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Determination of Age from the Sternal Rib in White Females: A Test of the Phase Method

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ABSTRACT: Sex differences in both the rate and pattern of aging in the sternal extremity of the rib necessitated the development of separate standards of age determination for males and females. A test of the male phase technique has already demonstrated its reliability and soundness. The present study was carried out to evaluate the female phase standards. A sample of 10 test ribs including 2 control specimens, was judged by 28 volunteers representing several levels of education and experience in the forensic and anthropological sciences. As in the male test, the judges were asked to assign each unknown rib to an age phase by comparing it with photographs of prototype specimens from the original study. Analysis of the results revealed minimal interobserver error between the doctoral and predoctoral groups, and no discernible association between morphological variation in the rib and antemortem history. Furthermore, rib assignment for both groups of judges averaged well within 1 phase of the ideal phase in which the specimen would have been placed based solely on chronological age.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, sternal rib, age estimation, sternal rib, interobserver error, white females

Previous studies [*1-4*] demonstrated that the sternal end of the rib is a viable indicator of age at death for individuals from late adolescence to "old age." This is particularly significant in light of the general difficulties in determining age in the adult skeleton and problems associated with other morphological techniques based on cranial suture closure and pubic symphyseal metamorphosis [*5-8*].

The authors' research revealed that the normal aging process in the rib is sex specific in both rate and pattern of metamorphosis. Differences between the sexes at this site were observed by the late 20s and increased with age [*4,9-12*]. "These findings were not unexpected in light of obvious differences in hormonal production and the existence of pronounced sexual dimorphism in other parts of the skeleton" [*4*]. While the ribs are not directly subjected to the trauma of pregnancy and parturition like the pubic symphysis, other factors undoubtedly create the observed osteological differences [*4*]. The most obvious of these appeared to be endocrine related. The development of a characteristically male pattern of marginal costochondral mineralization [*9,10*] was reported in a number of females who had undergone hysterectomy or oopharectomy [*13*]. This was supported by earlier findings that the male pattern of superior and inferior bony projections were not observed in female ribs until after the age of 60—an age by which most women are at least a few years into menopause [*4*].

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A test of the male phase standards showed them to be reliable, with estimation averaging within one phase of ideal [*14*]. However, because of the definite morphological differences between the sexes leading to the development of sex specific standards, it was necessary to assess the new female standards in a test similar to that carried out on males.

Besides ascertaining if scientists using this technique can accurately assign specimens to the female phases, it is also important to analyze the effect of experience with the rib phase method. Because of last year's male test [*14*], a comparison can be made to determine if judges who took that test perform as well or better on the female test and if these "experienced" judges would do better than the rest of their peers.

Thus, the purpose of this paper is threefold: (1) to analyze the effectiveness of the female standards for age determination from the sternal rib, (2) to compare male and female test results, and (3) to assess the effect of previous experience with the phase technique.

Materials and Methods

To accomplish these aims a sample of 10 white female ribs obtained from a medical examiner's office was brought to the 1985 Annual Meeting of the American Academy of Forensic Sciences held in Las Vegas. Only the sternal end of the right fourth rib was used. The bones were labeled with a randomly assigned number (R1 to R10). These specimens are illustrated in Fig. 1 in chronological order from youngest (14 years) to oldest (84 years).

Twenty-eight individuals attending the anthropology sessions of the conference volunteered to act as judges (J1-J28). They ranged from graduate students (predoctoral group N = two B.A.s, and four M.A.s) with limited experience to Ph.D.s and M.D.s with over twenty years of experience in physical and forensic anthropology or forensic pathology. Using the same procedure as was followed in the male test [*14*], each participant was asked to assign the ten unknown ribs to a phase by comparing them with the photographic standards from the original study [*4*]. These plates consisted of three views of prototype ribs in each of the nine phases (0-8). The judges were asked to write down the phase number of the photographs that each specimen most closely resembled on the basis of several morphological features. The detailed phase descriptions that would normally be used in the actual age determination process were not made available to the judges.

