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Epiphyseal Union Sequencing: Aiding in the Recognition and Sorting of Commingled Remains*

ABSTRACT: The presence of accessory osseous material within a seemingly single individual assemblage has the potential to result in misidentification of the remains. Detection of nonrelated material relies on the anthropologist being able to recognize incongruities among the elements. Inconsistencies in developmental status provide evidence to suggest that commingling may have occurred. Analyzing the sequence in which the various epiphyses unite can help to identify outlying elements that do not match the predicted developmental pattern of the remaining skeleton, thus indicating that the element may not belong to that individual. This paper considers the sequence in which 21 various epiphyses of the body unite to serve as a reference for identifying incongruent fusing patterns within a commingled assemblage. Two hundred and fifty-eight male individuals of Bosniak (Bosnian Muslim) descent between the ages of 14 and 30 years were included for analysis. Sequence order was determined for both "beginning" and "complete" union by comparing the fusing status of each epiphysis with each of the other 21 epiphyses. Considering both sequence patterns provides a wider spectrum of evidence from which to recognize incongruities than either sequence pattern could provide in isolation. Variations to the majority sequence pattern were also included to ensure that skeletons displaying less popular but acceptable sequence patterns would not be mistakenly considered as two individuals when using this research as a reference. Although substantial variation in the order in which epiphyses initiate and complete union was discovered within the sample, most epiphyseal relationships did not display any variable patterns. These "unvaried" relationships will be most useful in recognizing the presence of incongruent material if the pattern within an assemblage does not conform to the pattern documented in this study. Figures demonstrating the two sequence patterns are provided for easy application in the field.

KEYWORDS: forensic science, epiphyseal union, forensic, skeleton, commingling, juvenile, Balkans, Bosnia

Commingling of human remains is a major forensic concern that commonly follows mass fatalities including plane crashes, war, explosions, etc. (1,2). Failure to recognize that two or more individuals are represented in one assemblage can result in both misidentification and a primary lack of identification. The frequency with which commingling hampers identification efforts has led numerous authors to investigate methods that (1) permit the recognition of multiple individuals in a single assemblage, and (2) aid in the re-association of separated elements to a single individual. The most obvious indicator that commingling has occurred is the presence of two or more identical elements, e.g., two left femora. In the absence of repeated elements, however, commingling may be more difficult to recognize and relies upon the anthropologist being able to identify incongruities among osseous material. For example, variations in the size and shape of bilateral elements, disproportionate upper and lower body measurements, or inconsistencies in age, sex, or racial attributes can help to confirm that commingling has occurred and aid discrimination between individuals (2–7). Also useful, but less thoroughly investigated, is the recognition of incongruities in developmental status through epiphyseal union (3).

Commingling is especially problematic for those involved in the identification of the 8000 Bosnian men and boys who lost their lives during the fall of Srebrenica (July 11–15, 1995). The executed were initially buried in large earthen pits but fears that satellite imagery could locate the mass graves eventually led to exhumation and reburial of the remains into more clandestine secondary and even tertiary graves located further from Srebrenica (8–10). Exhumation and reburial was accomplished with backhoes that disrupted the already decomposing bodies, dividing them into many components. When transferred to secondary graves, they mixed with the bodies and partial remains of other individuals. As a result, the remains that have since been exhumed by archaeologists are often incomplete and/or frequently contain supernumerary elements. If duplicate elements are present within a body bag, then commingling can be relatively easy to discern. However, if missing elements from the primary individual are represented by a second or even third individual, then discovery of commingling may not be so obvious.

As so many of the individuals who lost their lives in the Srebrenica incident were young, phases of epiphyseal union could prove invaluable for detecting incongruities in skeletal development among juvenile remains commingled with accessory juvenile or adult elements. While discrepancies between juvenile and adult material may seem obvious, it is less conspicuous if the juvenile skeleton has approximated full maturity and many epiphyseal elements would be expected to display complete union. Understanding the sequence with which epiphyses unite can help to highlight elements that do not adhere to the expected pattern, thereby raising the possibility that they may not be indigenous. Of special importance is the use of population-specific standards to recognize incongruities as Bosnian males were found to differ slightly in their timing of epiphyseal union compared with standards of McKern and Stewart based on American soldiers killed during the Korean conflict (11,12).

