Paleoepidemiology of Degenerative Joint Disease

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Introduction

In order to contribute significantly to the description and understanding of human disease, paleoepidemiology must first recognize requirements which epidemiologists have long considered essential: 1) that the populations sampled are relevant to a set of specific hypotheses concerning a particular set of diseases; 2) that an adequate sample is employed to accurately represent the whole population; and 3) that wherever possible, sex and age parameters are accurately controlled.

Given a specific set of hypotheses worthy of being tested, paleoepidemiology can be used not only to describe the distribution of significant human diseases but also to help untangle and explain their etiology.

Epidemiology of Rheumatic Diseases

The rheumatic diseases have long been a focus of epidemiological research with emphasis placed on describing their distribution and severity by sex, age, and occupation.[1] General epidemiological information is gathered either by questionnaire survey to ascertain frequency of rheumatic complaints or by radiological survey of individual joints; the most comprehensive series of studies employ both approaches. Over a number of years Kellgren, Law-

rence, and their associates have extensively studied two English populations comprising over 4,000 individuals.[2-7] The populations sampled were specifically selected in order to test a set of hypotheses concerning the association of stress involved in mining occupations and the incidence of degenerative disease.

Similar studies, though of shorter duration, have been done in Finland,[8] the Netherlands,[9] Bulgaria,[10] Jamaica,[11] and the United States.[12-15] General epidemiological data on the incidence of rheumatic diseases have also been gathered from populations seen at autopsy.[16-21]

Osteological analysis of the incidence of degenerative rheumatic disease has so far been limited primarily to studies of the vertebral column.[22-28] Paleoepidemiological studies of degenerative disease of the peripheral skeleton have been rare, the only systematic research being done by Brothwell,[29] Anderson,[30] and Ortner.[31]

Paleoepidemiological Analysis of Degenerative Joint Disease

Paleoepidemiology of osteological remains can contribute additional perspectives to that offered by standard epidemiological investigation of recent populations. Tremendous dimension in time is added, encompassing varied populations with radically different lifestyles from those usually sampled today. Moreover, paleoepidemiology can also add a wide geographical perspective, for cadaver series and most epidemiological studies are usually confined to predominantly urban areas.

The kinds of degenerative changes seen on x-ray and particularly those seen at autopsy are analogous to those seen on direct visual examination of bones. The typical features of degenerative joint disease diagnosed by direct osteological examination include: 1) osteophytosis, or bony lipping around the periphery of the joint, 2) eburnation, or polishing of the articular surface, and 3) pitting, eventual destruction and remodeling of the articular surface.

Differential diagnosis is usually not a problem, but care must be employed to isolate the different aspects of degenerative disease (sometimes covered by the general names "arthritis" or "osteoarthritis," but these are ill-defined terms and clinically actually are misnomers):

1) *Spinal arthritis* (more properly called spondylosis or osteophytosis)—affects the fibrocartilage intervertebral joints, and its etiology and pathogenesis are distinct from degenerative joint disease of synovial joints;

2) *Rheumatoid arthritis*—affects the peripheral synovial joints by a predominantly lytic process with little or no hypertrophic bone formation[32];

3) *Degenerative joint disease*—affects the peripheral synovial joints and is characterized by a mixed pattern of hypertrophic bone formation (osteophyte) and lytic processes of the articular surface.

Materials and Methods

Four human skeletal populations sampled varied both in space and time. Modern American whites and blacks were represented by macerated specimens that came to autopsy at Washington University in St. Louis (these skeletons now comprise the Terry Collection at the Smithsonian Institution). The two other populations included 12th century American Indians from Pecos Pueblo, New Mexico (stored at the Peabody Museum, Harvard University), and protohistoric Alaskan Eskimos (also from the Smithsonian Institution).

These populations were selected because they differ greatly in their relationships to their respective environments. Eskimos use their bodies in a more rigorous fashion than either modern Americans or Pueblo Indians; therefore, the hypothesis to be tested concerns the effects of severe functional stress on degenerative disease. If such stress is an important etiological factor in the distribution of degenerative disease, Eskimos should show the greatest damage

and the most severe involvement of their joints, particularly in those areas under the most functional stress.

