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Patterns of Trauma among the Neandertals

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A high frequency of traumatic lesions and post-traumatic degenerative changes have been noted in Neandertal skeletons. To asses the implications of the *anatomical distribution* of these lesions, we have assigned them to one of seven regions: head/neck, trunk, shoulder/arm, hand, pelvis, leg and foot. The resultant distributions, both including and deleting injuries indicated only by post-traumatic degenerations and from Shanidar 1, were compared to anatomical lesion distributions for three Recent human archaeological samples (Bt-5, Libben and a pooled Nubian one), three modern clinical samples (late 20th century Albuquerque, early 20th century London and late 19th century New York City), and a specialized athletic sample (North American Rodeo performers). The majority of the Neandertal samples (as adjusted) are highly significantly different from the six normal Recent human samples, with only the most trimmed Neandertal sample being non-significantly different from the New York sample. However, all of the Neandertal distributions provide a close match to the Rodeo traumatic lesion pattern, primarily as a result of a high incidence of head & neck trauma. Although small sample size, preservation and a dearth of older individuals with inhibited mobility may contribute to the Neandertal lesion distribution, the similarity to the Rodeo lesion distribution suggests frequent close encounters with large ungulates unkindly disposed to the humans involved.

Keywords: NEANDERTALS, TRAUMA, STRESS, HUMAN PALEONTOLOGY.

Introduction

Traumatic lesions have been documented for the Neandertals of European and western Asia ever since Schaaffhausen (1858) described the fractured elbow and secondary consequences on the Neandertal 1 skeletal remains (see Schwalbe, 1901; Trinkhaus, Churchill & Ruff, 1994). Since then, it has become apparent that post-traumatic lesions are common on well-preserved Neandertal remains, with at least one (minor or major) defect being found on almost every reasonably complete partial skeleton of a Neandertal past the age of 25–30 years at death (Trinkaus, 1983; Brennan, 1991). This has implied an exceptionally high risk of injury among these late archaic humans, one that has been associated with their high frequencies of developmental lesions (Ogilvie, Curran & Trinkaus, 1989; Brennan, 1991) and probably low life expectancy (Trinkaus, 1994*a*) to indicate highly stressful lives (e.g. Brennan, 1991; Trinkaus, 1995*a,b*). It is also recognized that these healed or partially healed lesions indicate survival of the insult, in some cases for decades after the trauma (Trinkaus, 1983, 1995*b*).

Even though these lesions have been generally well-described and discussed for individual specimens, as well as with respect to their apparently high overall rate of incidence, it has not been possible to assess adequately the paleobiological implications of these lesions. This is due in part to the presence of lesions on both reasonably complete associated skeletons as well as isolated elements. More importantly, it is caused by difficulties in assigning ages-at-death to several of the specimens and especially the isolated elements; since the probability of accumulating one or more traumatic lesions increases with age, probably in a non-linear fashion given differential activity patterns and degrees of skeletal fragility in different life cycle segments, any age differences between samples could bias perceptions of stress levels. Consequently, it has not been possible to compute levels of risk (see Lovejoy & Heiple, 1981) for these Neandertal populations and to compare them to recent human samples.

Despite these limitations, combined with those inherent in any paleontological sample of incomplete material distributed over temporally and geographically dispersed populations, it is possible to gain some insight into Neandertal behavioural patterns by examining patterning in the *anatomical distribution* of their traumatic lesions. This is a method of analysis known since at least the work of Wood Jones (1910) but employed most often for the analysis of degenerative joint disease (e.g. Stewart, 1979; Jurmain, 1980; Bridges, 1992, 1994). From this perspective, we have attempted to test the null hypothesis that the anatomical distribution of traumatic injuries to the Neandertals falls within the range of variation of such distributions for normal recent human populations, given expected variations between human

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populations of contrasting social and economic conditions.

Materials and Methods

The Samples

To evaluate the anatomical distribution of traumatic lesions, data were tabulated from all of the available Neandertals, plus seven samples of Recent (later Holocene) humans. Six of the Recent human samples (three archaeological and three clinical) should be representative of the populations from which they derive with respect to the incidence of traumatic lesions; the last sample is a highly selected group of athletes. Since it is the anatomical distribution of lesions which is of concern here, the analytical samples are of the lesions, and not of the individuals sampled from the populations or local lineages in question. In the context of this, it should be noted that these samples were chosen in part for the availability of high quality data on sufficiently large samples of lesions; the latter aspect is important, since most of the skeletal samples which we or others have examined for the anatomical distribution of traumatic lesions have too little evidence of trauma to provide an adequately large sample of lesions for the kind of analysis undertaken here.

The Neandertal sample (Table 1) includes individuals referable to the Neandertal (*sensu lato*) lineage (Hublin, 1990; Trinkaus, 1991; Rak, 1993). They derive from deposits across western and central Europe and the Near East, and date between the middle of the last interglacial (*c.* 100 ka BP) and the middle of the last glacial (*c.* 35 ka BP). More specifically, the Krapina, Shanidar 4, and Tabun 1 remains probably derive from the middle of the last interglacial, whereas the remainder of the specimens derive from the early last glacial. Most of the specimens are distinct associated partial skeletons; the exceptions are the Šala 1 frontal and the Krapina remains. The latter fossils derive from the disarticulated and mixed remains of about two dozen individuals (Radovčić *et al.*, 1988; Trinkaus, 1995*a*), and it is possible that the five elements with lesions included here derive from less than five individuals.

