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Evidence of Handedness on Documented Skeletons

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ABSTRACT: The collection of skeletal material at the University of Maryland School of Medicine now includes a small sample of scapulae and long bones of the upper extremities taken from cadavers of known handedness. This sample has been used to begin studies for determining the accuracy of methods currently used for diagnosing handedness. Measurements have been taken of the deflection angle that results from dorsal inclination of the glenoid fossa, humeral length and head diameter, bicondylar width, and radial and ulnar lengths. A radiohumeral index and the total combined length of the long bones for each extremity as well as side difference in total length were calculated. These data plus the presence or absence of an extensor facet on the dorsal margin of the glenoid fossa have been compared with the known hand preference. Thus far, the data indicate that the extensor facet, greater dorsal inclination of the glenoid fossa, greater total length of long bones, and greater bicondylar width correlate with the dominant side. Since the sample size is small, further work is needed before a valid statistical analysis can be made.

KEY WORDS: physical anthropology, handedness, musculoskeletal system, glenoid fossa

A method, or some combination of methods, for accurately determining an individual's hand preference from skeletal remains would have obvious practical applications. A number of investigators have sought to establish reliable methods. For example, bone weight of adult skeletal material was studied by Dogra and Singh [*1*] and that of fetal skeletal material by Pande and Singh [*2*]. In both instances, significantly different weights between the two sides were reported and heavier weight was accepted as an indication of preference. Since arm and forearm bones are usually longer (and frequently more robust) on the right, Stewart [*3*] believes that markedly longer bones on the left may indicate left-handedness.

The Neanderthal skeletal remains found in the Neander Valley near Dusseldorf in 1856 included long bones of the left upper extremity and a portion of the right scapula. That the Neander individual sustained a severe injury to the left elbow is well known. After healing, the elbow joint probably could not flex beyond the point of 90 deg between forearm and arm, and this would make excessive use of the right upper extremity necessary. Observations of the right glenoid fossa revealed a dorsal inclination (deflection angle) outside the range reported for modern specimens, and Stewart [*4*] suggests that this may have been produced by such excessive use. No comparison can be made with the left scapula since it was not recovered.

While studying the Neander scapula, Stewart noticed that both dorsal and ventral margins of the fossa were bevelled. He had seen the same kind of modeling of the dorsal

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margin on a few right scapulae during his earlier study of Korean War dead [3]. Owing to Terry's description of only slight, if any, movement of the scapula during extension at the shoulder joint [5], Stewart reasons that during extension the head of the humerus rides up on the dorsal margin of the glenoid cavity and causes the bevelled condition. Therefore, he refers to the bevelled area as an *extensor facet.* Turning to the Terry Collection at the Smithsonian Institution for corroborative evidence that presence of the facet correlates with sidedness, he found 21 of 108 male skeletons with longer left upper extremity bones. Two of these exceeded 10 mm and were associated with both bevelling and more marked dorsal inclination of the left glenoid fossa. None of the 40 female skeletons had longer bones on the left side [6].

These studies suggest that heavier and longer bones, larger deflection angles, and bevelling of the dorsal margin of the glenoid cavity correlate with an individual's handedness. Unfortunately, the data have all been collected from skeletons for which no record as to handedness exists. Therefore, the evidence cannot be documented.

Approximately two years ago, I began collecting material from dissecting room populations for which handedness and related information, such as occupation, sports, and hobbies, have been documented. Because of limited storage space, inadequate equipment, and the great amount of time required for preparation, only the long bones of the upper extremities and the scapulae have been kept. Clavicles could not be saved because of dissecting procedures. The following is a preliminary report of a study designed to determine the accuracy of some methods currently being used for diagnosing handedness from skeletal remains. Although the sample size is small and further work is needed before a valid statistical analysis can be made, the data reported represent the first evidence of handedness obtained from documented skeletons.

Materials and Methods

Data were collected from ten pairs of upper extremities (five male, five female) taken from cadavers of known handedness. Length of the humerus, its maximum head diameter and bicondylar width, and the lengths of the radius and ulna were measured in the conventional manner. Radiohumeral indices were calculated.

The presence or absence of an extensor facet was revealed by shaving a pencil to expose approximately 75 mm of lead on one side and then drawing this across the margins of the glenoid fossa. This procedure marks both dorsal and ventral margins at the same time because the fossa is concave. If bevelling has occurred, a bony surface is seen extending dorsal or ventral to these lead markings and probably means that the margins were farther apart at an earlier time in the individual's life.[2] When the facet was present, its size was subjectively rated on a scale of 1 to 3, with 3 representing the greatest amount of bevelling observed (Fig. 1).

