

PATTERNS OF FRACTURES FROM NEOLITHIC TO MODERN TIMES

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We live less laborious, more risky, and longer lives than ancient peoples. Do our bones break more or less often? Has the sex difference changed? What are the chronological changes in overall frequency and pattern of fractures and their links with cultural change?

Data and methods

Eleven ancient samples include 2125 individuals from about 40 sites in Greece (and in Turkey for part of Neolithic and Early Bronze only). Less than 500 are unified single skeletons partly because of multiple burials especially in Late Bronze, Medieval, Baroque, and Romantic periods and from decay (cf. ANGEL 1971); Hence in Tables 1 and 2 sample size averages under 20 of each sex per bone except for the calvarium. Percentages distorted by small sample size I have put in quotation marks and in the lower line of Totals I pool all bones for each period and in the furthest right hand column I pool all periods for each bone. The modern White United States control sample comes from 2 sources: people who willed their bodies and whose complete skeletons are now in the Terry Collection (6 males and 18 females) and skeletons submitted to us by law enforcement agencies for forensic evaluation during the 1960s and early 1970s. The 46 males (plus 30 fragments) and 43 females (plus 7 fragmentary skeletons) range in age from about 17 to 75, average only about 6 years older than the ancient mean age at death, and come from middle-class (or upper) origins. Dissecting-room skeletons of disadvantaged people exposed to tougher genetic, nutritional, and socioeconomic forces and dying at 61 (males) and 63 (females) are not comparable with ancient populations.

I gathered these data on 8 field trips between 1937 and 1972 with the aid of many archaeologists and administrators and support from Harvard University, the Jefferson Medical College, the University Museum, the Smithsonian Institution, N. I. M., J. S. Guggenheim Foundation, Wenner-Gren Foundation for Anthropological Research, the American Philosophical Society. I thank people and institutions for their help. This includes the following people who at different times helped with listing the data on pathology: *Diane Johnson, Ruth-Ann Sando, Judith Mintzes, Hazel Fermino and Gloria Jenkins*; assisting in collecting health data on living Philadelphians were *Dr. Santo Longo, Dr. Richard King* (then medical students), *Dr. Michael Little, Mrs. Judith Schermer Hare*. I thank the F. B. I. and other law-enforcement agencies for the opportunity to study their skeletal material.

Material comes from the following sites: Çatal Hüyük, *Nea Nikomedeia*, Servia, *Franchthi cave, Lerna*, (Hageorgitika), *Astaka, Corinth, Athens, Aghios Kosmas, Karataş, Eleusis, Argos, Asine, Mykenai, Aghios Stephanos*, (Skopelos), *Thorikos, (Markopoulos), (Dimini), Mideia*,

Table 1
Incidence of healed fractures
1. táblázat
Gyógyult törések előfordulási aránya

Cultural Period <i>Korszak</i>		Early Neolithic <i>Korai neolit</i>	Early Bronze <i>Korabronzkor</i>	Middle Bronze <i>Közép- bronzkor</i>	Late Bronze <i>Késő- bronzkor</i>	Early Iron Age <i>Koravaskor</i>	Classic <i>Antik</i>
Dates — <i>Év</i>		6500	3000	2000	1500	1150	650
Age at Death <i>Elhalálzási kor</i>	M	34	34	36	39*	39	45
	N	103	182	117	180	97	91
Skull — <i>Koponya</i>							
Vault <i>Boltozat</i>	M	0	1	2	1	2	0
	N	30	116	80	126	51	72
Nose <i>Orr</i>	M	0	4	6	4	4	8
	N	19	61	54	49	25	40
Jaw <i>Állkapocs</i>	M	0	0	0	0	0	0
	N	24	115	77	64	40	38
Vertebrae — <i>Csigolyák</i>							
Cervical <i>Nyaki</i>	M	0	0	0	0	0	0
	N	5	47	50	19	14	12
Thoracic <i>Mellkasi</i>	M	(17)	2	2	4	15	0
	N	6	61	50	29	20	13
Lumbar <i>Ágyéki</i>	M	0	2	0	0	5	(11)
	N	6	63	52	35	20	18
Lower Extremity — <i>Alsó végtag</i>							
Pelvis	M	0	0	0	0	0	0
	N	14	36	56	32	24	20
Femur	M	6	1	1	2	0	0
	N	36	114	68	64	46	30
Tibia	M	0	3	2	2	9	0
	N	24	81	52	52	33	22
Fibula	M	0	4	0	0	(13)	0
	N	10	24	28	15	15	9
Foot <i>Láb</i>	M	(13)	2	4	0	0	0
	N	15	60	56	32	25	10
Upper Extremity — <i>Felső végtag</i>							
Clavicle	M	(10)	2	0	0	0	0
	N	10	58	41	28	22	20
Humerus	M	0	3	0	2	3	3
	N	24	102	75	55	39	31
Radius	M	5	4	2	5	0	4
	N	22	68	60	39	29	25

