Chapter 5

Implications of Changing Biomechanical and Nutritional Environments for Activity and Lifeway in the Eastern Spanish Borderlands

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There can be little doubt that the introduction of new and novel stressors—such as Old World infectious diseases—to native New World populations led to markedly reduced quality of health and catastrophic reductions in population size. Although the topic of demographic catastrophe is important, its emphasis in the popular as well as technical literature has tended to overshadow what we believe to be a highly significant aspect of contact-period human biology: namely, what is known about the *surviving* populations that were in contact with Europeans, sometimes over a period of generations? In what ways did these survivors adapt to wholly new circumstances affecting their lifeways?

This is not to say that epidemic disease in the region discussed in this chapter did not have a horrific effect on native population. Indeed, by the late seventeenth century the region had experienced dramatic population reduction, in no small part due to European-introduced infectious diseases. In all likelihood, the population losses resulted in increased demands on the survivors in a variety of ways. This chapter examines how native populations responded, in part, to these challenges.

In this chapter we address these questions through the study of a sequence of precontact- and contact-era human remains from Guale, a region and a tribal group extending from the mouth of the Savannah River to the area immediately to the south of the mouth of the St. Marys River in coastal northern Florida (figure 5.1). This area of the Atlantic coast is especially important for the study of contact-era biological change because the native populations inhabiting it were among some of the earliest to be encountered by Europeans north of Mexico (Jones 1978; Larsen 1990). Given the well-documented temporal, environmental, and dietary variables for this region, we are provided with an excellent opportunity to look in some detail at responses made by native populations before, during, and after initial contact with Europeans.

Our primary objective in this study is to seek a more comprehensive understanding of biobehavioral changes reflecting population response to the enormous challenges facing them during the period of time preceding their extinction. The present investigation approaches this objective by utilizing a diachronic analysis of two aspects of human variability that are behaviorally significant: (1) skeletal morphology of limb bone diaphyses; and (2) articular joint pathology. Study of skeletal morphology includes the application of beam theory developed by mechanical and civil engineers for structural analysis (Lanyon and Rubin 1985; Nordin and Frankel 1980). In the terminology used by engineers, the long bones of upper and lower limbs can be modeled as hollow beams, and the strength of these beams can be measured. Thus, just as engineers can measure the strength of beams, biological anthropologists can measure the strength of skeletal structures. The application of beam analysis facilitates an understanding of function and behavior by summarizing complex shapes viewed in cross section into a series of readily interpretable properties (Bridges 1989a; Hayes and Gerhart 1985; Ruff 1989).

These properties—called cross-sectional geometric properties—are used to estimate strength or resistance of a bone to two primary forces: bending and torsion (twisting). Limb bones, which are tubular in shape, represent strength under either or both of these forces, depending on the bone (for example, the upper limb versus lower limb) and the location along the shaft. Thus, it is possible to estimate in numerical form the resistance of bone to bending ("bending strength") and torsion ("torsional strength"). The application of this biomechanical approach in the analysis of archaeological skeletal remains has represented an important breakthrough in bioarchaeological study, especially in the elucidation of specific levels and types of activities in now-extinct human groups (e.g., Bridges 1989a, 1989b; Brock and Ruff 1988; Lovejoy et al. 1976; Robbins et al. 1989; Ruff and Hayes 1982, 1983; Ruff et al. 1984; see review in Ruff 1992).

Bone strength reflects distribution of skeletal tissue primarily in response to mechanical forces throughout the years of growth and development as well as adulthood. Thus, bone strength is not a measure of health status. As we will show in this chapter, it is possible for a population to undergo increase in bone strength yet at the same time decline in health status.

Pathology affecting articular joints pertains in this study to a disorder known as osteoarthritis (also called degenerative joint disease). Like structural analysis, study of osteoarthritis by anthropologists has been instrumental in providing insight into activity patterning, lifestyle, and mechanical stresses in many diverse settings worldwide (e.g., Angel et al. 1987; Bennike 1985; Bridges 1990; Hrdlička 1914; Jurmain 1977, 1990; Kelley and Angel 1987; Merbs 1983; Miles 1989; Parrington and Roberts 1990; Stewart 1947, 1966; Walker and

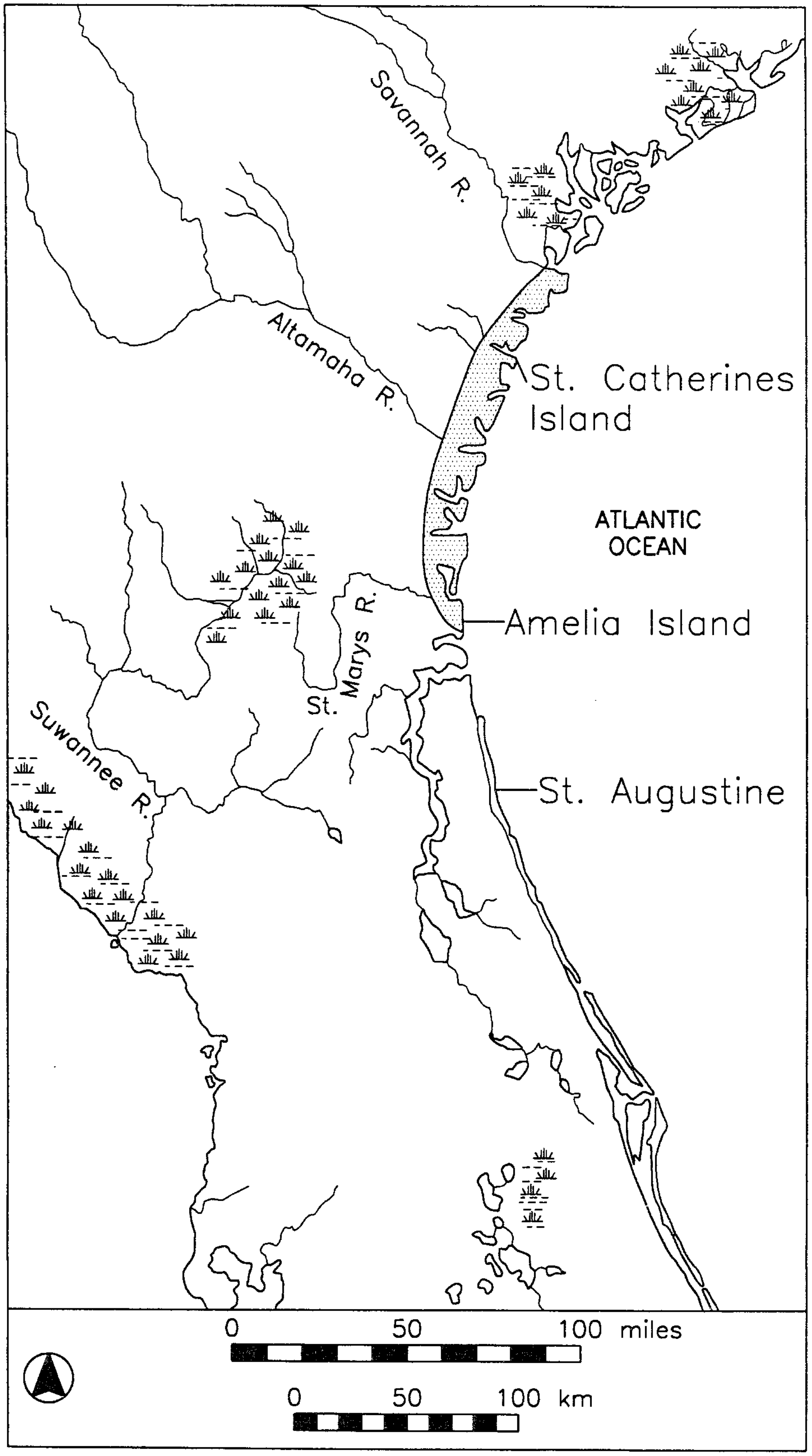

Figure 5.1. Map of northern peninsular Florida and coastal Georgia showing the location of Guale (shaded area) and geographical localities mentioned in the text.

