ОРИГИНАЛЬНАЯ СТАТЬЯ

RADIOLOGICAL ASSESSMENT OF AGE FROM THE EPIPHYSEAL FUSION OF THE KNEE JOINT

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Estimation of age is helpful in both civil and criminal cases. In the living individual age estimation is the most important issue to the court and the common citizens as well. The present study was carried out to study the estimation of age by epiphyses fusion at the knee joint, which is considered one of the modern and somewhat accurate methods of estimating age.

Purpose. To compare chronological age and age estimated according to the union from radiographic assessment of epiphyseal fusion at the knee joint in a sample of the Iraq population and to implement radiographic examination of the knee joint as an additional anatomical region for age estimation.

Materials and Methods. A prospective study was carried out on 55 medico-legal cases referred to the medico-legal directorate in Baghdad during 6-month period in 2022. The cases under study were classified into 2 groups: male (30) and female (25), their age ranged from (9-19 years). Radiographic method (anteroposterior and lateral knee x-ray) was used to subdivide the continuum of development into 5 specific stages of union and scored as stage 0 – nonunion, stage 1 – beginning union, stage 2 – active union, stage 3 – recent union, stage 4 – complete union.

Results. The present study showed that out of the total of 55 cases, 30 cases were male and 25 were female. A maximum number of cases belong to the 18-19 years of age group in both genders. The chronological age (years) of the youngest and oldest subjects was recorded at each stage of union for each of the three epiphyses at the knee for males and females. The mean age and stander deviation for each stage of fusion were mentioned. The mean age in males; at stage 0 was about 10.5 for all three bones (distal end of femur and proximal end of tibia and fibula). Stage 1 was about 13 years for the proximal end of the femur, 13.5 years for the distal end of the tibia, and 14 years for the distal end of the fibula. Stage 2 was about 15.5 years for all three bones, while in stage 3; the mean age for all three bones was about 17.5 years and regarding stage 4; the mean age was 18.5 years for the proximal end of the femur and 19 for distal end for both tibia and fibula. Females were less than males by about 1.5 years.

Conclusion. The present study concluded that the stage of epiphyseal union is correlated with chronological age in both males and females. Mean age gradually increases with each stage of union and also varies between male and female cases. A statistically significant difference in mean age was recorded between stages when compared to the previous stage for three epiphyses. Fusion of various epiphyses has been reported earlier in females (about 1.5 years) in comparison to males of the present series. Epiphyseal fusion of the lower end of the femur was observed earlier than the tibia and fibula.

Keywords: epiphyseal fusion, epiphyseal union, chronological age, knee joint.

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РЕНТГЕНОЛОГИЧЕСКАЯ ОЦЕНКА ВОЗРАСТА ПО ЗАКРЫТИЮ ЭПИФИЗАРНОЙ ЗОНЫ РОСТА КОЛЕННОГО СУСТАВА

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Определение возраста полезно как в гражданских, так и в уголовных делах. Настоящее исследование было проведено с целью изучения оценки возраста по сращению эпифизов костей, формирующих коленный сустав, что считается одним из современных и достаточно точных методов оценки возраста.

Цель. Сравнить хронологический возраст и возраст, определяемый по рентгенологической оценке закрытия эпифизарной зоны роста коленного сустава на выборке населения Ирака, и внедрить рентгенологический метод исследования коленного сустава как дополнительной анатомической области для определения возраста.

Материалы и методы. Проведено проспективное исследование по 55 судебно-медицинским делам, переданным в медико-правовое управление в Багдаде в течение 6 месяцев в 2022 году. Расследуемые дела были разделены на 2 группы: мужчины (30) и женщины (25), их возраст варьировался от 9 до 19 лет, рентгенологический метод (передне-задняя и боковая проекции коленного сустава) использовался для выделения 5 стадий закрытия эпифизарной зоны роста: стадия 0 – отсутствие сращения, стадия 1 – начальное сращение, стадия 2 – активное сращение, 3 стадия – недавнее сращение, 4 стадия – полное сращение.

