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Comparison of Ages of Epiphyseal Union in North American and Bosnian Skeletal Material

ABSTRACT: The accurate determination of age at death is a critical component in the analysis of human skeletal remains. Population specific techniques are often used without due consideration of the provenance of the material being studied. This communication considers the ages at which epiphyseal union occur in young Bosnian males and compares those findings to data published by McKern and Stewart on young North American soldiers killed during the Korean War. Of the ten epiphyses considered in this study, all elements were observed to be at least two years in advance in the Bosnian sample compared to the American sample. This article demonstrates that whilst standards based on an American sample produce broadly applicable age ranges for use on forensic work in the Balkans, the age ranges generated produce an upper age limit that is often two or more years older than the chronological age. Therefore, it is desirable, that wherever possible, appropriate standards should be devised for more accurate aging reflecting population specific profiles.

KEYWORDS: forensic sciences, epiphyseal closure, forensic, skeleton, ageing, juvenile, Balkans

Large-scale DNA programs are playing an increasingly prominent role in the identification of those missing as the result of wars and mass disasters (1,2). While DNA analysis has unquestionably increased identification capabilities, misidentifications resulting from extraneous factors such as random matches, contaminated remains, and commingling can occur and thereby impose restrictions on the achievement potential for this approach as the sole and dedicated means of establishing identity (3–5). It is also widely recognized that DNA analysis carries inherent limitations and is incapable of assigning undisputed identity in every situation. Therefore, for the sake of judicial expediency, identification programs that utilize a multidisciplinary approach are generally recommended (4–9). Therefore, traditional anthropological assessment of biological identity remains an essential component in the process, serving to limit misidentifications and provide additional information upon which to base and support a positive identification (10).

While DNA analysis has become a routine tool in the investigation of the unidentified its success in both national and international criminal investigations generally relies upon the ability to secure a match with a pre-existing profile stored on a database. However, in the case of a mass disaster or war crimes investigation where the casualties are predominantly law-abiding civilians, a pre-existing personal DNA profile is unlikely to exist and comparisons tend to be restricted to the profiles of living known relatives of the deceased. The International Commission on Missing Persons (ICMP) has established that one of the major limitations in a DNA led identification program is the inability to positively discriminate fraternal identity should neither sibling have offspring. In genetic terms, all true siblings are equally related to the parental generation and it is not possible to assign a positive identification on the basis of genetic information alone in the absence of an additional and surviving younger generation. As a result, ICMP utilizes a combined DNA and anthropological assessment in its analysis of the estimated 40,000 unidentified remains resulting from the armed conflicts in the former Yugoslavia, between 1991 and 1999.

The inability to differentiate between siblings presents a particular problem when attempting to identify the deceased from the "fall of Srebrenica" in which an estimated 8000 Bosnians lost their lives. The majority of those killed in this incident were male with extensive close familial groupings where it was not uncommon for a family to be represented by two or more sons of a very similar age. If neither sibling had offspring (i.e., direct genetic descendents) then a DNA comparison with living relatives is insufficient to distinguish between siblings, leaving ICMP reliant upon anthropological techniques to fulfill and complete the identification process.

For obvious reasons, this problem most commonly affects those in their late teenage years and early adulthood since they are the least likely to have children. Fortunately anthropological assessment of age at death is most reliable in the juvenile and young adult age ranges where the large number of developmental milestones facilitates accuracy and reliability in prediction (11). In circumstances such as these where the sibling relationship has been confirmed by DNA analysis, the anthropological information may be sufficiently accurate to permit discrimination between the siblings. Epiphyseal closure is a reliable indicator of age at death in young adults and of greatest discriminatory value (11–21).