Hollimon 1989; Webb 1989; Wells 1982; Wood Jones 1910; and many others; see reviews in Bourke 1967; Kennedy 1989; Larsen 1987; Ortner and Putschar 1985; Rogers et al. 1987). Osteoarthritis, therefore, offers a source of information complementary to structural analysis for reconstructing and understanding mechanical and behavioral aspects of earlier human populations.

Biocultural Context

Human skeletal remains representative of a succession of populations on the southeastern U.S. Atlantic coast have been the focus of a long-term investigation of prehistoric- and historic-era human ecology (Hutchinson and Larsen 1988; Larsen 1982, 1990; Larsen et al. 1990, 1992). These remains are grouped into four successive temporal periods that for purposes of comparison we have called Precontact Preagricultural (before A.D. 1150), Precontact Agricultural (A.D. 1150–1550), Early Contact (A.D. 1607–80), and Late Contact (A.D. 1686–1702). The Precontact Preagricultural–period populations followed an exclusively hunting-gathering-fishing subsistence strategy. Human remains representative of these prehistoric hunter-gatherers are from various Georgia coastal mortuary localities (Larsen 1982; Larsen and Thomas 1982). The Precontact Agricultural–period populations incorporated maize agriculture as a major component of the subsistence economy, but still included nondomesticated terrestrial and marine dietary resources. Human remains representative of these populations are from various late prehistoric sites, but are chiefly from Irene Mound, the largest Mississippian period site in the region (Caldwell and McCann 1941; Hulse 1941; Larsen 1982).

During much of the following contact period, Mission Santa Catalina de Guale on St. Catherines Island served as the northernmost extension of Spanish control in eastern North America (Thomas 1987). Under pressure from the English in the late seventeenth century, particularly following their founding of Charles Town (Charleston, South Carolina), the focus of this control shifted southward when the inhabitants of St. Catherines Island moved below the St. Marys River. They reestablished the mission on Amelia Island, renamed Mission Santa Catalina or Santa Maria de Guale (Hann 1990), but also referred to as Mission Santa Catalina de Guale de Santa Maria (Larsen 1990; Thomas 1987). Historical documentation indicates that, like their late prehistoric predecessors, these contact-period populations utilized dietary carbohydrates (maize), albeit to a greater degree (see below) than prior to the arrival of Europeans in the region. Human remains from the two missions on St. Catherines and Amelia islands are representative of the Early Contact and Late Contact periods, respectively (see Larsen 1990; Hardin 1986; Larsen and Saunders 1987). Archaeological, bioarchaeological, and historical evidence strongly suggests the human remains from these two populations and the earlier prehistoric periods represent a diachronically continuous biological population (Larsen 1982, 1990). This continuum allows us to evaluate the effects of contact and establishment of missions in a well-controlled setting. It is beyond the scope of this chapter to compare these populations with other mission skeletal series where the temporal and biocultural controls are not so tightly defined.

In previous studies we showed that concomitant with the transition from an exclusively hunting and gathering lifeway to one based partly on maize agriculture prior to contact, upper and lower limb bones (represented by humeri and femora, respectively) became shorter, and bone strength, as revealed by structural analysis, declined. These findings reflect, in part, a decrease in mechanical loadings of both limbs (Fresia et al. 1990; Larsen 1981, 1982; Larsen and Ruff 1991; Ruff and Larsen 1990; Ruff et al. 1984). Larsen (1982), moreover, documented a decrease in the prevalence of osteoarthritis in a comparison of Precontact Preagricultural and later agricultural populations. Although a variety of contributing factors have been identified in the etiology of this disorder, excessive and repetitive mechanical loading of articular joints figures most prominently in explaining osteoarthritic remodeling (see DeRousseau 1988; Duncan 1979; Jurmain 1977; Larsen 1982; Merbs 1983; Moskowitz 1987; Pascale and Grana 1989; Radin 1983; Walker and Hollimon 1989). This interpretation is supported by a number of researchers who have shown links between specific occupations and patterns of osteoarthritis (e.g., Kellgren and Lawrence 1958; Lawrence 1955). Thus, a decline in prevalence of osteoarthritis is consistent with a model of reduction in mechanical demand in this region during late prehistory.

What structural or pathological changes should we expect to see in the later contact-period human populations in this region? The written documentation available from historical sources indicates that the arrival of Spanish colonizers and the establishment of missions in the Eastern Borderlands, an area named *La Florida* by Ponce de León in 1513, occasioned dramatic behavioral and workload changes in native populations (Hann 1988). These changes were likely related in part to Spanish interest in native populations as an inexpensive labor source. Native labor was viewed by the Spanish as a central—if not the most important—element in their economic and political success in this region. Various historical accounts note the use of and dependence upon Indian laborers for cargo-bearing, agricultural production, construction projects, woodcutting, and other physically demanding activities (Hann 1988; Larsen 1990). For example, Governor Canzo, in his report to the Spanish Crown in 1602–3, noted: "with all this and the grain from the maize, the labor that they endure in the many cultivations that are given is great, and, if it were not for the help of the Indians that I make them give, and they come from the province of

Guale, Antonico, and from other caciques, it would not be possible to be able to sow any grain" (translation provided by John H. Hann; cited in Larsen 1990).

These historical accounts, therefore, suggest that the workload likely increased during the contact period in response to labor demands placed upon native populations. In answer to the above question, we should expect to see a reversal of the precontact trends in diaphyseal structure and joint pathology in contact-period populations.

Examination of femora and humeri from early Mission period Georgia coastal populations indeed showed a general reversal of the trend documented for precontact populations—limb bones became longer and stronger (Ruff and Larsen 1990). Comparison of males and females revealed somewhat different temporal changes, however. For example, anterior-posterior to medial-lateral bending strength of the femur increased in some males and decreased in others after contact, while female bending strength as a whole continued to decline (Ruff and Larsen 1990). Based on comparative data collected from other human populations (see Ruff 1987), these results suggested some males may have been more mobile after contact—perhaps reflecting their use as long-distance laborers—while females continued to decrease in mobility, a trend established prior to contact.

