method, as updated by Schopf in 1978.
- The skeletal maturity markers of Fishman.
- Method of Hägg and Taranger

This diverse set of techniques is dependent on epiphysis' transformational phase rather than diaphysis' progression. For the most part, all of the procedures rely on a thorough examination of the phalanges' subsequent phases of solidification.

Stage 1: The epiphysis or diaphysis are both the same length.

Stage 2: The diaphysis is surrounded by the epiphysis, which caps it.

Stage 3: The epiphysis or the diaphysis fuse together (U union).

B. Fishman Skeletal Maturity Indicator (1982)

Anatomical locations on the thumb, fifth finger, third finger, or radius were used by Fishman. This approach employs 11 anatomical locations that all exhibit consistency in the beginning of ossification throughout the course of adolescent development.

- S.M.I 1 PP3: The third finger's epiphysis or diaphysis are about the same breadth.
- S.M.I 2 MP3: Both the epiphysis and diaphysis of the middle phalange of the third finger have the same width. At the onset of the prepubertal growth spurt, this happens.
- S.M.I 3 MP5: The epiphysis of the fifth finger's middle phalange is the same width as the diaphysis.
- S.M.I 4 S: During a time of fast development, the thumb's adductor sesamoid develops or becomes apparent.
- S.M.I 5 DP3cap: In the distal phalange of both the fourth finger, an epiphysis caps the diaphysis. The velocity is at its peak.
- S.M.I 6 MP3cap: During a period of fast growth, the distal phalange of the third finger shows epiphysis capping over diaphysis.
- MP5cap: The capping of the epiphysis over the diaphysis may be observed in the fifth finger's middle phalange. The speed is at an all-time high.
- DP3UThe third finger's distal phalange displays epiphysis fusing over diaphysis. Time interval for decelerating growth rate.
- PP3: The proximal phalange of the third finger shows epiphysis fusion over diaphysis.
- MP3u: The epiphysis has united with the diaphysis inside the middle phalange of both the third finger. Time interval for decelerating growth rate.
- R U: The radius, which marks the end of development, shows the merger of epiphysis or diaphysis.

C. Greulich and Pyle (GP) atlas

It includes photographs of women's left hand or wrist orientations, as well as men's standard from birth to 18 years old for girls as well as 19 years old for males. A non-dominant wrist radiograph of the subject is evaluated to the required components reference radiograph provided in the atlas to determine the closest maturational stage. The age of the skeleton is calculated by comparing it to the age of the nearest standard. Most alternative radiograph-based procedures are slower and more difficult to utilize than the GP atlas methodology. In Australia, the United Kingdom, and the Middle East, the GP atlas criteria are generally acknowledged and applied to children. When this approach is used to Asian youngsters, Afro-Americans, and Hispanics, there is a discrepancy between the predicted age and chronological age .

a. Gilsanz and Ratib (GR) Atlas

A digital atlas created by Gilsanz but also Ritab in 2005 delivered idealised but also artificial pictures for specific age or gender standards of bone growth by examining in depth information, the size, shape, morphological characteristics, but also specific gravity of ossification centres in hand radiographs of healthy children, as well as high-technology that incorporate the usual characteristics of growth for each of the osteophytes. The updated GR atlas criteria are separated over six-monthly intervals for children aged 2 to 6, and annual intervals for children aged 7 to 17.

b. Tanners Whitehouse Method

Unlike the GP atlas, this approach is based on the degree of development for 20 identified locations of interest in each age group, such as the upper arm bone or hand. Each ROI is divided into four stages, each designated by the letters A, B, C, or D. A numerical score is assigned to each recognized bone at each step of the project. The ROI scores are added together to provide a total maturity score. This score is related to skeletal age in both men and females separately. For certain populations, this procedure is more complicated and time-consuming [12]–[15].

c. Tanner Whitehouse (TW3) Method

According to studies, the TW3 approach is more exact than the TW2 method since children grow faster and acquire a certain skeletal maturity score at a younger chronological age than previously. TW3 has been proven to have a little tendency to underestimate in females over the age of 12 and boys over the age of 13. TW3 is considered more trustworthy than GP, especially in specialised demographics, because the GP approach has a tendency to inflate ages, which might result in legal ramifications for an asylum seeker or refugee who claims to be a juvenile. As a result, for a more exact age estimation, combining the GP or TW3 approaches with data from other tests is advised.