As in the male test, the phase assignment of each specimen was based strictly on morphological characteristics before the actual chronological age was revealed. The authors' morphological phase was then compared to an "ideal phase" based solely on recorded age. The ideal phase was defined as that in which the specimen's age came closest to the calculated mean age per phase lying within the 95% confidence interval.

This test of the female phases differed from the male test in two aspects. For this study, the test ribs were chosen from the original sample used to set the standards for the phase technique. Secondly, to reveal any major perceptual differences the judges encountered between a bone itself and its photograph, two control ribs, R6 and R9 (Fig. 1), were included in the sample. These were the actual prototype bones (for Phases 1 and 4, respectively) pictured in the photographic plates that were used in this test.

Finally, the scores of the eight judges who had also participated in last year's male test [*4*] were compared with their previous performance and also with the other judges. Another comparison arising from this study involved one judge (J15) who tested the sample before (J15a) and after (J15b) listening to a presentation of the original research paper [*15*] in which the entire process of phase determination was explained and the phases described in detail. All of the other judges performed the test before the paper was read.

Results

The raw data for the test specimens and pertinent information from the original study establishing the phase technique for females [*4*] appear in Table 1. The sample ranged in age

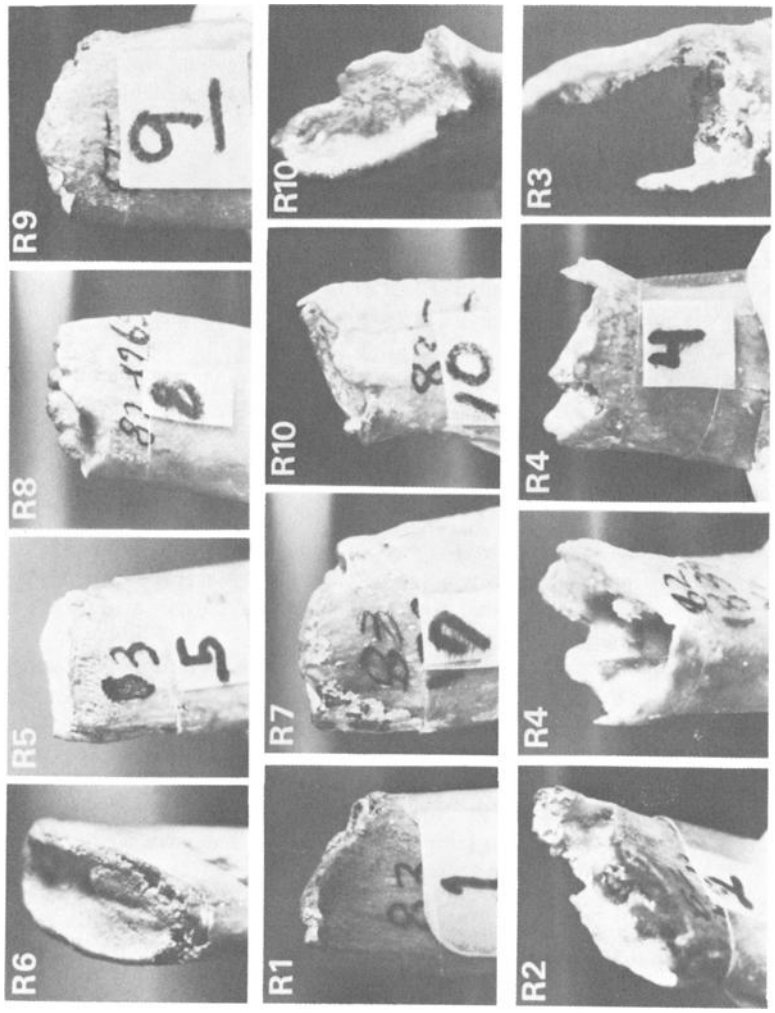

FIG. 1—*The test specimens,* R1–R10, *are illustrated in chronological age order.* R6 *and* R9, *prototypes from the original study* [4], *served as control specimens. Note the initial pit formation in the articular surface of* R6 *(Phase 1). Ribs* R4, R9, R3, R8, R10, *and* R5 *were all estimated more accurately than the overall average of 0.82 phase. Only* R1 *and* R7 *were misjudged by more than 1 phase.* R1 *and* R2 *do not show the typical configurations of their ideal phases (4 and 6, respectively).* R1 *does not exhibit the scalloped edge characteristic of Phase 4 (compare with* R9*), and was morphologically assigned to Phase 5.* R2, *which was morphologically placed in Phase 7, shows the bony projections from the rim and floor of the pit typical of that phase.* R3 *(age 84) clearly illustrates the long bony projections emanating from the inferior and superior margins.*

TABLE 1—*Actual age and authors' evaluation of test specimens and descriptive statistics of the phases based on the original study.*

Test Specimens				Original Study[a]			
Rib[b]	Authors' Morphol. Phase[c]	Age	Ideal Phase[d]	Mean Age	SD	95% Confidence Interval of Mean	Actual Age Range