Methods of Analysis

Skeletal Morphology and Size

Determination of cross-sectional geometric properties follow previously described procedures (Ruff and Hayes 1983; Ruff and Larsen 1990). Femora and humeri were oriented in standard anteroposterior (A-P) and mediolateral (M-L) planes and cut transversely using a fine-toothed saw at two locations on the femoral diaphysis and one location on the humeral diaphysis. Measured from the distal ends, the femoral sections are located at 50 percent (midshaft) and 80 percent (subtrochanteric) of bone length, and the humeral section is located at 35 percent (mid-distal) of bone length (figure 5.2). The endosteal (inner surface of bone) and periosteal (outer surface of bone) boundaries were subsequently traced from photographs of these sections rear-projected onto a digitizer screen. Calculations of properties were performed directly on a microcomputer with a digitizer screen. As an indicator of body size, we have recorded a measurement referred to as length′ (or "biomechanical length") for femora and humeri (Ruff and Hayes 1983; Ruff and Larsen 1990). For the femur, length′ is the distance from the distal surfaces of the condyles (knee region) to the superior margin of the neck (hip region). For the humerus, length′ is the distance from the proximal surface of the head (shoulder region) to the distal edge of the lateral lip of the trochlea (elbow region). For the remainder of this chapter, length′ will be referred to simply as "length."

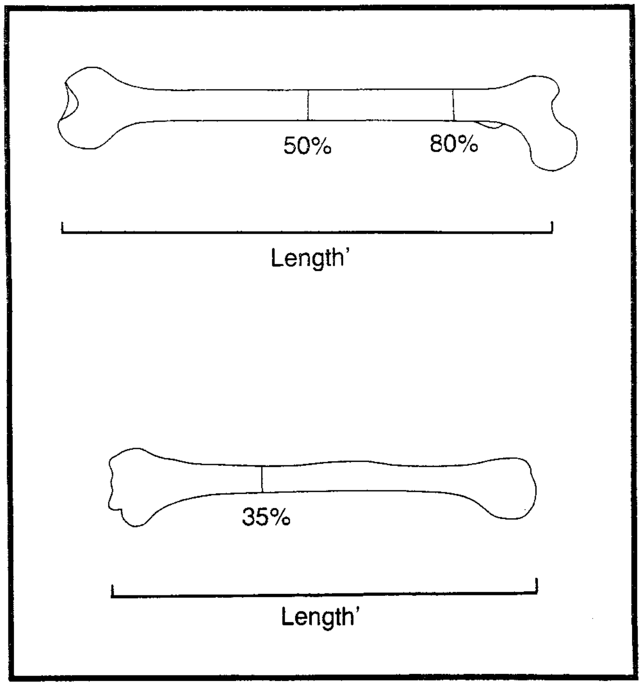

Figure 5.2. Locations of sections on femur (top) and humerus (bottom).

Two types of cross-sectional geometric properties reflecting bone strength—called "areas" and "second moments of area"—were calculated by a modified version of the computer program SLICE from boundary point coordinates (Nagurka and Hayes 1980). Explanation of formulas used to calculate these properties are provided in Ruff (1991). Area properties reflect the *amount* of bone in a cross section. They include cortical area (CA), medullary area (MA), and total subperiosteal area (TA). Second moments of area properties reflect the *distribution* of bone in a cross section relative to particular axes running through the section. The second moments of area properties include maximum and minimum second moments of area (I_{max}, I_{min}), second moments of area about mediolateral (I_x) and anteroposterior (I_y) axes, and the polar second moment of area (J). The "I" and "J" values represent measurements of bending and torsional strength respectively, the two primary loading modes that limb bones are subject to during life. In order to standardize for body size differences between periods and sexes, we have divided areas by bone length^2 and second moments of area by bone length^4 in the analysis (Ruff 1984). Only the length-standardized properties are reported here. We emphasize that these long bone cross-sectional geometric properties do not necessarily represent measures of health status. Rather, they reflect estimated resistance of bones to mechanical loading (their mechanical strength).

Pathology

Osteoarthritis is a complex disorder, but it appears to result from physiological imbalance between mechanical stress of articular joints—comprised of cartilage, bone, and other tissues—and the ability of those tissues to withstand that stress (Maquet 1983; Radin 1983). As such, it is not a disease per se, but a group of conditions whereby the common manifestation is joint deterioration by mechanical means (Radin 1982). Because we are dealing with skeletal remains only, we are only able to view the bone modifications, thus representing but one part of the articular damage seen in living subjects.

We follow DeRousseau's (1988, 7) definition of osteoarthritis in its application to the study of dry bones as including all degenerative articular joint changes. Articular surfaces and margins of bones representing the major weight-bearing and nonweight-bearing joints were examined, including intervertebral (cervical, thoracic, lumbar/sacral), shoulder, elbow, wrist, hand, hip, knee, ankle, and foot (table 5.1). We identified and recorded osteoarthritis as either present or absent for these articular joints. Presence of osteoarthritic remodeling was recorded if there was evidence of any one or a combination of the following hard tissue modifications: (1) proliferation of bone on joint mar-

Table 5.1. Articular surfaces and margins of major adult articular joints observed for presence or absence of osteoarthritis

Articular joint	Skeletal component observation
Cervical	Intervertebral body; superior and inferior articular processes
Thoracic	Intervertebral body; superior and inferior articular processes
Lumbar/sacrum	Intervertebral body; superior and inferior articular processes
Shoulder	Proximal humerus (head); scapula (glenoid)
Elbow	Distal humerus (trochlea, capitulum); proximal radius (head); proximal ulna (semilunar notch)
Wrist	Distal ulna (head, styloid process); distal radius (lunate-scaphoid articular surfaces); carpals; metacarpals (proximal)
Hand	Metacarpals (heads); proximal, intermediate, and terminal phalanges
Hip	Femur (head); innominate (acetabulum)
Knee	Femur (lateral and medial condyles); patella (condylar surfaces); tibia (lateral and medial condyles)
Ankle	Tibia (talar articular surfaces); tarsals; metatarsals (proximal)
Foot	Metatarsals (heads); proximal, intermediate, and terminal phalanges

Source: Adapted from Larsen 1982.