However, it is well documented that both ontogenetic and phylogenetic variation can result in varying levels of technique reliability especially when a method is derived on one sample of specific genetic, environmental and/or temporal origin and then utilized on a second sample where the biological parameters may be at some variance with the original sample (22). In a previous study of 59 identified cases from Srebrenica, Komar (23) found, that with regards to age determination, less than half of the cases fell within the age ranges assigned by the anthropologist utilizing accepted ageing techniques. It was suggested that the existing anthropological standards might prove inappropriate for the Bosnian population. This paper examines the difference in age assessment via epiphyseal

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closure timings using Bosnian material of known age at death when compared to a well-documented sample of North American origin.

McKern and Stewart's (16) data on American soldiers killed in the Korean War is useful for comparison with the Srebrenica sample as both represent a similar profile of young males of fighting age. The results of this preliminary study will examine whether population specific data on the rates of epiphyseal closure are essential for the accurate analysis of Bosnian war dead or if more generic techniques are sufficient to provide a guideline that will permit discrimination between individuals thereby negating the necessity to always or preferentially adopt a population specific approach.

Materials and Methods

Sample

The American material included only one individual under the age of seventeen years; therefore, seventeen was accepted as the lower limit for inclusion in this study. Age thirty was accepted as the upper limit for inclusion in this study as it is the latest age likely to show epiphyseal activity in the clavicle.

The Bosnian sample consists of 114 male subjects of known identity aged between 17 and 30 years. The remains are stored at the Podrinje Identification Project (PIP) facility in Tuzla, Bosnia which is dedicated to the identification of Bosnians associated with the fall of Srebrenica. Once DNA analysis had confirmed identity, age at death was established through ante-mortem records that had previously been verified with an official document such as a birth certificate.

It must be stressed that the Bosnians in this sample only represent those who were residing in Srebrenica during the time of its fall. Bosnia is comprised of three ethnic groups: the Bosnian Serbs, the Bosnian Croats, and the Bosniaks (Muslims). Srebrenica was inhabited by the Bosniaks; consequently, this study more specifically describes the growth profile of the Bosniaks rather than the entire Bosnian population.

Only year of birth of the Bosnian sample was available for this study. Date of death can be deduced to a time period extending from July 11–15, 1995, which marks the fall of Srebrenica. As a result, some Bosnian individuals may be stated as older than their chronological age if their birth-date falls after the 15th of July. It is important to note that this will always result in an older stated age as age cannot be underestimated following this rationale.

McKern and Stewart's data consists of 325 male individuals between the ages of seventeen and thirty years with dates of birth and death (including month and day) being available for each individual. The distribution of the ages at death for the two samples can be seen in Table 1. A simple comparison of the percentages of each age cohort shows that the two samples were of a remarkably similar profile.

The McKern and Stewart data utilised in this investigation originates from a computerized version of their raw data set rather than their published data. This is important to note as slight variations exist between the two. Raw data was preferential to the tables provided in their publication, which only included percentages of the sample that reached each stage of union rather than actual number of individuals. In addition, ages seventeen and eighteen were combined into one category, preventing separate analysis at both ages. Use of McKern and Stewart's raw data allowed for comparisons to be made between the two samples at both ages.

Method

Stages of epiphyseal closure were recorded for ten epiphyses in the Bosnian sample. These were selected as they represented the only epiphyses for which raw data were available from the McKern and Stewart study. Data were collected for the proximal humerus, distal radius, distal ulna, distal femur, proximal tibia, proximal fibula, iliac crest, ischial tuberosity, medial clavicle, and the acromion process. 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 used for analysis.

Each epiphysis was assigned a score according to McKern and Stewart's (16) methodology. One of five scores was assigned: 0 = no fusion, 1 = fusion is commencing but less than one third of the epiphysis shows union, 2 = active fusion or approximately one half of the epiphysis shows union, 3 = recent fusion or more than three quarters of the epiphysis shows union, 4 = complete fusion. Data was collected solely by author MS.