Two of the archaeological samples derive from prehistoric American Midwest Amerindian sites, the Carlston Annis (Bt-5) late Archaic Period site in northern Kentucky (Belovich, 1993, pers. comm.) and the Woodland Period Libben Site in the Black Swamp of northern Ohio (Lovejoy *et al.*, 1977; Lovejoy & Heiple, 1981; Lovejoy, pers. comm.). The former represents a relatively mobile hunting–gathering group, whereas the latter derives from a sedentary village-based foraging society. The third archaeological sample is one pooled from a series of cemeteries along the Nile Valley upstream from Aswan in southern Egypt, or the northern part of Nubia (*sensu lato*), dating from the Pre-Dynastic Period to the post-Roman Christian Period (Elliot Smith & Wood Jones, 1910). This last sample combines remains from populations spanning several millennia and varied political conditions. It nonetheless represents economically uniform village agricultural groups who were subjected to varying degrees of warfare and interpersonal violence (Hoffman, 1979; James, 1979; Trigger *et al.*, 1983).

The three modern clinical samples all represent fractures diagnosed and/or reported in modern medical settings. The London sample represents "all cases of fracture which were treated in the receiving room of the London Hospital during the year of 1907" (Wood Jones, 1910: p. 294). The New York sample was similarly collected, including "all cases of fractures, trivial or serious" (Wood Jones, 1910: p. 295) noted by L. A. Stinson at the Hudson Hospital in New York City during the late 19th century. The New Mexico sample derives from the 1992–1993 State of New Mexico Workers' Compensation disability list (NM Workers Compensation Administration, 1993), and includes all injuries reported as fractures. Since the last sample includes cases in which the individual was likely to obtain compensation for employment-related injury, it includes only fractures inflicted during work; this may bias the distribution toward ones associated with industrial (machine-related) activities.

The last sample represents a group of individuals who voluntarily engage in a high risk, physically-demanding professional sport, the North American Rodeo. The available data, provided by the Professional Rodeo Cowboys Association (P.R.C.A.) and the Mobile Sports Medicine Systems, Inc. (Andrews, 1992), records all reported injuries (N=2593) during the period of 1981 to 1990. This sample consists of a self-selected segment of the late 20th century North American population, whose behavioural pattern contrasts with that of the general urban–industrialized population from which it is drawn.

Data Collection and Analysis

The data tabulations by sample (Table 2) consist of counts, by functional anatomical region, of identified traumatic lesions. In each case, an effort was made to make the data as comparable as possible. However, given the different sources for these data, from both the living and the dead and from different authors, there are modest differences between the samples. However, they were tabulated and analysed in such a manner as to minimize the effects of any between sample contrasts in recording technique. In each case, the sample size consists of the number of identified lesions and not the number of individuals examined, and the counts by anatomical unit tabulate individual lesions or sets of probably related adjacent lesions.

The Neandertal sample consists of 27 lesions from 17 individuals, as described and referenced in Table 1. Most of them consist of clear fractures of ribs, limb bones or cranio–facial bones, in most cases verified by

Table 1. Traumatic lesions by individual for the Neandertal sample

Specimen	Sex	Bone	Lesion	Reference(s)
La Chapelle 1	M	C5-T3	Marked DJD with porosity, eburnation, Schmorl's nodes	Trinkaus, 1985*a*
		Rib	Anterior fracture	
		Os coxae	Marked unilateral DJD with porosity, eburnation and massive osteophytes	
La Ferrassie 1	M	Femur	Fractured greater trochanter	Trinkaus, 1985*a*
La Ferrassie 2	F	Fibula	Proximal diaphyseal fracture	Heim, 1982
Kebara 2	M	T5 & T6	Fractured spinous processes	Duday & Arensburg, 1991
		Metacarpal 2	Fractured proximal epiphysis	
Krapina 4	M?	Parietal	Exocranial injury	Radovčić *et al.*, 1988
Krapina 34.7	??	Parietal	Severe fracture	Radovčić *et al.*, 1988
Krapina 149	F?	Clavicle	Distal diaphyseal fracture	Gorjanović-Kramberger, 1908
Krapina 180	??	Ulna	Diaphyseal fracture and pseudoarthrosis	Gorjanović-Kramberger, 1908
Krapina 188.8	??	Ulna	Proximal diaphyseal fracture	Radovčić *et al.*, 1988
Neandertal 1	M	Occipital	Exocranial injury	Schwalbe, 1901
		Ulna	Proximal epiphyseal fracture	Schwalbe, 1901; Trinkaus *et al.*, 1994
La Quina 5	??	Upper limb	Probable injury to the left arm	Martin, 1923; Trinkaus *et al.*, 1994
Šala 1	F?	Frontal	Supraorbital exocranial injury	Vlček, 1969
Shanidar 1	M	Frontal	Exocranial squamosal injury	Trinkaus, 1983
		Zygomatic	Crushing lateral fracture	
		Humerus	Mid-distal diaphyseal fracture	
		Humerus	Distal epiphyseal pseudoarthrosis	
		Ankle, hallux	Markedly asymmetrical DJD	
		Metatarsal 5	Diaphyseal fracture	
Shanidar 3	M	Rib	Penetrating wound	Trinkaus, 1983
		Ankle & subtalar joint	Markedly asymmetrical DJD	
Shanidar 4	M	Rib	Fracture	Trinkaus, 1983
Shanidar 5	M	Frontal	Exocranial injury	Trinkaus, 1983
Tabun 1	F	Fibula	Distal diaphyseal lesion	