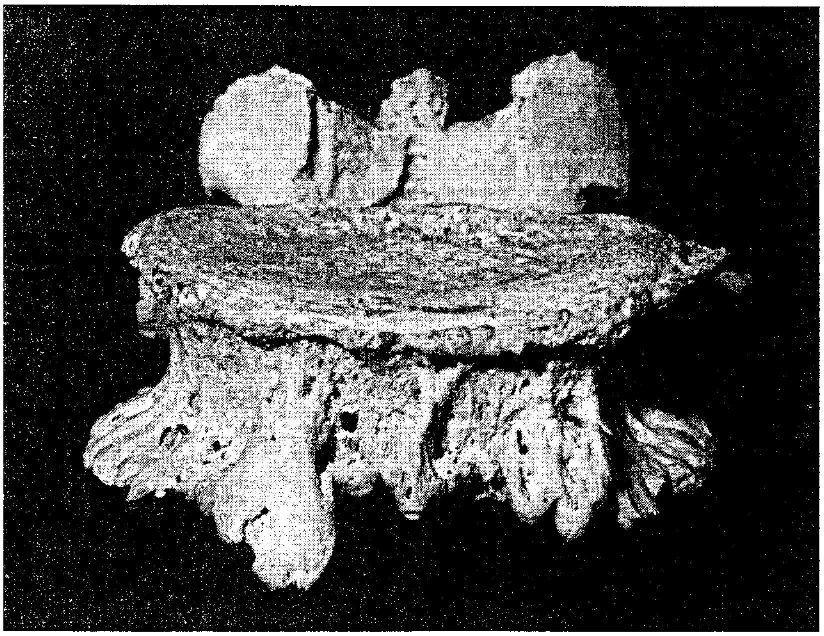

Figure 5.3. Bone proliferation on joint margins of lumbar vertebra (osteoarthritis).

gins (also called marginal or osteophytic lipping); (2) loss of bone on joint surfaces due to resorptive activity; or (3) loss of bone due to mechanical attrition or polishing resulting from direct bone-on-bone articulation following degeneration of cartilage (eburnation). By far, the most frequent manifestation of osteoarthritis in these remains is marginal lipping (figure 5.3).

In the course of data collection we noted that occasionally only one component skeletal element of an osteoarthritic joint was affected by the disorder. For example, in the shoulder the scapular glenoid fossa margin was more commonly affected than the humeral head for most individuals (cf. Wells 1982). However, from a functional perspective, we present summary data in reference to joints, rather than the individual component bones.

For the analysis of osteoarthritis, we do not include the Early Contact period. Data on osteoarthritis for this time period are as yet unavailable for analysis.

Both structural properties and prevalence of osteoarthritis are highly influenced by age structure in human populations. Therefore, consideration of age structure is presented as part of the data analysis. Diachronic assessment of age structure in the four periods has important implications for demographic change, especially in relation to diet and health status. However, this topic is beyond the scope of this chapter (but see the discussion in Larsen et al. 1990).

Results

Skeletal Morphology and Size

Temporal changes in femoral and humeral lengths and their respective cross-sectional geometric properties are presented in table 5.2. These data show important temporal changes for both males and females across the four periods.

Bone lengths, a general indicator of body size, show relatively more change in females than in males in the sequence. Females markedly reduce in body size in the Precontact Agricultural period, increase in body size in the Early Contact period, and slightly decline again in the Late Contact period. Males show a similar trend, but the increase in body size in the Early Contact period remains essentially unchanged in the Late Contact period.

Examination of temporal changes in femoral and humeral cross-sectional geometry shows a number of trends. In the femur both males and females change very little in CA in comparison to the two precontact-period groups, as we have reported earlier (Ruff et al. 1984). However, the endosteal and periosteal surfaces contract in both sexes, resulting in reductions in TA and MA. In the Early and Late Contact periods there are appreciable increases in TA and MA, indicating a reversal of the trends observed before contact. The effects of alteration in geometry are straightforward. That is, with the exception of two properties for males (subtrochanteric I_{max} and J), second moments of area decrease in the Precontact Agricultural period, but increase in the Early Contact period and again in the Late Contact period. This temporal trend demonstrates a consistent increase in these measures of bone strength during the Contact period, from Early to Late.

The humerus shows generally the same pattern of morphological change in comparing the four periods. In males all areas and second moments of area decrease in the Precontact period, but then increase in the Early Contact period and Late Contact period. However, in females humeral properties continue to decline in the Early Contact period. With the exception of CA, in the Late Contact period, the trend reverses. Therefore, humeri show a trend of mechanical strength change that is similar in males and females prior to contact. After contact, however, females continue to decrease while males increase. Both sexes show increases in mechanical strength in the Late Contact period.

Comparison of ratios of second moments of area reveals temporal trends in cross-sectional "shape" of femora and humeri. In males A-P/M-L bending strength in the midshaft femur (I_x/I_y) first decreases, then increases, and finally decreases again. In the mid-distal humerus there is an increase in A-P/M-L bending strength (I_x/I_y), followed by a slight decline in the last period. However, this index shows the same trend for both femur midshaft and mid-distal humerus in the last three periods. A decrease in circularity (reflecting

Table 5.2. Bone size and cross-sectional geometric property means standardized for bone length: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact

	PP	PA	EC	LC	Significant differences[a]
Males					
Femur	(n = 8)	(n = 11)	(n = 11)	(n = 22)	
Length′	424.9	411.2	421.5	419.4	PP/PA
Midshaft					
CA/ln^2	233.6	234.5	234.0	225.1	—
MA/ln^2	82.2	61.8	88.7	99.0	PP/PA, PA/EC, PA/LC
TA/ln^2	315.8	296.3	306.7	324.2	PA/LC
I_{max}/ln^4	88.6	77.9	87.6	93.5	PA/LC
I_{min}/ln^4	65.5	61.0	62.3	66.6	—
I_x/ln^4	86.8	71.7	80.5	81.7	PP/PA, PA/LC
I_y/ln^4	67.3	67.2	69.4	74.5	—
J/ln^4	154.1	138.9	149.9	160.1	PA/LC
I_x/I_y	1.28	1.08	1.20	1.13	PP/PA, PP/LC
Subtrochanteric					
CA/ln^2	225.0	220.8	232.9	225.7	—
MA/ln^2	123.6	83.6	114.7	123.1	PP/PA, PA/EC, PA/LC
TA/ln^2	348.6	304.3	347.6	348.8	PP/PA, PA/EC
I_{max}/ln^4	124.6	92.6	110.0	107.7	PP/PA, PA/EC
I_{min}/ln^4	59.1	51.5	67.5	67.2	PA/EC, PA/LC
J/ln^4	183.7	144.1	177.5	174.9	PP/PA, PA/EC, PA/LC
I_{max}/I_{min}	2.09	1.82	1.65	1.61	PP/PA, PP/EC, PP/LC, PA/EC, PA/LC
Humerus	(n = 15)	(n = 15)	(n = 13)	(n = 22)	
Length′	318.3	312.5	313.2	314.2	—
Mid-distal					
CA/ln^2	215.0	201.2	204.7	216.7	—
MA/ln^2	83.2	70.9	88.3	97.7	PA/LC
TA/ln^2	298.2	272.1	293.1	314.4	PP/PA, PA/LC
I_{max}/ln^4	73.8	62.8	71.1	77.5	PP/PA, PA/LC
I_{min}/ln^4	61.1	48.8	57.3	64.6	PP/PA, PA/LC
I_x/ln^4	66.4	56.0	66.4	73.0	PP/PA, PA/LC
I_y/ln^4	68.6	55.5	62.0	69.1	PP/PA, PA/LC
J/ln^4	135.0	111.6	128.4	142.1	PP/PA, PA/LC
I_x/I_y	0.98	1.01	1.10	1.07	PP/EC, PP/LC, PA/EC
Females					
Femur	(n = 12)	(n = 9)	(n = 11)	(n = 21)	
Length′	415.2	376.4	401.2	392.5	PP/PA, PP/LC, PA/EC, PA/LC