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Stevenson (13) and Todd (14,15) were among the first to report a sequential pattern of epiphyseal union by examining a variety of epiphyses. Both boldly concluded that the sequence of union was constant and identical in every human being; yet, somewhat incongruously, their reported patterns differed slightly, inadvertently highlighting the inconsistency of their statement. Stewart (16) noted this variance and also doubted the existence of a universal pattern that was true for all humankind. From his research on Eskimos and Native American Indians, he concluded that while sequence was largely consistent in similar groups, it could differ according to ethnic and socio-economic variation.

In comparable research regarding the appearance sequence of ossification centers found in the hand and wrist, Garn and Rohmann (17) discovered that considerable variation exists between individuals. Their research contradicted popular belief that described the order of appearance as regular and constant (18,19). Variation was later attributed to genetic control as correlations in sequence patterns among family members increased from parents and their children through siblings to monozygotic twins (20). Genetic influences were also believed to regulate union sequence in the bones of the hand as demonstrated by the highly similar sequence order in monozygotic twins compared with the increased dissimilarity found in dizygotic twins (21).

Given the highly variable sequence order that was found in the appearance times of the secondary centers in Garn and Rohmann's (17) study, it is also very likely that current research will reveal additional variation in the sequence order of epiphyseal union than that reported by Stevenson and colleagues (13–16). Documentation of the complete extent of human variability is necessary for sequencing information to be useful in a forensic setting, as without adequate knowledge of variation, inaccurate conclusions may be drawn for epiphyses that represent less common patterns.

To further increase forensic applicability, new research should also include data collected not only on the sequence of "complete" union, but also on the sequence of "beginning" union. Establishing dual spectra both sequence patterns provides optimal application for use in the sorting and re-association of commingled remains by maximizing the variables available for assessment. A study of epiphyseal union for a single population on this scale also provides the scientific community with an important reference sample for comparison with other populations and broadens our understanding of human skeletal development. This paper revisits sequence of union, documenting both "beginning" and "complete" phases, and provides data that may prove valuable in the forensic situation.

Materials and Methods

Sample

This project was able to take advantage of the rare opportunity to gather osteomorphic data on a large-scale basis from identified individuals of known age. Identifications were conducted by the International Commission on Missing Persons (ICMP) through DNA analysis.

Data collection took place at the Podrinja Identification Center in Tuzla, Bosnia, between November 2002 and November 2003 and again from May to June 2005. Data on 110 cases were collected during the 2002/2003 period, while 148 cases were added during the later 2005 season, thus providing a total of 258 cases. All individuals were Bosniak (Bosnian Muslim) males who ranged in age at death from 14 to 30 years. Only individuals who had been positively identified through DNA and anthropological assessment were included in this study; therefore, age is "confirmed." An age distribution of the sample is provided in Table 1.

TABLE 1—*Distribution of age cohorts.*

Age	No. of Individuals
14	3
15	7
16	15
17	20
18	24
19	20
20	26
21	26
22	13
23	14
24	18
25	18
26	13
27	11
28	14
29	9
30	7
Total	258

Methods

Twenty-one epiphyses were considered for analysis: medial clavicle, coracoid process, acromion process, proximal and distal humerus, medial epiphysis of the humerus, proximal and distal radius, proximal and distal ulna, iliac crest, acetabulum, ischial tuberosity, proximal femur, greater and lesser trochanter, distal femur, proximal and distal tibia, and proximal and distal fibula.

Progress of union was recorded by applying a three-phase scoring system to each epiphysis. A phase of "0" was assigned to those epiphyses that had not yet begun to unite, phase "1" to those that were actively engaged in union and demonstrated an epiphyseal line in the process of obliteration, and phase "2" for those that had completed union and their line of fusion had been obliterated, although an epiphyseal scar might remain. This scoring system was based on that of McKern and Stewart (12). Their five-phased system, however, was not used in its entirety as this analysis only considers epiphyses that have completed union in relation to those that have not completed union; thus, the additional phases were redundant. Reduction to a three-phased approach should remove much of the subjective error introduced by multiphased systems. Both right and left elements were scored when available. In the rare situation that the scores from the right and left side of an element differed, the most advanced stage was recorded.

Data were evaluated using the crosstabs procedure available from SPSS. The procedure individually cross-referenced the 21 epiphyses with each of the remaining 20 epiphyses, to produce a total of 210 3×3 charts. The frequencies with which each of the three phases occurred within the sample for the two epiphyses under investigation were displayed in chart form. Table 2 shows one example of a 3×3 chart comparing the results for the proximal humerus with the proximal fibula. An understanding of how each individual epiphysis relates to the other epiphyses was thus established.

