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Racial Variation in the Sternal Extremity of the Rib and Its Effect on Age Determination

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ABSTRACT: Most research on the aging process in the skeleton has not considered or elaborated differences that may exist between the races. Thus, techniques developed for the estimation of age assume that the racial background of the standards is compatible with the specimens to be assessed. However, racial differences in areas such as skeletal growth and bone density have been reported, along with specific variations in the aging process, in the ribs of disparate populations. The present investigation examines metamorphosis in the sternal ribs of American blacks (N = 53 males, N = 20 females), and tests the application of age estimation standards developed by the authors from a white population. All specimens were obtained from medical examiner's cases of known age, sex, and race. Although the sample was limited in both quantity and age range, analysis of the data revealed racial differences in both rate and pattern of metamorphosis. Statistical analysis showed that the calculated mean age per phase for black ribs was nearly identical to whites in Phases 1 through 4 or until the mean age of 28 years. By the early 30s, differences in morphology and their chronological association with the aging process became apparent and increased with age in both sexes. Blacks were consistently overaged from 3 to 10 years in Phases 5 through 7. Therefore, it was concluded that biological differences between these populations do exist and can affect age estimation from the rib. Social factors may also be involved, but they cannot be demonstrated from the available data. While the degree of interracial variation does not require completely new standards, the authors have suggested specific modifications of the white standards for use on black specimens.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, sternal rib, racial variation, American blacks, age determination

In the last few years, the authors established standards for determining age at death from the sternal end of the rib in white males and females [*1–3*]. They [*1*] first examined this site to assess further the relationship between directly observable changes in morphology and age as first noted by Kerley [*4*]. When it was determined that this area did indeed metamorphose throughout life, a technique was developed to quantify individually changes in the walls, floor, and the shape of the costochondral junction of the bone [*1*]. These changes were later combined into a phase method similar to that introduced by Todd [*5*] for the pubic symphysis, and included separate standards for white males [*2*] and females [*3*].

Statistical analysis of these sex specific techniques indicated that the morphological metamorphosis in the rib could be explained by the age variable. Furthermore, the authors con-

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ducted tests in which unknown ribs were judged by forensic anthropologists and pathologists and concluded that the standards were effective in estimating age from the adult skeleton [6, 7]. However, since the original studies were based on white males and females, it is important to determine if these standards are also applicable to other races or populations.

Todd [5] considered the possibility of racial variation as it relates to age determination from the skeleton in his work on the pubic symphysis, but concluded that it was not a significant factor. Brooks [8] also found no significant differences in various American races. Hanihara [9] noted that the Japanese were often overestimated by a few years based on Todd's standards, but he could not directly attribute this to race. Zhang [10], on the other hand, felt it was necessary to establish specific Chinese standards for the pubic symphysis.

Based on Hunt and Gleiser's [11] finding of differences in the tooth eruption timing of American whites and blacks, Burns and Maples [12] investigated the effect of race on age estimation from sectioned teeth and concluded that it is an important variable. In fact, their method is based on race specific formulas.

Radiological research on the rib itself has shown that race may also be an important variable in age determination. Michelson [13] studied age-related mineralization of the first rib in American whites and blacks and found that this change proceeded faster in blacks. Semine and Damon [14] conducted an exhaustive study comparing calcification in all of the rib cartilages of five different populations and observed significant differences. In a preliminary study, McCormick [15] noted that mineralization appeared to proceed faster in Mexican-Americans than in white or black Americans.

In light of the aforementioned radiological studies, the authors suspected that, not only may there be differing rates of ossification, but also interpopulation variation in the morphological manifestation of the aging process in the sternal rib. If racial differences were found to exist, it would then become necessary to modify the present standards for age determination from the rib for use on blacks.

Therefore, the purpose of this research is to determine, first, if the aging process in blacks follows the same morphological pattern and progresses at the same speed; secondly, if these interracial differences are significant enough to require modifications of the white standards.

Materials and Methods

The sternal extremity of the right fourth rib was collected from 73 blacks (53 males, 20 females) of known age, sex, and race autopsied at a medical examiner's office. The specimens were carefully cleaned of adherent soft tissue and cartilage in the same manner as in previous work on the rib [1–3].