continued

Table 5.2-*continued*

	PP	PA	EC	LC	Significant differences[a]
Midshaft					
CA/ln^2	190.2	186.4	210.0	204.3	PA/EC
MA/ln^2	93.2	70.5	76.2	101.8	PP/PA, PA/LC, EC/LC
TA/ln^2	283.5	256.9	286.2	306.1	PP/PA, PA/EC, PA/LC
I_{max}/ln^4	63.4	54.8	68.9	75.3	PA/EC, PA/LC
I_{min}/ln^4	51.9	44.9	54.4	66.6	PA/EC
I_x/ln^4	62.0	50.6	61.9	65.2	PP/PA, PA/EC, PA/LC
I_y/ln^4	53.4	49.2	61.4	70.7	PP/PA, PP/LC, PA/EC, PA/LC
J/ln^4	115.4	99.8	123.3	141.9	PA/EC, PA/LC
I_x/I_y	1.16	1.03	1.01	0.93	PP/LC
Subtrochanteric					
CA/ln^2	191.5	190.4	216.4	205.4	PA/EC
MA/ln^2	120.2	88.6	99.2	130.7	PP/PA, PA/LC, EC/LC
TA/ln^2	311.7	279.0	315.6	336.1	PP/PA, PA/EC, PA/LC
I_{max}/ln^4	94.7	81.8	95.0	101.1	PA/LC
I_{min}/ln^4	44.9	39.2	54.7	58.2	PP/EC, PP/LC, PA/EC, PA/LC
J/ln^4	139.6	121.0	149.7	159.4	PP/PA, PA/EC, PA/LC
I_{max}/I_{min}	2.14	2.10	1.75	1.78	PP/EC, PP/LC, PA/EC, PA/LC
Humerus	(n = 12)	(n = 14)	(n = 11)	(n = 21)	
Length′	305.8	290.2	302.2	298.0	PP/PA, PA/EC, PA/LC
Mid-distal					
CA/ln^2	179.4	173.2	166.6	161.7	—
MA/ln^2	72.5	71.7	65.5	96.3	PA/LC, EC/LC
TA/ln^2	251.9	244.9	232.1	258.0	EC/LC
I_{max}/ln^4	53.9	50.8	45.3	53.4	—
I_{min}/ln^4	40.7	38.4	34.2	39.5	—
I_x/ln^4	50.4	45.8	41.8	48.5	—
I_y/ln^4	44.3	43.4	37.5	44.5	—
J/ln^4	94.6	89.2	79.5	92.9	—
I_x/I_y	1.13	1.06	1.11	1.10	—

Note: CA = cortical area; MA = medullary area; TA = total subperiosteal area; I_{max} = maximum second moment of area (bending strength); I_{min} = minimum second moment of area (bending strength); I_x = second moment of area about mediolateral axis (anteroposterior bending strength); I_y = second moment of area about anteroposterior axis (mediolateral bending strength); J = polar second moment of area.

Femur length′ (in mm) is the distance measured from the condyles to the superior margin of the neck, and humerus length′ is the distance from the head to the lip of the trochlea; midshaft and subtrochanteric an increase in the index) in the Early Contact period is followed by an increase in circularity (reflecting a decrease in the index) in the Late Contact period. Temporal trends in midshaft femoral shape are similar in females, although females show no transitory increase in the index from the Precontact Agricultural to Early Contact periods. Females show relatively little change in this index in the humerus.

Finally, comparison of maximum-minimum bending strength in the subtrochanteric femur (I_{max}/I_{min}) shows a considerable temporal decline—that is, an increase in circularity—over all four periods in both males and females.

Pathology

The temporal change in prevalence of osteoarthritis is presented in table 5.3. This pattern is perhaps best revealed by combining all articular joints into a single comparative sample. This comparison indicates first that, for all three periods studied (exluding EC), males have a higher frequency of arthritic joints than females. Second, regardless of gender, a reduction in frequency of affected joints occurred prior to contact. This is followed, in the Late Contact period, by a sharp reversal, with a near tripling in frequency of articular joints affected by osteoarthritis.

Temporal change for individual joints is generally similar to the pattern observed for the combined joints (table 5.3). For example, in the cervical vertebrae 40 percent of Precontact Preagricultural male articular joints are arthritic. In the Precontact Agricultural period only about 10 percent of joints in males are arthritic. In the Late Contact period the frequency of affected joints increases to levels similar to, if not greater than, the Precontact Preagricultural period. In the elbow the Precontact Preagricultural period shows the highest prevalence of osteoarthritis. The knee shows a similar pattern, with the greatest prevalence of osteoarthritis in the Precontact Preagricultural pe-

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femur refer to 50 percent and 80 percent, respectively, of length′ measured from distal end of bone; mid-distal humerus refers to 35 percent of bone length′ measured from distal end; area indices over bone length (CA, MA, TA) are multiplied by 10^5, and second moment of area indices over bone length (I_{max}, I_{min}, I_x, I_y, J) are multiplied by 10^8. Humeral properties are averaged for right and left sides, when both were available, or values adjusted for average bilateral differences (see Ruff and Larsen 1990). Area indices (CA, MA, TA) provide relative measures of amount of cortical bone in a cross section and the relative size of the section and medullary cavity; I (bending strength) and J (torsional strength) reflect the distribution of bone about a neutral axis or point; ratios (I_x/I_y, I_{max}/I_{min}) reflect relative distribution of bone about perpendicular axes, and thus cross-sectional "shape" (see Ruff and Hayes 1983; Ruff and Larsen 1990; Ruff et al. 1984).

Sources: Ruff and Larsen 1990; Ruff et al. 1984; Larsen and Ruff unpublished data.

[a]$p<0.05$, t-test (two-tailed).

riod. Osteoarthritis in the foot shows the most unusual pattern. In Precontact females and males the foot is only very minimally affected by the disorder. However, in the Late Contact period there is a tremendous increase in frequency, especially in males.

