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Exploring Bilateral Asymmetry & Ante-Mortem Trauma in Pleistocene Narmada Hominin Fossil Clavicles

Research Article

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Abstract

The present study explores bilateral asymmetry accountable to ante-mortem trauma in two mid-late Pleistocene hominin clavicles discovered from Hathnora in the central Narmada valley, which had earlier yielded a partial cranium. The two female fossilized clavicles and the female cranium were initially thought of belonging to the same individual, but of late, it was confirmed that they belong to two different hominins. The clavicles come from a pygmoid/ short stocky female showing intriguing bilateral differences. The 3-D scans and comparative metric and non-metric analyses reveal that the two clavicles exhibit considerable bilateral asymmetry accountable for the left shoulder *ante-mortem* trauma and some years of post-trauma survival to allow healing of the broken end.

Introduction

Several experts have different interpretations of the functional anatomy and peculiarities of the human clavicles [9, 8, 16, 15, 27, 19, 28, 2]. The most common interpretation is that it functions as a strut bone connecting the upper limb with the axial skeleton transferring the upper-limb forces to the thorax. But, at the same time the clavicle stabilizes the gleno-humeral joint by limiting motion of the scapula and anchoring the joint to the ribs and sternum through the sternoclavicular joint. This happens with the help of six muscles, such as pectoralis major, deltoid, sternocleidomastoid, sternohyoid, trapezius, and subclavius, and four ligaments which support as well as transmit forces and also give it sigmoid or S-shaped or two smooth curves which may vary in depth. Thus, the clavicle endures a variety of loads, torsion and shear stresses and modeled to compressive (axial) and bending loads, resulting from weight and compression exerted by the upper limb on the glenoid. Variation in the cross-sectional shape along the bone reflects this variety of mechanical loadings supporting the multiple functional capacities of the clavicles.

Human clavicle is also unique in its development compared to other postcranial bones. It is the only postcranial bone to develop, in part, from membranous (i.e., "dermal" cell layer) tissues, as opposed to chondral models [39, 27]. It is also the first bone to ossify in the upper-limb complex and attains early much of its adult morphology during foetal growth, and its 'S' or double-curved shape is achieved well before birth, leaving further growth to occur primarily at the ends, especially the medial epiphysis [34]. Having much developed in utero, the clavicle is among the last bones to reach complete ossification of the epiphyses [33]. It has a developmental pathway that is different from the humerus, and therefore has a much longer period to acquire life style changes and adaptations to lateralized behaviours (bilateral asymmetry) relative to the humerus and radius.The clavicle has a great range of variation in size, in the development of the conoid and deltoid tubercles, the epiphyses as well as the rhomboid fossa. Modern human clavicle is associated with a higher scapula in relation to the thorax, while it is, lower in position in the Neanderthal. There are three main types of shapes in dorsal view [31, 32].

Observations

The author [20, 21, 23] reported two mid-late Pleistocene hominin clavicles from Hathnora in the Central Narmada valley, which had earlier yielded a partial female cranium [37]. The two fossilized clavicles were also sexed as belonging to a female and were therefore initially thought of belonging to the same individual [22], but

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of late, through excavations at Hathnora, it was confirmed that they come from two different stratigraphic and cultural contexts, and belong to two different hominins [6, 24-26].

The right clavicle

The right clavicle was initially confused to its sternal epiphysis partly broken off [20] owing to the narrow sternal end contrasting with modern humans, and therefore its maximum length was estimated to be 100 mm. But, soon it is found to be remarkably complete, well-preserved and extremely rare fossil of its kind with 90 mm maximum length, confirmed through the 3D Scans (Fig. 1) revealing that the sternal articular capsule and the facets are indeed intact.Its diaphysis is slightly flattish with S-shaped or sigmoid curves typical of a human clavicle, although its shortness and shallower curves give the clavicle a straighter look with little axial torsion comparable to the Andaman Pygmy [20] (Fig. 1C). The M. pectoralis major attachment on the anterosuperior aspect for the proximal diaphysis is rugose and distinct.The posterior diaphyseal border is rough and undulating but sharpens toward the eroded proximal part. The M. subclavius attachment area is distinctly rugose and undulating. The M. sternocleidomastoideus area located posterosuperiorly on the proximal diaphyseal end is distinct and relatively flat. On the posteroinferior aspect of the proximal diaphysis, M. sternohyoideus attachment is also well developed. The costoclavicular ligament facet (rhomboid fossa) is located medially on the inferior surface of the proximal diaphysis because of the flatness and little no axial torsion of the bone. Due to some erosion it extends almost to the midpoint of the bone is quite developed (21.9 x 8.0 mm) furrow and bilipped suggesting strong muscular attachment of the clavicle with the rib. The subclavian groove is like a deep and broad sulcus in the concavity of the inferior surface of the distal epiphysis and is anteriorly disposed. However, it becomes shallow and indistinct when it reaches the middle of the diaphysis.