Table 1 lists the age frequency distribution of the sample by decade. A total of 2 male and 4 female ribs were eliminated during preliminary examination either because they were damaged during cleaning, were obviously anomalous, or could not be separated from the cartilage. As in previous studies, only ribs that showed Phase 1 development or greater were included in the statistical analysis. Therefore, the final sample size was reduced to 63 (49 males, 14 females).

Since preliminary examination of the ribs revealed apparent differences, a comparison was made between physical activity levels of the occupations of blacks in this sample and whites from the preceding studies. Cases in which the death certificate listed occupation as student, unemployed, retired, or never worked were not included in this compilation because no general assumptions could be made about the physical exertion levels of these individuals.

Age was then estimated using the standards from the authors' phase techniques for white males and females [2, 3]. Estimation of phase was carried out jointly by two of the authors (MYI and SRL). This assessment was done without prior knowledge of the age of the speci-

TABLE 1—*Frequency and percentage distribution of specimens by age intervals.*

Age Intervals (in Years)	Males		Females	
	N	%	*N*	%
0-10	1	1.9	2	10.0
11-19	5	9.4		
20-29	19	35.8	7	35.0
30-39	15	28.3	5	25.0
40-49	4	7.6	3	15.0
50-59	7	13.2	2	10.0
60-69	2	3.8		
70-82			1	5.0
Total	53	100.0	20	100.0

mens. The data were analyzed using ONEWAY analysis of variance, BREAKDOWN and CROSSTABS subroutines of the *Statistical Package for the Social Sciences (SPSS)* [*16,17*]. The results were later compared with those obtained for whites.

Results

The left half of Table 2 contains descriptive statistics for both sexes of blacks. The sample ranged in age from 15 to 62 in males (Plates 1 and 2) and 21 to 57 in females (Plate 3). The mean age per phase increased steadily in both sexes. Phase 8 in males and Phases 1, 2, 7, and 8 in females were not represented in the sample.

When compared with data obtained from the previous studies on whites [*2,3*] on the right half of Table 2, it can be seen that the mean age per phase is nearly identical through Phase 5 in males and in Phases 3 and 4 in females. After these phases, the average age per phase

TABLE 2—*Descriptive statistics of blacks' phases and comparative data from whites.*[a]

Phase	Blacks				Whites			
	N	Mean	SD	Age Range	*N*	Mean	SD	Age Range
				MALES				
1	2	18.0	4.24	15-21	4	17.3	0.50	17-18
2	8	22.0	2.93	17-26	15	21.9	2.13	18-25
3	7	24.9	3.24	20-30	17	25.9	3.50	19-33
4	6	28.5	3.83	23-32	12	28.2	3.83	22-35
5	14	38.9	7.72	26-51	14	38.8	7.00	28-52
6	4	43.5	15.93	27-62	17	50.0	11.17	32-71
7	8	49.1	7.26	39-60	17	59.2	9.52	44-85
Total	49	34.1	12.15	15-62	108	71.5	7.51	17-85
				FEMALES				
3	1	21.0		21-21	5	22.6	1.67	20-24
4	4	27.0	6.48	21-36	10	27.7	4.62	24-40
5	4	37.0	14.40	26-57	17	40.0	12.22	29-77
6	5	44.8	6.14	37-54	18	50.7	14.93	32-79
Total	14	35.8	9.48	21-57	83	47.8	11.00	14-90

[a]Data for white males and females are from the studies by İşcan et al. [*2,3*].

became younger in blacks, ranging from three to six years (Phases 5 and 6) in females and six to ten years (Phases 6 and 7) in males.

An interracial comparison of the lower end of the age range showed that with the exception of Phases 3 and 4, blacks were younger, a trend that became more pronounced with increasing age from the late 20s onward.

The analysis of variance (Table 3) revealed that while the difference between phases was statistically significant at the $p < 0.001$ level in black males, black females were significant only at the $p < 0.058$ level. The η^2 value in males indicated that 70% of age-related changes could be accounted for by the characteristics chosen to define the phases. Again, this figure was much lower in females (51%). Furthermore, the η^2 values for both sexes of blacks as a whole were considerably lower than in whites (males = 85%, females = 76%).