The osteological samples used are as follows:

TERRY COLLECTION		PECOS COLLECTION	
white males	107	males	111
white females	103	females	97
total	210	total	208
black males	116	ESKIMO COLLECTION	
black females	118	males	80
total	234	females	66
		total	146

TOTAL SAMPLE = 798

Degenerative joint disease is analyzed through the use of ordinally scaled variables. Such grading criteria are used routinely in analysis of degenerative skeletal involvement, particularly in the vertebral column;[22,33] moreover, similar criteria are used to rate degenerative changes seen on x-ray[34] and at autopsy.[17]

In an earlier analysis[35] the four large peripheral joints (knee, hip, shoulder, and elbow) were investigated, but the most epidemiologically significant results related to the elbow joint; therefore, this joint will be the only one discussed here.

Degenerative Disease of the Elbow

Sixteen areas of localized degenerative involvement were rated for both right and left sides on the distal humerus, proximal ulna, and proximal radius:

1) *On the Distal Humerus:*
   a. Trochlea, medial margin
   b. Lateral trochlear ridge
   c. Capitulum, lateral margin
   d. Olecranon fossa
   e. Coronoid fossa
   f. Trochlea, articular surface
   g. Capitulum, articular surface

2) *On the Proximal Ulna:*
   a. Coronoid process, marginal lipping
   b. Olecranon process, marginal lipping
   c. Radial facet, marginal lipping
   d. Coronoid process, articular surface
   e. Olecranon process, articular surface
   f. Radial facet, articular surface

3) *On the Proximal Radius:*
   a. Head, superior surface
   b. Head, inferior margin
   c. Head, lateral articular surface

In addition to the 16 primary variables listed above, biological age was also used in the analysis. For the Terry Collection age was accurately documented on morgue records, but for the two archaeological populations standard techniques of age determination by pubic symphysis analysis were employed;[36-38] however, since aging by pubic symphysis analysis provides only a rough estimate of biological age, individuals were bracketed into ten-year categories.

The degree of severity of degenerative disease for the entire elbow joint was calculated by adding the 16 individual indicators of degenerative involvement and then recoding them into three categories: none/slight, moderate, and severe. This coding was calibrated as closely as possible with autopsy data[17] and clinical information concerning actual morbid changes.[39]

Results

The distributions of moderate and severe involvement for right and left elbow joints by age and sex are shown in Figures 1 through 4. As is readily apparent, compared to other populations, the joints of Eskimos are much more commonly and severely involved. Significance levels from χ^2 tests for cross-population comparisons are seen in Table 1.

In addition, this pattern of degenerative involvement tends to occur earlier in males than in females and is generally more severe on the right side of the body; in fact, the generally earlier age of onset in the right elbow is true for males from all four populations. Females present a mixed picture: white females are not involved at all on either side until late in life (sixth decade) and then only slightly; black females are involved earlier (fourth decade) and tend to be consistently more affected on the right side; however, Pecos and Eskimo females show earlier onset in the left elbow and generally more common and severe involvement of this side.

Endocrine factors have been suggested as a possible contributing factor in the onset of degenerative disease, primarily from epidemiological evidence indicating sharply increased incidence in late-middle-aged females.[40] Among Pecos females a possible role of endocrine factors is also suggested for the elbow joint where there is a sharp rise in frequency for both

right and left elbows in late middle age (fifth to sixth decades), with no severe lesions occurring before this age.

Black females are never severely involved before the sixth decade at which time both right and left elbows become affected; moreover, they show an increased frequency of involvement at this time which is most marked on the left side. White females also are not affected until the sixth decade when they are only very slightly involved. On the other hand, Eskimo females do not exhibit this pattern; indeed, the frequencies of involvement tend to decrease in late middle age (sample size of Eskimo females 41-50: Right elbow = 9; Left elbow = 5).

In order to isolate and understand the significant patterns of variation within the elbow joint, factor analysis[41] was performed using the 16 primary variables plus biological age. For the entire Terry Collection (black and white combined; N = 444) the pattern of variation is first displayed by an unrotated principal components solution (Table 2). As expected in this technique, the initial factor (Eigenvalue = 6.39; % of variation = 37.6) displays moderate loadings for all variables, possibly suggesting the presence of a generalized elbow osteoarthritis factor; however, the effect of age is markedly less in this joint than is true for the knee,[42] shoulder, or hip.[35] In fact, on this first generalized factor, age has the third lowest loading of all the variables.