I followed a method devised, carefully described, and illustrated by Stewart [4] to measure the deflection of the glenoid fossa. This involved using the most prominent point on the ventral margin of the fossa for orienting the scapula. I then measured deflection a second time, replacing the reference with one that represents the intersection of the ventral margin and the transverse axis that passes through the center of the fossa. This is probably more consistent with a reference point on the scapula given by Martin [7] and one I felt might be less subject to variation. However, both methods rendered the same results in the number of degrees by which the transverse axis deviates dorsally from a vertical (90-deg) plane. Since Stewart's method is less complicated, it is probably less conductive to investigator error and, therefore, better.

It should be noted that the handedness was documented by contact between me and

[2] T. D. Stewart, personal communication, 1979.

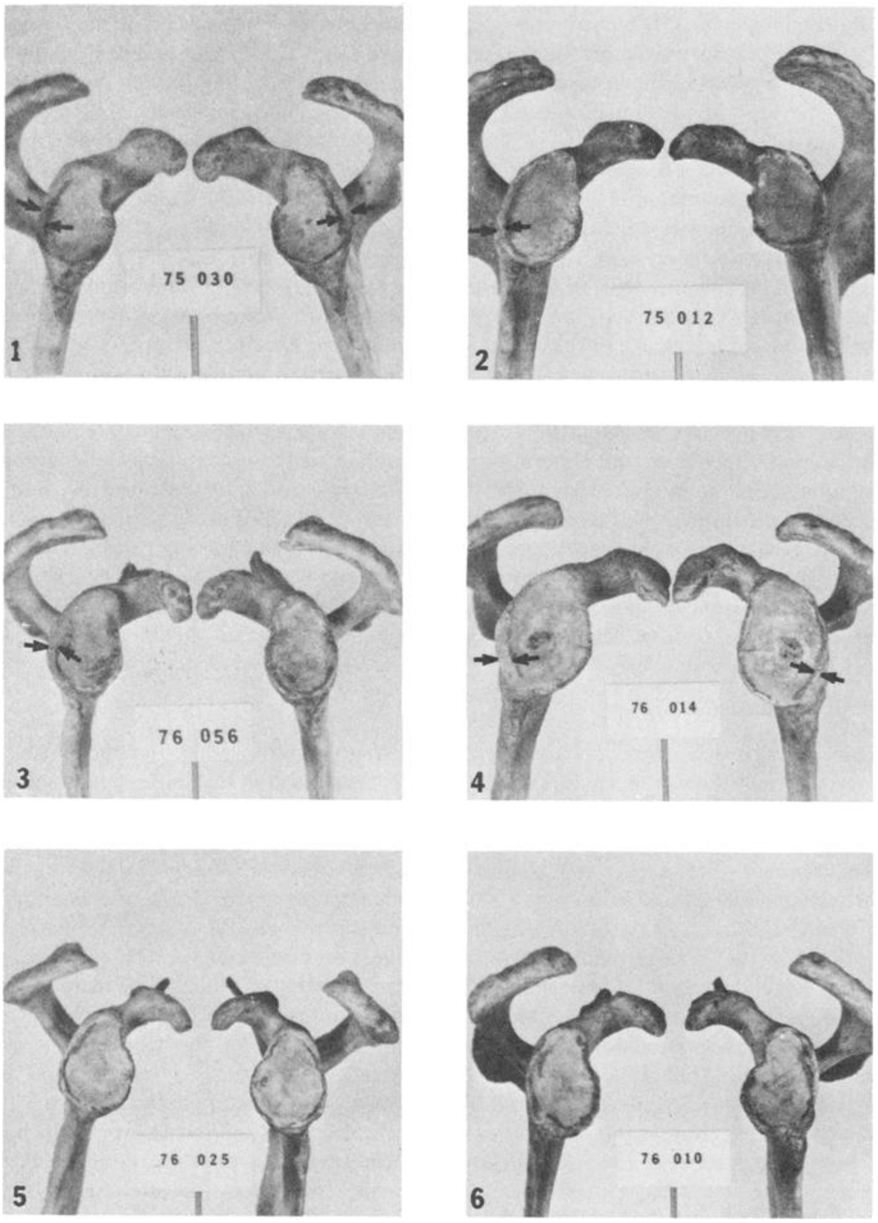

FIG. 1—*Glenoid fossae of right and left scapulae from cadavers of known handedness. Margins of the fossae are outlined with graphite. Bevelling is indicated by arrows.* (1) *Left-handed female; dorsal bevelling on both fossae rated 2.* (2) *Right-handed male; bevelling on right fossa = 2, left = 0.* (3) *Right-handed female; irregular bevelling on right rated 3; bevelling absent on left.* (4) *Ambidextrous male; bevelling on right = 3, left = 1.* (5) *Right-handed female; bevelling absent on both fossae; bone seen extending beyond dorsal margin is not bevelled.* (6) *Right-handed male; bevelling absent on both fossae; margin of right fossa very irregular.*

the decedents' next of kin. This resulted in my knowing that the collection included one left-handed female, one female who was "by nature" left-handed but had been trained to use her right, and one male who was reported to be ambidextrous. Although I collected data "blind," measurements were also made by three interested medical students to whom the above information was not available. Comparisons of our data showed no significant differences.