Table 4 shows the age distribution of specimens in each phase. In black males, Phases 1 through 4 spanned two decades each. This increased to four decades per phase from Phases 5 through 7. Black females covered one and two decades, respectively, in Phases 3 and 4, and three decades in Phases 5 and 6. The χ^2 statistics indicated that the distribution was significant at the $p < 0.001$ level in males, but not in females. In general, this distribution was similar to whites (which were, however, statistically significant in both sexes). Phase 6 exhibited the most variation in both race groups. Although the lack of specimens over sixty did not allow comparison in the upper age ranges in Phases 6 and 7, a trend toward earlier development of age-related changes was noted to begin in blacks in Phase 5 and increased with age.

When analyzed by decade (Table 4), black males spanned the greatest number of phases (1–6) in the 20s; however, 79% of the specimens were concentrated in 3 phases (Phases 2, 3, and 4) (compared with 93% in whites). Overall, blacks were more varied by age, while whites showed more variation by phase.

Finally, Table 5 presents a comparison of activity levels of the occupations of individuals in both the black and white samples for whom this information was available. It is readily apparent that the percentage of blacks (both sexes) engaged in jobs requiring the most physical exertion was more than twice that of whites.

Discussion

Many studies indicated that racial differences in growth during infancy, childhood, and adolescence are a product of genetics and environment [*18–20*]. As mentioned earlier, racial differences in the aging process in the adult skeleton had been reported to be relatively minor. Thus, it was not deemed necessary to establish separate standards for age estimation from, for example, the cranial sutures and pubic symphysis in American whites and blacks.

However, İşcan and Loth [*7*] cautioned that the aging process in the sternal rib could be population-specific. Therefore, the present study has been carried out, first, to compare the speed of morphological metamorphosis; second, to determine if indeed this transformation, observed in one race group, follows the same pattern in another; and third, if significant differences exist, to modify the age determination standards accordingly.

In terms of rate, the first deviation noted between the black and white groups was in a 15-year-old black male who showed definite Phase 1 development (Plate 1: Fig. 1*a, b,* and *c*). This is significant because no initial pit formation, which is the first indication of the cessation of growth in the sternal rib, was found in white males before age 17. Yet, it is not surprising in light of the somewhat earlier maturation of the black skeleton as a whole [*11,19,21*].

Metamorphosis proceeds at a similar speed in both groups until the late 20s. After this time, certain features change at a noticeably faster pace in blacks. Black ribs tend to look older than their white counterparts from the 30s on. Specifically, many black specimens were judged older than their actual chronological age because irregular, "pointy" rims (Plate 2: Fig. 4*a*) and pronounced superior or inferior projections or both (Plate 2: Fig. 7*a, b,*

