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Evidence for Spanish Influence on Activity Induced Musculoskeletal Stress Markers at Pecos Pueblo

NANCY E. MUNSON CHAPMAN†
Department of Anthropology, Arizona State University, Box 872402, Tempe, AZ 85287-2402, USA

ABSTRACT In the present study, hypotheses regarding the effect of Spanish contact on some habitual activities among the indigenous population of Pecos Pueblo, New Mexico, are tested using analyses of upper body musculoskeletal stress markers (MSM). Historical records demonstrate that the Spanish desired maize, animal hides, woven cotton mantas, and labour from the Puebloan Indians of this area. Therefore, it is hypothesized that a comparison of MSM data from pre- and post-Spanish contact groups at Pecos would display evidence of intensification of activities related to the procurement of these goods. The MSM data from this research do support the contention that Spanish contact had an effect on habitual activities performed by both sexes; however, the number of muscles demonstrating a statistically significant difference over time is limited. Yet trends in the mean MSM expression as well as rank order of these muscles and others uphold the hypothesized increase in maize production and processing as well as an increase in burden bearing. No evidence is found to support an increase in weaving activity. © 1997 John Wiley & Sons, Ltd.

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Introduction

Human skeletal remains have been utilized by anthropologists to investigate a wide variety of subjects including activity patterns among prehistoric and historic populations. One way to assess habitual activity patterns has been the use of skeletal and dental markers of stress, or activity induced pathologies.[1]

One specific kind of activity induced change to the skeleton or marker of occupational stress was observed in this work: musculoskeletal stress markers (MSM). These are distinct skeletal markings that occur where a muscle, tendon, or ligament inserts into the periosteum and the underlying bony cortex.[2] The study of MSM provides insight into muscle use, because bone is plastic and responds to muscular stress through morphological change. When muscle insertion sites are regularly subjected to stress, the number of capillaries in the periosteum increases, thereby stimulating osteonal remodelling at the point of greatest stress. This usually results in the hypertrophy of the bone at that area in the form of a rugged muscular attachment. The correlation between MSM development and specific muscle use is supported by various kinematic and electromyographic studies.[3–5] Many of the anthropological studies specifically examining evidence of musculoskeletal stresses involve historic populations for which written records of activities exist,[6–11] however, the analysis of MSM has been applied successfully to prehistoric human remains as well.[2,12–17]

†Correspondence to: N. E. Munson Chapman, Department of Anthropology, Arizona State University, Box 872402, Tempe, AZ 85287-2402, USA.

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The inhabitants of Pecos Pueblo were a large group of sedentary agriculturists who lived in north-central New Mexico from approximately AD 1200 until AD 1838 (Figure 1).[18,19] In 1598, the first Spanish settlement was established in New Mexico. The pueblos, including Pecos, were quickly subjugated. Along with the establishment of Spanish colonial interests in New Mexico came a system of land grants. The recipients of these grants were given access to the labour and products of the Pueblo groups on their lands.[20,21] Pecos also had close interaction with members of the Franciscan order, which included the construction of churches at the pueblo.[20]

The Spanish colonists were interested in extracting maize, animal hides, textiles in the form of woven cotton mantas (blankets), as well as labour from the indigenous groups (while the clergy viewed the Puebloans as souls to be saved).[19,20] Intensification of activities related to these goods is expected. Historically, Pueblo Indians, such as the inhabitants of Pecos, practiced a sexual division of labour[20,22,23] and there is no mention in the literature that the Spanish attempted to change established labour patterns at Pecos. Hence the MSM data may demonstrate the existence of gender specific chores.