Результаты. Настоящее исследование показало, что из 55 случаев, 30 соответствовали мужскому полу и 25 – женскому. Максимальное количество случаев приходится на возрастную группу 18-19 лет в независимости от пола. Хронологический возраст (в годах) самого младшего и старшего испытуемых регистрировали на каждом этапе закрытия эпифизарной зоны роста, для каждого из трех эпифизов коленного сустава, как у мужчин, так и у женщин. Кроме того, был определен средний возраст со стандартной девиацией для каждой стадии. Средний возраст мужского пола на стадии 0 составил 10,5 (для всех трех костей: дистального эпифиза бедренной кости, а также проксимальных эпифизов большеберцовой и малоберцовой костей); на стадии 1 – около 13 лет для проксимального эпифиза бедренной кости, 13,5 лет – для дистального эпифиза большеберцовой кости и 14 лет – для дистального эпифиза малоберцовой кости. На стадии 2 возраст составил около 15,5 лет по всем трем костям; для 3 стадии средний возраст по всем трем костям составил около 17,5 лет; на 4 стадии средний возраст для проксимального эпифиза бедренной кости составил около 18,5 лет и 19 лет для дистальных эпифизов большеберцовой и малоберцовой костей. Средний возраст закрытия эпифизарной зоны роста у женского пола наступал на 1,5 года раньше, чем у мужского.

Заключение. При настоящем исследовании было выявлено, что стадия закрытия эпифизарной зоны роста коррелирует с хронологическим возрастом как у мужчин, так и у женщин. Средний возраст постепенно увеличивается с каждой стадией сращения и также варьируется между мужчинами и женщинами. Статистически значимые различия были обнаружены в значении среднего возраста между различными стадиями закрытия эпифизарной зоны роста. Сращение эпифизов у женщин наблюдалось раньше (в среднем на 1,5 года) по сравнению с мужчинами. Сращение эпифиза дистального эпифиза бедренной кости наблюдалось раньше, чем большеберцовой и малоберцовой костей.

Ключевые слова: сращение эпифизов, закрытие эпифизарной зоны роста, коленный сустав.

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Introduction

Age estimation is an important parameter for medico-legal cases in both civil and criminal cases. Age estimation is the most important issue to the court and the common citizens as well, It is essential to establish the identity of the person at the time of admission to schools, colleges, institutes, or while competing in sports tournaments at regional or national levels. It is also important while taking consent or in cases relating to juvenile offenders, Competency as a witness, rape, kidnapping, fixation of criminal responsibility, employment in Govt, and marriage [1]. Age estimation in the clinical forensic department depends on dentation and radiological examination of bones and also by direct observation of dry bones (post-mortem examinations).

There are hundreds of ossification centers in the bones of the body. The appearance and fusion of some centers in the bones with others of the same bones form the basis of the estimation of age. The long bones of the lower limb play a vital role in the assessment of age both in living and dry remains [2]. The Age of epiphyseal union is an important objective method for age estimation, but these ages vary with racial, geographic, climatic, and various other factors. These variations have suggested the need for separate standards of ossification for separate regions [2].

To establish the chronological age of an individual from their skeletal development, at least one of the three phases of osseous development must be assessed: The age of appearance (i.e. ossification) of different parts of the bone. The morphological appearance and/or size of the bone and its constituent parts. The timing of fusion of different parts of a bone. The assessment of these three phases can occur either via direct observance of the bone or via radiographic images of the living individual [3].

The stages of fusion divide radiologically the process of fusion of epiphysis with the diaphysis into five stages:

Stage 0: No union –no evidence of commencement of union between epiphysis and diaphysis.

stage 1: beginning union- obliteration commences in the space between the epiphysis and diaphysis.

stage 2: active union-the epiphysis and diaphysis cap each other.

stage 3: recent union- space gets closed but the line of fusion is visible at the junction of epiphysis and diaphysis.

stage 4: complete union- epiphyseal space obliterated by bony fusion showing the same density as that of the shaft [4].

The knee is easily positioned so that anteroposterior radiographs can be taken and yield information for three epiphyses – the distal femur, proximal tibia, and proximal fibula [4].

Oladunni, Dennis, Nwabneze, and Steplea Onyia, India (2015), studied 100 males and 110 females, the number of stages was 5 by plain X-ray, the finding in their study suggested that the radiographic analysis of the knee was a valuable alternative for estimation of chronological age [5].

Keshav et al, (2017), studied 100 cases, 62 cases were male and 38 were female. The Maximum number of cases belongs to the 17-18 years of age group in both genders. The age of complete fusion between epiphysis and diaphysis in the lower end of the femur was observed at 17-19 years of age and above in males and 16-18 years of age and above in females in our study. The age of complete fusion between epiphysis and diaphysis in the upper end of the tibia was observed at 16-19 years of age and above in both genders and the proximal end of Fibula in males was observed at 17-20 years of age and above, while in females it was observed at 16-19 years of age and above [6].