The left clavicle

It preserves only the medial 2/3rd portion and lacks the lateral 1/3rd, i.e., the acromial epiphysis. The latter is broken off beyond the conoid tubercle, which is the common weak point of the clavicle. The broken end is smoothly rounded and blunt as if healed from an *ante mortem* trauma suffered during the lifetime of the hominin. The medial end is well preserved and possesses the sternal articular capsule and the facet typical of the clavicle. It is completely mineralized as the right clavicle and shares the same ash-gray hue, also shared by the rib fossil, all recovered from the same site.

Age and Sex of the clavicles

Both the clavicles are quite thick unlike the thinner juvenile modern clavicles and quite apparent of being of adult physiological age as revealed by the developed muscular rugosities. The sternal epiphysis-diaphysis fusion detection is difficult in the fossilized bones as the X-rays cast complete continuous shadow as if completely fused; the complete diaphyseo-epiphyseal fusion in modern human clavicles is generally observed having occurred between 25 -35 years of age [13, 10, 11, 7, 14, 33]. So, if modern standards hold true, the Narmada clavicles may belong to an adult individual of above 25 years of age at death.

Probably modern non-metric sexing criteria may equally hold well for the Middle Pleistocene Narmada Homo because the early Pleistocene African *Homo erectus* (=*H. ergaster*) shows modern upper chest morphology as observed by [8]. The Narmada clavicles also show advance trend of moderate rounding of the shafts (mesocleidy) approaching the lower threshold of *Homo sapiens*. Therefore, we may apply the modern sexing criteria to know the sex of Narmada clavicles. On these criteria both the Narmada clavicles may be sexed as of female as they show: (i) the narrow sternal end or a lesser Inner-End Index -a sum of the antero-posterior and supero-inferior diameters at the sternal end [17]; (ii) the conspicuous conoid tubercle; (iii) the smaller acromial facet- quite evident on the otherwise robust / male-like looking right clavicle; (iv) the straighter or less curved diaphysis of both clavicles; (v) the unusually short clavicle length [35, 38, 36].

But, the metrical criteria to differentiate the two sexes as suggested by [13, 11], for various north Indian populations are inapplicable for the very short clavicles. However, the clavicles of the female pygmies of the shortest Andaman Islanders, namely the Onge of the Little Andaman and the Greater Andamanese of Middle Andaman, show similar length (Table 1) and also approach in general

Figure.1. 3-D Scans of the Narmada Right Clavicle (complete) (A) and Left Clavicle (partial) (B) in four views, C. Scans of the Andaman Pygmy right and left clavicles
D: Metric Landmarks on Right Clavicle: 1-8 are various antero-posterior diameters in caudal plane; AB= maximum length, CD=Conoid length.

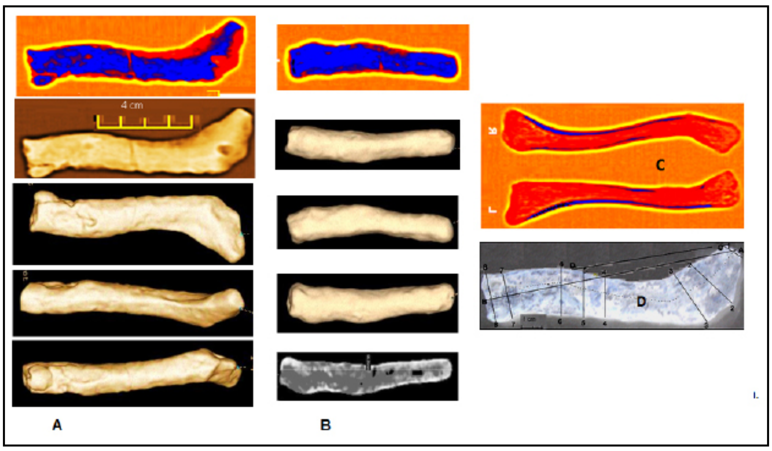

Table 1. Select morphometrics of Narmada, Andamanese and modern mainland Indian Clavicles showing bilateral asymmetry.