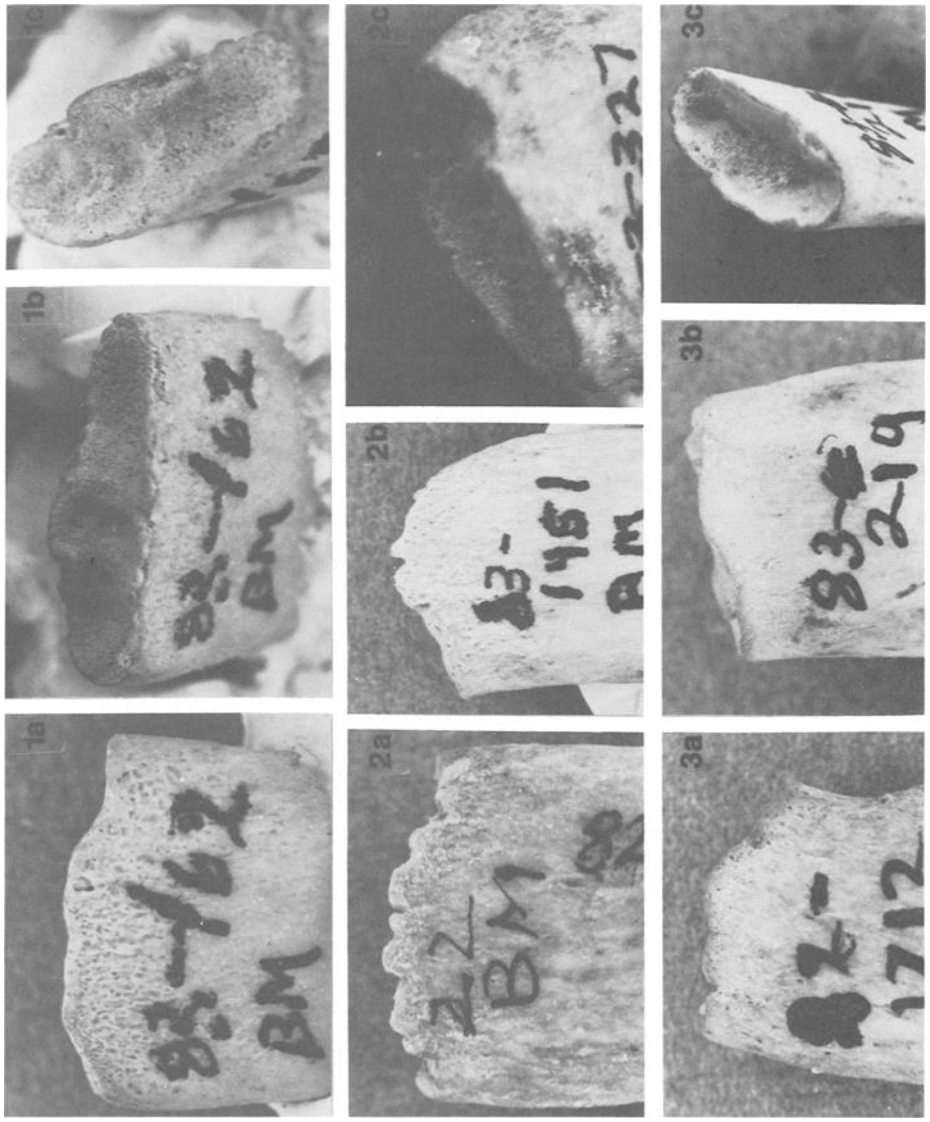
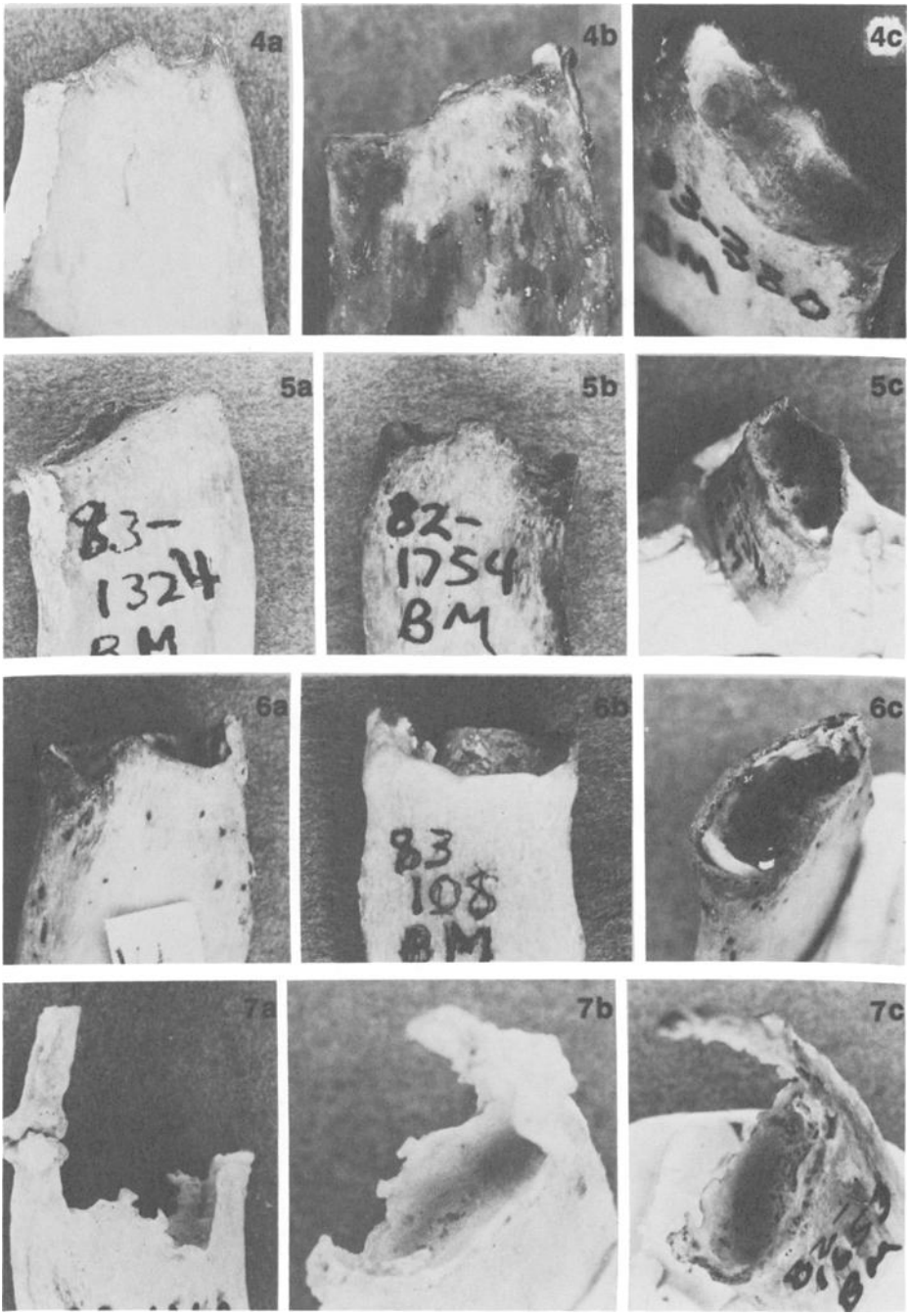