Deepak Maharia, in India, studied 80 subjects, the finding in their study suggested that the age of complete union in knee joint were as follow: in male; the femur was at 17-19years, the tibia was 16-19, the fibula was at 17-19years, while in female; both femur and tibia were at16-19 years while fibula was at 17-20 years [7].

The present study was carried out to study the estimation of age through epiphyses fusion at the knee joint by Digital X-Ray study in the age group of 9 to 19 years. Samples taken from various People were referred to the forensic medicine directorate in Baghdad. The study aimed to compare chronological age and age estimated according to the union from radiographic assessment of epiphyseal fusion at the knee joint in a sample of the Iraqi population and to implement a radiographic examination of

Fig. 1 a (Рис. 1 а)

Fig. 1 b (Рис. 1 б)

Fig. 1. X-rays, knee joint.

Anteroposterior and lateral projections. X-rays stage 0.

Рис. 1. Рентгенограммы, коленный сустав.

Передне-задняя и боковая проекции. Рентгенологическая стадия 0.

the knee joint as an additional anatomical region for age estimation.

Materials and Methods.

Study design and settings.

This prospective study was conducted at Medico-Legal Directorate in Baghdad City during the period from March 2022 to December 2022. Fifty-five subjects were subjected to radiography (30 males, 25 females). The radiographs were examined to establish the relationship between the epiphyseal union at the knee and chronological age. All subjects aged 9–19 years who presented for the medico-legal directorate in Baghdad. Information for the date of birth was used to calculate chronological age, thus allowing the calculation of exact age (year). Five stages of the epiphyseal union were identified (stage 0, stage 1, stage 2, stage 3, stage 4), and anteroposterior and lateral radiographs were used together when assessing the stage of the epiphyseal union [8]. The study is approved by the Iraqi Board of Medical Specializations.

Inclusion criteria

• Subjects should be living in Baghdad region for more than 5 years.

• Subjects should be free from any physical disability or any chronic illness.

• Subjects should have accurate records of their date of birth.

• Subjects with their knee x-ray anteroposterior and lateral were available.

Exclusion criteria

• Age smaller than 9 years and older than 19 years.

• Subjects not from Baghdad.

• There are no official papers showing the exact age.

• History of chronic disease.

• History of trauma to the knee joint.

• Subjects with knee joint deformity.

• Poor socio-economic class.

Data collection

A questionnaire was filled out, which included information about the date of birth, age, sex, residential area, any disease or deformity in the knee joint, any chronic illness, and occupation. Material and equipment: Plain x-ray machine (eco ray, kv 500, colo907149). Anteroposterior and lateral views: Ap position, the method of taking an x-ray was in a supine position where the leg was extended and the x-ray focused on the patella and directed vertically in mas 4-5 and the kv was about (50-60).

In lateral position, the subject lying on the right side, pelvis not rotated, right knee forward and extend another limb behind it, central ray5-7 degrees cephalad at the knee joint (2-5) cm distal to the medial epicondyle, then pictures were taken for these plain x- rays by digital (Sony) camera.

Fig. 2 (Рис. 2)

Fig. 2. X-rays, knee joint.

Lateral and anteroposterior projections. X-ray stage 1.

Рис. 2. Рентгенограммы, коленный сустав.

Боковая и передне-задняя проекции. Рентгенологическая стадия 1.

The stages of epiphyseal union:

Stage 0 – Non-union: The diaphysis and epiphyseal bones are adjacent to each other but not yet in an intimate relationship. The epiphysis is separate from the plate (arrow) (fig. 1). This should be apparent in at least one view on the radiograph, as a continuous radiolucent gap between the epiphysis and diaphysis [8, 9].

Stage 1 – beginning union the epiphyseal and diaphysis surfaces closely approximate each other (fig. 2). The radiolucent strip between adjacent surfaces of the epiphysis and diaphysis has become a narrowed comparison with the stage of non-union. The radiolucent gap is not continuous from anterior to posterior or medial to lateral. Towards the central region of the growth plate, there is a definite breaking up of the adjacent outlines of the epiphyseal and metaphyseal margins. This appears as a hazy area centrally which is of greater density than the adjacent bone (arrow). The radio-dense appearance on the radiograph is a consequence of the extension of bone across the intervening gap between the shaft and epiphysis. Greater than half the growth plate is judged to be radiolucent. This indicates that the union has begun centrally but has not as yet commenced on the remainder of the growth plate. If an investigator is uncertain about what stage to assign after assessing both radiographic views, the later stage should be selected [2].