Results and Discussion

Table 1 presents, by side for each individual, an evaluation of the size of the extensor facet, the measured size of the deflection angle, bicondylar width, and the total (combined) length of the humerus, radius, and ulna. Finally, the side difference between total long bone lengths and evidence of arthritic changes are given. Data on head diameter of the humerus are not reported because a difference of more than 1 mm was found in only one specimen and that was probably owing to a pronounced "lipping" on the head of the left humerus. Radiohumeral indices are not included since these also showed no side differences that could be significant. While sex and age are noted, race is not. Hardyck et al [*8*] did an extensive behavioral study of school children and concluded that race and sex have little meaningful relationship to the incidence of handedness.

Where a side difference between extensor facets was observed, the more pronounced one was on the right. The one unambiguously left-handed individual presented left and right facets of nearly equal size (Fig. 1-1). A larger deflection angle is on the side of preference if a difference of 4 deg or more exists. Bicondylar width difference exceeds 2 mm in only two instances, and the wider measurements came from the right humerus of right-handed individuals. A side difference of 5 mm or more in the total length of long bones is present in the upper extremities of six specimens (three males, three females), including those reported as left-handed or ambidextrous. The longer lengths are on the side of handedness or on the preferred side if the longer extensor facet is used as an indicator of preference in the cases of the female Specimen 75-161 (born left-handed, trained to use right) and male Specimen 76-014 (ambidextrous).

The strongest evidence of sidedness is present on male Specimen 75-012. There is prominent dorsal bevelling on the right glenoid fossa compared to none on the left (Fig. 1-2), greater right bicondylar width, and total length of long bones greater by 2.2 cm on the right. Of particular interest is the fact that the left elbow joint is markedly deformed (Fig. 2). The contours of the articular surfaces suggest that the decendent may have suffered a childhood injury that interfered with normal growth and development and that subsequent use modeled the surfaces in such a way that flexion and extension may not have been noticeably restricted. The individual was a skilled laborer whose work required considerable motion at the shoulder and elbow joints, but he is reported to have shown no signs of disability in the left limb. Nevertheless, it is difficult to imagine that his limb action was not influenced to some degree.

In this documented sample, the handedness of all save two individuals could be diagnosed by at least one of the skeletal features studied without conflicting evidence from any of the others. Male Specimen 76-028 showed no side difference. Male Specimen 76-008 had a slightly more pronounced extensor facet on the right and a deflection angle larger by 2 deg on the left. Although these differences are not considered significant, they are interesting in view of the fact that there is evidence of arthritis in the right elbow and left shoulder joints. He is reported to have been a laborer but the nature of his work is not known. If it were, perhaps some kind of habitual physical activity could be inferred and greater insight gained. For instance, female Specimen 75-161 is reported to have been naturally left-handed, to have been trained in school to write with her right, and to have sewed with either. She frequently played badminton. Could the slightly larger extensor

TABLE 1—*Data from ten pairs of upper extremities belonging to cadavers of known handedness.* [a]

Specimen ID No.	Age	Side	Extensor Facet[b]	Deflection Angle[c]	Bicondylar Width	Total Length of Long Bones[d]	Side Difference in Total Length	Arthritic Changes
					Females			
75-043	94	r[e]	...	7	6.3	54.7[f]	+1.0	slight, right elbow
		l	...	5	6.0	53.7[f]	...	...
75-030	58	r	2	8	5.3	75.2	...	...
		l[e]	2	13	5.5	75.7	+0.5	...
75-161[g]	88	r[e]	3	8	5.8	82.9	+1.0	...
		l[e]	2	9	5.8	81.9	...	...
76-025	60	r[e]	...	6	5.8	77.1	+0.1	slight, left shoulder
		l	...	1	5.6	77.0	...	
76-056	?	r[e]	3	12	6.0	82.9	...	...
		l	...	12	5.8	83.3	+0.4	
					Males			
75-012	52	r[e]	2	10	6.0	56.5[f]	+2.2	marked degeneration, left elbow[h]
		l	...	9	5.6	54.3[f]	...	
76-014[i]	70	r[e]	3	12	7.2	91.5	+0.9	slight, left shoulder
		l[e]	1	10	7.2	90.6	...	
76-008	67	r[e]	2	13	6.6	89.5	...	left shoulder, right elbow
		l	1	15	6.6	89.8	+0.3	
76-010	76	r[e]	...	6	6.1	58.8[f]	+0.8	...
		l	...	2	6.2	58.0[f]	...	
76-028	79	r[e]	...	4	7.1	56.6[f]	+0.2	...
		l	...	5	6.9	56.4[f]		