1a
1b
1c
2a
2b
2c
3a
3b
3c

PLATE 1—*Black male ribs: Phases 1 through 3.* Phase 1: *Figures 1*a, b, *and* c *are of a 15-year-old black male showing prototypic Phase 1 development. This morphological configuration was not found to occur before age 17 in white males. Note the initial pit formation and billowy medial articular surface.* Phase 2: *Figures* 2a *and* b *show different types of scallop patterns found in blacks. Sometimes, scallops are absent completely in blacks who show all the other characteristics of this phase, especially the shallow, young looking V-shaped pit (Fig. 2c).* Phase 3: *Blacks in this phase can range from the typical pattern of regular but receding scallops found in whites (Fig. 3a), to the an unscalloped but smooth, regular rim shown in Fig. 3*b. *The interior of the pit approximates whites in texture, narrow U-shape and moderate depth (Fig. 3c).*


4a
4b
4c
5a
83-
1324
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82-
1754
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83
108
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6c
7a
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7c

PLATE 2—*Black male ribs: Phases 4 through 7.* Phase 4: *Figure* 4a *illustrates the pointed anterior or posterior rim, and* 4b, *the flattened configuration common in blacks. The pit interior condition and U-shape (*4c*) is much the same as in whites.* Phase 5: *Again, in contrast to the arched anterior or posterior configuration in whites, the black rib exhibits a flattened (Fig.* 5a*) or pointy rim (Fig.* 5b*). However, similarities in the interior of the wider, deeper pit persist (Fig.* 5c*).* Phase 6: *Because of the definite rim irregularity (Fig.* 6a*), and more importantly, the pit interior (Fig.* 6c*), this 34-year-old specimen was overaged as Phase 6. Figure* 6b *shows a 51-year-old rib with similar pit, but different rim configuration that may be more indicative of Phase 6 in blacks.* Phase 7: *Projections extending from the superior and inferior margins of the rib (Fig.* 7a, b, *and* c*) are characteristic of this phase in both race groups, but they appear earlier and are often more pronounced in blacks. Porosity inside the pit is advanced (Fig.* 7b *and* c*), but the bones themselves are still quite firm. Note the partially healed fracture in the projection of the rib pictured in Fig.* 7a.