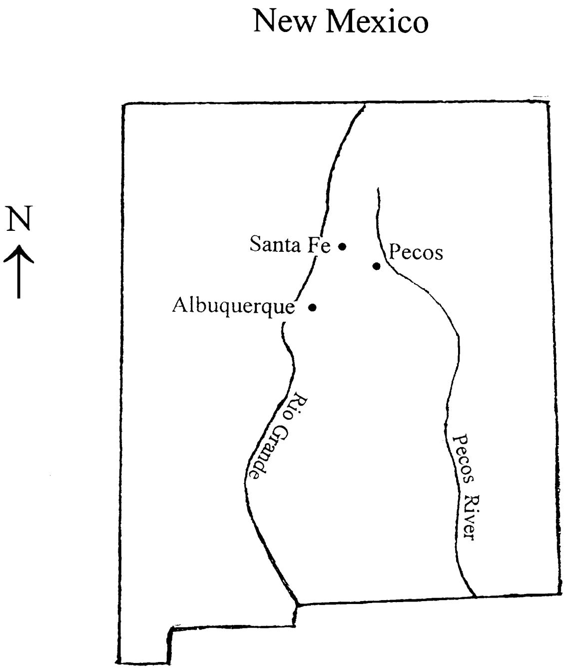

Figure 1. Sketch location of Pecos Pueblo in relation to modern Sante Fe and Albuquerque, New Mexico.

The first hypothesis tested in this study involved intensification of agricultural activities to produce surplus maize. Among males from Pecos an increase in maize production would be evident among MSM for *latissimus dorsi*, *deltoideus*, *brachialis*, *brachioradialis*, *triceps brachialis*, and *anconeus*; shoulder and arm muscles likely to be utilized during the planting and maintenance of crops as well as for a broad range of other activities. For example, the anterior fibres of *deltoideus* flex the arm and *latissimus dorsi* extends the arm as one hoes. *Brachialis* and *brachioradialis* flex the forearm as one pulls the hoe towards the body. *Triceps brachii* and *anconeus* are active in flexing and extending the forearm during movement of a digging stick in a vertical plane. Remains of digging sticks were recovered from Pecos.[24]

Second, the females of Pecos would exhibit an increased development of MSM for muscles such as *deltoideus*, *teres major* and *pectoralis major*, which were used in processing maize with manos and metates. Manos and metates were found at Pecos by the earliest Spanish visitors and recovered during Kidder's excavations.[24,25] Females assumed a kneeling position while holding the mano in both hands, and begin the grinding motion close to their body, moving the mano down and away from themselves, along the length of the metate. The stroke ends with the elbows flexed and the forearm fully adducted. The anterior fibres of *deltoideus* as well as *pectoralis major* flex the upper arm while the posterior fibres of *deltoideus* and *teres major* extend the upper arm. *Brachialis* and *triceps brachii* would flex and extend the forearm respectively.

Third, an intensification in the weaving of mantas, an activity documented as being performed by males,[22] would be a possible result of Spanish contact. Kidder reported evidence of weaving at Pecos with the recovery of loom loop holders in three kivas as well as eight weaving tools.[18,24] Therefore, increased robusticity is expected in the hand and wrist flexors and extensors, as well as the forearm supinators and pronators of Pecos males.

Table 1. Total number of individuals utilized for statistical analysis.

	Pre-contact		Post-contact	
	Female	Male	Female	Male
Young adult	32	13	14	15
Middle aged adult	27	33	19	22
Old adult	3	1	3	3
Total	62	47	36	40

The use of Pueblo inhabitants for labour to move products as well as construct various structures such as church buildings is the final aspect of this research. Males of Pecos pueblo would be expected to demonstrate an increase in MSM expression for the trapezoid and conoid ligaments, *deltoideus*, *trapezius*, *triceps brachii* and *biceps brachii*. These shoulder and arm muscles and ligaments could be utilized during burden-bearing for the Spanish between Pecos and the capital in Sante Fe, or other sites.[20] Males would have been responsible for making the adobe bricks and assembling the wood necessary for church architecture, as well. Another labour demand was for the procurement of salt, pinyons, and firewood for trade and local consumption.[23]

Materials and methods

The Pecos Pueblo skeletal collection represents over 1800 individuals recovered during excavations sponsored by Phillips Academy and directed by Alfred V. Kidder between 1915 and 1930.[18,26] Data for analysis were collected from 185 adult individuals (18 years of age or older). These individuals were chosen based on four criteria. The first criterion was membership in one of two time periods. This was accomplished utilizing Kidder's temporal placements of pottery accompanying the remains; glaze periods Black-on-White I and II correspond to AD 1200–1450 pre-contact, and periods V and VI correspond to post-AD 1600, Spanish contact. For greater ease I refer to these times as pre- and post-contact.