* Note: Percentages distorted by small size of sample are in parentheses (). This inevitable difficulty, resulting from poor preservation of skeletons in the ground, means that the total frequencies listed by bone or period are not reliable; pooled percentages are more accurate but, of course, mask the overall effect of change at a particular period.

in percent, adult males*

százalékban, adultus férfiaknál*

Hellenistic <i>Hellén</i>		Roman <i>Római kor</i>	Medieval <i>Középkor</i>	Baroque <i>Barokk</i>	Romantic <i>Romantika</i> <i>kora</i>	Modern USA <i>Mai USA</i>	Ancient total by period <i>Együtt</i> <i>korszakonként</i>	Pooled <i>Összevontan</i>
300 B.C.	A.D. 120	600	1400	1800	1960			
42+	40	38—	34	40	43—			38.3
91	78	65	29	208	71			1241
1	0	2	7	1	6		1.5	1.2
85	64	61	28	180	64			893
5	9	9	4	6	31		5.4	5.6
62	53	44	23	164	58			594
0	0	0	0	0	4		0	0
35	13	22	3	8	54			458
0	0	0	0	0	0		0	0
11	9	3	3	4	41			177
0	0	0	0	(33)	4+	(6.6)		3.8
13	8	4	4	3	44			211
0	0	0	0	(20)	6+	(4.4)		2.1
13	13	4	4	5	46			235
0	0	0	(25)	0	0	(2.3)		.4
13	12	6	4	5	49			222
(6)	(7)	(0)	4	1	4	2.5		1.7
16	14	10	26	103	50			527
(7)	0	(0)	0	2	8+	2.2		2.4
15	12	8	23	49	47			371
(11)	0	(25)	0	(0)	5—	(4.8)		3.6
9	9	4	12	2	43			137
0	(9)	0	0	(50)	5	(7.1)		3.5
10	11	4	3	4	41			230
(8)	(11)	0	0	(25)	10	(6.0)		2.3
12	9	6	4	4	41			214
0	0	0	(8)	2	6+	1.9		1.9
17	12	9	12	43	47			419
0	(21)	(0)	(0)	0	6	3.7		3.7
15	14	7	7	14	49			300

* *Megjegyzés:* A minta csekély elemszáma miatt torzult százalékokat zárójelben adjuk meg. Ez az elkerülhetetlen nehézség a csontvázak kedvezőtlen megtartásából ered, és azt jelenti, hogy a csontonként vagy korszakonként felsorolt össz-gyakorisági adatok nem megbízhatóak; az összevont százalékszámok pontosabbak, de természetesen leplezik a változás átfogó hatását egy-egy meghatározott időszakban.

Cultural Period <i>Korszak</i>		Early Neolithic <i>Korai neolitikus</i>	Early Bronze <i>Korabronzkor</i>	Middle Bronze <i>Középbronzkor</i>	Late Bronze <i>Későbronzkor</i>	Early Iron age <i>Koravaskor</i>	Classic <i>Antik</i>
Dates — <i>Év</i>		6500	3000	2000	1500	1150	650
Ulna	M	12	8	5	10	5	(12)
	N	25	50	56	31	21	17
Hand	M	(0)	18	0	4	14	(0)
<i>Kéz</i>	N	6	33	53	23	22	10
Total — <i>Összesen</i>							
Bone average	M	(3.9)	3.3	1.5	2.1	4.4	2.3
<i>Csont átlag</i>							
Pooled — <i>Összevontan</i>	M	3.4	2.5	1.5	1.9	3.6	2.3—
	N	295	1089	908	693	446	387
Mean N	M	18.4	68.1	56.8	45.2	27.9	24.2
Wounds — <i>Sérülések</i>							
Vault	M	20	7	12	9	12	3
<i>Boltozat</i>	N	30	116	80	126	51	72