R6	1	14	1	14.0			
R5	2	16	2	17.4	1.52	15.5-19.3	16-20
R8	3	20	3	22.6	1.67	20.5-24.7	20-24
R9	4	26	4	27.7	4.62	24.4-31.0	24-40
R1	5	30	4	27.7	4.62	24.4-31.0	24-40
R7	5	41	5	40.0	12.22	33.7-46.3	29-77
R10	6	46	6	50.7	14.93	43.3-58.1	32-79
R2	7	52	6	50.7	14.93	43.3-58.1	32-79
R4	7	60	7	65.2	11.24	59.2-71.2	48-83
R3	8	84	8	76.4	8.83	79.4-82.3	62-90

[a]Modified from İşcan et al. [*4*], Table 2.
[b]Specimens written in italics are used as controls.
[c]Determined by authors without prior knowledge of age.
[d]Ideal phase as determined by confidence interval in Table 1.

from 14 to 84 years and covered Phases 1 through 8. No ribs in Phase 0 were used. A comparison of Columns 2 and 4 reveal that the authors' morphologically assigned phase for 2 of the 10 test ribs (R1, age 30 and R2, age 52) fell outside the upper limit of the 95% confidence interval of the chronologically ideal phase. The other 8 ribs were in agreement with the ideal phase.

Table 2 lists the judges' phase estimates of the test ribs in terms of their deviation from the ideal phase. For example, a score of −1 indicates an underestimation of one phase, a 0 registers agreement with the ideal phase, and a +1 is an overestimation of one phase. The mean deviation was calculated for each judge individually, in two groups (doctoral and predoctoral), and overall for the entire group of judges.

The last column in Table 2 contains the judges' mean deviation from which their performance can be assessed. Individually, 22 of the 28 judges averaged 1 phase or less from ideal, and no one missed by more than 1.6 phases. Overall, the entire group averaged well under 1 phase deviation, at 0.82. When the group was divided on the basis of academic credentials, it was found that the predoctoral group, with a mean deviation of 0.72, fared somewhat better than the doctoral group at 0.85.

As was mentioned earlier, J15 took the test both before and after a presentation of the original study [*15*]. A comparison shows that J15 improved from having one of the worst scores (1.6) to the best score (0.2) (Table 2).

Ribs R6 and R9 were prototype specimens pictured in the phase illustrations and were used as controls to assess how well the judges could match the bone to its own picture or at least assign it to the correct phase (Fig. 1). The mean deviation for R9 was 0.50 phase which ranked it as the second best. On the other hand, R6 was not as well assessed (0.90) with only 3 other ribs judged at that level or worse.

The overall mean deviation was also calculated for each rib by dividing the total phase deviations per rib by the number of judges. It can be seen in the last row of Table 2 that 8 of the 10 test ribs were assessed to within 0.9 phase of ideal and no rib was missed by more than 1.61 phases.