The most associated variables are consistently related to osteophyte formation throughout the joint: inferior radial head, lateral capitulum, and on the olecranon process of the ulna. Changes within the radiohumeral articulation and the proximal radioulnar joint are also moderately associated on this initial factor.

Besides age, the most unassociated variables are the lateral trochlear ridge and the coronoid surface of the ulna. The least correlated areas along with age are thus related to the ulnohumeral articulation and its strictly flexion/extension movements within the elbow.

The second factor (Eigenvalue = 1.51; % of variation = 8.9) isolates degenerative changes in the ulnohumeral component as contrasted to those in either the radioulnar or the radiohumeral articulations. Functionally, this factor isolates variation associated with strict flexion/extension in an opposite direction from variation due to mainly pronation/supination (with some flexion/extension) within the joint. Interestingly, changes within the coronoid and

Fig.1. ELBOW JOINT – Males
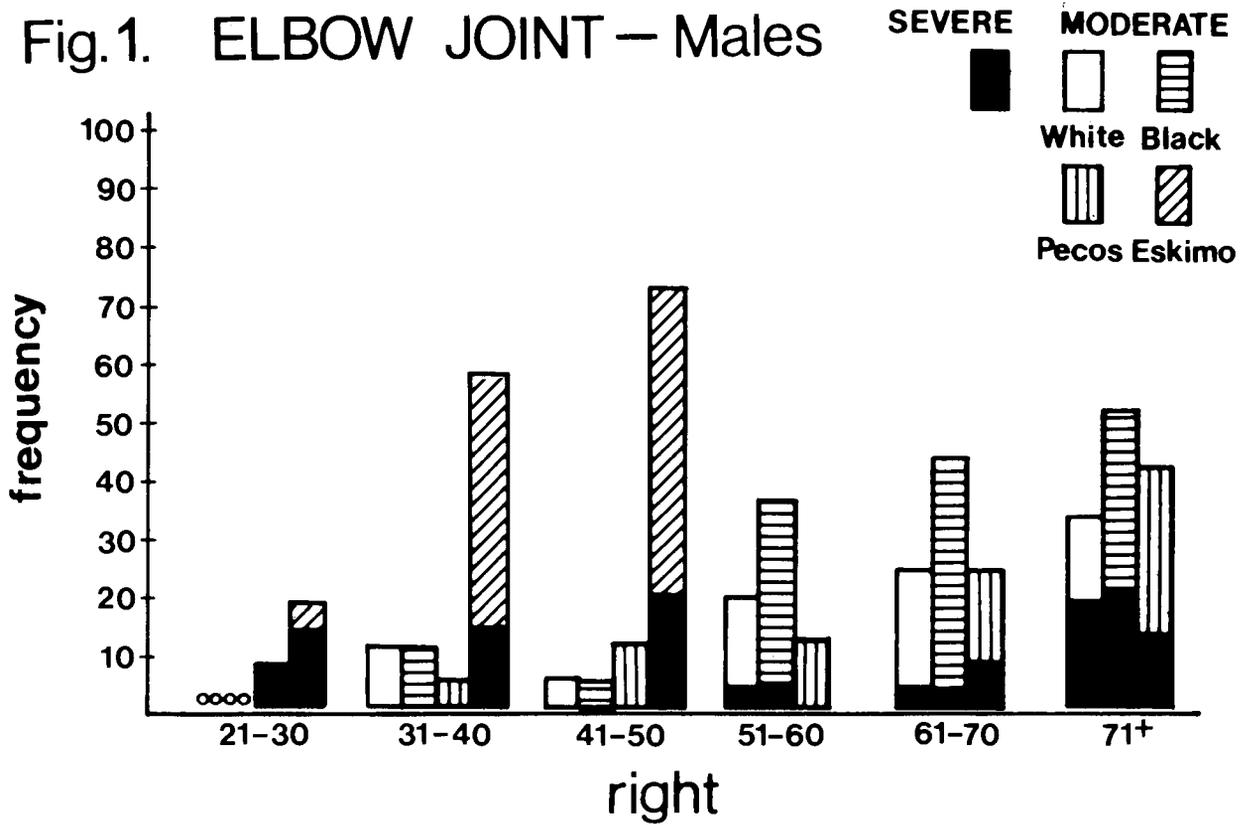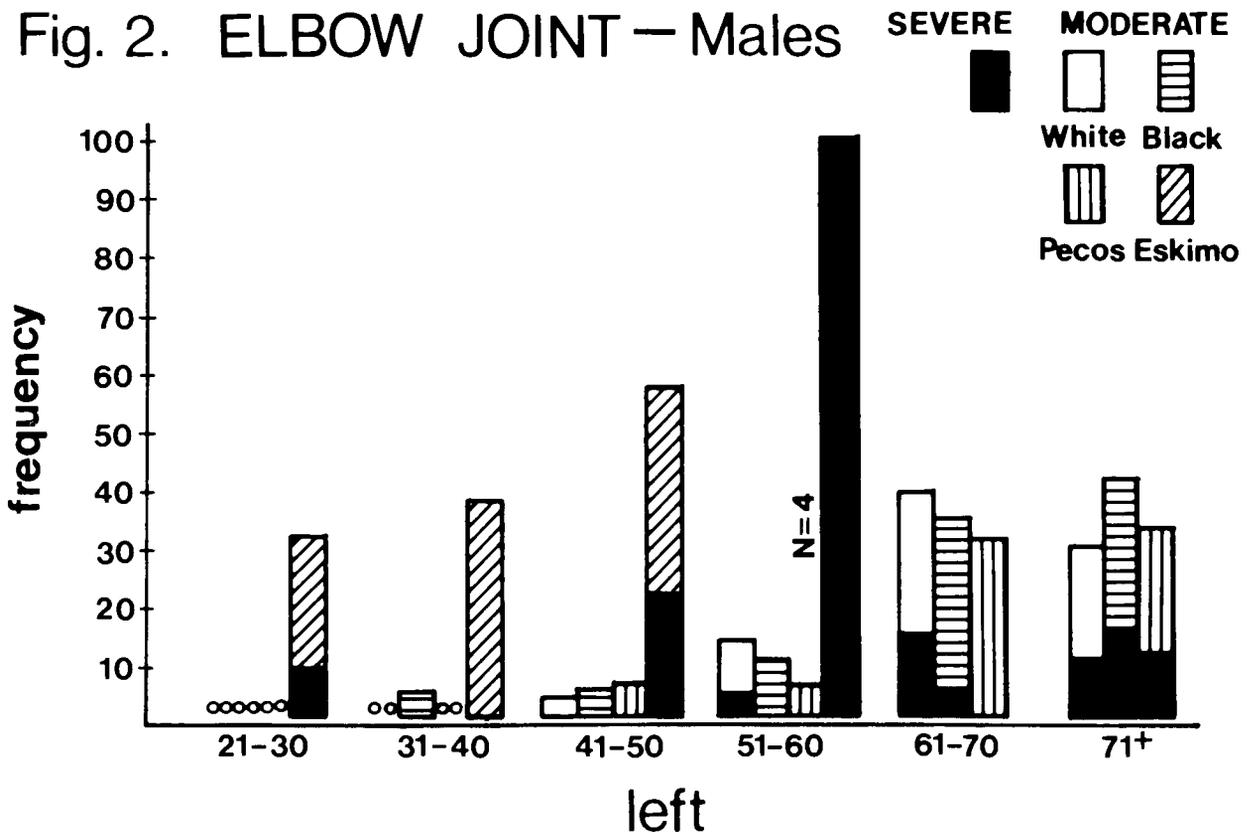
Fig. 2. ELBOW JOINT – Males

Figs 1 through 4—The distribution of moderate and severe involvement for right and left elbow joints by age and sex. N = sample size and is used when sample is unusually small.