The second criterion was the degree of completeness of the remains. Third, the ability to confidently sex and age the remains was important. The sample was then divided into three categories: younger adults (18 to 35 years of age), middle aged adults (35 to 50 years of age), and older adults (greater than 50 years of age) (Table 1).

The last criterion for inclusion of specimens in this study was the presence of pathological conditions. In cases where it was felt that a pathological condition may have resulted in abnormal levels of muscle activity, all the affected/possibly affected bones were deleted from the study.

All upper extremity skeletal material including the clavicles, scapulae, humeri, radii, and ulnae were visually scored for three categories of musculoskeletal stress markers: robusticity markers, stress lesions, and ossification exostoses. Robusticity markers refer to the 'normal' skeletal reaction to habitual muscle activity. Stress lesions refer to those areas that display a groove into the bony cortex which superficially resembles a lytic lesion. Ossification exostoses are bony 'spurs' projecting from the cortex of the bone, which may be the result of abrupt macrotrauma.

The robusticity of 24 muscle attachment sites were observed; 21 muscle insertions and three muscle origins. Three ligament insertion sites were also recorded (Table 2). The method of scoring the expression of the MSM categories followed the system developed by Hawkey.[14] Under Hawkey's system, visual observations of the MSM sites are made and scored on a continuum of 0 to 3 (absent to strong) for each category. Intermediate scores, i.e. 1.5, can also be assigned. Written description of the scores for the three MSM categories, as well as illustrations of them, are presented elsewhere.[2,14]

To facilitate univariate statistical analyses of the data, the MSM expression scores were assigned the following numerical values: 0=no expression, 1=grade 1 robusticity, 2=grade 2 robusticity, 3=grade 3 robusticity, 4=grade 1 stress lesion, 5=grade 2 stress lesion, 6=grade 3 stress lesion. Unobservable muscle sites were coded as missing data and did not enter into any analyses. As ossification exostoses sometimes are the result of abrupt macrotrauma, they were recorded separately and are not included in the following statistical analyses.

Table 2. Muscle/ligament insertion and three origin sites utilized.

Muscle	Abbreviation	Location
Pectoralis minor	PMNR	Scapula
Trapezius	TRAP	Scapula
Subclavius	SUBC	Clavicle
Conoid ligament	CLIG	Clavicle
Rhomboid ligament	RLIG	Clavicle
Trapezoid ligament	TZLIG	Clavicle
Trapezius	TRAPC	Clavicle
Supraspinatus	SUPRA	Humerus
Infraspinatus	INFRA	Humerus
Teres minor	TMIN	Humerus
Subscapularis	SUBS	Humerus
Latissimus dorsi	LAT	Humerus
Teres major	TMJR	Humerus
Pectoralis major	PMJR	Humerus
Deltoideus	DELT	Humerus
Coracobrachialis	CORA	Humerus
Flexors[a]	FLEX	Humerus
Extensors[a]	EXT	Humerus
Triceps brachii	TRI	Ulna
Anconeus	ANC	Ulna
Brachialis	BRAC	Ulna
Supinator[a]	SUPO	Ulna
Biceps brachii	BIC	Radius
Supinator	SUPI	Radius
Pronator teres	PROT	Radius
Pronator quadratus	PROQ	Radius
Brachioradialis	BRAD	Radius

[a]Origin site of muscle attachment was utilized.