Although the test performance of the judges was expressed in terms of phase deviation from the ideal, deviation in years can easily be approximated for each test specimen by calcu-

TABLE 2—*Deviation of judges'* (J) *estimates of the test ribs* (R) *from the ideal phase.*

	Test Ribs										Judges' Deviation:	
Judges[a]	*R6*[a] 1	R5 2	R8 3	*R9*[a] 4	R1 4	R7 5	R10 6	R2 6	R4 7	R3 8	Total	Mean
Authors	0	0	0	0	+1	0	0	+1	0	0	2	0.2
Judges with doctoral degrees												
J1	−1	−1	+1	−1	−2	−1	−4	−2	0	0	13	1.3
J2	+4	+3	+1	+2	+1	+2	+1	0	0	−2	16	1.6
J3	0	0	−1	−1	−1	−1	−1	+2	0	0	7	0.7
J4	0	−1	0	+1	−2	0	0	+1	0	0	5	0.5
J5	0	−1	−1	−1	−2	0	−1	0	+1	0	7	0.7
J6	0	−1	−3	0	−2	0	−3	+1	0	0	10	1.0
J7	−1	−1	0	0	−2	−3	0	+1	0	0	8	0.8
J8	−1	−1	−1	0	−2	0	−1	+1	+1	0	8	0.8
J9	0	−1	+2	+1	−1	−3	0	+1	0	0	9	0.9
J10	+5	+3	0	−1	+1	+1	+1	+2	+1	0	15	1.5
J11	0	0	0	+2	−1	−1	0	+1	0	0	5	0.5
J12	−1	0	−2	0	+1	−1	0	+1	+1	0	7	0.7
J13	−1	0	0	0	−2	−1	−1	0	0	0	5	0.5
J14	−1	−1	−1	0	−2	−2	−1	0	+1	0	9	0.9
J15a	0	−1	0	+1	−2	−1	−4	+1	−1	−5	16	1.6
J15b	0	0	0	0	+1	0	0	+1	0	0	2	0.2
J16	−1	+3	0	0	+1	+1	0	+2	+1	0	9	0.9
J17	−1	0	0	0	−2	−3	−1	+1	+1	0	8	0.8
J18	0	0	−1	0	−3	−3	−1	+1	0	0	9	0.9
J19	0	0	0	0	+1	−3	0	+1	0	0	5	0.5
J20	0	−1	−2	0	−2	−3	−1	0	0	−7	16	1.6
J21	−1	0	0	0	+1	0	0	+1	0	0	3	0.3
J22	−1	−1	−1	0	+3	−2	−1	0	−2	0	11	1.1
Total	19	19	17	10	36	31	18	20	9	9		
Mean	0.86	0.86	0.77	0.45	1.63	1.41	0.82	0.91	0.41	0.41	...	0.85
Judges without doctoral degrees												
J23	0	−1	0	+2	−1	−2	−1	+1	0	0	8	0.8
J24	0	0	0	0	−2	0	0	+1	+1	−1	5	0.5
J25	+5	0	0	0	+1	0	0	+1	0	0	7	0.7
J26	0	0	0	0	+1	0	0	+1	0	0	2	0.2
J27	0	−1	0	−1	−3	0	0	0	−1	0	6	0.6
J28	−1	−1	−1	+1	−1	−1	0	+1	+1	−7	15	1.5
Total	6	3	1	4	9	3	1	5	3	8		
Mean	1.00	0.50	0.17	0.67	1.50	0.50	0.17	0.83	0.50	1.33	...	0.72
Overall deviation:												
Total	25	22	18	14	45	34	19	25	12	17	...	...
Mean	0.90	0.79	0.64	0.50	1.61	1.21	0.68	0.90	0.43	0.61	...	0.82

[a]Ribs in italics, used as controls, are prototype specimens in their respective phases [*4*]. Judges in italics also participated in the male test [*14*].