radiography. In four cases, lesions have been included which are certainly the result of post-traumatic degenerative joint disease (DJD) but are not associated with identifiable fractures, in part due to poor preservation. Three of these (La Chapelle-aux-Saints 1 left hip, the Shanidar 1 right talocrural and hallucial tarsometatarsal articulations, and the Shanidar 3 right talocrural and subtalar articulations) (Trinkaus, 1983, 1985*a*) consist of pronounced unilateral lower limb DJD (with extensive subchondral porosity and eburnation plus large osteophyte formation), in which the preserved contralateral side shows no evidence of degeneration. In addition, La Chapelle-aux-Saints 1 exhibits marked lower cervical and upper thoracic DJD (with extensive porosity, Schmorl's nodes, facet eburnation and osteophyte formation) (Trinkaus, 1985*a*), whereas its lower thoracic and lumbar vertebral regions are healthy; this contrasts with the more general pattern in which degenerative vertebral DJD is similar in the lower cervical and lumbar regions and serious DJD is proportionately rare in the thoracic region (Stewart, 1979; Bridges, 1994; Dawson & Trinkaus, 1995). In addition, one Neandertal individual, Shanidar 1, presents 22·2% of the 27 lesions.

Consequently, given the possible bias provided by this individual and by the inclusion of DJD lesions in addition to clear fractures for the Neandertal sample, lesions counts (Table 2) are tabulated four ways. First, the total count is provided ("Neandertal Total"). Second, Shanidar 1 is deleted from the sample, reducing the lesion count to 21 ("Neandertals w/o Shanidar 1"). Third, Shanidar 1 is included but the lesions identified only on the basis of DJD are deleted, providing a lesion sample of 23 ("Neandertals w/o DJD"). And

Table 2. Frequencies of traumatic lesions by anatomical region for four samples of Neandertals (total, without DJD, without Shanidar 1, and without Shanidar 1 plus lower limb degenerative joint disease), three recent human archeological samples (Bt-5, Libben, Nubia), three clinical samples (London, New York, and New Mexico) and one modern athlete sample (Rodeo). The raw count is followed by the percentage

	Head/ Neck	Trunk	Shoulder/ Arm	Hand	Pelvis	Leg	Foot
Neandertal total	8 29·6%	4 14·8%	7 25·9%	1 3·7%	1 3·7%	3 11·1%	3 11·1%
Neandertals w/o DJD	7 30·4%	4 17·4%	7 30·4%	1 4·3%	0 0·0%	3 13·0%	1 4·3%
Neandertals w/o Shan. 1	6 28·6%	4 19·0%	5 23·8%	1 4·8%	1 4·8%	3 14·3%	1 4·8%
Neand. w/o Shanidar 1 & DJD	5 27·8%	4 22·2%	5 27·8%	1 5·6%	0 0·0%	3 16·7%	0 0·0%
Bt-5 (*N*=223)	4 1·8%	114 51·1%	50 22·4%	14 6·3%	7 3·1%	20 9·0%	14 6·3%
Libben (*N*=94)	6 6·4%	20 21·3%	28 29·7%	0 0·0%	0 0·0%	37 39·4%	3 3·2%
Nubia (*N*=160)	17 10·6%	11 6·9%	85 53·1%	3 1·9%	6 3·8%	36 22·6%	2 1·3%
London (*N*=1730)	108 6·2%	121 7·0%	547 31·6%	421 24·4%	3 0·2%	409 23·6%	121 7·0%
New York (*N*=11959)	1640 13·7%	1469 12·3%	3025 25·3%	2624 21·9%	65 0·5%	2466 20·6%	670 5·6%
New Mexico (*N*=792)	13 1·6%	99 12·5%	183 23·1%	187 23·6%	17 2·1%	88 11·1%	205 25·9%
Rodeo (*N*=181)	71 39·2%	18 9·9%	47 25·9%	11 6·1%	6 3·3%	11 6·1%	17 9·4%

fourth, Shanidar 1 and the three additional lesions identified as post-traumatic given an unusual distribution of marked DJD (La Chapelle-aux-Saints 1 and Shanidar 3) were deleted, resulting in a minimum lesion count of 18 for the Neandertal sample ("Neandertals w/o Shanidar 1 & DJD").

In this, the tabulation for the Neandertals which is probably most comparable between the fossil sample and the Recent archaeological and clinical human samples is the third one, all but the DJD identified traumatic lesions. However, it is the total sample which is undoubtedly the most comparable to the Rodeo sample (see below). Consequently, it is the "Neandertals w/o DJD" tabulation which is primarily compared to the six representative Recent human samples (Figures 1 and 2; see below), whereas it is the "Neandertal Total" tabulation which is preferentially compared to the Rodeo sample (Figure 3).

For the Bt-5 and Libben Amerindian remains, the lesion counts are raw counts of observed fractures. For the Nubian sample, Wood Jones (1910) lumped together multiple adjacent rib fractures as one lesion, and included injuries (such as stab wounds) that likely caused death and showed no signs of healing. However, he did not include marks, such as from decapitation, that he interpreted as inflicted during postmortem manipulation of the body. The three clinical samples include counts of fractures observed clinically (and usually with radiographic confirmation).