It was then possible to determine the sequence with which the epiphyses unite according to each developmental phase. Using Table 2 as an example, the sequence of union for the proximal humerus and proximal fibula could be established. To determine

TABLE 2—*Frequency distribution of no union (phase 0), active union (phase 1), and complete union (phase 2) in relation to the proximal fibula and proximal humerus.*

	Phase	Proximal Fibula 0	1	2	Total
Proximal humerus	0	28	4	1	33
	1	2	7	32	41
	2			134	134
Total		30	11	167	208

"beginning" union, the number of individuals whose proximal fibula displayed some form of union (phases 1 or 2) but their proximal humerus remained open (phase 0; $n = 5$) were compared with the number of individuals whose proximal humerus displayed union (phases 1 or 2; $n = 2$) but their proximal fibula remained open (phase 0). Table 2 reveals that more individuals ($n = 5$ vs. $n = 2$) demonstrated the proximal fibula initiating union before the proximal humerus. Because two individuals did not conform to that pattern, however, some degree of variation was present in the established sequence order.

Establishing the sequence of complete union was carried out using the same method but different variables were considered. The number of individuals whose proximal fibula had completed union (phase 2) while their proximal humerus had not (phases 0 or 1; $n = 33$) were compared with the number of individuals whose proximal humerus had completed union, whereas their proximal fibula had not (phases 0 or 1; $n = 0$). No individuals displayed the latter sequence pattern and therefore, in this sample, the proximal fibula always completes union before the proximal humerus.

Results

Sequences of "beginning" and "complete" union were developed from the information contained within the 3 × 3 charts, and their summaries are depicted in Figs. 1 and 2. Each figure demonstrates sequencing of each epiphysis according to its respective phase of union, i.e. beginning and complete fusion. A modal sequence pattern was established representing the "normal pattern" that was observed in the majority of individuals present in the sample. Variations to that pattern are also depicted.

The modal sequence pattern is represented by the central "tree trunk" within the figure and demonstrates progressive maturity from top to bottom. Figure 1 reveals that the acetabulum was the first epiphysis observed to initiate union and the medial clavicle was the last. Within the sequence of "beginning" union (Fig. 1), there was an inability to detect the sequential order of the proximal ulna and the distal humerus in relation to each other. This was due to the failure of any case within the sample meeting the requirement necessary for determining union. As a result, both the proximal ulna and the distal humerus were positioned on the same line.

Variations to the modal pattern are demonstrated through the use of "tree branches." Each "branch" signifies the extent of variation that occurs in relation to the reference "trunk" epiphysis. The "twig" projections extending from the branches identify those epiphyses that exhibit the minority pattern; those positioned to the left of the trunk were occasionally observed to commence (Fig. 1) or complete (Fig. 2) union before the referenced "trunk" epiphysis, while those located to the right were sometimes observed to commence or complete after the referenced "trunk" epiphysis. Considering Fig. 1, it can be seen that contrary to the modal pattern of sequencing, the distal tibia, medial humerus, and proximal femur could at times commence union in advance of the proximal radius.

The frequency with which the variable pattern occurred in relation to the total number of cases utilized for sequencing information is also provided in the figures, written under the epiphyseal name. Thus, using the same example of the proximal radius, seven cases provided sequencing information between the proximal femur and proximal radius. Of those seven, only two exhibited the proximal femur initiating union before the proximal radius; the other five represented the modal pattern. Highly detailed information such as this is critical to demonstrate the confidence with which an anthropologist can assign to the epiphyseal status.

Epiphyses that have no "branches" extending from their "trunk" were not seen to exhibit any variation in sequence order to that of the modal pattern in this sample. The relationship between a "trunk" epiphysis and an epiphysis not identified by a "twig" extending from the trunk's branch is also 100%. The distal femur (Fig. 1) for example is the only epiphysis found to vary in its sequence order with the proximal tibia; all other epiphyses share an "unvaried" relationship with the proximal tibia. These "unvaried" relationships are most useful to the anthropologist who must discriminate between commingled remains. An indication of the number of individuals utilized in defining the relationship is necessary, however, to avoid placing undue emphasis upon a sequence pattern derived from an inadequate number of cases. The numbers of individuals involved in determining the nonvaried epiphyseal relationship are provided in Tables 3 and 4.