Fig. 3. ELBOW JOINT—Females

SEVERE MODERATE

White Black

Pecos Eskimo

frequency

right

Fig. 4. ELBOW JOINT—Females

SEVERE MODERATE

White Black

Pecos Eskimo

frequency

left

TABLE 1
Statistical Measures of Significance Levels Between Study Groups

	Right elbow		Left elbow	
	21-40	41+	21-40	41+
MALES				
*Terry/Pecos	——	——	——	——
*Terry/Eskimo	0.001	0.001	0.001	0.001
Pecos/Eskimo	0.05	0.001	0.01	0.001
White/Black	——	——	——	——
FEMALES				
*Terry/Pecos	——	——	——	——
*Terry/Eskimo	0.05	——	0.01	0.001
Pecos/Eskimo	0.01	——	0.01	0.01
White/Black	——	0.10	——	0.10

* = White and Black combined
—— = > 0.10.

olecranon fossae vary directly with the pronation/supination component and inversely with those variables associated with strictly flexion/extension movements. Conversely, age is most associated with changes in the flexion/extension component but appears essentially independent of the pronation/supination function.

Rotation (oblique) simplifies this pattern of vari-

ation even further. The first rotated factor is most associated with those areas involved in rotary function: superior radial surface, capitular surface, inferior lipping of radial head, lipping of capitulum, lipping of the radial facet on the ulna, and lipping of the lateral margin of the head of the radius. In addition, other areas of osteophyte formation (trochlea, olecranon, coronoid processes) are also moderately loaded on this factor. Even more distinctly than in the unrotated solution, age and changes on the articular surfaces of the ulnohumeral component are now clearly unassociated.

Conversely, the second rotated factor is almost exclusively associated with variation in the ulnohumeral joint. The trochlear surface on the humerus as well as both surfaces of the olecranon and coronoid processes of the ulna are strongly associated here. The articular surface of the radial facet of the ulna is also highly loaded, and this is the only variable in any way connected with rotary function correlated with changes in the strictly flexion/extension component; however, surface changes in this part of the joint are independent of even peripheral lipping around this area. In fact, the Pearson correlation between these two variables (Ulna C and Ulna F) is only .2408. Apparently, surface changes on the radial

TABLE 2
Factor Loadings for Right Elbow Analysis—Terry Collection (N* = 444)

	UNROTATED (principal components)			ROTATED (oblique solution)		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Age	.42	−.44	.44			.74
Lateral trochlear ridge	.63	.11		.59		
Trochlea-medial margin	.38	−.44	.43			.72
Capitulum-lateral margin	.75	.11		.69	−.10	
Olecranon fossa	.64	.23		.69		
Coronoid fossa	.66	.34	−.13	.80		−.17
Trochlea-articular surface	.38	−.48	−.32		−.67	.11
Capitulum-articular surface	.66	.27		.74		
Coronoid process-lip	.63	−.22	.40	.31		.62
Olecranon process-lip	.75		.27	.57		.42
Radial facet-lip	.68	.16		.67		
Coronoid process-surface	.45	−.41	−.10		−.46	.27
Olecranon process-surface	.35	−.39	−.41		−.67	
Radial facet-surface	.45	−.37	−.55	.11	−.78	−.14
Radial head-superior surface	.75	.18	.12	.74		.16
Radial head-inferior margin	.83	.19		.82		
Radial head-lateral surface	.70	.13	−.15	.67	−.16	

Values < .1 are omitted
* N = number of individuals

facet are either in some way functionally tied to flexion/extension movements or act idiosyncratically with respect to elbow function. In this second factor, age is again insignificantly correlated, thus suggesting that aging does not play a major role in degeneration of either functional component within the elbow.

Only on the third factor in the rotated solution does age appear to be a primary factor in its association with the lateral trochlear ridge and lipping of the coronoid process of the ulna. Apparently, age does not act directly on variation within the major functional components of the elbow but only on a few localized areas. The consistent association of age with changes on the lateral trochlear ridge is probably explained by the particular coding for this variable, the first stage of which is characterized by rounding and rubbing down of this ridge. As Goodfellow and Bullough[43] noted, such progressive remodeling with closer joint congruity is characteristic of advancing age in the elbow.

Since the pattern of degenerative involvement of the elbow is especially distinct among Eskimos, this population was also subjected to multivariate analysis (Table 3).

Stress-correlated variation is even more distinct among the Eskimo sample than was true for the Terry Collection, as age is relatively the least correlated variable in the initial factor (compared to the third lowest in the Terry analysis). In the Eskimos there are again strong associations for all parts of the mixed rotary component of the elbow and relatively low ones for those related to strictly flexion-extension function; moreover, the Eskimos tend to show more relative involvement of those specific joint areas most associated with strong pronation/supination function of the forearm, the capitular surface of the humerus, and the superior surface of the head of the radius.