Table 5.3. Osteoarthritis prevalence

	PP		PA		LC		Signficant differences[a]
Joint	%	n	%	n	%	n	
Males							
Cervical	40.0	20	11.3	53	44.4	27	PA/LC
Thoracic	12.5	16	11.8	51	65.4	26	PA/LC
Lumbar/sacral	34.6	26	16.3	80	52.9	51	PP/PA,PA/LC
Shoulder	10.5	38	1.7	120	11.1	27	PP/PA,PA/LC
Elbow	13.7	51	6.1	114	10.3	29	PP/PA
Wrist	2.6	39	0.9	106	10.0	30	PA/LC
Hand	0.0	28	2.0	100	3.2	31	—
Hip	0.0	51	9.1	110	6.4	31	—
Knee	18.6	59	12.6	111	7.4	27	—
Ankle	4.1	49	9.2	109	10.0	30	—
Foot	0.0	26	1.1	93	41.6	24	PA/LC
Combined	9.0	403	6.9	1,047	30.5	333	PP/PA,PA/LC
Females							
Cervical	17.2	29	1.4	73	42.3	26	PP/PA,PA/LC
Thoracic	6.7	30	1.4	72	57.5	33	PA/LC
Lumbar/sacral	19.5	51	9.9	111	54.5	55	PP/PA,PA/LC
Shoulder	2.4	83	0.7	144	56.0	25	PA/LC
Elbow	9.6	94	0.0	167	2.9	34	PP/PA,PA/LC
Wrist	2.6	77	0.0	140	5.3	38	PA/LC
Hand	0.0	50	0.8	129	5.3	38	—
Hip	4.3	93	0.0	148	0.0	36	PP/PA
Knee	15.0	94	3.4	147	8.6	35	PP/PA
Ankle	4.5	88	0.0	139	15.6	32	PP/PA,PA/LC
Foot	0.0	48	0.0	120	11.1	27	PA/LC
Combined	7.0	737	1.5	1,390	23.7	379	PP/PA,PA/LC

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; LC = Late Contact. The number of articular joints was observed for the presence or absence of osteoarthritis for three periods only; data are not available for the Early Contact period.

Sources: Larsen 1982; Griffin and Larsen 1989.

[a]$p<0.05$, chi-square.

Interestingly, in the Late Contact period the sex differences in vertebral osteoarthritis became much less pronounced. Females and males in the Late Contact period had similar prevalence of osteoarthritis, unlike the pattern observed in either of the Precontact groups, Preagricultural or Agricultural.

Discussion

The results of this research can be summarized by four primary temporal trends in cross-sectional geometric properties and osteoarthritis in southeastern U.S. Atlantic coastal native populations. First, following a decrease in body size with the adoption of an agricultural lifeway, body size increases in the Early Contact period, followed by a slight decrease in female body size in the Late Contact period. Second, after an initial decline, a reversal developed in relative bone strength, represented by a general expansion of bone cortex in the Early Contact period, followed by further cortical expansion in the Late Contact period. Third, comparison of cross-sectional shape of the midshaft and subtrochanteric sections of the femur shows a general increase in circularity through time. The mid-distal humerus becomes less circular after contact. Fourth, a general pattern of decrease in prevalence of osteoarthritis prior to contact is followed by an increase in the Late Contact period.

These results likely reflect a complex combination of changing nutritional and mechanical loading patterns affecting the skeletal tissues in these populations. We have previously argued that a decrease in body size in the Precontact agriculturalists relative to the Precontact hunter-gatherers likely reflects a decline in nutrition, with the shift to a diet incorporating maize (Ruff et al. 1984). Thus, increase in body size during the Contact period might reflect a general improvement of nutrition—at least in terms of the *quantity* of food consumed, particularly in female body size. Carbon and nitrogen isotopic data derived from analysis of bone collagen samples (table 5.4; Schoeninger et al. 1990), as well as dental caries prevalence (table 5.5; Larsen et al. 1991), would certainly suggest that nutritional improvement, in terms of *quality* of diet, was not operating in this situation. Both the isotopic and caries analyses indicate an increase in consumption of maize in the Contact period, with a probable decline in reliance on marine resources. Maize is a notoriously poor source of protein as it is deficient in several essential amino acids (FAO 1970). This finding alone indicates a decline in nutritional quality. Moreover, archaeological data indicate an increase in consumption of carbohydrates, likely accompanied by a decline in resource diversity, particularly animal sources of protein (Larsen 1990). Historical documentation reveals that native populations experienced periods of food shortages following epidemics or other events such as burning of crops and the taking of stored foods by the Spanish military (Jones 1978).

Table 5.4. Carbon and nitrogen stable isotope summary statistics

	$\delta^{13}C$			$\delta^{15}N$		
Period	Mean	n	Range	Mean	n	Range
PP	-14.5	20	-18.6, -13.4	12.8	20	10.6, 14.4
PA	-13.0	9	-16.4, -10.0	10.7	9	9.5, 13.3
EC	-11.5	22	-14.3, -9.6	9.4	22	7.4, 10.8
LC	-11.5	21	-12.6, -10.0	10.0	22	8.3, 11.6

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

Sources: Larsen et al. 1990; Schoeniger et al. 1990.

These accounts very clearly indicate a decline in nutritional quality that almost certainly continued throughout the entire Contact period.

Females appear to show relatively more change than males in body size, as represented by bone lengths. The reason for these differences are not entirely clear, but may relate to the fact that females—who traditionally are associated more closely with settlements than males—may have been more subject to some changes detected in skeletal remains, such as body size. Until more extensive historical documentation of dietary and behavioral differences between males and females is encountered, it will not be possible to provide additional speculation on this point.

With regard to bone geometry, Ruff (1987) has shown that A-P relative to M-L bending strength of the midshaft femur (as measured by the ratio of I_x/I_y) can be used as an index of relative degree of mobility (e.g., amount of running or long-distance travel) in human populations. That is, relatively greater A-P bending strength—as indicated by greater values of I_x/I_y—generally reflects greater mobility in human populations. For example, comparison of prehistoric hunter-gatherers, prehistoric agriculturalists, and industrial (Western) populations by Ruff (1987) revealed that hunter-gatherers have the greatest A-P bending strength and industrial populations have the least A-P bending strength in the femur midshaft. He notes this is consistent with increase in roundness of the bone shaft in recent humans, most likely as a result of reduced mechanical loading of the lower limb in sedentary, industrial populations.

Examination of cross-sectional properties of individuals in the Early Contact period sample from Santa Catalina de Guale on St. Catherines Island shows that, relative to the Precontact Agricultural period, some males became more mobile (although on average they were less mobile) while females continued to decline in mobility. Moreover, both sexes showed an increase in circularity

Table 5.5. Dental caries prevalence

	PP		PA		EC		LC	
Maxilla	%	n[a]	%	n	%	n	%	n
I1	0.8	113	2.3	177	3.8	104	18.8	85
I2	0.0	95	2.8	178	1.5	126	20.0	85
C	0.0	126	8.3	244	1.1	170	23.9	92
P3	0.0	149	17.3	248	5.4	201	29.7	84
P4	0.0	149	11.6	255	4.9	201	38.6	88
M1	0.5	188	14.8	325	10.2	245	45.3	86
M2	1.0	193	12.5	306	11.1	234	66.1	65
M3	4.9	163	13.6	228	17.7	175	63.9	61
dI1	0.0	12	10.5	19	0.0	9	4.3	23
dI2	0.0	10	11.5	18	0.0	10	4.3	23
dC	0.0	18	0.0	28	0.0	20	13.3	30
dM1	0.0	26	19.1	47	20.0	25	24.3	37
dM2	0.0	20	8.2	49	7.5	53	32.0	25
Mandible								
I1	0.0	64	0.0	164	1.6	118	6.9	86
I2	0.0	84	1.5	197	0.7	128	20.6	97
C	0.0	126	2.6	233	1.5	199	24.2	99
P3	0.0	136	5.1	277	2.8	250	30.8	94
P4	0.0	151	10.9	257	3.4	232	46.3	82
M1	1.7	174	22.9	320	13.8	238	68.0	72
M2	3.5	174	24.5	280	15.7	228	80.7	57
M3	2.9	173	25.0	248	23.4	188	72.7	55
dI1	0.0	7	0.0	9	20.0	5	6.8	29
dI2	0.0	11	0.0	15	0.0	10	5.7	35
dC	0.0	19	0.0	26	0.0	21	2.7	36
dM1	0.0	28	5.4	56	0.0	37	0.0	43
dM2	0.0	29	5.4	56	15.2	46	33.3	33
Total	1.3	2,438	11.4	4,260	8.0	3,273	34.2	1,602

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

Sources: Larsen 1982; Larsen et al. 1991.