Table 5 provides age parameters representing the three phases of union status for each epiphysis. Overlaps of age ranges are extensive. The oldest ages to have not yet initiated union along with the youngest ages of those to first exhibit complete union are nearly all contained within a narrow 3-year window represented by ages 18–20 years for the upper limit of phase "0" and between 15 and 18 years for the youngest phase "2." Likewise, age ranges representing those actively engaged in union are nearly all contained within a window between 15 and 20 years of age. The medial clavicle was the only epiphysis that consistently did not adhere to these patterns.

Discussion

The similar age parameters produced by most epiphyses in Table 5 illustrate that noting discrepancies in developmental patterns is likely to be a more informative method of recognizing commingled juvenile elements than evaluation through age discrepancies. Skeletal aging of elements may not produce sufficient discriminatory evidence to detect inconsistent elements as the age range for epiphyseal union shows extensive overlap. The problem of assigning chronological age to skeletal remains based on the attainment of developmental milestones has always presented difficulties due to differential rates of maturity (22,23). Age ranges must be wide enough to represent all potential variation including both early and late developers. While wide age ranges ensure that remains whose developmental level lies to either extreme will fall within the confines of the perimeter, it limits the potential of noting age incongruities among skeletal elements. Fortunately, development occurs as a whole and individuals who display precocious maturity of one element are likely to display precocity in other elements (23). Incongruent developmental patterns produced by the combination of two individuals are likely to be more conspicuous than are age discrepancies. The use of maturity indicators is of greater discriminatory value as the