Stage 2 – active union (fig. 3). The epiphysis and diaphysis now cap each other. 'Capping 'refers to how the epiphysis overlaps the metaphysis as maturation proceeds [2]. The terminal plate of the epiphysis is no longer distinguishable. A fusion line or zone of greater density than the adjacent bone replaces the epiphyseal cartilage. The presence of the radio-dense region indicates that fusion is actively occurring (arrow). Small areas of radiolucency separating the epiphysis and diaphysis may be evident towards the margins of the bone. Less than half the growth plate is judged to be radiolucent. This indicates that union is actively occurring but has not yet reached the margins of the bones [2].

Stage 3 – recent union (fig. 4). The epiphysis and diaphysis have united to form a single unit of bone, i.e. there is complete capping. The position of the former epiphysis and diaphysis can still be distinguished. A fine line of fusion of greater density may remain between the epiphysis and diaphysis (arrow). There is discontinuity of trabecular between the former epiphysis and diaphysis. Although the epiphysis caps the diaphysis there may still be a slight notch (arrow) at the margin of the growth plate (less than 2

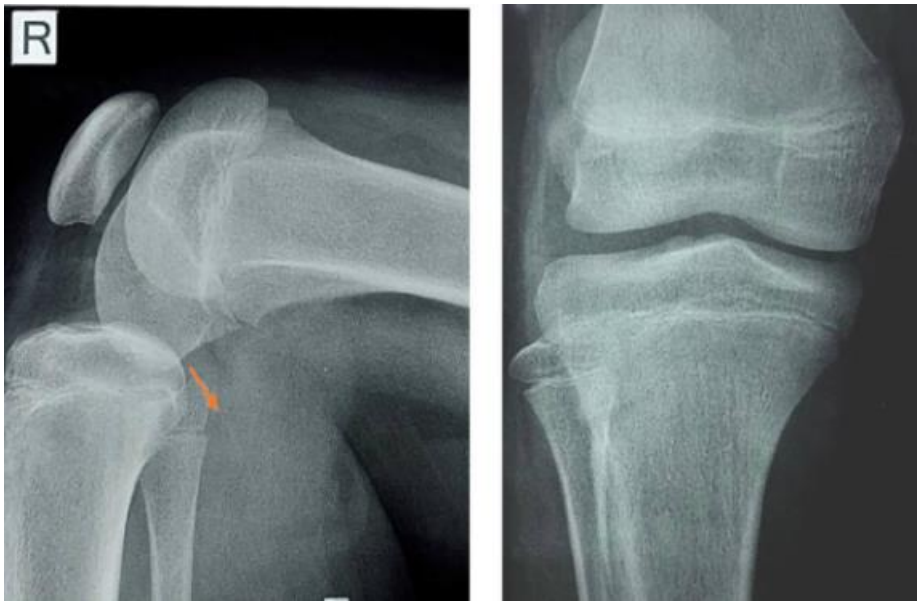

Fig. 3 (Рис. 3)

Fig. 3. X-rays, knee joint.

Lateral and anteroposterior projections. X-ray stage 2.

Рис. 3. Рентгенограммы, коленный сустав.

Боковая и передне-задняя проекции. Рентгенологическая стадия 2.

Fig. 4 (Рис. 4)

Fig. 4. X-rays, knee joint.

Antero-posterior and lateral projections. X-ray stage 3.

Рис. 4. Рентгенограммы, коленный сустав.

Передне-задняя и боковая проекции. Рентгенологическая стадия 3.

mm) that has not yet completely calcified. The combination of discontinuity of trabecular between the epiphysis and diaphysis and the notches at the peripheral margins of the bone indicates that the bone is recently united.

Stage 4 – complete union (fig. 5). The epiphysis and diaphysis are united as a single unit of bone. Remodeling has taken place and there is continuity of trabecular from shaft to former epiphysis. This presents a uniformity of internal bone pattern throughout the end of the long bone up to the articular surface. All trace of epiphyseal differentiation has been lost. There are no radiolucent notches evident at the peripheral margin of the bone, indicating that the growth plate has now completely ossified and the bone is fused in its entirety. A thin terminal line, the epiphyseal scar, which marks part of the location of the former epiphyseal-metaphyseal junction may remain in some cases [2].

Results.