In the investigation of all the hypotheses, MSM from the right side of the body were utilized. This standardization was done to avoid the possibility that side dominance would skew results. In modern populations 90 per cent of individuals demonstrate a right side dominance in the upper limbs.[27] Hawkey demonstrated a similar finding in prehistoric as well as historic Thule and Gran Quivira populations.[14] Other works utilizing activity induced pathology observed that the majority of their samples demonstrated right-handedness.[6,12]

Table 3. Muscles/ligament demonstrating statistically significant relationship between MSM robusticity and age category for males and females from Pecos.

Males		Females	
Muscle	Location	Muscle	Location
Pectoralis major	Humerus	Rhomboid ligament	Clavicle
Deltoideus	Humerus	Pectoralis minor	Scapula
Teres minor	Humerus	Teres major	Humerus
Teres major	Humerus	Deltoideus	Humerus
Extensors[a]	Humerus	Flexors[a]	Humerus

[a]Origin site of muscle attachment was utilized.

Descriptive statistics including frequency of occurrence, percentage affected, mean expression score, and standard deviation were calculated for all muscle and ligament sites. Although a large sample size was obtained initially, later partitioning into groups based on sex, age, and time period yielded much reduced sample sizes. Unfortunately, not all muscle insertion sites were present on each individual, thereby further reducing the sample size. After preliminary descriptive statistics were calculated for all age groups, chi-square tests were performed to determine if significant differences existed in muscle robusticity betweeen young and middle-aged adults. Those muscles demonstrating such a relationship at a statistically significant level ($p \leqslant 0.05$) are listed in Table 3. For all other muscle insertion sites the younger and middle-aged adult groups were combined to increase sample sizes for the subsequent analyses. These statistical analyses were performed utilizing SAS 6.09[28] in a UNIX shell environment.

The degree of variance between time periods was calculated through the creation of weighted mean scores for muscle insertions by sex and time period. To examine more closely the question of sexual dimorphism, pairwise comparisons of the differences in the rank order of MSM scores were performed. Rank order comparisons are preferred because male and female MSM scores may be influenced by differences in overall body size.[2,14] A Spearman rank-order correlation coefficient was calculated by hand on the rank orders to invesigate possible change through time. For all analyses of variance, the level of statistical significance was set at $p \leqslant 0.05$.

Results

The mean MSM values for each muscle site by age, sex, and time period are presented in Tables 4 through 7. A weighted mean was determined to create a statistical break point between the largest and smallest values, reflecting the most and least active muscles. It should be noted that none of the mean MSM expressions increased or

Table 4. MSM scores for upper body muscles, ranked from most utilized to least utilized, for all pre-contact young and middle aged adult males, right side.

Muscle/ligament utilized	Location	Number of individuals	Mean MSM score
Brachialis	Ulna	35	1.657
Pectoralis major[a]	Humerus	22	1.363
Subscapularis	Humerus	27	1.092
Rhomboid ligament	Clavicle	21	1.047
Teres major[a]	Humerus	24	1.041
Infraspinatus	Humerus	28	0.964
Teres minor[a]	Humerus	16	0.937
Flexors[b]	Humerus	33	0.909
Trapezius	Scapula	25	0.900
Biceps brachii[a]	Radius	20	0.875
Extensors[a,b]	Humerus	18	0.833
Supraspinatus	Humerus	26	0.826
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Pectoralis minor	Scapula	15	0.733
Conoid ligament	Clavicle	24	0.666
Subclavius	Clavicle	25	0.620
Deltoideus[a]	Humerus	26	0.557
Brachioradialis	Radius	22	0.431
Latissimus dorsi	Humerus	31	0.419
Pronator teres	Radius	30	0.416
Trapezoid ligament	Clavicle	20	0.375
Anconeus	Ulna	31	0.274
Supinator	Radius	30	0.266
Supinator[b]	Ulna	35	0.185
Triceps brachii	Ulna	33	0.181
Trapezius	Clavicle	20	0.125
Pronator quadratus	Radius	31	0.080
Coracobrachialis	Humerus	37	0.040

- - - - =statistical break-point between stronger and more moderate use of muscles/ligments.
[a]Middle aged adult category only.
[b]Origin site of muscle attachment was utilized.