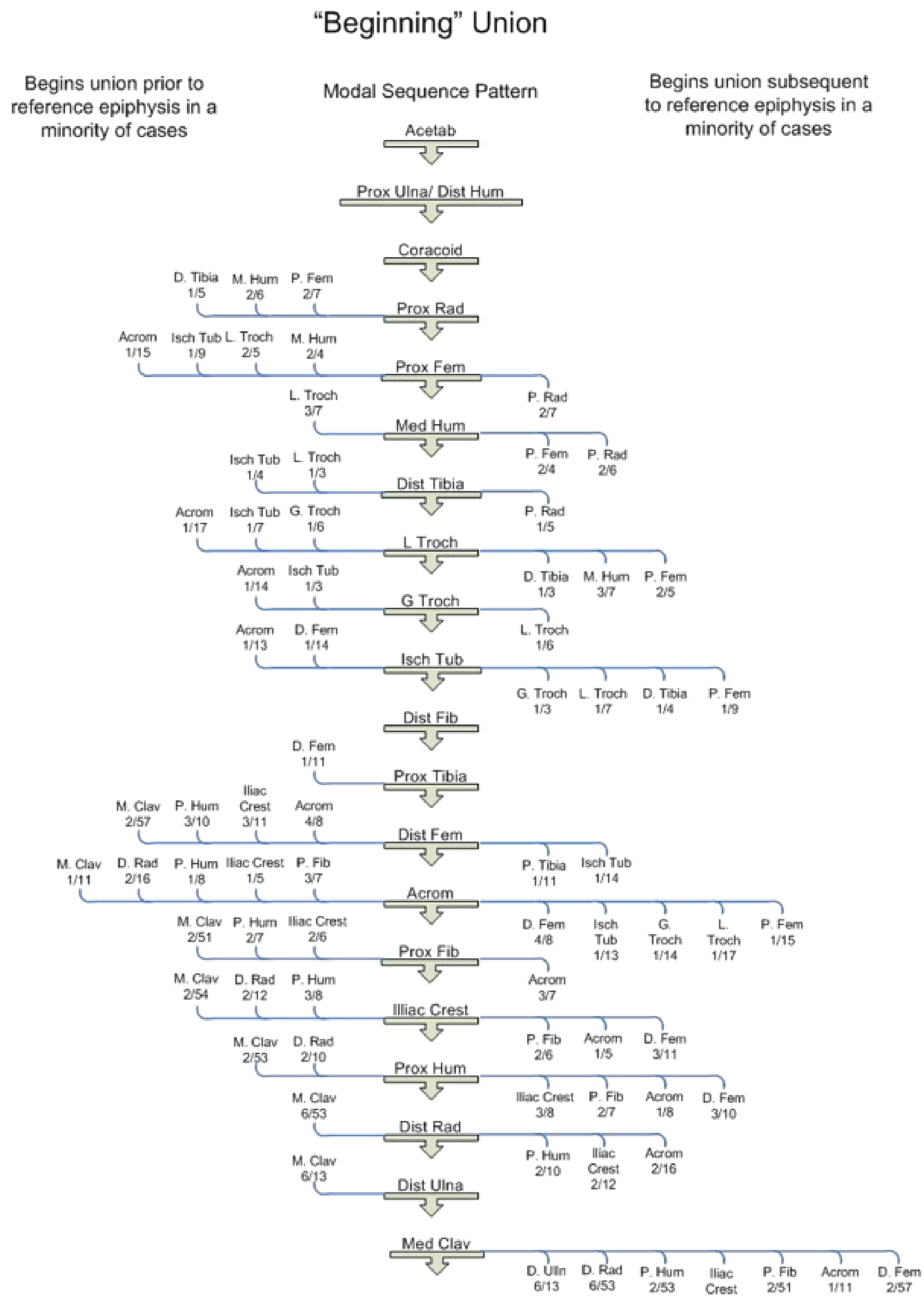

FIG. 1—*Sequence of "beginning" union. A modal sequence pattern representing the majority sample was established and is provided as the central trunk. Sequence progression between the proximal ulna and distal humerus could not be determined; thus, they share the same line. Variations to the modal pattern are depicted through the use of branches. Each twig of the branch demonstrates an epiphysis that was observed to vary in its sequence order with the reference trunk epiphysis (epiphysis from which the main branch extends). Ratios display the frequency with which the variable pattern occurs within the sample in relation to the total number of cases that met the requirements for sequencing information.*

developmental status of one element can be used to assess the status of others.

Sequence of "Beginning" Union

While variations to individual sequences were found, the overall pattern with which various epiphyses initiated union was relatively constant in this sample (Table 4). Of the 210 possible epiphysial relationships, only 37 (18%) expressed variation. Of these 37 pairs, 16 displayed only one exception to the modal pattern, most of which was the sole responsibility of only two individuals within the sample. As is often the case, the unusual timing of one epiphysis can affect sequence order with numerous other epiphyses. The precocious union of one individual's ischial tuberosity led to variation with the femoral head, distal tibia, and greater and lesser trochanter, while another individual's precocious acromion process disrupted sequence order with the ischial tuberosity, greater and lesser trochanters, and femoral head.