MEASUREMENT	Narmada (N=2)		Andamanese (N=16)			Indian mainlanders (N=14)			Mean Bilateral Asymmetry [[R – L]	
	Right	Left	Min	Mean	Max	Min	Mean	Max	Narmada	Modern (N=30)
Preserved Clavicle Length	88	69.4	96	106.9	114.9	119.3	130.2	150.8	-	-
Max. Clavicle Length (CL)	90	88.0est	96	107	115	119	130.6	150.8	2	-0.3
Prox. Curv. Chord = Conoid Length (COL)	73.5	68	77.5	85.9	92	101.1	107.3	124.6	5	1
Midshaft Diaphyseal AP diameter (MDAP)	13.5	13.4	8	8.8	10	9.9	11	14.2	0.1	0.3
Midshaft Diaphyseal SI diameter (MDSI)	11	11.2	6.6	8	9	8	10.4	13	-0.2	0.6
Midshaft Diaphyseal Circumference (MDCF)	41	38	23.5	27.6	30	30	34.4	43	5	1.3
Sternal Epiphyseal AP diameter (STAP)	17.1	15.3	15.1	19.1	21.6	17	21	25.1	1.8	2
Sternal Epiphyseal SI diameter (STSI)	11	13	13.1	18.1	20.6	14.3	18.2	22.7	-2	-0.5
Caliber Index (CALI=MD CF./ CL.x100)	45.6	43	22.6	26.1	30.2	23.2	26.4	30.1	2.6	1.2
Inner-End Index (INEI=STAP + MDSI)	28	28.3	31	37.4	41.6	33.4	39.1	47	-0.2	2.2
Conoid Index (CONI=COL./ CLx100)	81.7	78.4	76.7	80.5	83.8	78.3	82.1	86.4	3.3	0.9
Midshaft Index (MIDI=MD-SI/MDAP x 100)	81.5	83.6	109.8	80	91.3	80	94.7	110.1	-2.1	3.1
Robust. Index (ROBI=M-DAP+MDSI/CL x 100)	27.2	28	17.7	13.7	15.7	14	16.4	20.9	-0.8	0.9

AP =Antero-posterior; SI = Supero-inferior

Table 2. Degree of development of select Non-metric traits in Narmada and 11 pairs of modern clavicles.

Trait	Narmada R L	Modern human Clavicles (11 pairs)										
		4	5	6	7	8	9	10	11	12	13	4a
		R L	R L	R L	R L	R L	R L	R L	R L	R L	R L	R L
COT	2 2	2 0	1 1	4 4	2r 2r	2r 2r	4r 4r	3r 1	2 3	2r 2	3r 1r	3 3r
DET	0 2	2 3	1 1	3 4	4 1	3 0	1 0	1 3	3 3	0 0	1 0	1 1
DER	1 0	0 0	1 1	1 1	0 0	1 1	0 1	1 1	1 1	1 0	1 0	1 1
RHF	4 1	1 2	3 4	4 3	3 3	4 1	3 2	2 1	3 4	4 4	3 1	4 4
ROB	4 3	2 2	2 1	3 2	1 1	3 1	2 2	1 1	1 2	2 2	2 1	1 1

COT = conoid tubercle, DET=deltoid tubercle, DER=deltoid ridge, RHF=rhomboid fossa, ROB=robustness, r = ridged, 0 = blunt / absent, 1 = sharp / little, 2 = moderate, 3 = large, 4= very large.

morphology, especially in the lesser curvature and the rounded deltoid region exhibited by the left Narmada clavicle.

Comparative analysis of the clavicles

The Narmada clavicles were compared with a mixed-sex sample of 30 adult modern clavicles (14 modern mainland humans and 16 Andaman Islanders) besides incorporating a few ancient Indian clavicles in the palaeoanthropological repository of the Anthropological Survey of India, Kolkata. The pygmy sample is from the Onge- the forest dweller Negrito forager of the Andaman Islands, who now number less than a 100. The clavicles of the modern human sample represent a heterogeneous eastern Indian population in the repository of the Anthropological Survey of India, Kolkata. In all the clavicles were studied for 36 mensural traits of which five constitute indices, besides for five non-mensural traits (Table 2). The selection and methods of measurements of the variables were as per the criteria followed by [4, 30, 3, 18, 17], besides more additions in the variables.

Bilateral differences and Asymmetry

Compared to the right clavicle, the left clavicle presents some of its own uniqueness, which could easily detract one to assign it to the same individual as represented by the right clavicle. These are: (i) the diaphysis is more rounded and gracile with more axial twist; (ii) the sternal epiphysis and the articular facet more rounded; (iii) as a consequence of the above, the conoid tubercle is conspicuous, the deltoid ridge and deltoid tuberclerounded,and fine narrow subclavian groove; (iv) on the contrary, the right clavicle has a sharp deltoid ridge leading to diminished deltoid tubercle, and possesses a deep subclavian and costoclavicular attachment facet (rhomboid fossa), which in the left clavicle is less distinct and infero-laterally disposed unlike the centrally located one of the right clavicle; (v) the muscular rugosities of the M. sternocleidomastoideus, M. subclavius and M. pectoralis majorare also more developed in the right clavicle than in the left; (vi) the antero-medial border of the left clavicle is slightly uneven compared to that of the right clavicle.