The Rodeo data set consists of a tabulation of traumatic injuries, which are divided into "minor" and "severe" ones; it is not universally clear whether a fracture was associated with the injury, but the "severe" injuries counted either included evidence of fracture or were of such severity that, if untreated, were highly likely to cause bony reactions (exocranial reactions and articular DJD) comparable to the sum of the traumatic lesions counted on the fossil and skeletal remains. This resulted in a sample of 181 lesions that represents only 7·0% of the total number of injuries reported.

The lesions were tabulated by seven anatomical regions, head/neck, trunk, shoulder/arm, hand, pelvis, leg and foot. The first includes primarily cranial injuries, but also counts cervical injuries since those are related to head mobility. Trunk lesions are those occurring on the vertebrae, sternum and ribs, and hip injuries include both those to the pelvis as a whole plus

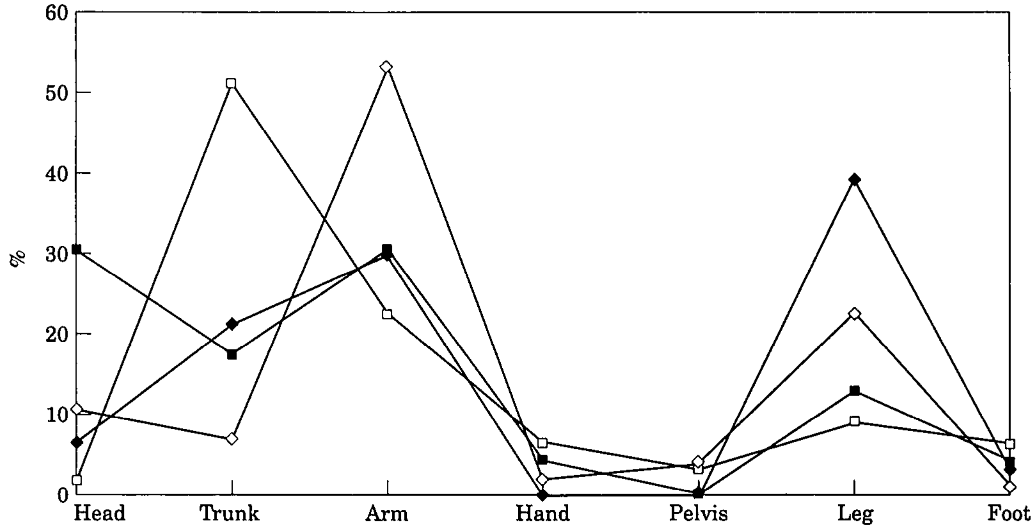

Figure 1. Percentage distributions of traumatic lesions by anatomical region for the Neandertals without DJD sample (solid squares) versus Recent human archeological samples. See Table 2 and text for sample composition. —■—: Neandertals; —□—: Bt-5; —◆—: Libben; —◇—Nubia.

those involving the acetabular articulation. Even though shoulder and proximal femoral injuries could be included with trunk and hip lesions respectively, given the tendency for authors to count the clavicle, scaplula and femur as portions of the limbs, they are here included as portions of the arm and leg respectively. Hands and feet are counted separately, since their frequent contact with objects and the substrate makes their susceptibility contrast with those of the long bones of the limbs.

For the clinical samples the whole skeleton is represented uniformly. In the archaeological samples, some loss and destruction of small and/or fragile elements (especially of the face, axial skeleton, hands and feet) may reduce their frequencies in the samples. The same taphonomic pattern of representation applies to the Neandertal sample. However, despite generally poorer preservation for the fossils, most of the individuals represented here are either moderately complete partial skeletons or derive from the Krapina sample, with its relatively complete preservation despite the dearth of some of the more fragile elements (Trinkaus, 1985*b*; Radovčić *et al.*, 1988). Only Šala 1 is represented by an isolated element, a complete frontal bone.

The raw data and percentage distributions are presented in Table 2. The percentage distributions for the appropriate Neandertal samples were then compared graphically to the archaeological samples (Figure 1), the modern clinical samples (Figure 2) and the Rodeo sample (Figure 3). In addition, chi-square and associated P values were computed, based on the raw lesion counts, between each Neandertal sample and the recent human ones, using Stat-Xact Turbo (Mehta & Patel, 1992) (Table 3). To ascertain which portions of the distributions were contributing most to the differences between the samples, the raw counts were further analysed using adjusted residuals of the chi-squares, in which the adjusted residuals are distributed as standard normal deviates (Everitt, 1975) (Table 4).

Results

The anatomical distribution of traumatic lesions among the Neandertals (the without DJD tabulation) exhibits both similarities and interesting contrasts relative to the Recent human archaeological and clinical samples (Table 2, Figures 1 & 2). Relative to all of them, the Neandertals have a high incidence of head and neck injuries, at 30·4%, more than twice that of the sample with the next highest figure, the New York clinical one at 13·7%. The Neandertals also have a modest number of leg injuries, with its figure of 13·0% being similar to those of the Bt-5 Archaic Amerindian sample (at 9.0%) and the New Mexico clinical sample (at 11.1%) but well below those of the other four samples. The percentage of Neandertal hand trauma (4·3%) is low compared to all three of the clinical samples, but it is matched by the three archaeological samples; this might reflect taphonomic biases affecting preservation in the skeletal samples or a higher incidence of hand injuries in the machinery-dependent clinical samples. For the other anatomical regions, the recent human samples are either uniformly similar to the Neandertals (pelvis) or scatter around the Neandertal value (trunk, shoulder/arm, and foot).