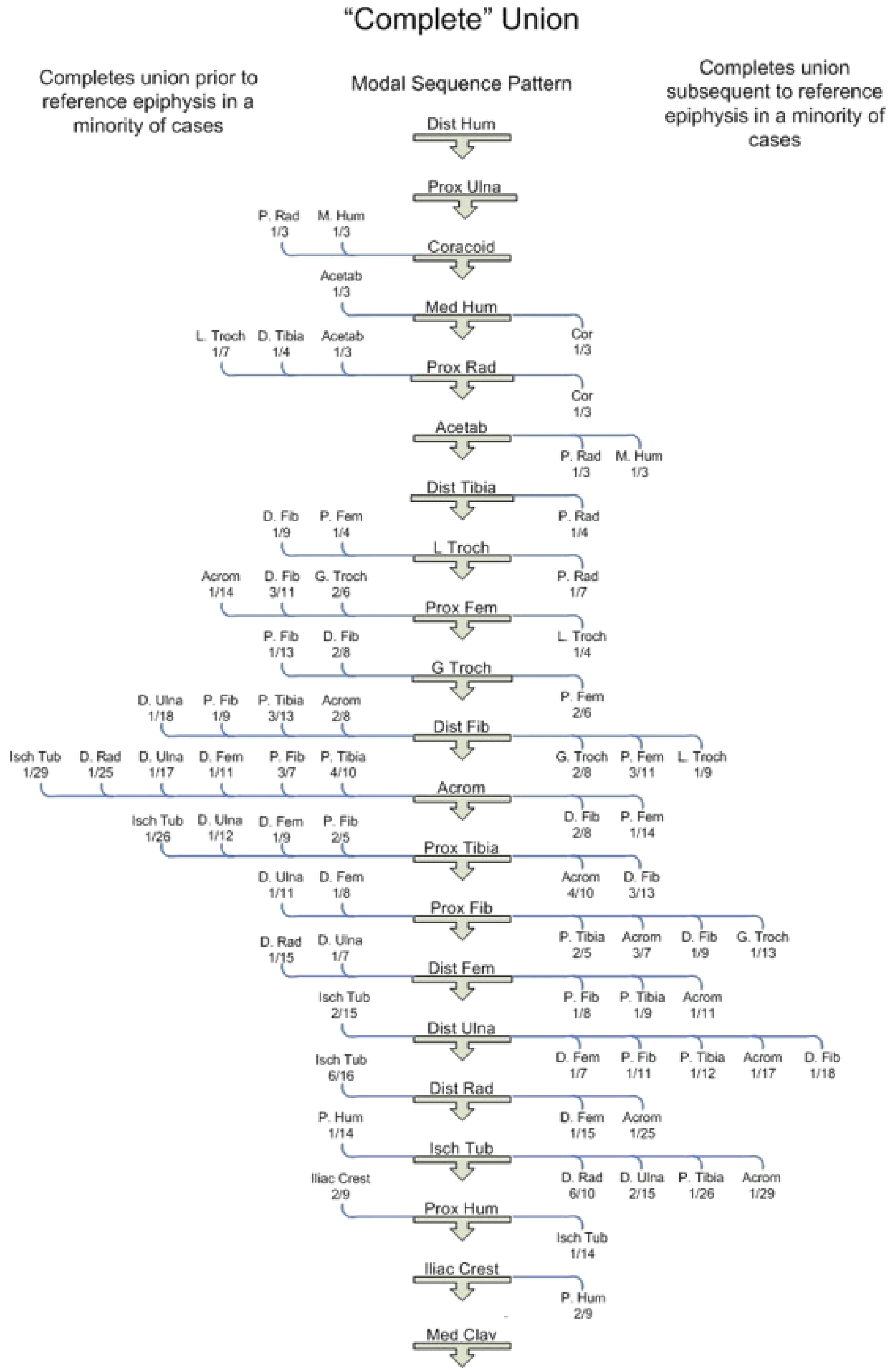

FIG. 2—*Sequence of "complete" union. A modal sequence pattern representing the majority sample was established and is provided in the central trunk. Variations to the modal pattern are depicted through the use of branches. Each trig of the branch demonstrates an epiphysis that varies in its sequence order with the reference "trunk" epiphysis (epiphysis from which the main branch extends). Ratios display the frequency with which the variable pattern occurs within the sample in relation to the total number of cases that meet the requirements for sequencing information.*

Sequence of "Complete" Union

Of the 210 epiphyseal relationships, 34 pairs (16%) expressed variation in their order of "complete union" (Table 5), 21 of which displayed only one variation to the modal sequence pattern. Unlike "beginning" union, most of this variation was created by a multiple of cases rather than being the sole responsibility of one or two individuals who displayed unusual timing in one epiphysis. The retarded union of one acromion process did, however, create considerable variation with other epiphyses, affecting the ischial tuberosity, distal radius, distal ulna, and distal femur.

Sequence Comparisons

Table 6 displays the modal sequence orders of both "beginning" and "completion" of union. With few exceptions, most of the epiphyses share similar positions in their sequence pattern of both "beginning" and "complete" union. The distal epiphysis

TABLE 3—*Number of cases utilized in establishing epiphyseal relationships associated with "beginning" union.*

	Distal Humerus	Proximal Ulna	Coracoid	Proximal Radius	Proximal Femur	Medial Humerus	Distal Tibia	Lesser Trochanter	Greater Trochanter	Ischial Trochanter	Distal Fibula	Proximal Tibia	Distal Femur	Acromion	Proximal Fibula	Iliac Crest	Proximal Humerus	Distal Radius	Distal Ulna	Medial Clavicle
Acetabulum	2	2	4	9	12	12	11	12	15	15	14	15	25	22	20	26	22	21	25	51
Distal humerus		No Information	2	10	14	14	13	15	19	22	15	21	31	29	28	33	34	36	44	46
Proximal ulna			2	10	13	13	13	15	18	20	16	20	29	28	26	31	32	37	45	83
Coracoid				5	7	8	6	7	10	11	9	11	20	18	15	18	18	18	21	46
Proximal radius					7	6	5	5	7	8	6	8	16	15	14	18	21	27	32	68
Proximal femur						4	1	5	5	9	5	10	19	15	18	24	22	24	31	71
Medial humerus							1	7	5	18	4	7	16	15	14	12	21	25	32	70
Distal tibia								3	2	4	4	5	15	15	16	19	18	20	25	64
Lesser trochanter									6	7	3	7	18	17	15	21	18	22	27	80
Greater trochanter										3	2	4	14	14	14	19	16	20	25	67
Ischial tuberosity											2	2	14	13	13	18	15	18	24	63
Distal fibula												1	12	10	12	14	3	17	22	60
Proximal tibia													11	8	10	14	11	16	20	59
Distal femur														8	5	11	10	11	15	57
Acromion															7	5	8	16	17	11
Proximal fibula																6	7	7	11	51
Iliac crest																	8	12	13	54
Proximal humerus																		10	11	53
Distal radius																			5	53
Distal ulna																				13