The great distinction between the two fossil clavicles was initially argued to two different individuals. But, it was unlikely that two females are represented in the same site,one leaving the right and the other the left clavicle. But, why so much bilateral difference, prompted comparative analysis presented in Table 1 and Table 2.

Discussion And Conclusions

The main points in favour of the two clavicles coming from the same individual are: the similar inferred adult age, the same female sex, and the same siteand similar gray hue, similar maximum clavicular lengths (90 mm for right clavicle and 88 mm for the left clavicle) also suggesting contemporaneity. In addition, the degree of robusticity is also similar in the two clavicles as revealed from their robusticity and caliber indices and by other mensural traits shown in Table 1, which also incorporates the data for 30 modern clavicles. The Table 2 reveals considerable non-metric bilateral variation in modern clavicles for various parameters, which is noteworthy in the development of the rhomboid fossa, the deltoid and conoid tubercles, and the deltoid ridge. The two Narmada clavicles also exhibit considerable bilateral variation, and therefore, the likelihood of occurrence of one left and another right clavicle of two different adult females at the same siteis ruled out.

Human clavicular asymmetry is significantly left-biased in length and right-biased in diaphyseal breadth [2, 1, 16, 4, 6]. This length asymmetry is contra lateral to the length asymmetry observed in humeri in the same sample, though clavicles and humeri have same-side directional asymmetry in diaphyseal breadths. This pattern provides more support for the notion that the clavicle is an integral functional element of the upper-limb complex. As in previous research of all the major long bones of the postcranium, the diaphyseal breadths were found to exhibit greater amounts of asymmetry than the long-bone lengths. Despite some variation, these patterns are universal among all modern humans sampled. Females have significantly greater directional asymmetry in humeral length, whereas males have significantly more directional humeral diaphyseal asymmetry, but this sexual dimorphism is not evident in the clavicle. Results further suggest that different regions of the bones react differently to behaviour (i.e., mechanical loading) and/or genetic influences. The clavicle, although a functional component of the upper limb, has a developmental pathway that is different from the humerus, which therefore results in some discontinuity in shared patterns of asymmetry between these bones. Diaphyseal breadths however, continue to exhibit greater sensitivity to loading than lengths of long bones [2]. Comparisons of groups that had different patterns of activity and loading behaviors emphasize the observable effects of these differences among patterns of asymmetry.

There are many studies, which support presence of bilateral variation in the clavicle due to a differential use of the two shoulders/arms employed habitually in various occupations or life styles, which result in more variation than the climate [18]. For example, a distinctly deep and prominent 'rhomboid fossa' is regarded a clear sign of 'handedness' [10, 29]. In view of this, the deeper rhomboid fossa on Narmada right clavicle suggests a 'distinctly right-handed' individual- who likely "over-used" the right shoulder/arm.

There are additional morphological traits preserved on Narmada clavicles which further attest bilateral asymmetry as follows: (i) shelf-like ex-ostosis at the M. sternocleidomastoideus at the medial curvature, which adds to its strength; (ii) Rugged M. subclavius and deep subclavian groove- having turned into a sulcus; (iii) expanded and sharp deltoid ridge lacking the deltoid tubercle; (iv) strongly developed anterior diaphyseal border having turned into a tiny keel or a linear mid-rib.

The above features would support very strong shoulder and chest muscles of the right side. These peculiar developments probably indicate stress-induced anomalous bilateral asymmetry with the left side less in use. This may also suggest that the hyper- robustness of the Narmada clavicle could be an individual peculiarity attributed to unusual stressful bilateral asymmetry, though the robustness in general may also be a characteristic of the "archaic" hominins and of the 'short and stocky' or "Pygmoid" hominins. It appears quite likely that the bilateral asymmetry could have resulted from the injured left clavicle, i.e., theante mortem trauma-which consequently led to an "over-use" of the right side. The broken lithified end of the left clavicle attests a pre-fossilization fracture of the left clavicle/shoulder. The mineralized distal end is smoothly rounded or blunt as generally seen in healed up bones, suggesting therefore, that the hominin probably lived for quite some time with the injured left shoulder before death.

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