[a]Number of teeth observed for presence or absence of carious lesions for all four periods.

of the subtrochanteric region (as measured by the ratio I_{max}/I_{min}). The increase in circularity has been previously interpreted as representing a decline in general activity levels in human populations (see Ruff and Larsen 1990).

In sum, we interpret the cross-sectional property changes to reflect a combination of decrease in mobility and general activity levels. Reduced levels of activity, both with regard to mobility and general activity, seem to reflect a more sedentary lifeway as Indians relocated near missions during the contact era.

The increases in specific geometric properties (versus ratios) in the Contact-era skeletal remains are more difficult to explain. It is possible that body weight relative to stature was systematically altered in the Contact-period native populations. Mechanical demand on the lower limb is related to stresses derived from a combination of activity *and* body weight. Mechanical loading, therefore, should be proportional to body weight, multiplied by a factor related to level of activity. In the present study we assume that the proportion of body weight to bone length remained constant through the temporal sequence when we divided cross-sectional properties by second and fourth powers of bone length in order to standardize them for size. By length-standardizing the properties, two variables—activity level and body weight/bone length—may have been established that could affect cross-sectional properties (Ruff and Larsen 1990). Bone length is highly correlated with stature. Therefore, this is equivalent to asking whether body weight and/or stature of these populations was altered in the Early and Late Contact periods.

Due to an increase in sedentism and the overall effects of dietary change and population disruption, it is possible to argue that the proportion of body weight to stature increased. A greater dietary focus on carbohydrates in combination with increase in sedentism and confinement of movement could have led to relative weight gain in the Contact-period mission populations. If so, this would increase the body weight-bone length ratio and, thus, the length-standardized properties in the femur, despite declines in level of activity. Moreover, at least in the lower limb, diaphyseal morphology is sensitive to changes in body weight during adulthood (Ruff et al. 1991).

It is difficult to test this hypothesis (primarily because soft tissue is usually not preserved in the archaeological record). However, we suggest that a weight gain interpretation is consistent with the increases in body weight and dietary change in North American native populations undergoing transitions to more sedentary lifestyles in nineteenth- and twentieth-century contexts. Although these populations are not strictly analogous to mission Indians, comparisons provide insight into common experiences regarding sedentism and weight gain. Hrdlička (1908) and Johnston and Schell (1979) have noted, for example, a tendency for high body weight and obesity in relatively sedentary Native American populations consuming greater amounts of dietary carbohydrates, such as those living on reservations or in urban settings. During the contact period in Spanish Florida, native populations were encouraged by either suggestion or coercion to settle around missions and increase maize production. Thus, Bishop Calderón's remark, made in 1675 in reference to the Indians of La Florida, that "They are fleshy, and rarely is there a small one" (cited in

Hann 1988, 158) may reflect these changing settlement and dietary conditions occurring over a century of missionization.

Unlike the femora (or male humeri), female humeri show a continued reduction in bone strength through the Early Contact period. The humerus is subject to mechanical loading patterns derived solely from activity use, and not from forces related to body weight (such as in lower limb bones). Apparently, relatively lower mechanical loads were placed on the upper limbs of females in the Early Contact period relative to the Precontact periods. We have no way of knowing why bone strength in female arms decreased in the Early Contact period. We can only speculate that women used their arms in different functions requiring reduced physical demand.

In both Early and Late Contact males and Late Contact females, an increase in bone strength in the humerus suggests increased use of their upper limbs. In all likelihood these changes in the Late Contact period reflect an increase in mechanical demand on the upper limb. Although it is exceedingly difficult to pinpoint the causal factors behind these changes, they are likely related to the increase in demands placed on these populations by the Spanish in labor-related projects, including subsistence activities. Although females in Southeastern societies were primarily responsible for subsistence-related tasks, such as care of fields and food preparation (Hudson 1976; Swanton 1946), one historical account indicates that pounding of maize into flour by missionized groups was the responsibility of males (Hann 1986). Hann (1988) has also noted the use of Indian laborers in activities involving heavy carrying and lifting, sometimes over great distances. Although these historical references to activities do not provide conclusive evidence as to sexual division of labor, the fact that structural properties increase during the Late Contact period in both females and males suggests that during this time both sexes may have engaged in similar types of activities, or at least activities involving similar loading modes.

Other factors—especially age composition of the skeletal samples—might also influence specific cross-sectional properties. In this regard, Ruff and Hayes (1982, 1983) have compared second moments of area between age groups in the Pecos Pueblo (New Mexico) skeletal series and found subperiosteal expansion and increase in cross-sectional geometric properties with advancing age. These workers suggested that expansion of long bone diaphyses in cross section represents a compensatory response to general bone loss and cortical thinning. Thus, despite general bone loss with advancing age, particularly during and after the fifth decade of life, increase in second moments of area contributes to the ability of the bone to resist bending and torsional loads (Hayes and Gerhart 1985). Comparison of age at death data from the four periods shows a decline in mean age at death in the Precontact Agricultural period, followed by substantial increases in mean age at death in the respective Early and Late

Table 5.6. Mean age at death

Age group	PP	PA	EC	LC
Adult	31.1	25.8	27.2	39.5
Total	26.1	19.7	21.2	28.8

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

Contact periods (table 5.6). Therefore, the changing age composition of the skeletal samples may contribute to the temporal trends in areas and second moments of area observed.

With regard to the comparisons of the Precontact Preagricultural and Precontact Agricultural populations, we selected individuals of approximately equal ages at death in order to avoid problems associated with age bias and cross-sectional geometry (table 5.6; and see discussion in Ruff et al. 1984). Therefore, at least with regard to the Precontact comparisons, it is unlikely that age is an important factor in explaining the reduction in cross-sectional geometric properties in the Precontact Agricultural period. The comparisons between the Precontact Agricultural and Early Contact series and between the Early and Late Contact series are more problematic, however. With respect to the two Contact-period groups, it was not possible to select individuals with ages strictly comparable to the Precontact groups because the Contact-period samples represent generally older adults than the Precontact samples. Data comparisons indicate that, although age composition of the skeletal samples may partially explain the temporal changes in cross-sectional geometric properties, behavioral (and perhaps nutritional) considerations are more important. For example, despite an eight-year *increase* in mean age at death of female individuals represented by humeri in the comparison of the Precontact Agricultural and Early Contact periods (table 5.7), all areas and second moments of area *decrease.* If age was the only explanatory factor in determining areas and second moments of area in female humeri, then we would expect to see commensurate increases in these properties. On the contrary, decreases in these properties suggest behaviorally related factors as the underlying cause for these structural changes. This finding strongly suggests, therefore, a reduction in bone strength in female upper limbs occurs during the Early Contact period, and is a factor not simply related to age of the female cohorts.