Among the relationships, those epiphyses listed in the first column were always observed to initiate union before those listed in the first row. This information is important so that epiphyseal relationships derived from too few cases are not overemphasized. The sequence order of the proximal ulna and distal humerus could not be determined due to a lack of a single individual within the sample displaying union in one of the epiphyses and no union in the other.

TABLE 4—*Number of cases utilized in establishing epiphyseal relationships associated with "complete" union.*

	Proximal Ulna	Coracoid	Medial Humerus	Proximal Radius	Acetabulum	Distal Tibia	Lesser Trochanter	Proximal Femur	Greater Trochanter	Distal Fibula	Acromion	Proximal Tibia	Proximal Fibula	Distal Femur	Distal Ulna	Distal Radius	Ischial Tuberosity	Proximal Humerus	Iliac Crest	Medial Clavicle
Distal humerus	8	7	14	14	9	18	24	28	30	27	38	37	35	48	51	56	66	80	84	165
Proximal ulna		2	5	7	4	8	13	17	18	19	29	27	25	37	43	48	53	70	70	153
Coracoid			3	3	3	5	11	10	13	11	18	14	12	21	17	20	26	35	37	78
Medial humerus				3	3	5	8	12	13	16	24	22	22	32	39	45	50	67	68	148
Proximal radius					3	4	7	8	10	12	19	19	18	27	33	42	44	60	59	142
Acetabulum						3	8	8	11	8	15	13	6	19	15	17	26	31	39	75
Distal tibia							5	7	9	14	18	21	20	28	27	35	45	54	62	134
Lesser trochanter								4	4	9	14	16	15	24	28	35	42	55	63	137
Proximal femur									6	11	14	14	13	22	26	32	39	51	60	134
Greater trochanter										8	10	12	13	20	24	31	38	51	59	133
Distal fibula											8	13	9	15	18	25	32	42	48	121
Acromion												10	7	11	17	25	29	41	43	122
Proximal tibia													5	9	12	19	26	36	41	115
Proximal fibula														8	11	16	23	33	37	111
Distal femur															7	15	17	31	37	112
Distal ulna																8	15	27	28	111
Dist radius																	16	18	19	101
Ischial tuberosity																		14	19	95
Proximal humerus																			9	83
Iliac crest																				39

Among the relationships, those epiphyses listed in the first column were always observed to initiate union before those listed in the first row. This information is important so that epiphyseal relationships derived from too few cases are not overemphasized.

TABLE 5—*Age parameters for each epiphysis.*

Epiphysis	Oldest: Phase 0	Age Range: Phase 1	Youngest: Phase 2
Acetabulum	?	< 14–18	15
Distal humerus	14	15–18	15
Proximal ulna	18	15–18	15
Coracoid	18	15–18	15
Proximal radius	18	15–18	16
Femoral head	18	15–20	15
Medial humerus	18	15–18	15
Distal tibia	18	16–18	16
Lesser trochanter	18	16–20	15
Greater trochanter	18	16–20	15
Ischial tuberosity	18	16–20	17
Distal fibula	18	16–20	17
Proximal tibia	18	16–20	17
Distal femur	19	16–20	17
Acromion	18	17–20	17
Proximal fibula	18	16–20	17
Iliac crest	20	17–24	18
Proximal humerus	20	16–21	18
Distal radius	19	16–20	17
Distal ulna	20	17–20	17
Medial clavicle	23	17–29	21

The oldest age found to exhibit phase "0" no union, age ranges associated with phase "1" active union, and the youngest age associated with phase "2" complete union. Some of the parameters for the acetabulum are unknown as union initiates at a younger age than was collected in this sample.