As with the Terry sample, osteophytes throughout the joint have significant loadings on this first factor. Since this initial factor is not heavily age-dependent, osteophyte formation seems to stand in a different functional relationship to surface degenerative change than is true for any of the other large peripheral joints.[35] In the elbow, osteophytes appear to form as a direct corollary of articular surface degeneration and are linked specifically to degeneration resulting from a strong mixed-rotary movement. Ortner[31] also has noted that degenerative changes in this part of the joint are related specifically to sporadically severe rather than constant stress.

This stress-associated factor contributes signifi-

TABLE 3
Factor Loadings for Right Elbow Analysis—Eskimo Collection (N* = 146)

| | UNROTATED (principal components) | | | ROTATED (oblique solution) | | |
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Age	.36	−.44	−.60			−.80
Lateral trochlear ridge	.80		−.15	.72		−.23
Trochlea-medial margin	.47	−.42	−.44	.17	−.13	−.67
Capitulum-lateral margin	.84	.24		.90		
Olecranon fossa	.82	.12		.79		
Coronoid fossa	.86	.24		.91		
Trochlea-articular surface	.39	−.63	.39	−.16	−.88	
Capitulum-articular surface	.85	.27		.94	.13	
Coronoid process-lip	.87	−.21		.60	−.34	−.23
Olecranon process-lip	.87	−.18		.64	−.26	−.27
Radial facet-lip	.85	.13		.83		
Coronoid process-surface	.54	−.50	.17		−.64	−.20
Olecranon process-surface	.54	−.30	.54	.18	−.74	.23
Radial facet-surface	.44	.15	.31	.45	−.17	.29
Radial head-superior surface	.88	.12		.85		
Radial head-inferior margin	.81	.12		.80		−.10
Radial head-lateral surface	.82	.30		.93		.10

Values < .1 are omitted
* N = number of individuals

cantly to the overall pattern of variation among the Eskimos when compared to modern Americans. In the Eskimo analysis the percentage of variation of this first factor is 53.6%, while for the Terry Collection it contributes only 37.6% to the total variation. The pattern of strictly sagittal function (Table 3, Factor 2) is also clearly distinct in the Eskimo population.

The respective rotated factor solutions clarify the above patterns with even greater emphasis among Eskimos on the radiohumeral articulation in the first factor and the ulnohumeral component in the second factor. The third factor also generally corresponds in the two populations, but in the Eskimos, age appears even more isolated from all other variation within the joint.

The results of the various factor analyses point clearly to the role of functional stress in degenerative involvement of the elbow. In fact, stress-associated variation appears to be of primary importance in this joint. Not only are there age-independent changes in the elbow, but they also tend to be localized with respect to variable joint function. The most pronounced pattern of degeneration is associated with mixed-rotary motion (especially the radiohumeral component), while degeneration of the ulnohumeral component (associated with strictly hinge motion) is secondary and independent of mixed-rotated function. While biological age contributes somewhat more to the sagittal functional component, it does not play any significant part in degenerative variation within the elbow (except for a tertiary effect on some localized areas).

Discussion

Function within the elbow is intimately associated with the nature and location of degenerative changes that occur there. The distinctive pattern of degeneration within the mixed-rotary component, seen particularly in Eskimos, is related to the greater amount of functional stress in this part of the joint. Within the radiohumeral articulation, two kinds of movements, rotation in pronation/supination and gliding in flexion/extension, occur conjointly, and there is thus quantitatively more rubbing in this part of the elbow than in other articular areas of the joint.[31,43,44] Degenerative changes are so marked here because the area over which stress is distributed in the radiohumeral articulation is quite small, being localized to the radial head and center of the capitulum; in fact, Ortner[31] estimates the total area of stress

distribution here as less than one fifth of that in the ulnohumeral component.

Soft tissue analysis has also confirmed the greater tendency for elbow involvement in the rotary component. Heine[17] observed the greatest amount of degeneration in the head of the radius, lateral trochlear ridge, and on the capitulum. In addition, Goodfellow and Bullough[43] in a study of 28 cadavers observed a similar pattern with the greatest degeneration on the complementary surfaces of the radiohumeral articulation.