These patterns are confirmed by the global chi-square and associated P values (Table 3). In this, the Neandertal sample is significantly different from all three of the archaeological and two of the clinical samples; the one exception, the New York sample, is different only at the $P \approx 0{\cdot}15$ level. Examination of the

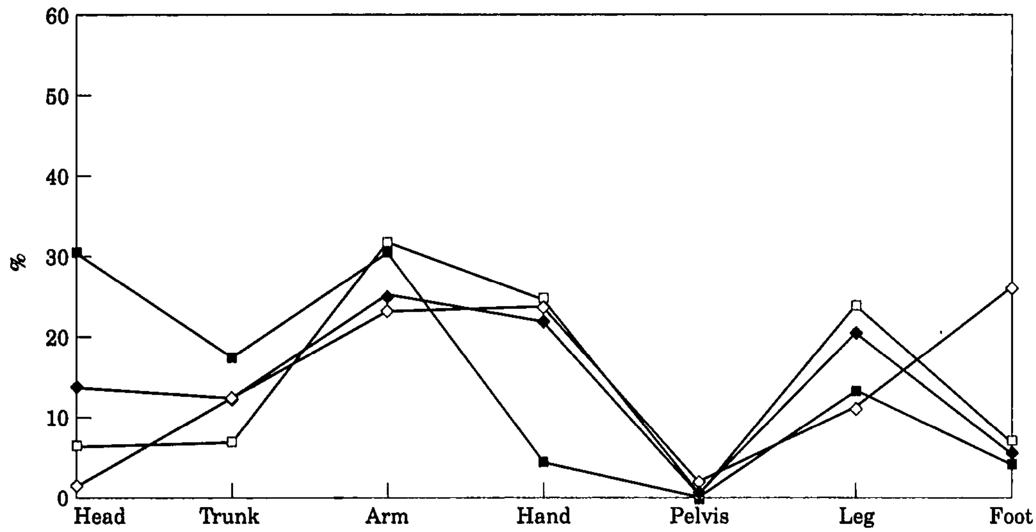

Figure 2. Percentage distributions of traumatic lesions by anatomical region for the Neandertals without DJD sample (solid squares) versus Recent human clinical samples. See Table 2 and text for sample composition. —■—: Neandertals; —□—: London; —◆—: New York; —◇—: New Mexico.

Table 3. Chi-square values and associated P values for pair-wise comparisons between each of the Neandertal samples and the recent human samples. Computed using Stat-Xact Turbo (Mehta & Patel, 1992)

	Neandertal total	Neandertals w/o DJD	Neandertals w/o Shanidar 1	Neandertals w/o Shandar 1 & DJD
Bt-5	46·97 $P<0·0001$***	45·12 $P<0·0001$***	38·55 $P<0·0001$***	35·19 $P<0·0001$***
Libben	25·03 $P=0·0003$***	17·66 $P=0·0034$**	20·53 $P=0·0022$**	15·04 $P=0·0102$*
Nubia	21·73 $P=0·0014$**	14·24 $P=0·0271$*	13·94 $P=0·0303$*	12·56 $P=0·0506$
London	46·27 $P<0·0001$***	28·82 $P=0·0001$***	43·85 $P<0·0001$***	22·90 $P=0·0008$***
New York	16·72 $P=0·0104$*	9·47 $P=0·1489$	14·20 $P=0·0275$*	7·52 $P=0·2754$
New Mexico	87·01 $P<0·0001$***	84·71 $P<0·0001$***	71·74 $P<0·0001$*	63·58 $P<0·0001$*
Rodeo	2·29 $P=0·8908$	4·41 $P=0·6075$	4·48 $P=0·6125$	7·72 $P=0·2594$

*$P<0·05$
**$P<0·01$
***$P<0·001$

chi-square-adjusted residual P levels (Table 4) largely confirms this pattern, in which all except the New York sample are significantly different at the $P<0·01$ level in at least one anatomical region. In this, however, even the New York sample is significantly different from the Neandertals without DJD sample at the $P<0·05$ level for both the head/neck and hand. In general, it is mostly the greater number of head injuries among the Neandertals that differentiates their distribution from the Recent human ones. These are combined with various contributions from other anatomical regions depending upon the sample (e.g. trunk for Bt-5, pelvis and leg for Libben, foot for Nubia, and pelvis for London).