TABLE 6—*Modal sequence patterns representing beginning and complete union.*

Beginning Union	Complete Union
Acetabulum	Distal humerus
Distal humerus/Proximal ulna	Proximal ulna
Coracoid	Coracoid
Proximal radius	Medial humerus
Proximal femur	Proximal radius
Medial humerus	Acetabulum
Distal tibia	Distal tibia
Lesser trochanter	Lesser trochanter
Greater trochanter	Proximal femur
Ischial tuberosity	Greater trochanter
Distal fibula	Distal fibula
Proximal tibia	Acromion
Distal femur	Proximal tibia
Acromion	Proximal fibula
Proximal fibula	Distal femur
Iliac crest	Distal ulna
Proximal humerus	Distal radius
Distal radius	Ischial tuberosity
Distal ulna	Proximal humerus
Medial clavicle	Iliac crest
	Medial clavicle

Patterns were established by the majority of individuals.

of the humerus, for example, is the second epiphysis to begin union and the first epiphysis to complete. Likewise, the proximal ulna is the third and second to begin and complete union. Exceptions to this tendency are easily recognized, however, with regard to the acetabulum and ischial tuberosity.

The extended time required for the acetabulum to complete union in relation to it being the first epiphysis to begin union can easily be explained by the complexity of the joint surface. All six epiphyses that comprise the acetabulum (anterior, posterior, and vertical tri-radiate in addition to the superior and posterior epiphyses and the os acetabuli) were considered in analysis and were required to have reached completion before the unit as a whole was scored as complete. Given that six separate epiphyses were considered as a whole, it is to be expected that union will be somewhat protracted.

There is also a significant delay in the timings of commencement and completion of fusion in the ischial tuberosity. The disparity in positioning of this epiphysis in Table 6 equates to the extended age range shown in Table 5. The author experienced some difficulty in clearly defining a point at which the tuberal epiphysis was complete in relation to the development of the ramal epiphysis.

Forensic Application

The number of variations that each "trunk" epiphysis displays within Figs. 1 and 2 reveals the potential value of that epiphysis for discriminating between incongruent developmental statuses. Epiphyses that display numerous variations will be less useful in determining commingled remains as their developmental progression proves less constant and more erratic. Fusing patterns change according to phases of union, however, so that an epiphysis that displays considerable variation when beginning union may display much less variation upon completion. Likewise, the usefulness of that epiphysis will also vary according its stage of development; hence, it is important to assess the full developmental spectrum. For example, the initiation of union of the medial clavicle (Fig. 1) varies with a considerable number of other epiphyses ($n = 7$), but its completion does not vary with any (Fig. 2). If an actively fusing clavicle is present within an assemblage that also displays no union for some of the later-fusing epiphyses, then little concern would be raised. However, if a completely fused clavicle is present within an assemblage that contains an actively fusing proximal humerus, then warning should be raised.

The usefulness of a distinct epiphyseal relationship may also vary according to the phase of union being assessed. Figure 1 shows that the proximal humerus generally initiates union before the distal humerus; however, the reverse order was also observed in two of the 10 cases. Complete union of the distal radius, on the other hand, always occurs before the proximal humerus. Given the significant number of cases (Table 5) involved in determining the sequence pattern, the relationship is highly valuable. Thus, an assemblage that contains a distal radius beginning union before the proximal humerus reveals little insight regarding the elements' commonality. However, a completed proximal humerus located within the same assemblage as an actively uniting distal radius gives a strong indication that the two elements might not belong to the same individual.

The recognition of developmentally incongruent material ultimately rests with the anthropologist. If suspicious elements are discovered, the anthropologist must deliberate upon the element's potential removal. Documenting the full extent of human variation provides evidence as to whether epiphyses that do not adhere to the modal pattern should be considered outliers that do not belong to the individual, or whether it is possible that a suspect epiphysis is simply representative of a less common pattern. Thorough documentation allows for informative decisions to be made. The number of cases involved in establishing sequence pattern should also directly influence the anthropologist's decision. If a suspect epiphysis does not conform to any previously documented pattern, yet only a small number of individuals were utilized to establish the pattern, then the observed breech of sequence order would probably not provide sufficient confidence to remove the element from the assemblage. It is essential, therefore, that this work continues to increase sample size and allow greater confidence in the decision that must be made. It is equally important that comparisons are undertaken with material from a different provenance.

Conclusion

Understanding the sequence in which the various epiphyses of the body unite assists identification of incongruent osseous-elements that may arise if two or more individuals, who vary in developmental status, are included in one assemblage. Utilization of both "beginning" and "complete" sequence patterns provides a wider spectrum of evidence to detect incongruities than either pattern would allow if used in isolation. This paper provides specific documentation of both modal sequence patterns and includes all observed variations from the norm. The information is depicted in clear figures to aid easy reference in the field. This study also adds to our understanding of human skeletal development.

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