[b]Numbers in this row indicate the ideal phase in which the rib would be placed as determined by the 95% confidence interval based on its known age. The values in columns below each ideal phase indicate the judges' deviations from the ideal phase number. See text for further clarification.

lating the difference between the actual age of the test rib and the mean age for the estimated phase (Table 1). For example, as given in Table 2, J1 underestimated R9 (actual age 26) by 1 phase as Phase 3 (mean age 22.6). The difference of 3.4 years (26 − 22.6) is the number of years that rib was underestimated by J1. If a judge overestimated the rib phase, then the difference in years can be computed by simply subtracting the actual age of the rib from the mean age of the estimated phase. For example, J2 overestimated R1 (actual age 30) by 1 phase as Phase 5 (mean age 40). This indicates an overestimation of about 10 years. However, it must be kept in mind that the mean age per phase has a plus or minus factor of half the 95% confidence interval. Therefore, while R1 was 10 years younger than the mean age

for Phase 5, it was only about 3 years below the lower end of the age range for that phase (Table 1).

Table 3 elaborates the overall deviation of each test rib, focusing on directionality. In eight of ten cases, 86% or more of the estimates fell within one phase of ideal, and the direction of error tended to be on the side of underestimation. For seven of the ribs, a higher percentage of misjudgments were for a younger phase, and only three were more often overestimated.

The antemortem history of each rib is presented in Table 4 and can be compared with the judges' overall accuracy of phase estimation in the last column of that table. Specimen R1, who died of drug intoxication with no known medical history, was the least accurately judged. The best estimation was made on R4 who died of atherosclerotic heart disease (ACHD).

A comparison of the performance of the eight judges who took both the male and female test was made with the rest of the doctoral group and overall group results. As Table 5 illustrates, these repeating judges (mean deviation 0.79) did slightly better than their peers (mean deviation 0.85) and the overall performance on the female test. They also averaged greater accuracy on this test than the male test [*14*].

Discussion

Earlier statistical analysis showed that the morphological features upon which both the male and female phase techniques were based were valid predictors of age [*3,4*]. However, it was deemed necessary to also conduct a test of the female standards (as was done on males) because the definitive age-related patterns are manifest differently than those found in males.

In both sexes, the aging process in the rib began in adolescence and continued throughout life. Observable changes were noted in adolescence and further development was detectable in 3- to 5-year intervals until age 28 (Phase 4). As in males, the intervals increased sharply to about 10 years from this point on. While the earliest changes were similar in both sexes, there were differences in the age of onset and range of persistence. Females were found to start showing age-related changes a few years earlier than males, an age differential that was

TABLE 3—*Total number of cases under-, correct, and over-estimated.*

Deviation from Ideal Phase	Test Ribs									
	R6	R5	R8	R9	R1	R7	R10	R2	R4	R3
−7										2
−5										
−4							1			
−3			1		2	6	1			
−2			2		11	3		1	1	1
−1	11	13	7	5	5	6	10		1	1
0	14	12	15	17		10	14	7	17	24
+1			2	3	9	2	2	17	9	
+2			1	3		1		3		
+3		3			1					
+4	1									
+5	2									
% Estimates:										
Under	39	46	36	18	64	53	43	4	7	14
Correct	50	43	53	61	0	36	50	25	61	86
Over	11	11	10	21	36	11	7	71	32	0
±1 phase	89	89	86	89	50	64	93	86	96	89