Heraion, (Nauplion), Pylos, Kephallenia (4 sites: Diakata, Metaxata, Mavrata, Mazarakata), (Salamis), (Marathon), Olynthus, Sounion, Laureion, (Thespiae), (Tanagra), (Kouvara), (Eretria), (Sparta), Halai, (Aigina), (Pelion), (Tripolis), (Leonidi), (Mandra). Sites italicized are multi-period; sites in parentheses produced only skulls.

Discussion

Total fracture frequencies in Tables 1 and 2 show two contrasts. First, females have just over half the fractures of males. Correction for the 3 to 9-year greater longevity of males would be very small according to modern data of BUHR and COOKE (1959), at most .1 or .2%. BUHR and COOKE (1959) show a 3:1 male:female ratio in their "wage-earning" fracture pattern (vertebral column, ribs, medial malleolus, foot, hand) and a 2:1 ratio in their "pre-wage-earning" pattern (tibia shaft, clavicle, distal humerus). Increasing age dramatically changes this female advantage. Ordinary dissecting room skeletons (Terry collection, 50 of each sex) average 6.6% for males aged 61 and 6.9% for females aged 63, and BUHR and COOKE's (1959) "post-wage-earning" pattern (proximal femur, pelvis, both malleoli, proximal humerus) similarly shows a 1:1.4 male:female ratio. This reversal of the natural advantage of females must reflect loss of bone with age (BAKER and ANGEL 1965, FROST 1964, 1966, TROTTER et al. 1960, GARN 1970). The second contrast is a doubling of fractures in modern times: overall ancient frequencies per bone are 2.6% (males) and 1.3% (females) compared with modern frequencies of 6.9% (males) and 3.5% (females). This contrast clearly results from our greater living hazards: automobiles, staircases, city crowding and violent crime. But the size of the difference is surprising. U.S. Black skeletons, aged 38, average under 3% per

1. táblázat folytatása

Hellenistic <i>Hellén</i>	Roman <i>Római kor</i>	Medieval <i>Középkor</i>	Baroque <i>Barokk</i>	Romantic <i>Romantika kora</i>	Modern USA <i>Maí USA</i>	Ancient total by period <i>Együtt korszakokonként</i>	Pooled <i>Összevontan</i>
300 B.C.	A.D. 120	600	1400	1800	1960		
(0)	(14)	(0)	(0)	(0)	0	(6.0)	7.4
12	14	6	6	4	49		242
0	(0)	0	(0)	(0)	9	(3.3)	5.6
12	10	4	3	3	35		179
2.4	4.4	(2.3)	(3.0)	(8.8)	6.6	(3.6)	2.8
2.3	4.3	2.9	3.6	3.4	6.9		2.6
350	277	204	165	595	758		5419
21.9	17.3	12.8	10.3	37.2	47.4	33.9	
9	6	15	7	6	11	9.6	8.6
85	64	16	28	180	64		893

bone. 191 male medical students (age 26) state 3.9%, 278 lower middle-class males (age 51) state 1.2% and 330 females (age 53) state only .9% fractures per bone; this population we sampled by a door-to-door personal health survey from Jefferson Medical College in Philadelphia and clearly received understatement of fractures.

Chronological change is not significant but is suggestive. With rise of civilization from seventh to second millennium B.C. (ANGEL 1946, 1972, in press) fractures diminish. During the disturbances of the Early Iron Age after the Trojan War fractures increase, with the rapid rise of Classical civilization they again decrease, and afterwards rise irregularly. Up to the development of modern industrial civilization fractures and cultural level tend to be negatively associated, as one expects.