TABLE 1—*Distribution profile of the American and Bosnian samples.*

	McKern & Stewart		Bosnian	
Age	*n*	% of Total	*N*	% of Total
17	11	3	9	8
18	44	13	15	13
19	51	16	11	10
20	47	14	15	13
21	38	12	14	12
22	23	7	7	6
23	26	8	3	3
24	16	5	11	10
25	13	4	8	7
26	15	5	5	4
27	12	4	4	3.5
28	12	4	6	5
29	6	2	4	3.5
30	11	3	2	2
Total	325	100	114	100

Results

Observational Comparisons

Tables 2–11 show the age distributions for each stage of union in the ten epiphyses for both the Bosnian and the American material. Tables 12 and 13 show the ages representing latest non-union, earliest complete union, latest in-complete union and the age ranges for partial union.

In both samples, every epiphysis, with the exception of the medial aspect of the clavicle (in the American sample), showed some evidence of commencing union by the age of 17 years. As this paper does not consider individuals younger than this age, no comment can be made about the timings of earliest commencement of fusion in any group apart from McKern and Stewart's data on the medial clavicle, which shows that fusion may not have been initiated prior to 18 years of age.

When examining the latest age to achieve beginning union, the American sample appears to have more late developers, i.e., the latest age to represent non-union (stage 0) is generally older in the American sample than in the Bosnian sample. The distal radius, distal femur, proximal tibia, proximal fibula, iliac crest, ischial tuberosity, medial clavicle, and acromion process remains open longer in the American than in the Bosnian sample. The greatest difference between the two samples in the latest age to show "non-fusion" is concentrated within the girdles.

Trends were also observed for the age at which each epiphysis reached complete union. For most epiphyses, both samples

TABLE 2—*Age distribution of stages of union for the proximal humerus.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	27.3	18.2	9.1	27.2	18.2	9	55.6		22.2	22.2	
18	44	13.6	2.2	27.3	36.4	20.5	13	15.3	15.4	23.1	30.8	15.4
19	51	3.8	2.0	11.8	51.0	31.4	10	10.0	10.0	20.0	50.0	10.0
20	47	2.1	2.1	4.3	40.4	51.1	14	7.1	7.2	7.1	35.7	42.9
21	37			2.7	21.6	75.7	14				7.1	92.9
22	23				17.4	82.6	7					100
23	26				3.8	96.2	3					100
24+	85					100	36					100

TABLE 3—*Age distribution of stages of union for the distal radius.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	45.5		9.1	18.2	27.2	8	75.0			12.5	12.5
18	44	18.3	4.5	15.9	31.8	29.5	13	46.2	7.7	15.3		30.8
19	50	6.0		6.0	46.0	42.0	9		11.1	11.1	33.4	44.4
20	46	4.3		2.2	28.3	65.2	13		7.7		38.5	53.8
21	38				15.8	84.2	13					100
22	23				13.0	87.0	6					100
23	26					100	3					100
24+	84					100	36					100

TABLE 4—*Age distribution of stages of union for the distal ulna.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	45.5		9.1	18.2	27.2	9	66.7			11.1	22.2
18	44	27.3	2.3	11.4	22.6	36.4	13	46.2	7.7	15.3	7.7	23.1
19	50	6.0		6.0	36.0	52.0	9	11.1	11.1		11.1	66.8
20	47	4.3	2.1		23.4	70.2	14	7.1		7.1	28.6	57.1
21	38				7.9	92.1	13					100
22	23				8.7	91.3	6					100
23	26					100	3					100
24+	84					100	36					100

TABLE 5—*Age distribution of stages of union for the distal femur.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	45.5			9.0	45.5	8	50.0	12.5	12.5		25.0
18	44	11.4	2.3	4.5	22.7	59.1	14	14.3	14.3	21.4	14.3	35.7
19	51	2.0		3.9	9.8	84.3	11			18.2	9.1	72.7
20	47			2.1	10.6	87.2	14				7.1	92.9
21	38				5.3	94.7	13					100
22	23					100	7					100
23	26					100	3					100
24+	84					100	35					100

already contained individuals who had achieved complete union by 17 years, the youngest age for which data was collected. Earliest complete union, however, was delayed a year in the proximal humerus, iliac crest and ischial tuberosity from the Bosnian sample. However the clavicle remained un-fused for two years longer in the American sample. The oldest age to achieve complete union demonstrates greater variation between the two samples. Union consistently continues for an additional one to three years in every epiphysis in the American sample, with the exception of the medial clavicle. The age at which the entire American sample achieves