At first, 4 cases (2 males and 2 females) had radiographs of both left and right knees taken concomitantly.0n examination of these 4 cases it was found no statistically significant difference in the stage of fusion between right and left sides for three Epiphysis. All statistical results were based on only the right sides and were included for statistical analysis to avoid duplication of results. The study was carried out on 55 cases referred to the medico-legal directorate in Bagdad. Males in the total study cases constituted 55% (30 cases) while females constitute 45 % (25 cases). There were 2 cases for each gender at 9 years of age while there were 6 male cases and 4 female cases at 19 years of age as shown in table №1.

The frequency of subjects in each age group from 9-19 years was most frequent at age 19 there were 10 subjects (fig. 6). The maximum age number was recorded at stage 0 (14 among 55 subjects) as shown in table 2 while the percentage of each stage is shown in Figure 7, as follows:

Stage – 0: 14 cases (25%),
Stage – 1: 8 cases (15%),
Stage – 2: 9 cases (16%),
Stage – 3: 11 cases (20%),
Stage – 4: 13cases (24%).

The distribution of the sample at each stage of union for each age group is presented in Tables №3, №4 and №5 for females and in Tables №6, №7 and №8 for males. For each of the three epiphyses for both males and females, the progression of epiphyseal union through several definite stages of union with increasing chronological age is visible.

Fig. 5 (Рис. 5)

Fig. 5. X-rays, knee joint.

Anteroposterior and lateral projections, X-ray stage 4.

Рис. 5. Рентгенограммы, коленный сустав.

Передне-задняя и боковая проекции. Рентгенологическая стадия 4.

Table №1. A number of cases for both gender.

		Age											Total
		9	10	11	12	13	14	15	16	17	18	19	
Gender	Male	2	4	3	1	2	2	3	2	2	3	6	30
	Female	2	2	2	2	2	2	2	2	2	3	4	25
Total		4	6	5	3	4	4	5	4	4	6	10	55

Table №2. Numbers of individuals at each stage.

		Gender		Total
		Male	**Female**	
Stages	stage0	10	4	14
	stage1	4	4	8
	stage2	5	4	9
	stage3	5	6	11
	stage4	6	7	13
Total		30	25	55

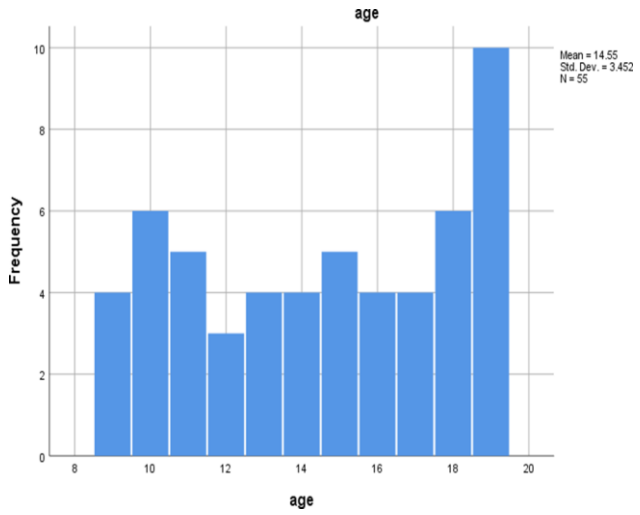

Fig. 6 (Рис. 6)

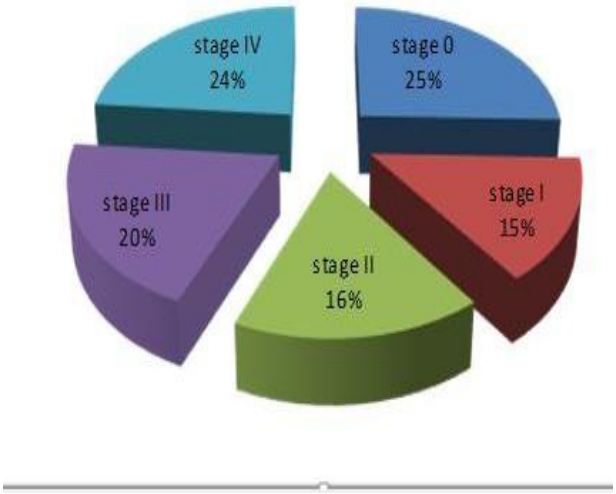

Fig. 7 (Рис. 7)

Fig. 6. Diagram.

Frequency of each age group.

Рис. 6. Диаграмма.

Распределение по возрастным группам.

Fig. 5. Diagram.

Percentage of each stage.

Рис. 5. Диаграмма.

Распределение по стадиям.

Table №3. Numbers of individuals at each stage of union for the distal end of the femur, for each age group for female subjects.