- *Pelvis*

The calcification of triradiate cartilage, as well as the presence or fusions of center of iliac crests and ischial tuberosity, are used to estimate age from pelvis X-rays. In 15 years, the triradiate cartilage is calcified to the point where three bones, the ischium, ilium, or pubis, fuse to the form sole hip bone. The iliac crest appears in men at the age of 16 or females at the age of 15, as well as unites with the iliac bones at the age of 19. Ischial tuberosity emerges in men at the age of 17 or in women at age of the 15, or it fuses at age of the 20. The quantity of calcification of the human pelvis as a marker of maturity is referred to as the Risser sign. The stages of iliac apophysis ossification or fusion were divided by Risser into six categories (Risser Stages 0–5), with higher numbers signifying progress toward bone growth. On X-ray, stage 0 indicates the lack of an ossification center in the apophysis, whereas stages 5 indicates whole ossification or fusions of iliac apophysis.

The Risser approach is used in two ways, with the differences influencing stages 2–4. United States of America (USA) The apophysis excursion is divided into iliac crest quarters using the Risser staging system, which begins anterolaterally and progresses poster medially. Stage 1 represents 0-33 percent of apophysis excursion, stage 2 represents 33-37 percent, stage 3 indicates more than 66 percent of fusion, and stage 4 represents complete ossification but also apophyseal fusion, according to Risser performance systems.