The inclusion of the DJD-only lesions in the total Neandertal sample, or the deletion of Shanidar 1 or Shanidar 1 plus the DJD-only lesions have minor effects on the results (Tables 3 & 4). The total Neandertal sample is significantly different from all of the Recent archaeological and clinical samples at the

Table 4. Significance levels for chi-square-adjusted residuals for pairwise comparisons between each of the Neandertal samples and the recent human samples

	Head/ neck	Trunk	Shoulder/ arm	Hand	Pelvis	Leg	Foot
Neandertal total							
Bt-5	***	***	ns	ns	ns	ns	ns
Libben	***	ns	ns	ns	*	**	ns
Nubia	**	ns	**	ns	ns	ns	**
London	***	ns	ns	*	***	ns	ns
New York	*	ns	ns	*	*	ns	ns
New Mex.	***	ns	ns	*	ns	ns	ns
Rodeo	ns	ns	ns	ns	ns	ns	ns
Neandertals w/o DJD							
Bt-5	***	**	ns	ns	ns	ns	ns
Libben	**	ns	ns	*	ns	*	ns
Nubia	**	ns	*	ns	ns	ns	ns
London	***	*	ns	*	ns	ns	ns
New York	*	ns	ns	*	ns	ns	ns
New Mex.	***	ns	ns	*	ns	ns	*
Rodeo	ns	ns	ns	ns	ns	ns	ns
Neandertals w/o Shanidar 1							
Bt-5	***	**	ns	ns	ns	ns	ns
Libben	**	ns	ns	*	*	*	ns
Nubia	*	ns	*	ns	ns	ns	*
London	***	*	ns	*	***	ns	ns
New York	*	ns	ns	ns	**	ns	ns
New Mex.	***	ns	ns	*	ns	ns	*
Rodeo	ns	ns	ns	ns	ns	ns	ns
Neandertals w/o Shanidar 1 & DJD							
Bt-5	***	*	ns	ns	ns	ns	ns
Libben	**	ns	ns	*	ns	ns	ns
Nubia	*	*	*	ns	ns	ns	ns
London	***	*	ns	ns	ns	ns	ns
New York	ns	ns	ns	ns	ns	ns	ns
New Mex.	***	ns	ns	ns	ns	ns	*
Rodeo	ns	ns	ns	ns	ns	ns	ns

ns: not significant at the $P<0{\cdot}05$ level
*: $P<0{\cdot}05$
**: $P<0{\cdot}01$
***: $P<0{\cdot}001$

$P\leqslant 0{\cdot}01$ level, with the greatest contribution coming again from differences in the head/neck region. The Nubian and New York samples become only moderately significantly different from the Neandertal minus Shanidar 1 sample. And the New York and Nubian samples become non-significantly different from the Neandertal minus Shanidar 1 and DJD samples, even though the P value for the Nubian sample is equal to 0·05. Yet, for all of these cases except the New York versus the Neandertal minus Shanidar 1 and DJD-only lesion sample, a significant difference of at least $P<0{\cdot}05$ remains for the head/neck category, with scattered significant differences for the other anatomical regions depending upon the sample.

The pattern changes markedly with the comparison of the Neandertal lesion samples to the Rodeo athletes severe injury distribution (Tables 3 & 4, Figure 3). There are little more than trivial differences between the various Neandertal lesion tabulations and the Rodeo one. The Rodeo sample has a slightly higher head injury frequency, and the Neandertals have moderately higher trunk, arm and leg trauma rates. This is reflected in the chi-square-P values in which none of the comparisons approach significance at the $P<0{\cdot}20$ level, and most of them have $P>0{\cdot}60$. Most importantly, the best comparison between the Rodeo lesion sample and a Neandertal one, to the "Neandertal total" tabulation, produces a global chi-square-$P=0{\cdot}89$!

Discussion

These results therefore reject the null hypothesis that the anatomical distributions of traumatic lesions in the "Neandertal Total" and "Neandertals w/o Shanidar 1"

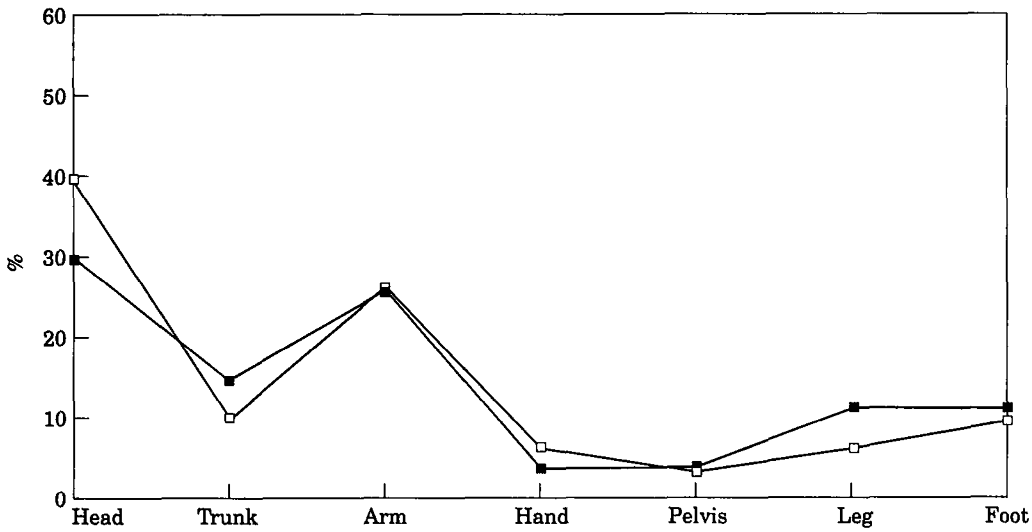

Figure 3. Percentage distributions of traumatic lesions by anatomical region for the Neandertal total lesion sample (solid squares) versus a sample of modern human Rodeo athletes. See Table 2 and text for sample composition. —■—: Neandertals; —□—: Rodeo.

samples fall within the range of variation of such distributions for normal recent human populations. It is possble to find a reasonably close fit (with P still $<0{\cdot}30$) only when the Neandertal sample is trimmed of both Shanidar 1 and DJD lesions. The Neandertal tabulation probably most comparable to the Recent human clinical and archaeological samples, the "Neandertal w/o DJD" sample, is approached only by the late 19th century New York clinical sample, and that still remains different at $P=0{\cdot}15$ overall and at $P<0{\cdot}05$ with respect to the incidence of head/neck and hand trauma.