[a] Linear measurements in centimetres.
[b] Rated on an ascending scale of 1 to 3.
[c] Measured in degrees.
[d] Combined length of humerus, radius, and ulna.
[e] Preferred side.
[f] Ulna not included (some styloid processes were broken).
[g] Left-handed but trained to use right.
[h] May have been caused by childhood injury.
[i] Reported as ambidextrous.

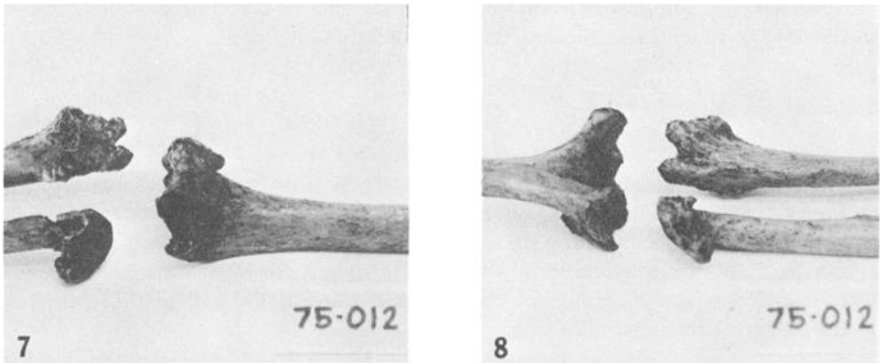

FIG. 2—*Grossly deformed left elbow joint, Specimen 75-012;* (7) *anterior view and* (8) *posterior view.*

facet and greater length of long bones on the right have been produced by holding the racket with the right hand? Male Specimen 76-104 (Fig. 1-4) is reported to have been ambidextrous. The extensor facet is considerably larger and the deflection angle is slightly greater on the right. He played baseball and football and bowled. I think that it is not unreasonable to infer that he batted and bowled right-handedly. Concerning these two ambiguous specimens, it is interesting to note that both were ambidextrous, to some degree, but they were not alone in demonstrating extensor facets on both fossae. Therefore, facets on both sides apparently bear no relationship to ambidexterity.

There is evidence that the presence of facets and physical activity do correlate positively. Four specimens have no facet on either of the glenoid fossae. None of the four are reported to have engaged in sports or hobbies that required frequent extension at the shoulder joint, and all of them followed occupations that required little physical activity. Five of the specimens possessing facets engaged in an occupation or sport that required considerable physical activity. I have no information in this regard for Specimen 76-056 (Fig. 1-3).

Contrary to Stewart's findings [*4,6*], my sample gives no evidence of a relationship between sizes of extensor facets and deflection angles. Two of the four specimens lacking facets, female 76-025 (Fig. 1-5) and male 76-010 (Fig. 1-6), have deflection angles on the right larger by 5 and 4 deg, respectively. Only one of the six specimens demonstrating facets was found to have a side difference in the deflection angle that exceeded 2 deg. Whether the dorsal inclination of the glenoid fossa is increased by handedness or already established at birth is not known.[3] Perhaps it is established at birth and in some instances sufficiently pronounced that subseqent extension at the shoulder joint does not result in effective "riding up" of the humeral head and no modeling of the dorsal margin of the fossa occurs.

The sample size on which this report is based is too small for a valid statistical analysis of the data. However, the evidence gathered suggests that the four skeletal characteristics investigated represent basic distinctions between handedness, which are in turn affected by activity and perhaps by physical characteristics already established at birth. In this regard, the significance of the deflection angle as a distinguishing feature could be better evaluated if data were obtained from fetal and neonatal material.

A larger study is planned but years are required for collecting specimens and, once they are collected, preparing the material for study is time-consuming. I would like to urge others who are interested and who have access to cadavers that can be documented

[3]T. D. Stewart, personal communication, 1979.

as to handedness, physical activity, joint disease, and so forth to conduct their own investigations or to send specimens to me to be added to my sample.

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