The bone by bone pattern is more revealing. The commonest prehistoric injury is the parry fracture of the ulna usually in males from warding off a blow usually with the left forearm (cf. ANGEL 1970, 1971a). Then come fractures of lower thoracic vertebrae, hand, and radius, usually Colles' but occasionally from direct violence (ANGEL 1971) including the variety in which the biceps brachii supinates the upper fragment (ANGEL 1945). Humerus and lower extremity shaft fractures are usually rarest; healed greenstick fractures at Early Neolithic Çatal Hüyük plausibly come from children falling down roof entrance ladders in the dark (ANGEL 1971a), and a complex of foot injuries occurs at Middle Bronze Lerna (ANGEL 1971). Skull vault fractures are rare compared to head wounds, especially in males, from slingshots and hand-to-hand fighting. Nose fractures occur, but less often than expected. In historic times emphasis on forearm fractures continues and nose fractures apparently increase. Violence toward the head does not decrease.

Table 2
Incidence of healed fractures
2. táblázat
Gyógyult törések előfordulási aránya

Cultural Period <i>Korszak</i>	Early Neolithic <i>Korai neolitik</i>	Early Bronze <i>Kora- bronzkor</i>	Middle Bronze <i>Közép- bronzkor</i>	Late Bronze <i>Késő- bronzkor</i>	Early Iron Age <i>Koravaskor</i>	Classic <i>Antik</i>
Dates — <i>Év</i>	6500	3000	2000	1500	1150	650
Age at death <i>Elhalálzási kor</i>	M 30 N 156	30— 219	31 89	32 111	31 83	36 55
Skull — <i>Koponya</i>						
Vault <i>Boltozat</i>	M 0 N 61	0 96	0 55	0 77	2 50	0 40
Nose <i>Orr</i>	M 0 N 24	0 41	4 26	3 33	0 30	0 22
Jaw <i>Allkapocs</i>	M 3 N 71	1 99	0 61	0 52	0 53	0 25
Vertebrae — <i>Csigolyák</i>						
Cervical <i>Nyaki</i>	M 0 N 9	0 42	0 32	0 21	6 18	0 6
Thoracic <i>Mellkasi</i>	M 0 N 10	13 39	0 35	3 30	11 28	0 11
Lumbar <i>Ágyéki</i>	M (15) N 13	2 56	0 34	0 22	0 35	0 12
Lower Extremity — <i>Alsó végtag</i>						
Pelvis	M 0 N 19	0 40	2 45	3 38	3 32	0 16
Femur	M 5 N 43	2 123	2 54	0 50	0 52	0 21
Tibia	M 0 N 20	0 71	0 48	2 40	0 47	0 20
Fibula	M 0 N 11	0 15	0 16	0 11	0 14	0 18
Foot <i>Láb</i>	M 0 N 24	2 63	0 45	0 34	0 31	(11) 9
Upper Extremity — <i>Felső végtag</i>						
Clavicle	M 0 N 15	2 45	0 32	4 24	0 30	0 13
Humerus	M 6 N 34	0 107	2 54	0 43	0 52	0 24
Radius	M 0 N 20	2 54	4 47	0 31	5 41	0 16
Ulna	M 0 N 14	3 31	6 31	0 24	0 27	0 10

* Note: see Table 1. — *Megjegyzést lásd az 1. táblázatnál.*

in percent, adult females*

százalékban, adultus nőknél*

Hellenistic <i>Hellén</i>	Roman <i>Római kor</i>	Medieval <i>Középkor</i>	Baroque <i>Barokk</i>	Romantic <i>Romantika kora</i>	Modern USA <i>Mai USA</i>	Ancient total by period <i>Együtt, korszakonként</i>	Pooled <i>Összevontan</i>
300 B.C.	A.D. 120	600	1400	1800	1960		
36	35	31	28	37	40		32.5
38	50	28	26	29	48		884
0	0	0	0	0	0	.2	.2
37	33	26	25	20	46		520
0	4	0	0	0	5	1.0	1.1
25	27	20	20	14	42		282
0	0	0	0	0	2	.4	.7
24	18	10	3	2	43		418
0	0	0	0	0	2+	.5	.7
8	7	2	2	5	40		152
(8)	0	(0)	(0)	(0)	3-	(3.2)	5.4
13	11	2	2	5	39		186
0	0	0	0	0	3-	1.5	1.5
13	11	2	2	4	36		206
0	0	0	0	(14)	8	2.0	1.8
12	13	3	3	7	39		228
0	0	0	0	2	0	1.0	1.3
14	18	16	12	59	42		452
0	0	0	0	0	2+	.2	.3
10	14	3	17	27	40		317
0	0	0	0	0	3-	0	0
4	4	1	5	2	39		91
0	0	0	0	0	6	1.2	.9
9	6	3	2	5	34		231
(0)	(0)	0	0	0	8	.5	1.1
9	8	2	2	2	37		182
0	0	0	0	4	2+	1.1	1.0
15	17	5	6	28	40		385
(8)	(9)	(0)	(0)	0	8-	2.5	2.8
12	11	2	4	9	39		247
(13)	(17)	(0)	(0)	0	3-	(3.5)	3.1
8	6	2	2	5	39		160