The only sample which closely matches the Neandertal distributions is the unrepresentative, selected one of Rodeo athletes. These two samples are similar and contrast with the other samples, primarily in their high frequency of head and neck injuries. This raises the question as to what factor(s) might be responsible for both the contrast between the Neandertals and the six human population samples and the similarity between the Neandertal and Rodeo samples.

It is possible that the relatively small sample size for the Neandertal traumatic lesions, however tabulated, may have contributed through producing an unrepresentative sampling of the original distribution of Neandertal traumatic lesions. Moreover, the effects on the P values of deleting a minority of the fossil individuals (Tables 3 & 4) testifies to some sensitivity of the results to sample size. Yet, all of the chi-square-P value calculations were done using the raw counts of lesions (rather than percentages), so that true sample size was taken into account. Consequently, sample size alone is not likely to account for the pattern.

There is also the issue of differential preservation of skeletal elements. One would expect cranial remains to be differentially represented in the hominid sample, given the generally greater preservation and recognizability of them in Pleistocene deposits (Brain, 1981; Trinkaus, 1985*b*). Yet, only Šala 1 is represented by an isolated element (albeit a cranial one). The Neandertal partial skeletons closely fit the anatomical pattern of preservation of Recent human archaeological remains (Trinkaus, 1985*b*), and the Krapina remains are not very deviant from it (distinguished primarily by their abundance of dental remains and dearth of hand remains (Trinkaus, 1985*b*), the degree of which has been reduced by the identification of additional human postcranial elements from the site (Radovčić *et al.*, 1988).

At the same time, one must remember that the Neandertal sample retains few older individuals (Trinkaus, 1995*a*), and it is unlikely that it contains any who would have experienced senile osteoporosis. Consequently, the traumatic injuries are largely those which occurred during the prime age years of adulthood, with at least two of them (the arm fractures of Neandertal 1 and Shanidar 1) being sustained during immature life (Schwalbe, 1901; Trinkaus, 1983; Trinkaus *et al.*, 1994). This dearth of older individuals in the sample may, nonetheless, be correlated with one of the aspects of their lesion pattern; namely, the Neandertals exhibit few pelvic and leg injuries (especially if one deletes the three lower limb injuries identified only by unilateral DJD). Moreover, none of their lower limb injuries would have impeded locomotion (however painful they might have been), and a couple (especially the fibular injuries of La Ferrassie 2 and Tabun 1) are trivial. This is in contrast to the upper limb, where at least two individuals (Neandertal 1 and Shanidar 1) and possibly a third (La Quina 5) had traumatic experiences which seriously limited the utility of one limb (Trinkaus *et al.*, 1994). Since most of our Neandertal specimens derive from rockshelter deposits, it is possible that this pattern, as well as the dearth of older Neandertals in the sample (Trinkaus, 1995*a*), is the product of a need for maintained mobility among these hominids. Those no longer capable of keeping up with the social group, whether as a result of age or serious lower limb trauma, may have simply been left behind, to die in localities where their remains were not preserved and recovered.

This suggestion relies on the generally accepted assumption that all of the sampled Neandertal populations were highly mobile foragers, even though this view has been challenged, for the Levant in particular (Lieberman, 1993; Bar-Yosef, 1994; but see Trinkaus, 1993). In addition, although many have argued that the Neandertals took care of their elderly and seriously injured, based on some of the same lesions tabulated here (Table 1) and the presence of burials, we would argue from the dearth of older Neandertals (Trinkaus, 1995*a*) and the absence of incapacitating lower limb injury in our sample (Table 1), that these hominids did not sacrifice the survival of the social group as a whole when it was threatened by an immobile individual. The resultant bias in the record may therefore account for some of the patterning observed here in Neandertal traumatic lesions.

The overriding aspect in the distribution of traumatic lesions among the Neandertals, and the one feature that makes them most similar to the Rodeo athlete lesion sample, remains the high frequency of head and neck injuries. In this, these two samples are approached (in *P* values, if not particularly in absolute frequencies) (compare Tables 2 & 4) only by the late 19th century New York sample and, to a lesser extent, the Nubian one. In the Rodeo sample, the high incidence of head and neck injuries is undoubtedly a product of what is best described as "close encounters of a nasty kind," given their predilection for activities that either bring their heads into close contact with members of *Bos taurus* or propel them in unpredictable ways from the backs of irritated members of *Equus caballus* and large *B. indicus*. Their relatively high, but not exceptional, frequencies of shoulder and arm injuries are probably related to this behaviour as well. It is less clear why the New York and Nubian samples should approach the Neandertals in relative numbers of head and neck injuries. With respect to the latter it may be related to the generally high incidence of injuries from interpersonal violence experienced by these ecologically constrained populations along the Nile flood plain (Wood Jones, 1910); could the New York injury pattern be similarly attributed to interpersonal violence?