Table 5. MSM scores for upper body muscles, ranked from most utilized to least utilized, for all pre-contact young and middle aged adult females, right side.

Muscle/ligament utilized	Location	Number of individuals	Mean MSM score
Brachialis	Ulna	48	1.458
Pectoralis major	Humerus	47	1.287
Flexors[a,b]	Humerus	19	1.180
Rhomboid ligament[a]	Clavicle	15	1.100
Teres major[a]	Humerus	21	1.000
Extensors[a,b]	Humerus	18	1.000
Subscapularis	Humerus	32	0.984
Infraspinatus	Humerus	25	0.940
Pectoralis minor[a]	Scapula	9	0.833
Biceps brachii	Radius	22	0.704
Teres minor	Humerus	24	0.687
Conoid ligament	Clavicle	32	0.625
- - - -			
Deltoideus[a]	Humerus	22	0.590
Trapezoid ligament	Clavicle	27	0.425
Pronator teres	Radius	42	0.369
Subclavius	Clavicle	33	0.348
Latissimus dorsi	Humerus	26	0.326
Supinator	Radius	38	0.263
Brachioradialis	Radius	23	0.195
Supinator[b]	Ulna	45	0.188
Anconeus	Ulna	34	0.176
Triceps brachii	Ulna	37	0.121
Pronator quadratus	Radius	41	0.109
Coracobrachialis	Humerus	48	0.104
Trapezius	Clavicle	24	0.083

- - - - =statistical break-point between stronger and more moderate use of muscles/ligments.
[a]Middle aged adult category only.
[b]Origin site of muscle attachment was utilized.

decreased at a level equal to or greater than 0.5, the smallest increment on the observation scale. However, a small number of muscles did demonstrate a statistically significant difference between pre-contact and post-contact in analyses utilizing the chi-square test.

Two muscles and one ligament demonstrate a significant relationship between MSM expression and time period among males (Table 8). All of these indicate an increase in MSM expression through time: the conoid ligament, *latissimus dorsi*, and *anconeus*. Among Pecos females (Table 8), two of the three muscles that demonstrate a significant relationship between the MSM expression and time period exhibit an increase in expression. These muscles are the *deltoideus* and *supinator* (origin). The expression of *pronator quadratus* decreased over time. Chance alone could be responsible for two of the muscles/ligaments demonstrating a statistically significant difference between time periods for both sexes.

Rank orders of selected muscles/ligaments as determined from their mean MSM value, and divided by sex and time period, are presented in Table 9. These rank orders demonstrate sexual dimorphism in muscle use of the people at Pecos. The ranking also gives some indication of trends in muscle activity changes through time that were not apparent from the earlier chi-square analyses. A Spearman rank-order correlation coefficient was calculated for males and females separately for all muscles. It was discovered that a strong positive correlation between the pre- and post-contact rank of a muscle existed for both males and females (Spearman's r for females=0.973, for males=0.962).

Table 6. MSM scores for upper body muscles, ranked from most utilized to least utilized, for all post-contact young and middle aged adult males, right side.

Muscle/ligament utilized	Location	Number of individuals	Mean MSM score
Brachialis	Ulna	30	1.733
Rhomboid ligament	Clavicle	20	1.525
Pectoralis major[a]	Humerus	20	1.325
Subscapularis	Humerus	22	1.113
Biceps brachii[a]	Radius	19	1.052
Teres major[a]	Humerus	20	1.025
Flexors[b]	Humerus	26	0.980
Infraspinatus	Humerus	24	0.979
Extensors[b]	Humerus	18	0.944
Trapezius	Scapula	25	0.920
Teres minor[a]	Humerus	17	0.911
Supraspinatus	Humerus	23	0.869
Conoid ligament	Clavicle	18	0.861
- - - -	- - - -	- - - -	- - - -
Deltoideus[a]	Humerus	21	0.619
Subclavius	Clavicle	21	0.595
Latissimus dorsi	Humerus	26	0.557
Pectoralis minor	Scapula	16	0.531
Trapezoid ligament	Clavicle	17	0.441
Anconeus	Ulna	26	0.423
Pronator teres	Radius	26	0.403
Supinator[b]	Ulna	31	0.354
Supinator	Radius	24	0.354
Triceps brachii	Ulna	27	0.351
Brachioradialis	Radius	21	0.238
Trapezius	Clavicle	18	0.194
Pronator quadratus	Radius	29	0.155
Coracobrachialis	Humerus	32	0.093