In an osteological study of a small California Indian sample Angel[44] found 6 of 13 male elbows severely affected. He concluded that this high frequency of degenerative elbow disease was related to functional stress factors and suggests spear throwing with an atlatl as a likely possibility.

Angel further suggests the possibility of genetic factors in degenerative disease and cites Nagura's[45] findings of abnormally high frequencies of osteochondritis dissecans in the elbows of Japanese athletes. This condition, resulting from traumatically-induced avascular necrosis, was observed by Nagura to appear clinically more often in males and most often in the right elbow. Most of these cases were baseball players who subject their throwing arms to repeated severe functional stress. This condition appears to be fairly common in such individuals—although no epidemiological studies have been done—the inference being that chronic functional stress can cause severe degenerative disease in the elbow joints of young adults.

Epidemiological investigations have established a clear association between high levels of occupational stress and an increased incidence of degenerative elbow disease. Pneumatic tool use in particular has been observed to increase the frequency and severity of degenerative involvement.[46-49]

The significantly higher incidence and more severe involvement seen in Eskimos is also probably associated with high levels of functional stress; however, it is not sufficient merely to allude to a general correspondence between environmental stress and the incidence of degenerative joint disease. In order to build a convincing argument for its etiology, more precise data on specific modes of cultural behavior must be correlated with the pattern of degenerative involvement. If lifestyles do indeed influence the distribution of degenerative disease, it should be possible to frame hypotheses isolating the kinds of activities which are most likely to have degenerative effects

and those parts of the body which will most probably be involved.

Recent ethnographic studies, as well as ethnohistorical reconstruction, leave little doubt that extreme functional stress associated with the environment is an unavoidable concomitant of Eskimo life.[50,51] Stress associated with this lifestyle is both often of a high amplitude and lasts a good part of the day throughout the year. It is not surprising, therefore, that Eskimos have the highest frequency and greatest severity of degenerative disease of any of the populations sampled. Eskimo lifestyles also demand that children become actively engaged at an early age[51]; thus, Eskimos, particularly males, have the earliest age of onset of degenerative disease.

The most significant environmental stresses and the ways in which they affect the elbow joint include all the common means of protohistoric arctic transportation. Sled driving was probably the most demanding exercise, subjecting all the large joints to both severe and frequent stress. Riding over rough ice was particularly arduous, jolting, jarring, and often throwing the driver off the sled.[50] The driver thus had to hold on constantly, placing severe stress on all joints of the upper limbs both right and left. Such physical activity agrees well with the pattern of elbow disease seen among Eskimos: both sides involved for both men and women. Since sled driving (and pushing) was often done by women as well as men, the correlation between the activity and the pattern of involvement is noteworthy. Surprisingly, Nelson[50] in a full year of study of modern Eskimos did not observe a single case of extreme trauma associated with sled driving, the worst injury being a severe leg bruise. The stress effect of this activity, thus, probably involves the cumulative result of repeated traumata similar to those observed in epidemiological studies of pneumatic drill users.

Leaning on an ice prod while walking on ice or thrusting through the surface of the ice to check for depth also places great amounts of bilateral stress on the arms. Either of these activities could well contribute to the high incidence of elbow disease among Eskimos. In addition, boat rowing subjects the upper limb to a great deal of stress. Such activity, involving repeated powerful extension of the arm, would place a high functional stress on the elbow especially; moreover, this would be largely bilateral in nature, again corresponding to the pattern of elbow involvement observed in the Eskimo population.

Other activities associated with hunting in boats,

such as harpooning, lancing, and holding onto the line, once a whale or walrus was harpooned, are all associated with considerable functional stress on the upper limbs. Moreover, two of these activities (harpooning and lancing) are laterally oriented and should thus affect the body asymmetrically. Such physical activities do, in fact, correlate well with the somewhat greater degree of right elbow involvement seen in male Eskimos.

All members of the community would have subjected their whole bodies, especially their upper extremities, to severe stress when pulling captured whales onto shore for butchering. This latter activity, taking several hours, would have added to the stress load on the upper limbs.