Age (Years)		Femur stage of union (female)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Female	9-10	4	0	0	0	0	4
	11-12	0	3	1	0	0	4
	13-14	0	0	4	0	0	4
	15-16	0	0	0	4	0	4
	17-18	0	0	0	1	4	5
	>18	0	0	0	0	4	4
Total		4	3	5	5	8	25

Table №4. Numbers of individuals at each stage of union for the proximal end of the tibia, for each age group for female subjects.

Age (Years)		Tibia stage of union (female)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Female	9-10	4	0	0	0	0	4
	11-12	0	4	0	0	0	4
	13-14	0	0	4	0	0	4
	15-16	0	0	0	4	0	4
	17-18	0	0	0	2	3	5
	>18	0	0	0	0	4	4
Total		4	4	4	6	7	25

Table №5. Numbers of the individual at each stage of union for the proximal end of the fibula, for each age group for female subjects.

Age (Years)		Fibula stage of union (female)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Female	9-10	4	0	0	0	0	4
	11-12	1	3	0	0	0	4
	13-14	0	0	4	0	0	4
	15-16	0	0	0	4	0	4
	17-18	0	0	0	3	2	5
	>18	0	0	0	0	4	4
Total		5	3	4	7	6	25

Table №6. Number of individuals at each stage of union for the distal of the femur, for each age group for males.

Age (Years)		Femur stage of union (male)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Male	9-10 years	5	0	0	0	0	5
	11-12 years	4	1	0	0	0	5
	13-14 years	0	4	0	0	0	4
	15-16 years	0	0	5	0	0	5
	17-18 years	0	0	0	3	2	5
	>18 years	0	0	0	0	6	6
Total		9	5	5	3	8	30

Table №7. Number of individuals at each stage of union for the proximal end of the tibia, for each age group for males.

Age (Years)		Tibia stage of union (male)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Male	9-10 years	5	0	0	0	0	5
	11-12 years	5	0	0	0	0	5
	13-14 years	0	4	0	0	0	4
	15-16 years	0	0	5	0	0	5
	17-18 years	0	0	0	5	0	5
	>18 years	0	0	0	0	6	6
Total		10	4	5	5	6	30

Table №8. Number of individuals at each stage of union for the fibula, for each age group for males.

Age (Years)		Fibula stage of union (male)					Total
		stage 0	stage 1	stage 2	stage 3	stage 4	
Male	9-10 years	5	0	0	0	0	5
	11-12 years	5	0	0	0	0	5
	13-14 years	0	4	0	0	0	4
	15-16 years	0	2	3	0	0	5
	17-18 years	0	0	0	5	0	5
	>18 years	0	0	0	0	6	6
Total		10	6	3	5	6	30

In females in the age group (9 - 10), the three bones (distal end of the femur and proximal ends of tibia and fibula in the 4 subjects were in stage 0 as shown in Tables №3, №4, №5. At the age group (11 - 12) 3 of 4 subjects were in stage 1 and 1 subject was in stage 2 regarding the distal end of the femoral bone as shown in table №3 while all 4 subjects were in stage 1 for the proximal end of tibia as shown in table №4 and 1 subject was in stage 0 and 3 subjects were in(stage 1 regarding the proximal end of the fibula as shown in table №5. In the age group (13 - 14) the three bones in the 4 subjects were in stage 2. In the age group (15 - 16) the three bones in the 4 subjects were in stage 3. In the age group (17 - 18) 1 of 5 subjects was in stage 3 and 4 subjects were in stage 4 regarding the distal end of the femoral bone, while 2 of 5 subjects were in stage 3 and 3 subjects were in stage 4 for the proximal end of tibia, and 3 subjects were in stage 3 and 2 subjects were in stage 4 for the proximal end of the fibula. At the age group (18 - 19) all 4 subjects for both the distal end of the femur and the proximal ends of the tibia and fibula were in stage 4. In both males and females beginning union of the distal femoral epiphysis was earlier than the proximal epiphysis of both tibia and fibula mostly observed in between stages 1 and 2, while the beginning of the proximal epiphysis of the fibula was later than the femur and tibia mostly observed in between stages 3and 4 as shown in table 5 and 8.