Cultural Period <i>Korszak</i>	Early Neolithic <i>Korai neolitik</i>	Early Bronze <i>Korai bronzkor</i>	Middle Bronze <i>Közép- bronzkor</i>	Late Bronze <i>Késő- bronzkor</i>	Early Iron Age <i>Koravaskor</i>	Classic <i>Antik</i>	
Dates — <i>Év</i>	6500	3000	2000	1500	1150	650	
Hand	M	0	3	3	0	0	(17)
<i>Kéz</i>	N	8	31	38	25	21	6
Total — <i>Összesen</i>							
Bone average	M	1.8	1.9	1.4	.9	1.7	(1.8)
<i>Csont átlag</i>							
Pooled — <i>Összevontan</i>	M	2.0	1.5	1.4	.9	1.4	.8
	N	396	953	653	555	561	259
Mean \bar{N}	M	24.8	59.6	40.8	34.7	35.1	16.2
Wounds — <i>Sérülések</i>							
Vault	M	3	6	7	0	2	0
<i>Boltozat</i>	N	61	96	55	77	50	40

The modern sample is dominated by nose fractures in males, with zygoma just above half this high level. Then come clavicle, radius (*not* ulna), hand, tibia, skull vault in males and pelvis in females. Vertebral fractures don't increase proportionately. Modern increased violence aims at face and upper body with arms used to block falls rather than blows, because of less hand-to-hand fighting. Healed head wounds increase little, similarly. Dissecting-room populations may have been more on the receiving end of personal violence since nose fractures are at 42% for males and 13% for females and ulna fractures at 10% and 4%, though only one third of these are parry fractures. But the striking distinctiveness of this sample at age 62 is dominance of bone-loss fractures especially in females: femur (neck) fractures at 2% and 19%, (cf. ANGEL 1964), lumbar fractures at 0 and 8%, radius fractures (mostly Colles' and Smith's) at 4% and 15%, and fibula fractures (malleolus) at 14% and 10% respectively for males and females.

How many people had one or more fractures? At Middle Bronze Lerna I guess (ANGEL 1971) at least 10%. In the modern sample 31 of about 58 males and 14 of about 43 females — about one half and one third respectively — show fractures. 52 male and 22 female fractured bones give 1.7 per male and 1.6 per female showing fractures, or about 1 per male and .5 per female overall. 12 males and 6 females have more than one fracture each; 4 of the 12 have *only* skull vault plus nose or jaw fractures, and 7 of the remaining 13 males with nose fractures have no postcranial breaks (some are isolated skulls). Hence about 15% of each sex are prone to fractures, influenced by accidents in males and aging osteoporosis in females. In ancient times the proportion would have been less, but incompleteness of skeletons prevents accurate estimate.