TABLE 6—*Age distribution of stages of union for the proximal tibia.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	9.1	9.1	18.2	9.1	54.5	8	25.0		25.0	12.5	37.5
18	44	6.8		6.8	25.0	61.4	13	7.7	7.7	15.3	23.1	46.2
19	51	2.0			17.6	80.4	11			9.1	27.3	63.6
20	46				13.0	87.0	12				8.3	91.7
21	38				5.3	94.7	13					100
22	23				4.3	95.7	7					100
23	26					100	3					100
24+	84					100	35					100

TABLE 7—*Age distribution of stages of union for the proximal fibula.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	36.4		9.1		54.5	7	42.8	14.3		14.3	28.6
18	44	13.6		2.3	18.2	65.9	13	38.5	7.6		15.4	38.5
19	51	2.0		5.9	3.9	88.2	10					100
20	44			2.3		97.7	11				9.1	90.9
21	38				5.3	94.7	12					100
22	23					100	7					100
23	24					100	3					100
24+	84					100	35					100

TABLE 8—*Age distribution of stages of union for the iliac crest.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	36.4	9.1	9.1	36.3	9.1	8	37.5	37.5	12.5	12.5	
18	44	13.7	15.9	31.8	15.9	22.7	14	35.7	35.7	7.1	14.4	7.1
19	51	3.9	3.9	31.4	23.5	37.3	11		27.3	27.3	36.3	9.1
20	47	2.1	8.5	4.3	25.5	59.6	14		7.1	35.7	28.6	28.6
21	38		2.6	7.9	15.8	73.7	13			7.7	7.7	84.6
22	23			4.3	4.3	91.4	7					100
23	26					100	3					100
24+	83					100	34					100

TABLE 9—*Age distribution of stages of union for the ischial tuberosity.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	45.5	9.1	18.1	18.2	9.1	7	28.6	57.1		14.3	
18	44	50.0	13.6	11.4	11.4	13.6	14	7.1	42.9	14.3	28.6	7.1
19	50	16.0	20.0	12.0	20.0	32.0	10		20.0	20.0	40.0	20.0
20	46	17.4	15.2	8.7	19.6	39.1	14			21.4	35.7	42.9
21	38	2.6	5.3	2.6	26.3	63.2	13				7.7	92.3
22	23	8.7			4.3	87.0	7					100
23	26			3.8	3.8	92.4	3					100
24+	83					100	35					100

complete union of the medial clavicle is unknown, as some individuals are still actively fusing at 30 years.

When considering the above-mentioned trends collectively, a more holistic picture develops. The Americans show greater maturity in the earlier years but Bosnian maturity advances more quickly and in the end terminates earlier. The advanced Bosnian maturity is evident in Tables 12 and 13, where age ranges that represent the time frame utilized by each epiphysis to progress from "beginning union" to "complete union" are provided. Also note that the youngest age to achieve complete union is sometimes older in the

TABLE 10—*Age distribution of stages of union for the medial aspect of the clavicle.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	100					9	88.9	11.1			
18	44	72.7	25.0	2.3			13	84.6	7.7	7.7		
19	51	64.7	17.6	15.7	2.0		10	60.0	20.0	10.0	10.0	
20	46	47.8	19.6	28.3	4.3		13	69.2	23.1	7.7		
21	37	35.1	24.3	32.4	8.2		13	7.7	15.4	61.5	7.7	7.7
22	23	21.7	8.8	47.8	21.7		5	20.0		60.0	20.0	
23	25	4.0	16.0	36.0	36.0	8.0	3			33.3		66.7
24	16	6.2		12.5	62.5	18.8	10				70.0	30.0
25	13			15.4	23.1	61.5	8				87.5	12.5
26	15				40.0	60.0	5			20.0	80.0	
27	12			8.3	33.4	58.3	4				25.0	75.0
28	12	8.3			25.0	66.7	6				66.7	33.3
29	6			16.7	16.7	66.6	4					100
30	11	9.1			9.1	81.8	2					100