- - - - =statistical break-point between stronger and more moderate use of muscles/ligments.
[a]Middle aged adult category only.
[b]Origin site of muscle attachment was utilized.

Table 7. MSM scores for upper body muscles, ranked from most utilized to least utilized, for all post-contact young and middle aged adult females, right side.

Muscle/ligament utilized	Location	Number of individuals	Mean MSM score
Brachialis	Ulna	20	1.500
Pectoralis major	Humerus	24	1.270
Flexors[a,b]	Humerus	11	1.136
Rhomboid ligament[a]	Clavicle	14	1.071
Subscapularis	Humerus	18	1.055
Infraspinatus	Humerus	21	0.952
Teres major[a]	Humerus	16	0.937
Extensors[a,b]	Humerus	15	0.933
Deltoideus[a]	Humerus	16	0.875
Supraspinatus	Humerus	16	0.781
Biceps brachii	Radius	21	0.714
Teres minor	Humerus	19	0.710
Conoid ligament	Clavicle	21	0.690
- - - -	- - - -	- - - -	- - - -
Pectoralis minor[a]	Scapula	8	0.562
Subclavius	Clavicle	22	0.545
Latissimus dorsi	Humerus	24	0.458
Trapezius	Scapula	20	0.425
Trapezoid ligament	Clavicle	16	0.406
Supinator[b]	Ulna	20	0.375
Supinator	Radius	24	0.375
Pronator teres	Radius	24	0.291
Brachioradialis	Radius	11	0.227
Trapezius	Clavicle	17	0.147
Triceps brachii	Ulna	17	0.147
Anconeus	Ulna	19	0.131
Coracobrachialis	Humerus	26	0.038
Pronator quadratus	Radius	20	0.000

- - - - =statistical break-point between stronger and more moderate use of muscles/ligments.
[a]Middle aged adult category only.
[b]Origin site of muscle attachment was utilized.

Discussion

Intensification of maize production among females

The robusticity of the *deltoideus* attachment demonstrates a statistically significant increase over time. *Latissimus dorsi* increases in mean MSM expression, although it is not statistically significant. Both muscles display a similar trend in rank order over time. *Brachialis* was the most utilized upper body muscle during both time periods. During the post-contact period three of the four rotator cuff muscles — *supraspinatus*, *infraspinatus*, and *subscapularis* — demonstrate a small increase in rank order. The rotator cuff muscles are very important in maintaining the glenohumeral articulation during arm flexion as well as aiding in adduction/abduction. All of these muscles could be utilized during an activity such as maize-grinding or hoeing.

Intensification of maize production among males

Latissimus dorsi and *anconeus* exhibit a statistically significant increase in MSM expression among Pecos males. Although they do not demonstrate a statistically significant difference in their mean scores, the *deltoideus*, *triceps brachii*, and *biceps brachii* muscles, exhibit a similar trend (for example, *deltoideus* pre-contact mean robusticity score is 0.557 and the post-contact mean is 0.619) which is also reflected in the rank orders. *Brachialis* increased in mean MSM expression and was the

Table 8. Upper limb muscles/ligaments demonstrating statistically significant relationship between MSM robusticity and time period for males and females from Pecos.