The chronological age (years) of the youngest and oldest subjects for each stage of union for each of the three epiphyses at the knee for males and females was recorded. The mean age (years) and the standard deviation for each stage of fusion are also presented. For example, in males, the youngest subject recorded as having a beginning union of the distal femoral epiphysis was aged 9 years, and the oldest subject was 12 years. However, the mean age of male subjects demonstrating beginning union was 10.5 years. The mean ages show a gradual increase with each stage of union and vary between male and female subjects. A statistically significant difference in mean age was noted between each stage when compared with the stage previous to it ($P < 0.05$). In females, there was no difference in mean age between the femur and tibia in stages 0 and 3 and between tibia and fibula in stage2 and 4, and all three bones in stage 1. In males, there was no significant difference in mean age between all three bones in stages 0, 2, and 3. The proximal fibu-

Table №9. Mean, SD, and range in age for each stage of a union at each of the epiphysis at the knee for males and females.

Female

		Stage of union	Age(years) of youngest (a) and oldest (b) showingfusion		Mean age (years)	SD
			(a)	(b)		
Femur		0	9	10	9.5	0.7
		1	11	12	11.5	0.7
		2	12	14	13	1
		3	15	17	16	1
		4	17	19	18	1
Tibia		0	9	10	9.5	0.7
		1	11	12	11.5	0.7
		2	13	14	13.5	0.7
		3	15	17	16	1
		4	18	19	18.5	0.7
Fibula		0	9	11	10	1
		1	11	12	11.5	0.7
		2	13	14	13.5	0.7
		3	15	18	16.5	1.29
		4	18	19	18.5	0.7

Males

		Stage of union	Age(years) of youngest (a) and oldest (b) showingfusion		Mean age (years)	SD
			(a)	(b)		
Femur		0	9	12	10.5	1.29
		1	12	14	13	1
		2	15	16	15.5	0.7
		3	17	18	17.5	0.7
		4	18	19	18.5	0.7
Tibia		0	9	12	10.5	1.29
		1	13	14	13.5	0.7
		2	15	16	15.5	0.7
		3	17	18	17.5	0.7
		4	19	19	19	_
Fibula		0	9	12	10.5	1.29
		1	13	15	14	1
		2	15	16	15.5	0.7
		3	17	18	17.5	0.7
		4	19	19	19	_

Table №10. Relation between age and stages of the union of three bones (femur, tibia, fibula) in females.

Female age	Pearson Correlation	1	0.976**	0.982**	0.973**
	Sig. (2-tailed)		0.0001	0.0001	0.0001
	N	25	25	25	25
Femur stageof union (female)	Pearson Correlation	0.976**	1	0.982**	0.968**
	Sig. (2-tailed)	0.0001		0.0001	0.0001
	N	25	25	25	25
Tibia stageof union (female)	Pearson Correlation	0.982**	0.982**	1	0.982**
	Sig. (2-tailed)	0.0001	0.0001		0.0001
	N	25	25	25	25
Fibula stageof union (female)	Pearson Correlation	0.973**	0.968**	0.982**	1
	Sig. (2-tailed)	0.0001	0.0001	0.0001	
	N	25	25	25	25

Table №11. Relation between age and stages of union for the three bones (femur, tibia, fibula).

Male age	Pearson Correlation	1	0.970**	0.972**	0.961**
	Sig. (2-tailed)		0.0001	0.0001	0.0001
	N	30	30	30	30
Femur stage of union (male)	Pearson Correlation	0.970**	1	0.982**	0.972**
	Sig. (2-tailed)	0.0001		0.0001	0.0001
	N	30	30	30	30
Tibia stage of union (male)	Pearson Correlation	0.972**	0.982**	1	0.987**
	Sig. (2-tailed)	0.0001	0.0001		0.0001
	N	30	30	30	30
Fibula stage of union (male)	Pearson Correlation	0.961**	0.972**	0.987**	1
	Sig. (2-tailed)	0.0001	0.0001	0.0001	
	N	30	30	30	30

Table №12. Appearance and union of ossification centers in the knee joint (in males).

Bone	Center of ossification	Age of Appearance	Stages of union	Age of Union (Years)
Femur	Lower end	9 months IUL(At birth)	Stage0-1	10.5-13
			Stage 2-3	15.5-17.5
			Stage 4	18.5
Tibia	Upper end	At birth	Stage 0-1	10.5-13.5
			Stage 2-3	15.5-17.5
			Stage 4	19
Fibula	Upper end	4 years	Stage 0-1	10.5-14
			Stage 2-3	15.5-17.5
			Stage 4	19

lar epiphysis can also be seen to commence union at a later stage than the epiphyses of the femur and tibia. Six male and 10 female subjects were recorded as having reached the state of completed union of the fibula by comparison with one and two subjects for the femur, and two and three subjects for the tibia, respectively as shown in table №9.