TABLE 4—*Cause of death and relevant medical history from death certificate.*

Rib	Age	Cause of Death (Medical History)	Occupation	Height, ft and in.[a]	Weight, lbs[a]	Overall Deviation
R6	14	auto accident (unknown)	student	5′3″	176	0.90
R5	16	auto accident (none)	student	5′7″	138	0.79
R8	20	auto accident (unknown)	bookkeeper	5′3″	114	0.64
R9	26	gunshot (unknown)	waitress	5′3″	126	0.50
R1	30	drug intoxication (unknown)	homemaker	5′4″	100	1.61
R7	41	gunshot (mental illness)	homemaker	5′2″	172	1.21
R10	46	drowning (unknown)	banker	5′4″	122	0.68
R2	52	ketoacidosis (diabetes)	retailer	5′7″	164	0.90
R4	60	ACHD (unknown)	none	...	...	0.43
R3	84	auto accident (unknown)	administrator	5′3″	140	0.61

[a]These data are obtained from the death certificate or autopsy reports and may not be the same as the antemortem values. 1 ft = 30 cm, 1 in. = 2.54 mm, and 1 lb = 0.45 kg.

TABLE 5—*Comparison of the results of judges who took both male and female tests.*

Test Ribs										Judges' Mean Test Deviation	
R6	R5	R8	R9	R1	R7	R10	R2	R4	R3		
1	2	3	4	4	5	6	6	7	8	Female	Male[a]
Mean for repeating judges											
0.38	0.75	1.00	0.25	1.88	1.75	0.75	0.88	0.25	0	0.79	0.90
Mean for doctoral group											
0.86	0.86	0.77	0.45	1.63	1.41	0.82	0.91	0.41	0.41	0.85	0.92
Overall mean											
0.90	0.79	0.64	0.50	1.61	1.21	0.68	0.90	0.43	0.61	0.82	0.97

[a]Male data from İşcan and Loth [*14*], Table 2.

maintained until both approached the age of 30. Furthermore, although the edge of the costochondral junction of the rib becomes scalloped in both sexes, this was first noted in females at about the mean age of 17 and persisted in some specimens until almost 40. In males, however, the scallops were most prominent by about the mean age of 22 and have not been seen after 30. A pattern difference, such as the change from a V- to a U-shaped pit at the medial articular surface of the rib is sharply defined in males, whereas in females, the pit can either become a flared V or a U [*3,4*].

Because of the sex-related differences that led to the development of separate standards for females, it was necessary to assess the same factors addressed in the male test, along with several others arising in part from a comparison of the two tests. In the discussion of the male rib test [*14*], it was pointed out that factors like the "principles underlying the development of the . . . technique," "educational level of the judges," and "antemortem health and

occupation of the decedent" are important variables that could affect the reliability of this, or for that matter, any technique for the determination of age from the skeleton. The importance of detailed instructions and morphological descriptions in accurately applying the phase technique was also evaluated.

From the results of the male test, the authors concluded that the underlying principles of the phase technique are basically sound, level of education and experience play only a minor role in the successful application of this method, and antemortem factors have been accounted for in the age determination standards. That test also indicated that it was possible to use only the photographic plates for successful age estimation, but information contained in the instructions would undoubtedly improve accuracy.

The results of the female test were somewhat better on the whole than those for the male test. The overall mean deviation in the judges' estimations of females was 0.82 phase compared with 0.97 for males. Furthermore, variation between test specimens was much less in the female test ranging from 0.43 to 1.61 phase as opposed to a range of 0 to over 3 phases in males. A possible explanation for this rather wide discrepancy is the fact that all of the female test ribs were drawn from the original study sample, while most of the male test ribs were collected separately.

Another difference is that in the male test, younger specimens were better assessed than older ones, as opposed to this test in which ribs were missed most often in the middle age phases. In males, Phases 7 and 8 were the most poorly assessed, but in females, 4 and 5 were the only phases misjudged by over a phase. The male results were not unexpected since variation increased with age, and the errors could be explained almost completely by the lack of instructions since the ribs did not strongly resemble the type specimens. However, the female results were somewhat puzzling, especially for R7. This specimen looked very much like the prototype for Phase 5, and certainly did not appear younger, as most judges guessed. It was not surprising that R1 was problematical since it was not assigned to its chronological phase (Phase 4) in the original study, but based on its morphological configuration, included in Phase 5. Yet, the authors were again puzzled that the majority of judges underaged it.