TABLE 11—*Age distribution of stages of union for the acromion process.*

		McKern & Stewart Stages of Union						Bosnian Stages of Union				
Age	No.	0	1	2	3	4	No.	0	1	2	3	4
17	11	45.5			9.0	45.5	8	37.5		12.5		50.0
18	44	11.4	4.5	6.8	6.8	70.5	13	7.7	15.4	15.4	7.7	53.8
19	51	9.8	2.0		3.9	84.3	10	10.0				90.0
20	47	4.3		2.1	2.1	91.5	13					100
21	38				5.3	94.7	12					100
22	23	4.3				95.7	6					100
23	26					100	3					100
24+	85					100	36					100

TABLE 12—*Summary statistics for the American sample.*

Epiphysis	Age of Latest Non-union	Age of Earliest Complete Union	Age of Latest In-Complete Union	Age Range for Partial Union
Proximal Humerus	20	17	23	?–23
Distal Radius	20	17	22	?–22
Distal Ulna	20	17	22	?–22
Distal Femur	19	17	21	?–21
Proximal Tibia	19	17	22	?–22
Proximal Fibula	19	17	21	?–21
Iliac Crest	20	17	22	?–22
Ischial Tuberosity	22	17	23	?–23
Medial Clavicle	30	23	30+	18–30+
Acromion Process	22	17	22	?–22

TABLE 13—*Summary statistics for the Bosnian sample.*

Epiphysis	Age of Latest Non-union	Age of Earliest Complete Union	Age of Latest Complete Union	Age Range for Partial Union
Proximal Humerus	20	18	21	?–21
Distal Radius	18	17	20	?–20
Distal Ulna	20	17	20	?–20
Distal Femur	18	17	20	?–20
Proximal Tibia	18	17	20	?–20
Proximal Fibula	18	17	20	?–20
Iliac Crest	18	18	21	?–21
Ischial Tuberosity	18	19	20	?–20
Medial Clavicle	22	21	28	?–28
Acromion Process	19	17	19	?-19

Bosnian sample. Since no data is available for ages younger than 17, no conclusions can be drawn as to which sample first exhibits "beginning union." The extended period required for American maturation demonstrates more variability in the sample, whereas the Bosnians appear more homogenous in their development.

Statistical Comparisons

To ensure that greater variation in American fusion times was not simply the result of the smaller Bosnian sample size, which is likely to exhibit less variation, ages and scores from the two samples were subjected to statistical evaluation. To simplify comparisons, stages 1, 2, and 3 were combined to create one phase, the "fusing phase." This produced a possibility of three phases, a "non-fusing" phase, a "fusing" phase, and a "complete" phase. A Kendall's Tau-b statistical test was performed to investigate the null hypotheses that there are no significant differences between the phases of union between the groups for each specific age. Tests were run for each epiphysis at each age and the results are presented in Table 14.

As the Bosnian sample nears "complete union" it frequently displays advanced maturity in comparison to the American sample. This trend is demonstrated by significant differences found at the epiphyses of the humeral head, distal radius, ischial tuberosity, and the acromion process. In each epiphysis, the entire (or nearly entire) Bosnian sample has attained "complete union" at the age when significance was achieved, whereas varying percentages of