Muscle	Location	d.f.	χ^2	*p*
Males				
Conoid ligament	Clavicle	1	4.582	0.032
Latissimus dorsi	Humerus	2	6.470	0.039
Anconeus	Ulna	1	8.148	0.004
Females				
Deltoideus	Humerus	1	5.546	0.019
Supinator[a]	Radius	1	5.662	0.017
Pronator quadratus	Radius	1	5.150	0.023

[a]Origin site of muscle attachment was utilized.

most utilized upper body muscle in both time periods. These muscles act in a way that would be consistent with hoeing, chopping wood, and other general horticultural activities. The extensors would be important for grasping tools. The increase in *triceps brachii* as well as *anconeus* may indicate wood chopping activities, as *anconeus* is a complement to the triceps during short, forceful movements of extension. While felling trees, abduction/adduction of the arm are provided by *deltoideus* and *latissimus dorsi*.

Intensification of weaving among males

There was no statistically significant change in MSM expression over time for any of the hand and wrist extensors and flexors or the supinators and pronators in the males. An examination of the rank orders for these muscles does not readily support the hypothesized intensification in weaving. The flexors and extensors do exhibit a slight increase in ranking over time, as do the *supinator* and *pronator quadratus*. It is possible that the small increases in the flexors and extensors are also part of the increase in horticultural activities. Overall, these results do not support an intensification in weaving activities as a result of Spanish contact. Although an examination of MSM of the carpals, metacarpals and phalanges was not included in the present study, future work along these lines may offer promising results.

Use of males for labour

The males of Pecos demonstrate a statistically significant increase over time in the MSM expression of the conoid ligament. This suggests use of the arm above 90° in flexion or abduction as the conoid ligament, along with the trapezoid ligament, helps maintain the acromioclavicular joint during upward rotation of the scapula. The large conoid expression would be consistent with chopping wood, where one gains greatest force from a swing which starts above the shoulder level. It is also suggestive of carrying burdens on the shoulders and/or upper back where the arms are bent and the hands are maintained around the head/neck region to stabilize the load. If, however, loads were carried

Table 9. Rank order differences in MSM robusticity between males and females by time period discussed in text.

	Pre-contact muscle rank			Post-contact muscle rank		
Site	Males	Females	Difference	Males	Females	Difference
PMNR	25	30	5	16	21	5
TRAP	29	13	16	29	16	13
RLIG	35	35	0	41	35	6
TZLIG	12	18	6	15	15	0
TMIN	31	26	5	28	26	2
SUBS	36	32	4	35	34	1
DELT	18	23	5	21	30	9
FLEX	30	40	10	32	39	7
EXT	27	33.5	6.5	30	31	1
TRI	5	5	0	9	5.5	3.5
ANC	8	6	2	14	4	9
SUPO	6	7	1	10.5	13.5	3
BIC	28	27	1	34	27.5	6.5
SUPI	7	10	3	10.5	13.5	3

in front of the body (this would not be supported by ethnographic literature) with the forearm at a 90° angle to the torso, both the *triceps brachii* and *biceps brachii* would be firing simultaneously to maintain this position. Hence, carrying loads in this manner could also be responsible for the increase in the rank orders of both of these muscles. The earlier discussion of increased general horticultural activities also supports the idea of the employment of males from Pecos to farm land and acquire wood.

Sexual dimorphism at Pecos in the upper body

The investigation of sexual dimorphism supports these discussions of change in MSM expression between pre-contact and post-contact time periods for both sexes. The largest difference in muscle use between the males and females of Pecos is seen in *trapezius* and *deltoideus*. In both pre- and post-contact males, *trapezius* demonstrates a rank order difference greater than 10 when compared with females. The *trapezius* muscle is very important in the upward rotation of the scapula to increase the range of abduction and elevation of the arm. The greater rank of *trapezius* in males would be consistent with the greater participation of males in horticultural activities where the arm is flexed or abducted past 90°, as in the action of chopping wood. It should be noted that trees would have been felled at Pecos, too.