In any case, it is unlikely that Neandertal pattern is largely the result of such bellicose behaviour. Although interpersonal aggression undoubtedly occurred among members of Neandertal social groups, and we have one case (the Shanidar 3 rib injury) which can be interpreted as the result of interpersonal violence (Trinkaus, 1983), their undoubtedly low population densities probably made dispersal a far more viable alternative to conflict resolution than the interpersonal violence which so often characterizes conflict resolution among sedentary Recent human populations.

It appears more likely that behavioural patterns paralleling those of Rodeo athletes explain the Neandertal injury patterns. This is not meant to imply that Neandertals would have met the behavioural qualifications for membership in the P.R.C.A. More likely, it relates to their normal means of predation. For example, Stiner (1990, 1992, 1993) has argued for the active hunting of prime-aged medium-sized ungulates in the late Middle Paleolithic of central-western Italy, and Chase (1986) has similarly argued for the regular hunting of medium-sized ungulates by Neandertals in southwestern France. In addition, Chase (1986), Kozowski (1990), Stiner (1992) and Farizy, David & Jaubert (1994) have described faunal assemblages dominated by single prey species. In fact, at one late Middle Paleolithic site, Mauran in southern France, 99% of the faunal assemblage consists of the remains of large bovines (*Bison bison*) (Farizy *et al.*, 1994). The question remains whether the kinds of weaponry apparently available to them would have made close-quarter hunting essential (Churchill, 1993).

Assuming that many of the pointed lithic elements were indeed used as projectile points (although some were primarily used as scrapers, and only a minority of them show evidence of hafting microwear and/or impact fracture (Beyries, 1987; Shea, 1988, 1990), the resultant spears would have been thick and heavy, usable only as thrusting spears and not as effective throwing projectiles. Similarly, the wooden spears for which we have evidence [Clacton (Oakley *et al.*, 1977) and Lehringen (Jacob-Friesen, 1956)] would have been most effective in close quarter predation on ungulates. This combines with late archaic human morphological evidence (Trinkaus, 1983, 1992; Churchill & Trinkaus, 1990) suggesting infrequent throwing behaviour among the Neandertals, despite their elevated upper limb strength (Trinkaus, 1983; Churchill, 1994; Trinkaus *et al.*, 1994). Given the tendency of ungulates to react strongly to being impaled, the frequency of head and neck, as well as upper limb, injuries seen in the Neandertals should not be surprising.

Following on this, it is interesting that even though traumatic injuries are present among both male and female Neandertals, 85·7% of the head and neck injuries on individuals for whom sex can be reasonably inferred ($N=7$) are from males (Table 1). This would support arguments (e.g. Frayer & Wolpoff, 1985), based on the degree of sexual dimorphism of the Neandertals (Smith, 1980; Trinkaus, 1980; Heim, 1983), that there was a sexual division of labour among the Neandertals (at least in some activities). However, if one compares this frequency (six males versus one female) to the distribution by sex of reasonably complete Neandertal crania (12 males versus seven females), the sex distributions are not significantly different (chi-square-$P=0{\cdot}274$), suggesting that most (but not necessarily all) of this sex difference in head/neck injuries is due to a sex bias in the original sample.

Finally, it should be noted that the most appropriate comparison for the Neandertals has not been included, that provided by Paleolithic early modern human remains from Europe and the Near East. Those are the populations which experienced foraging adaptations most similar to those of Neandertals. There were nonetheless significant improvements in hunting technology, involving the development of bone points and hafting elements and the production of standardized elongated blades and points which could be effectively hafted into projectile weaponry, with the early Upper Paleolithic of Europe and the pre-Aurignacian transitional industries of the Levant (Marks & Volkman, 1983; Volkman & Kaufman, 1983; Mellars, 1989; Kozowski, 1990). Lesion data comparable to that for the Neandertals are currently not available for Upper Paleolithic human remains, but notes on individual specimens or samples (e.g. Bonnet, 1919; McCown & Keith, 1939; Jelínek, 1954; Dastugue, 1967; Brennan, 1991; Vlček, 1991) note primarily injuries of the cranium and upper limb. This suggests, but in no way confirms, that the pattern observed among the Neandertals may have characterized later Paleolithic populations in general and not just the Neandertals. It should also be noted that Weidenreich (1943, 1951) noted high frequencies of cranial injuries in the Zhou-Kou-Dian and Ngandong Middle Pleistocene hominid sample, although the rarity of postcranial elements and the absence of associated skeletons in those samples precludes knowing whether this reflects a predominance of cranial trauma or merely an overall high level of bodily injury.

Conclusion

The anatomical distribution of traumatic lesions among the European and Near Eastern Neandertals documents an exceptionally high rate of head and neck injury among them. This is accompanied by a relatively high rate of shoulder and arm trauma and proportionately low amounts of lower limb injury, as well as by an absence of healed lower limb injuries serious enough to prevent moblity. Even though this pattern is approached probabilistically by two Recent human samples, it is most closely matched by the pattern seen in North American professional Rodeo athletes. Consequently, it is proposed that this overall pattern was the product of frequent close encounters of a dangerous kind with prey animals (promoted by a projectile technology which required proximity to those animals), combined with differential mobility and survival of individuals with severe lower limb injuries.

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