The authors found one particularly glaring error of misjudgment. Rib R3 (age 84) was one of the best assessed (Fig. 1). It was missed by only 5 judges. However, 3 of those were off by 5 to 7 phases. Upon reexamination of this specimen, which exhibited the typically male pattern of superior and inferior projections found only in women over 60, it was noted that if the projections and paper-thin texture were ignored, the rib could possibly resemble a Phase 1 or 2 prototype. Texture and projections of this nature were fully described in the original article [*4*], and if the judges had access to the instructions, this type of error might have been avoided. As in the male test, texture, bone quality, and relative firmness were found to be important markers. However, these are much more effectively imparted in written instructions than in a photograph.

The importance of detailed instructions and explanations was further underscored by the notable improvement in the performance of J15 after listening to a presentation of the original study. Not only did this judge's score improve dramatically, but was also exactly the same as the authors' placement of the ribs.

As far as levels of education are concerned, the predoctoral group performed better on this test, but the reverse was true for the male test. In light of this finding, interobserver error based on levels of education and experience is obviously not a factor. It should be kept in mind, however, that the predoctoral group was composed entirely of graduate students (B.A.s and M.A.s) in physical anthropology, therefore, they must have at least some experience in human osteology, and enough interest in the field to attend a specialized meeting of this nature.

Analysis of antemortem factors indicated no clear-cut or consistent association between cause of death, medical history, height, weight, or occupation and the accuracy of age determination from the rib. Although it is possible that some of these factors play a role in the

aging process [*16–19*], this attempted correlation was necessarily limited by the small size of the test sample. However, as in males, 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.

Beyond the aforementioned variables, additional factors were considered in the female test. These included previous exposure to the phase technique for males, and perceptual differences between the bone and a prototypic photograph. The repeating judges as a group improved their score from a mean of 0.90 on the males to 0.79 on the females. However, while their previous experience of a year ago probably helped, it would be difficult to quantify because the overall average deviation for all judges on the female test (0.82) was lower than that scored on the male test (0.97).

Two control specimens (R6 and R9) were included in the test to determine if individuals using this technique might have some difficulty in relating the actual bone to a photographic representation. Surprisingly, neither rib was the most accurately judged. Specimen R9 was, overall, the second best in the sample, while R6 had the third worst assessment. Thus, this aspect must be considered as a source of potential error. The most obvious cause of perceptual difficulties is likely to be the size differential between the pictures, which were enlarged to emphasize detail, and the considerably smaller rib. In the case of R6, the prototype for Phase 1, another factor must be weighed. The only difference between Phases 0 and 1 is the rather subtle transition from a "nearly flat" articular surface to the formation of a "beginning, amorphous indentation" or pit in the sternal extremity [*4*]. Half the judges correctly phased this rib, and only three missed by more than one phase. However, the remaining eleven judges all underestimated R6 by one phase as a 0. Thus, it appears that there is also some difficulty distinguishing between these phases. It was interesting to note that the repeating judges scored considerably better on the controls than the rest of the group, and none of them missed by more than one phase.

In conclusion, it can be reiterated that age can be reliably estimated from the sternal rib to within one phase of the chronologically ideal age-phase. Sex differences incorporated into the standards do not appear to affect the application of this method. Experience with the phase technique itself also lead to better results partly by the concomitant improvement in relating a bone to a photographic prototype. As in the males, accuracy would be considerably better if instructions and explanations are used in the phasing process.

Although the determination of age from the rib and the differences between the sexes were analyzed and tested in this and previous studies, the application of this technique may be limited to a given population group. The samples from which the standards were developed were composed only of American white males and females, therefore, its applicability to a nonwhite or geographically different group may not provide similar results. Furthermore, behavioral differences, including habits and levels of physical activity, might result in somewhat altered morphological manifestations of the aging process. Future studies should be carried out to address these issues.

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