Unhealed injuries apparently causing death I have omitted. Apparently fatal head wounds (cf. ANGEL 1943, 1945, 1968, 1970, 1971, 1971a, 1973) occur in all prehistoric periods, always rarely, usually in males. They appear to come from blows of club or axe, sometimes with radiating cracks or contre-coup

2. táblázat folytatása

Hellenistic Hellén	Roman Római kor	Medieval Középkor	Baroque Barokk	Romantic Romantika kora	Modern USA Mai USA	Ancient total by period Égyütt, korszakonként	Pooled Összetontan
300 B.C.	A.D. 120	600	1400	1800	1960		
0	0	—	0	0	3	2.1	2.0
9	4	0	2	3	38		147
1.8	(1.9)	(0)	(0)	(1.2)	3.6	(1.3)	1.5
1.4	1.4	0	0	1.5	3.5		1.3
222	208	89	109	197	633		4204
13.9	13.0	5.6	6.8	12.3	29.6	26.3	
0	6	0	8	5	7	3.4	3.5
37	33	26	25	20	46		520

effects, at least one with trephination (ANGEL 1971, 1973, also a healed trephination, 1943), perforations from arrows or spears, and a decapitation with hesitation marks (ANGEL 1945), perhaps done just after death; there is one example in historic times of Romantic date. Cut marks or other *ad mortem* damage to the thorax I have not seen, but this is difficult with archaeological material. The modern sample shows bony violence at death in 23 males and 13 females, although this is an overestimate because of the forensic origin of $\frac{3}{4}$ of the sample.

Summary

Eleven samples, averaging about 60 skeletons each, cover the changes in civilization in the Eastern Mediterranean from 7th millennium B.C. to 20th century A.D. and compare with a modern White American sample of over 100 skeletons averaging little older in age at death. Per bone frequency of fractures starting at 3.4% and 2.0% for males and females declines to 2nd millennium low of 1.7% and 1.2%, rises in Early Iron Age to 3.6% and 1.4%, drops to about 2.3% and 1% with Classical civilization, then fluctuates upward until spectacular modern rise to 6.9% and 3.5%. Females have fewer fractures throughout, especially in head and face, with least difference in vertebrae. Prehistoric parry fractures of ulna, head wounds, radius and hand fractures link with hand-to-hand fighting and lower thoracic vertebrae fractures with stress. Nose fractures increase a bit in historic times and dominate modern males, followed by clavicle, radius, hand, tibia, and in males skull and in females pelvis fractures: injuries to head end of body and falls. Dissecting-room samples dying at 62 show bone-loss pattern: femur neck, lumbar, pelvis, radius, ankle. Nose fractures rise 10% for socioeconomic reasons. Up to modern times fracture frequency is negatively associated with level of civilization.

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CSONTTÖRÉSEK MÓDJAI A NEOLITIKUMTÓL NAPJAINKIG

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(Összefoglalás)

Az átlagban egyenként 60 csontvázból álló tizenegy minta feloleli a keleti mediterrán térség civilizációs változásait az i. e. 7. évezredtől az i. sz. 20. századig. Ezt az anyagot összehasonlítjuk egy száznál nagyobb számú csontvázból álló mai fehér amerikai mintával, melynek egyedei a régi populációk születéskori átlagéletkoránál kissé idősebbek. A törések gyakorisága csontonként férfiaknál és nőknél 3,4, ill. 2,0%-kal kezdődik, és a 2. évezredre 1,7, ill. 1,2%-ra esik vissza; a koravaskorban 3,6, ill. 1,4%-ra emelkedik, az antik civilizációval 2,3, ill. 1%-ra esik le, azután fölfelé fluktuál a modernkori látványos 6,9, ill. 3,5%-os csúsig. A nőknél végig kevesebb a törés, kivált a fejen és arcon; az eltérés a legkisebb a csigolyákban. A történelem előtti korban a singsont ütések kivédése következtében előállott törései, a fejsébek, az orsócsont és a kéz törései a kézitusával vannak kapcsolatban, az alsó csigolyák törései pedig az erős igénybevétel következményei. Az orrtörések száma a történelmi időkben kissé emelkedik, és ezek dominálnak a mai férfiaknál; utánuk a kulcsesont, orsócsont, kéz, sípesont, valamint férfiaknál a koponya, nőknél pedig a medencecsont törései következnek: azaz a test felső részének sérülései és az esések. A 62 éves korban elhalt egyénekből álló bonctermi minták a csontvesztés módját mutatják: combnyak, ágyéki, medence, orsócsont és boka. Társadalmi-gazdasági okok miatt az orrtörések 10%-kal emelkednek. Egészen a mai időkig a törések gyakorisága negatív kapcsolatot mutat a kultúrszinthez.

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