Among pre- and post-contact females, *deltoideus* is more highly utilized than among males and this difference increases through time. *Deltoideus* would be heavily recruited during maize grinding. That this muscle demonstrated a statistically significant increase among females through time helps support the utility of rank orders. Females also consistently demonstrate greater use of *pectoralis minor* than males. *Pectoralis minor* functions to bring the scapula forward and down as might be involved in extension of the arm during the grinding of maize. When examining the flexors and extensors of the wrist and hands, along with the supinators and pronators, it became apparent that females in both time periods demonstrated greater use of all these except for the pronators. However, the difference between the sexes was consistently larger in the flexors. The difference in rank of the extensors almost disappeared by the post-contact period. Overall, the supinator was not highly utilized by either sex during either time period. The greater expression among pre- and post-contact females of the flexors and extensors is consistent with grinding maize. These results, which suggest greater female participation in maize-grinding, are similar to Bridges' findings based on biomechanical load analysis of late prehistoric agricultural groups in the southeastern USA.[29]

That males do not demonstrate a similar level of flexor and extensor utilization again may be indicative of a number of things: the result of a lack of data collection from the hand bones, the possibility that fewer males wove in comparison to the number of women grinding maize, and that weaving may not have been a frequently performed activity compared with the grinding of maize.

The post-contact males demonstrate a large difference in rank order of the rhomboid ligament compared with females of the same period. This difference is the result of an increase in rank order of the male rhomboid ligament over time. A rank order increase among males for the rhomboid ligament (which limits the elevation of the clavicle) may indicate a larger amout of burden bearing among the males. An increase in rank order of the trapezoid and conoid ligament is also seen in males over time.

It must be noted that the trapezoid ligament in pre-contact females was affected in ways that differ from its activity among males of the same time period. The pre-contact females demonstrate little difference compared with the pre-contact males in the rank ordering of the rhomboid or conoid ligaments. This difference, however, increases during the post-contact time period. The change in rank differences between males and females may be the result of a decrease in use on the part of females and an increase on the part of the males as well as the result of other subtle movements of various muscles.

The difference between the sexes in the amount of *teres minor* and *subscapularis* activity decreases through time. Pre-contact males exhibit greater use of both muscles than the females of the same period. Greater utilization of these muscles by males would be consistent with the wide range of upper arm motion during activities such as hoeing and chopping wood. It was expected that *teres minor* use would increase among females through time as a result of increased maize processing, however, while the mean MSM expression increased slightly the rank order did not change.

Triceps brachii and *anconeus* are more highly ranked in post-contact males versus females of the same time period. During the pre-contact period almost no difference exists between the sexes in these muscle rankings. This difference appears to be a reflection of the increase in muscle use for maize production and manual labour discussed above. The suite of activities performed by females, as reconstructed from the historical and archaeological data, does not include tasks requiring short, sharp extension of the forearm as one sees during wood chopping or hoeing. The differences in the post-contact time, with males exhibiting a higher *biceps brachii* ranking, might be part of this complex, and/or lifting and carrying burdens.

Conclusions

The MSM data from this research suggest that Spanish contact did have an effect on some of the daily activities practiced by the inhabitants of Pecos Pueblo. Some muscles for both males and females demonstrate a statistically significant increase through time. This information, coupled with changes in the rank ordering of many muscles and ligaments, is consistent with a hypothesized increase in activities related to the production and processing of maize. Evidence also exists that supports the hypothesized increase in burden bearing by post-contact males. No evidence was found to support a hypothesized increase in the production of woven cotton mantas. Yet, none of the mean MSM expression scores increased or decreased through time at a level equal to or greater than 0.5, the smallest increment on the observation scale. As a result, Spanish contact at Pecos, although probably very influential in many biocultural innovations, did not result in muscle exertion levels beyond those expressed by the inhabitants of Pecos prior to contact.

This study demonstrates the usefulness of MSM data in the examination of questions regarding sexual division of labour. For the Pecos materials, an examination of muscle rankings from most to least utilized demonstrates several cases of sexual dimorphism in muscle use. This dimorphism agrees with historically recorded patterns for the division of labour among Puebloan groups.

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