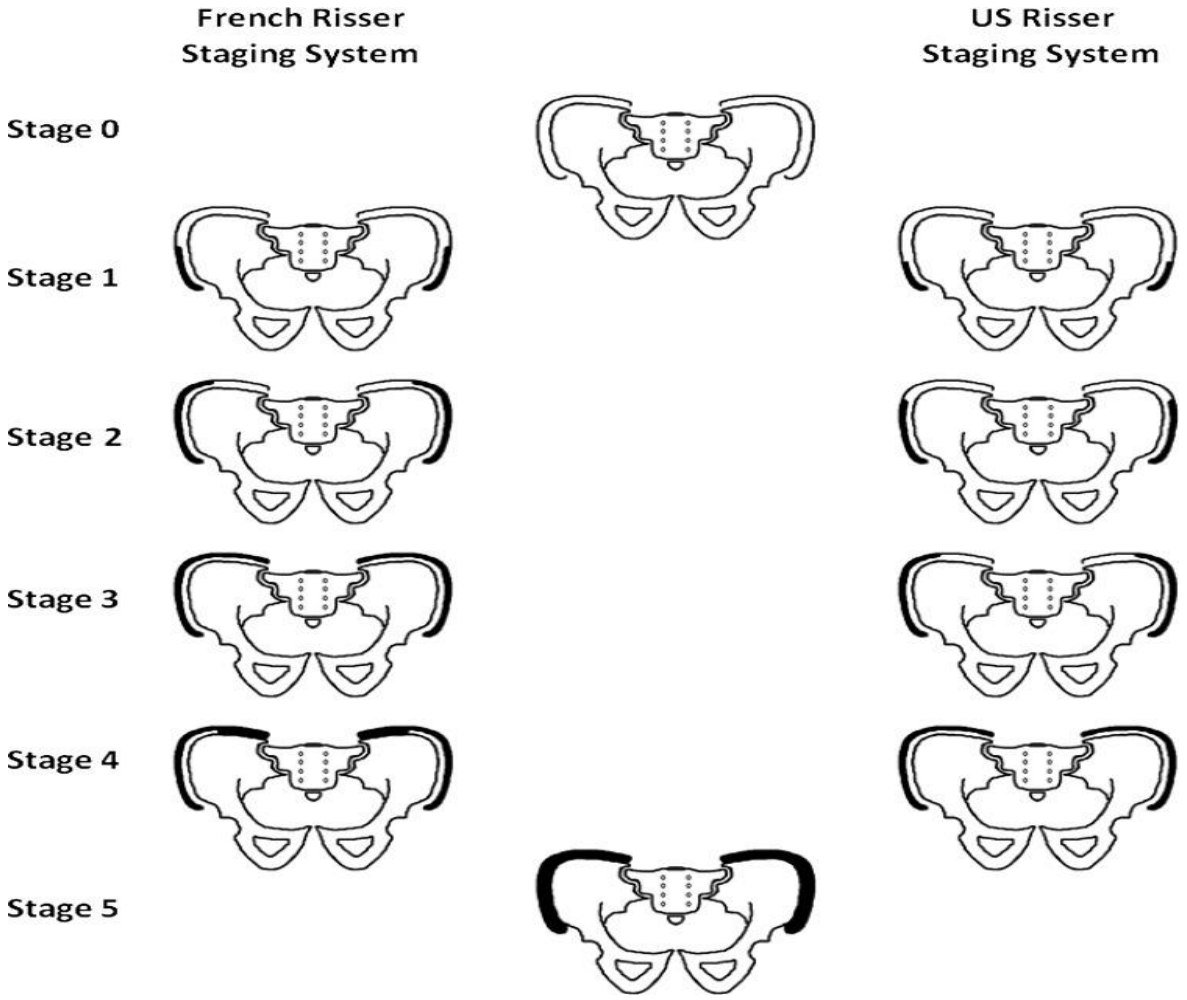


Figure 4: Illustrate the French Risser staging system and US Risser Staging system.

Figure 4 depicts Risser system in United State or France. Both approaches are divided into six phases. Stage 0 is defined as the lack of apophysis ossification in these systems. In the French approach, stages 1, 2, and 3 depict the ossification of the iliac wing. The apophysis connects the iliac wing posteriorly in stage 1, and the apophysis is entirely fused to the iliac wing in stage 5. In the United States, the first four phases of apophysis ossification are separated into quarters (1, 2, 3, 4). Risser Stage 5 is the time when the ossified apophysis meets the iliac wing.

Cameriere's method for the age assessment in living, a process that generates an estimate of regions on X-rays, suggests this (called AM). The area of the ossification centre of the iliac crest (ICA) or even the area of the iliac wing (IW) must be measured for this method; the ICA/IW ratio is utilised for linear regression analysis or the creation of a formula that allows age estimate. The Kreitner and Kellinghaus method, which employs a staging system with main stages (1–4) but also substages (a–c) for the growth of stages 2 or 3, was first used to determine age based on clavicle ossification. The approach was developed by Wittschieber et al. and used to the creation of the iliac crest. This modification to the original Kreitner but also Kellinghaus (KK) iliac crest procedure resulted in the development of essential phases or substages. The KK-MS classification system divides the apophyseal nucleus ossification and iliac apophysis fusion with the pelvic bone into eight phases or substages (1, 2b, 2a, 2c, 3b, 3c, 3a, 4). Both processes are thought to start anywhere along the iliac crest in this classification, with no specific progression.

II. DISCUSSION

There are a variety of ways for estimating a person's age, and it is important to choose one that is fast and simple. Analyzing hand or wrist radiographs looks to be the most common option, since it is regarded the standard procedure, and there are several websites that may assist in estimating a person's age. In most cases, a mixture of the GP or TW3 methods is employed to estimate age. Then, determining the age from the skull is regarded to become

one of the oldest and most reliable procedures. The sutures of both the skull ossify at a certain point in time, which substantially aids in determining age. Analyzing the sutures of the skull will undoubtedly provide us with a precise age range and will aid in the identification of a person. The pelvic girdle may be employed in the case of a dead individual since it has two separate locations, the pubic symphysis as well as the auricular surface, that also are among the most precise markers known.

III. CONCLUSION

The importance of age estimate in forensics is that it aids in the identification of a person from their skeletal remains. Knowing whether a criminal is a juvenile or an adult is also helpful in determining the appropriate penalty. Radiographs have shown to be a useful technique for evaluating bones for ossification stages, which aids in age estimation. Certain approaches, such as those stated above, are used to estimate the age of various bones. Forensic anthropologists utilize these approaches to identify a person based on their age range. Bones have shown to be a reliable source of evidence, including a wealth of information that may be used to the calculate an individual age. In the future, computer-assisted imaging or CT scans will be very useful in evaluating bones and providing a more exact age estimate.

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