TABLE 14—*Results of Kendall's tau-b tests.*

	Significance Values Comparing the Stages of Union Between the Two Samples													
	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Humeral Head	0.08	0.7	0.09	0.51	0.09	0.05	0.36	*	*	*	*	*	*	*
Distal Radius	0.18	0.34	0.74	0.54	0.01	0.1	*	*	*	*	*	*	*	*
Distal Ulna	0.43	0.21	0.56	0.38	0.08	0.17	*	*	*	*	*	*	*	*
Distal Femur	0.57	0.17	0.44	0.51	0.16	*	*	*	*	*	*	*	*	*
Proximal Tibia	0.35	0.37	0.31	0.62	0.16	0.32	*	*	*	*	*	*	*	*
Proximal Fibula	0.44	0.06	0.03	0.45	0.16	*	*	*	*	*	*	*	*	*
Iliac Crest	0.77	0.04	0.05	0.05	0.38	0.16	*	*	*	*	*	*	*	*
Ischial Tuberosity	0.66	0.01	0.95	0.34	0.01	0.08	0.23	*	*	*	*	*	*	*
Clavicle	0.29	0.33	0.78	0.16	0.01	0.93	0.13	0.38	0.01	0.00	0.53	0.26	0.09	0.23
Acromion	0.78	0.38	0.65	0.05	0.16	0.32	*	*	*	*	*	*	*	*

* Both samples displayed equality, therefore no statistics were computed.

the American population are still actively engaged in fusion. For example, at age 22, 100% of the Bosnian sample has completed union of the proximal humerus compared to 17.4% of the American sample that are still actively engaged.

Delayed onset of union in the American sample is demonstrated by the significant difference found at the ischial tuberosity at age 18. Here, 50% of Americans have not yet begun fusion as compared to 7.1% of Bosnian individuals.

Delayed onset of "beginning union" and delayed onset of "complete union" in the Bosnian sample is demonstrated by the significant results found at the iliac crest. At age 18, a larger percent of Bosnian individuals have not yet begun fusing (35.7%), compared to 13.7% of American individuals. In addition, only a small number of Bosnian individuals have reached complete union (7.1%), whereas 22.7% of American individuals have completed union. Ages 19 and 20 display retarded onset of union in the American sample as well as delayed completion of union in the Bosnian sample. For example, by age 19, all Bosnian individuals have begun fusing, whereas 3.9% of Americans have not; yet, 37.3% of Americans have completed union as opposed to 9.1% of the Bosnians.

Significant findings found at the clavicle prove more difficult to interpret due to the extended time period allotted for fusion of the medial clavicle, which allows for greater intra-sample variation as well as variation between the two samples. As a result, significant findings are perhaps dubious. Age 21 demonstrates delayed maturity in both onset and completion of union in the American sample compared to the Bosnian sample. In the Bosnian sample, 7.7% display no union, and 7.7% have completed union. The American sample consists of 35.1% who display no union and 0% of the sample has reached complete union by age 21. The significance value should be regarded with care, however, as at age 21, a higher percentage of the Bosnian sample (20.0%) displays no union and no individuals have reached complete union. Similar confusion occurs at ages 25 and 26, however, with the opposite effect. At both ages, considerably fewer Bosnians (12.5% and 0%) have achieved complete union compared to the Americans (61.5% and 60.0%). However, larger percentages of Bosnians have reached complete union at younger ages, indicating that the significant results are of little value. A dubious result such as this was also found at the proximal fibula.

Discussion

Morphological analysis demonstrates that all epiphyses considered in this study were observed to achieve complete union one to three years earlier in the Bosnian sample than in the American. Statistical evidence confirmed that significant sample related differences occurred in relation to age and duration of active epiphyseal union. Computations run on the proximal humerus, distal radius, ischial tuberosity and acromion process reveal that completion of union occurs significantly earlier in the Bosnians than in the Americans. The iliac crest displays greater immaturity in the younger Bosnians, while the ischial tuberosity displays delays in the final onset of union in the American sample.

The variation expressed in human maturity results through multifactorial influences that incorporate both genetic and environmental factors. In particular, nutritional status is known to contribute significantly to growth and developmental potential with poor nutrition commonly resulting in delayed development and restricted stature (24–28). McKern and Stewart (16) note that some of their data was collected on POWs who suffered extreme starvation with the majority of the POWs held captive for three to six months before death. However the majority was over 24 years of age and, therefore skeletal maturity should not have been overly influenced by environmental deprivation although this could possibly be used to explain the extensive differences viewed in the medial clavicular epiphysis which is a late developer. McKern and Stewart concluded that data on POWs could be analyzed along with data on KIAs without any serious risk of skewing the results due to malnutrition.