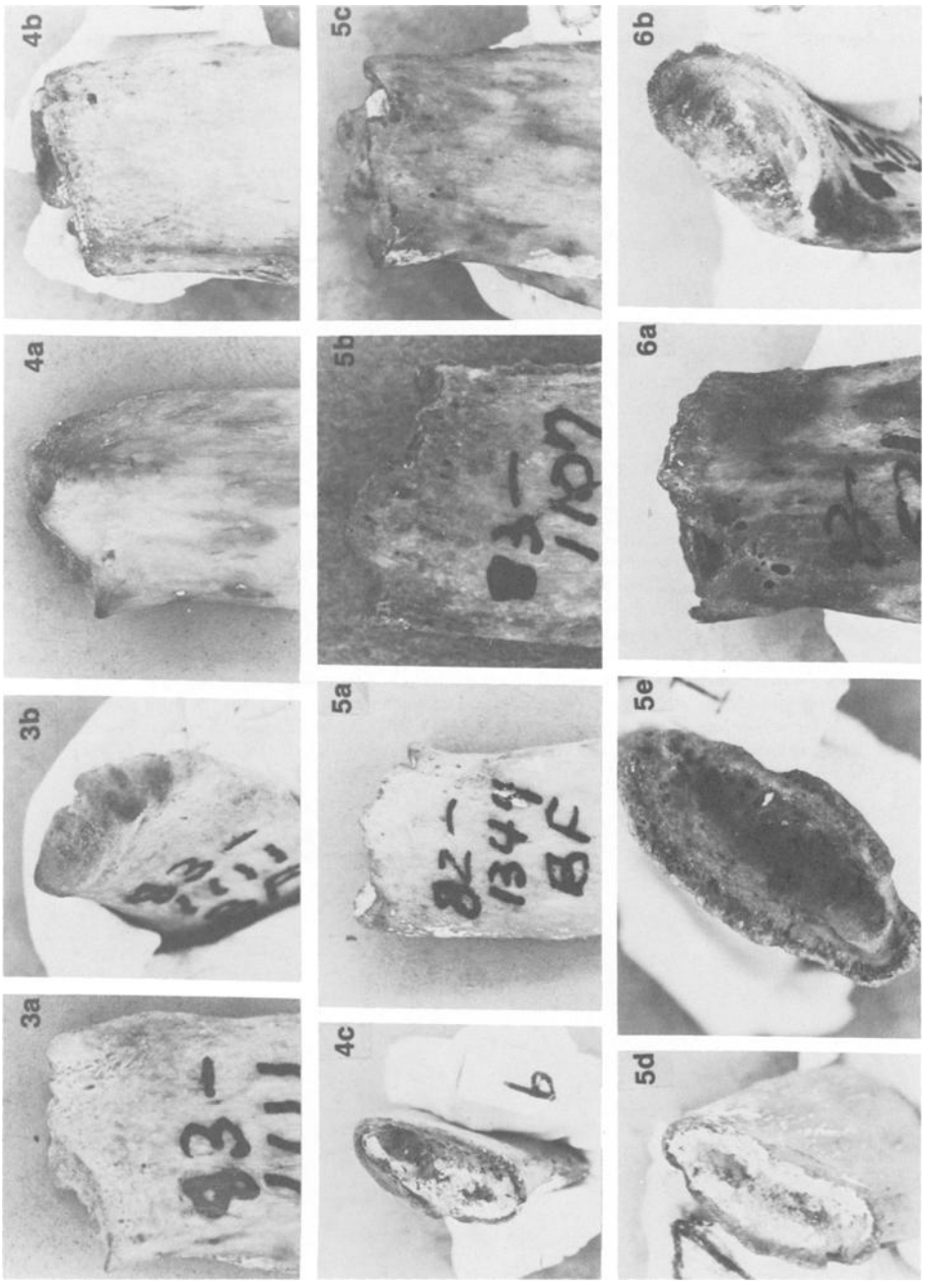
3a
3b
4a
4b
4c
5a
5b
5c
5d
5e
6a
6b

PLATE 3—*Black female ribs: Phases 3 through 6.* Phase 3: *This rib was correctly placed in Phase 3 on the basis of its very young looking shallow pit interior with obvious billowing (Fig. 3b) as opposed to the somewhat older looking scallops that are already receding (Fig. 3a).* Phase 4: *In contrast to white females, scallops were not found in this phase. Furthermore, while whites usually exhibit a rounded arc or flattened anterior or posterior rim, blacks showed a flat (Fig. 4b) or pointed rim configuration (Fig. 4a). The pit interior was more U-shaped and contained more plaque-like deposits (Fig. 4c).* Phase 5: *Figure* 5a, b, *and* c *illustrate the varied rim configurations found in this phase in blacks. The rounded anterior or posterior rim typical of whites was not noted in blacks. The pit interior as seen in Fig.* 5d *is the same as in whites, while the more porous pit in Fig.* 5e *appears to be a transition to the next phase.* Phase 6: *Phase 6 is quite similar in appearance in both race groups, especially the pit interior seen in Fig.* 6b. *However, the bone itself does not show the dramatic loss of firmness that is quite noticeable in whites in this phase.*