There were positive relationships between age groups and stages of unions for all three bones (femur, tibia, fibula) and the significance or p (value) was less than 0.01* as shown in Table №10 and Table №11. *correlation is significant at the 0.011 level (2-tailed). Table №12 shows a useful summary of the appearance and union of ossification centers in the knee joint for practical application.

Discussion.

At present day, clinical and forensic investigations demand techniques that can provide estimates of chronological age. Persistent revision of the techniques in practice must be undertaken to maintain the accuracy of these estimations of age.

The cardinal basis of age estimation techniques in juveniles is that the skeleton is not static and is constantly changing in small increments until the adult state is reached. However, it appears that rather than examining the process as a whole, there has instead been a focus on the endpoint of development similar to a previous study [10].

Males in our total study cases were higher than females. This was similar to the study done previously male predominance may be due to; the percentage of male reviewers in the forensic directorate being greater than that of females [6].

According to statistical results, the vast majority of cases were in the age group of more than 18 years and the reason for this is that this age group is more in need of citizenship or civil status ID for work, travel, and marriage. This finding agrees with a study done previously [5].

As similar to this study Kausar, and Varghese utilized the information that ordered changes occur at the growth plate during epiphyseal fusion and this was applied to produce a method that sub-divides the process of epiphyseal union into five different stages by plain X-ray [11]. Others subsequently adapted this method for use on a skeletal sample. It was assumed that if the continuum of development could be divided into anatomical specimens, then similarly this process of epiphyseal union could be divided on radiograph [1, 6].

In this study, we referred to fusion as the age category at which 75% or more of the group showed complete union while Johnston refers to fusion as the age category at which 50% or more of the group show complete union. Authors place the age of complete union at the age group showing greater than 85% of cases united, whereas others referred to the age of complete union when 100% of cases are united [8, 9]. There is a visible inconsistency between authors in providing a range in age for the time of complete union. As a result, it makes the comparison between the age ranges provided quite difficult.

In both males and females, the beginning union of the distal femoral epiphysis was earlier than the proximal epiphysis of both tibia and fibula mostly observed in between stages 1 and 2, while the beginning of the proximal epiphysis of the fibula was later than the femur and tibia mostly observed in between stages 3 and 4. This finding agrees with a study done previously by O'Connor and disagrees with a study done by Paterson which found that the beginning union of the proximal epiphysis of the tibia was later than the femur and fibula [2, 12].

The study showed that females develop at a younger age than their male counterparts about 1.5-2 years. This is in agreement with the results of previous studies which found that females typically develop approximately two years in advance of males and this is related to the estrogen hormone [13, 14].

The mean age indicated the typical age at which each stage of union occurs. It showed a gradual increase with each stage of union with variation between males and females, this finding agrees with the study of O'Connor [2].

The study showed that the mean age for stage 0 in females was earlier than in males, this finding agrees with a previous study done by O'Connor, while others reported older ages by comparison. This difference might be due to the large number of cases included in their studies [2, 11].

It was also found that the mean age for beginning union (stage 1) was also earlier in females. This finding agrees with studies and disagrees with the study done by, the difference might be due to the type of samples he was based on the skeletal remains of human bodies [14 - 16].

Females showed active union (stage 2) at an earlier age than males in all three bones. This finding is slightly lower than the finding of a previous study done by about two years [4]. This difference might be due to differences in time and place. While agreeing with the finding of Keshave Soni and O'Connor [2, 17].

The study also revealed that the mean age for recent union (stage 3) for all 3 bones was also earlier in females than males as well as the mean age for complete union (stage 4) for the

distal end of the femur and the upper end of the tibia and fibula. The findings in this study were following different authors as Oladuniand O'Connor who stated that complete fusion occurs at age (18 - 19) years of age [2]. The finding in this study was slightly higher than [17, 18]. This difference might be due to the sample size and the difference in time and place.

Conclusion.

The stages of an epiphyseal union of the knee joint were correlated with chronological age in both males and females. The fusion of various epiphyses was found earlier in females (about 1-2 years) than in males. The epiphyseal fusion of the lower end of the femur was observed earlier than the epiphyseal fusion of the upper part of the tibia and fibula. The knee joint is a reliable joint for age estimation when no other joints are available such as in accident scenes or mass disasters. Conducting a further study on a large sample of the population for both males and females. A comparison study between northern and southern regions in Iraq is recommended for a more reliable estimate.

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