Malnutrition did however affect the Bosnians. Serb forces surrounded the town of Srebrenica for nearly two years prior to the end of the conflict, with little opportunity for food and aid to penetrate its borders (25). Tahirović (30) shows that wartime hardships negatively impacted female maturity. Young women of Srebrenica experienced delayed onset of menarche as compared to other Bosnian women living in towns that were less affected by the war. Adolescent stature has also been shown to be negatively impacted in the Bosnian population (31).

Despite the harsh environmental stresses that the Bosnian's endured, the Bosnian sample consistently completes union at a younger age. This provides strong argument that genetic factors are more influential. Variation between American and Bosnian samples has also been detected in stature and limb proportions (32 and 33), and craniometrics (34). Considering the diverse ancestry of the American and Bosnian people, Ross (34) uses differential gene frequencies to explain craniometric differences. Marjanovic et al. (35) and Klaric et al. (36) both report that allelic frequency distributions of Bosnians more closely correspond to neighboring southeastern European populations than to mostly western European populations. This is applicable in that the US was settled by mostly western Europeans. Additionally, the wide range of ethnic diversity living in the United States is also likely to create a larger gene pool (that exhibits greater genetic variation) than would be expected to be seen in the Bosnian population. McKern

and Stewart's data includes caucausoids, negroids and mongoloids; non-caucausiods comprise 9.6% of the sample. It is plausible that increased genetic variation results can manifest itself in more diverse fusing time, thus explaining the additional time necessary for the American sample to complete union.

It is unlikely that any of the identified variation could be the result of inaccuracies in reported chronological age. Miscalculated ages are unlikely in the American sample as chronological age was obtained through military records. It is also unlikely in the Bosnian sample as a birth certificate was used to support antemortem information provided by family members. Year of birth, however, was the only information made available for this paper. Therefore, individuals born after July 15 (day of death) would have been assigned an age that is one year older than their actual chronological age as they never reached their birthday for that year. The lack of information regarding day and month of birth would never result in an individual being assigned an age younger than their actual chronological age. Since Bosnian material was found to achieve complete union earlier than American material, inaccurately aging a Bosnian individual a year older would work to decrease variation rather than increase the differences.

In spite of confirmed differences between the two samples, this study demonstrates that the McKern and Stewart data can be applied to age Bosnian juveniles with a reasonable and perhaps acceptable degree of accuracy. If all epiphyses are observed to fuse earlier in the Bosnian sample, then any age range provided by the American sample is wide enough to include all individuals from the Bosnian data set. However, should statistical methods be applied that calculate age probability, prior knowledge of the Bosnian's maturational profile will produce more accurate results. This technique is most applicable when trying to discern the identity of siblings that are of similar age. Therefore, it is recommended that population specific standards are developed on Bosnian sub-adults and applied when possible. This finding is consistent with additional research that found American standards inadequate and recommends the use of Bosnian specific formulae when estimating stature (32 and 33).

Conclusion

This study supports the previously unsubstantiated observations made by ICMP anthropologists who were of the opinion that many Bosnian youths appeared "skeletally older" than their chronological age. Initial examination of the data showed that each of the ten epiphyses under consideration in this study was seen to reach complete fusion in 100% of the population one to three years earlier in the Bosnian sample than in the American sample. Statistical tests also confirm that complete fusion occurs significantly earlier in the epiphyses of the proximal humerus, distal radius, ischial tuberosity, and the acromion process.

This study shows that McKern and Stewart's data on epiphyseal closure satisfies accuracy requirements for Bosnian material when providing age ranges that represent observed union times. Population specific data, however, will prove more accurate and reliable when advanced statistical analysis is utilized. This is particularly important when determining the identity of siblings of a similar age. Further research is being undertaken to develop standards appropriate for the Bosnian material.

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