TABLE 3—*ONEWAY analysis of variance.*

Source of Variation	df	Mean Squares	*F* ratio	η^2
		MALES		
Between phases	6	826.94	16.39[a]	0.70
Within phases	42	50.46		
Total	48			
		FEMALES		
Between phases	3	313.19	3.48[b]	0.51
Within phases	10	89.88		
Total	13			

[a]Significant at $p < 0.001$ level.
[b]Significant at $p < 0.058$ level.

and *c*) were found to start forming years earlier than in whites. These characteristics are important since they figure heavily in the criteria for the white standards in older individuals. They are thought to result from the continuous periosteal deposition of new bone overlying the costal cartilage, along with mineralization of the cartilage itself [*1,2,22-24*]. Radiologically, these phenomena manifest themselves as dense mineralization of the costal cartilage. Thus, these observations of the fourth rib are consistent with Michelson's [*13*] findings that mineralization is more rapid in blacks.

Although the given morphological patterns occur at a younger age in the black rib, the bones themselves were found to remain much firmer in both sexes, at least through the 60-year range of the sample. In whites, a noticeable loss of firmness occurs in the 40s in males and by the 30s in females. In blacks, the first palpable loss of firmness was not seen until the 60s in males and the 50s in females. However, as in younger specimens, the development of porosity on the interior surface of the pit remains about the same as in whites. Therefore, the phase instructions regarding texture may not be applicable to blacks. This finding is consistent with the work of Baker and Angel [*25*] who determined that the skeleton in blacks tends to be denser than in whites.

Unfortunately, the small size of the female sample (Plate 3) severely limited the authors' ability to make viable conclusions and comparisons with their white counterparts. It was, however, obvious that black females maintain much better overall bone texture and density than whites of the same age. Furthermore, the specimens that were analyzed gave every indication that black females (like black males), show the same pattern of early aging when judged by white standards.

The aforementioned differences in rate were determined by comparing certain morphological features that are known to occur at a particular age in whites. However, it became obvious that there was also racial variation in the expression of these morphological features themselves.

An early difference between the races was noted in the scalloping pattern that characterizes ribs in the late teens and early 20s, and is, in fact, a "requirement" for classification as Phase 2 (male). The scallops, which serve as a very reliable, consistent age marker in white males are not as consistent or pronounced in blacks. In blacks, they are often less regular (Plate 1: Fig. 2*a* and *b*) and may even be absent completely in specimens that would otherwise be assigned to Phase 2 (Plate 1: Fig. 2*c*). Some blacks in their late 20s did show the same Phase 3-type scallops as their white counterparts (Plate 1: Fig. 3*a*).

Another morphological difference was observed in blacks in their 30s. The anterior or posterior articular rim of the bone is usually rounded (arched) or flattened in whites at that

TABLE 4—*Frequency distribution of phases by age intervals.*[a]

Phases	Age Interval 14-19	20-29	30-39	40-49	50-59	60-69	Total *N*
			MALES				
7			12.5	37.5	37.5	12.5[b]	
			7.1	75.0	42.9	50.0[c]	
			(*N* = 1)	(*N* = 3)	(*N* = 3)	(*N* = 1)	8
6		25.0	25.0		25.0	25.0	
		5.3	7.1		14.3	50.0	
		(*N* = 1)	(*N* = 1)		(*N* = 1)	(*N* = 1)	4
5		14.3	57.1	7.1	21.4		
		10.5	57.1	25.0	42.9		
		(*N* = 2)	(*N* = 8)	(*N* = 1)	(*N* = 3)		14
4		50.0	50.0				
		15.8	21.4				
		(*N* = 3)	(*N* = 3)				6
3		85.7	14.3				
		31.6	7.1				
		(*N* = 6)	(*N* = 1)				7
2	25.0	75.0					
	66.7	31.6					
	(*N* = 2)	(*N* = 6)					8
1	50.0	50.0					
	33.3	5.3					
	(*N* = 1)	(*N* = 1)					2
Total *N*	3	19	14	4	7	2	49
			FEMALES				
6			20.0	60.0	20.0		
			33.3	100.0	50.0		
			(*N* = 1)	(*N* = 3)	(*N* = 1)		5
5		50.0	25.0		25.0		
		33.3	33.3		50.0		
		(*N* = 2)	(*N* = 1)		(*N* = 1)		4
4		75.0	25.0				
		50.0	33.3				
		(*N* = 3)	(*N* = 1)				4
3		100.0					
		16.7					
		(*N* = 1)					1
Total *N*		6	3	3	2		14

[a] χ^2 (males) = 59.77 with 30 degrees of freedom (significant at $p < 0.001$ level). χ^2 (females) = 10.73 with 9 degrees of freedom (not significant: $p > 0.05$).