Extreme laterally oriented functional stress would have been involved in bird hunting with bolas or bow and arrows, an activity in which both men and women participated. The fact that degenerative elbow disease is extremely frequent in Eskimo women leading the traditional lifestyle as well as men may be associated with such common activity patterns; however, the customary Eskimo feminine activity of working hides may have been especially important in initiating degenerative elbow disease. This activity, demanding strong extension of the forearm, would have placed long-term severe stress on the elbow.

Table 4 summarizes the major forms of Eskimo cultural activities that would most likely influence the pattern of degenerative involvement.

Archaeological and ethnographic evidence concerning the lifestyle of Pueblo Indians indicate that the greatest amount of stress was associated with agricultural tasks. Initial clearing of fields, weeding, harvesting, and grinding corn in a metate all involved considerable stress, particularly on the upper limbs; however, ethnographic evidence from a modern Pueblo population indicates that the growing season was probably short in ancient times.[52] The frequency of applied functional stress should therefore have been correspondingly lower than that for Eskimos who were actively engaged in rigorous subsistence activities for most of the year. Almost certainly Eskimos regularly subjected their bodies to much more severe individual stress than was typical for Pueblo Indians.

Since the lifestyle of these settled agriculturists was apparently much less continuously strenuous than that which typified arctic hunters, it is noteworthy to find the severity of degenerative disease concomitantly higher for Eskimos than for Pueblo In-

TABLE 4
Eskimo Activity Patterns

	BILATERAL	UNILATERAL
MALES	Use of ice prod Sled driving and pushing Rowing; holding onto tow line	Harpooning, lancing; bola throwing; bow and arrow Butchering: whale and walrus
FEMALES	Sled driving and pushing Hide preparation	Bola throwing

dians. Therefore, there seems to be good evidence to support the hypothesis that stress-associated behavior can lead to earlier onset and more severe involvement of degenerative disease.

An alternative hypothesis could also include the effects of diet. The Eskimo diet consisted exclusively of meat,[50,51] while Pueblo Indians had only limited meat resources.[53] Experimental studies with mice[54,55] have found a correlation between high-fat diets and the incidence of degenerative disease; an association between serum cholesterol levels and osteoarthritis of the hands has also been found in humans.[56] However, if degenerative disease were stimulated by dietary/metabolically induced agents, it should be manifested as a general phenomenon throughout the body. Findings of a low incidence of osteoarthritis of the hands in Eskimos,[57] therefore, tend not to support such a systemic, metabolically oriented etiology.

The characteristic lifestyle of modern American urban populations also is not generally as functionally strenuous as that of the Eskimos, and degenerative elbow disease is significantly less frequent among modern Americans than among Eskimos. Comparisons between modern Americans and Pueblo Indians are not so distinct, as no significant differences in frequency of involvement are found. No doubt, certain occupational tasks (such as pneumatic tool use, heavy construction work, and others) could easily duplicate or exceed stress levels typical for settled agriculturists.

Among the modern American population sampled, blacks tend to show somewhat more involvement than whites which may also relate to levels of functional stress. Urban ethnography[58] indicates that blacks are more frequently employed in occupations demanding heavy manual labor than are whites; thus, the higher incidence of degenerative disease seen in black Americans may well be a direct result of the more severe functional demands of strenuous occupations. Once again there appears to be solid evidence pointing to a significant contribution of stress-associated factors in the etiology of degenerative joint disease.

Summary

Much of the paleoepidemiological data on degenerative elbow disease points strongly toward the influence of functional stress factors. Patterns of variation within the joint indicate that most changes are independent of age; moreover, the patterns of degenerative involvement are clearly localized to mixed-rotary and strictly sagittal, functional components within the elbow.

The distribution of elbow involvement within and between populations also strongly supports the stress hypothesis. Eskimos stand alone in the frequency and severity of involvement, and blacks tend to be more affected than whites. Furthermore, these differences are consistently more pronounced among males and tend to be expressed in more severe form on the right side of the body.

Finally, there is some indication that systemic factors are also acting in those groups not under severe cultural stress (that is, all females except Eskimos). White, black, and Pecos females all show a tendency to have sharply increased frequencies of involvement in late middle age, implying the possible influence of endocrine changes associated with menopause.

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