[b] Row percentage.

[c] Column percentage.

age. In blacks, however, this structure is either pointed (Plate 2: Figs. 4*a* and 6*a*), squared off (Plate 2: Fig. 5*b*), or flattened (Plate 2: Figs. 4*b* and 5*a*). This pointy rim configuration, prominent in blacks in the early 30s, closely resembles the costochondral junction of many whites in their 60s. However, the walls are not very thin and the inside of the pit is clearly young looking in blacks (Plate 2: Fig. 4*c*). While, in general, the condition of the interior of the pit seems to better reflect age in blacks than the rim shape, there are exceptions. Figure 6*c* of Plate 2 illustrates the interior of the pit from a 34-year-old rib that bears a startling resemblance to the prototype Phase 6 white male with a mean age of 50.

Finally, the superior/inferior projections that became prominent in the 40s in white

TABLE 5—*Comparison of occupational activity levels.*

Activity Level[a]	Males				Females			
	White		Black		White		Black	
	N	%	*N*	%	*N*	%	*N*	%
Sedentary	21	25.6	6	17.6	17	27.9	2	16.7
Moderate	37	42.1	7	20.6	37	60.6	7	58.3
Active	24	29.3	21	61.8	7	11.5	3	25.0
Total	82	100.0	34	100.0	61	100.0	12	100.0

[a]These levels include, for example: secretaries and administrators, as sedentary; law enforcement officers, homemakers, and automobile mechanics as moderate; and construction workers and waiters/waitresses as active.

males, first appeared in the 30s in blacks and continued with greater frequency and size in the 40s (Plate 2: Fig. 7*c*) and 50s (Plate 2: Fig. 7*a*).

It has already been shown that the aging process in the adult skeleton can be affected by factors such as occupation, physical activity, endocrine function, alcohol or drug abuse, socioeconomic background, and nutritional intake [*14,26–33*]. The present study has also indicated that the observed metamorphosis in the sternal rib of whites and blacks follows different courses of progression, both in rate and morphology. Therefore, racial (biological) origin also becomes a significant factor.

The reasons for this variation cannot be satisfactorily explained by the available data. Genetic influences are probably operating, since Phase 1 development, indicating the cessation of growth at this site [*1,2*], began earlier in blacks. This is also supported by the consistent nature of the observed differences.

Environmental factors undoubtedly play a role in creating the differences found in the rib. Semine and Damon [*14*] linked differences in the pattern and rate of aging in the ribs of two populations to diet. In the present study, there are cultural and socioeconomic disparities between the races which may also result in nutritional differences. Physical activity, including occupation, should also be considered, since this can affect the rate of remodeling in the skeleton. This investigation showed that a much higher percentage (over 50%) of blacks had jobs requiring greater physical exertion than whites. While this probably accounts for some of the differences observed in later years, there was not enough information, such as length of time in a particular type of job, to support definite conclusions at this time.

Disease does not appear to be a factor here because no overwhelming differences in the frequency of particular pathological conditions and substance abuse were noted between the races. Furthermore, while these conditions affect aging, "the inclusion of a wide range of individuals with diverse histories in the initial study sample had very likely accounted for these possible effects by incorporating them into the phase standards" [*7*].

Selection of specimens from the medical examiner's population should produce a bias consistent for both races. The criteria are death and suspected trauma as the cause. However, confounding social differences, which are racially linked, cannot be eliminated. More detailed inquiries into cultural factors such as nutrition, and lifestyle, need to be conducted.

In conclusion, the results of this study indicate that differences in the ribs, both in rate and morphological pattern of aging, exist between whites and blacks. Therefore, the authors have suggested modifications of the white standards for use on blacks.

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