Additionally, some Late Contact male femora properties are smaller (or of similar magnitude) to those of the Precontact Preagricultural period, despite a greater mean age at death of individuals represented by femora in that group. Therefore, we believe that although age likely contributes (through continued

Table 5.7. Mean age at death for femora and humeri

Period	Sex	Femora	Humeri
PP	Female	30.3	29.8
PP	Male	25.5	29.6
PA	Female	26.1	29.0
PA	Male	23.8	26.8
EC	Female	35.9	37.0
EC	Male	32.5	31.9
LC	Female	42.1	42.1
LC	Male	38.1	38.1

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

medullary and subperiosteal expansion) to the increases in second moments of area during the Contact period, behavioral factors are equally likely, if not more important, in understanding these changes.

Osteoarthritis, too, is strongly influenced by age. Most older adults in modern human populations are affected by the disorder (Eichner 1989; Hough and Sokoloff 1989). Indeed, in each of the series reported in this investigation, the age-progressive nature is well illustrated (tables 5.8 and 5.9). As expected, older individuals have a higher prevalence of osteoarthritis. If prevalence of osteoarthritis was to be predicted by age structure of the samples alone, that predic-

Table 5.8. Individuals affected by osteoarthritis per 5-year age category

	PP		PA		LC		Significant differences
Age	%	n[a]	%	n	%	n	
16.1-20	0.0	9	6.7	30	33.3	3	—
20.1-25	11.1	18	5.7	35	0.0	3	—
25.1-30	10.0	10	9.1	11	60.0	5	PA/LC[b]
30.1-35	0.0	1	42.9	7	25.0	8	—
35.1-40	66.7	6	20.0	10	78.6	14	PP/PA,[b] PA/LC[c]
40.1-45	25.0	4	33.3	3	81.0	21	—
45.1+	46.7	15	62.5	8	85.7	21	—
Total	23.8	63	15.4	104	69.3	75	PA/LC[d]

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

[a]Number of aged adult individuals with at least one articular joint affected by osteoarthritis.

[b]$p<0.1$, Fisher's Exact Test (two-tailed).

[c]$p<0.01$, chi-square (with Yates' Correction for Continuity).

[d]$p<0.0001$, chi-square.

Table 5.9. Individuals affected by osteoarthritis per combined age categories

	PP		PA		LC		Significant differences
Age	%	n[a]	%	n	%	n	
16.1-35	7.9	38	9.6	83	31.6	19	PA/LC[b]
35.1+	48.0	25	38.1	21	82.1	56	PA/LC[c]
Total	23.8	63	15.4	104	69.3	75	PA/LC[d]

Note: PP = Precontact Preagricultural; PA = Precontact Agricultural; EC = Early Contact; LC = Late Contact.

[a]Number of aged adult individuals with at least one articular joint affected by osteoarthritis.

[b]$p<0.05$, chi-square (with Yates' Correction for Continuity).

[c]$p<0.0005$, chi-square (with Yates' Correction for Continuity).

[d]$p<0.0001$, chi-square.

tion would likely fit the pattern we have discussed. The decrease in prevalence of osteoarthritis from the Precontact Preagricultural to Agricultural periods should fit the pattern of decline in mean age at death in these two periods. Similarly, the dramatic increase in prevalence of osteoarthritis in comparing the Precontact Agricultural and Late Contact periods should be predicted by the increase in mean age at death.

In order to test the hypothesis that prevalence of osteoarthritis is dependent on the changing age profiles of the skeletal samples, we have categorized the individuals affected by the disorder into respective 5-year age groups (table 5.8). Predictably, within each of the three periods, the prevalence of osteoarthritis increases with age. However, comparison between the three periods within each of the age categories shows, proportionately, a general reduction in prevalence of osteoarthritis in the Precontact Agricultural group relative to the Precontact Preagricultural group. Specifically, proportionately fewer individuals were affected by osteoarthritis in the Precontact Agricultural period than in Precontact Preagricultural period for the 5-year age categories.

The most striking proportionate change, however, is illustrated by comparing the Precontact Agricultural– and Late Contact–period groups (table 5.8). For each of the 5-year age categories, the proportion of individuals affected by osteoarthritis markedly increases in the Late Contact period. Statistically significant increases are found in the 25.1–30 and 35.1–40 age categories. By collapsing the 5-year categories into two groups, young adults (16.1–35) and old adults (35.1+), the proportionate decline in osteoarthritis between the two Precontact groups is shown more clearly among the older adults (table 5.9). The comparison of Precontact Agricultural and Late Contact groups, however, shows significant increases in the proportion of individuals affected by osteoarthritis for both age categories. We conclude that, although the changing frequencies of articular joints showing osteoarthritic remodeling may be related in part to the changing age profiles for each period, the prevalence of osteoarthritis between periods reflects a real rather than an apparent change.

The reversal in prevalence of osteoarthritis indicates that the Late Contact population engaged in activities that excessively loaded articular joints. Moreover, the similarity in prevalence of osteoarthritis between females and males of specific articular areas, such as the intervertebral joints (table 5.3), suggests that differences in gender-based work roles lessened in the Contact period relative to previous periods. This finding is supported by study of upper limb (humerus) asymmetry patterns in cross-sectional geometry that show the least amount of sexual dimorphism during the Contact period relative to Precontact period (see Fresia et al. 1990). On the other hand, other articular joints indicate substantial sex differences in degree of loading. For example, although both sexes show marked increases in foot osteoarthritis, the increase is much greater for males.

The interpretations presented in this chapter are not meant to imply that mechanical changes are the only factors responsible for structural alterations of the skeleton. However, it is interesting to note that standardized values of bone mass or volume (CA) remain largely unchanged for both males and females across the four periods, regardless of bone type (table 5.2). In contrast, over the same temporal span, properties relating to *distribution* of bone within cross sections show large changes. This kind of change suggests structural adaptations of the skeleton to localized (mechanical) rather than systemic (nutritional) factors (cf. Ruff et al. 1984), although the two are obviously interrelated to some degree (see above).

Conclusions

These findings underscore the importance of looking at native populations as *adapting* during a very critical period of their evolution. In this study we have shown that the investigation of human skeletal remains allows for an examination of responses to alterations in the biomechanical and nutritional environments of precontact- and contact-era native populations.

During the period of colonization of the Southeast coast, native populations did not undergo a reduction in body size or robusticity. These data show that the arrival of Europeans and the establishment of mission centers resulted in behavioral changes that increased robusticity and prevalence of osteoarthritis, the latter of which may reflect increased work demands, particularly those associated with repetitive and stereotypic activities (e.g., heavy lifting), resulting in frequent overloading of articular joints. An increase in body weight in the more sedentary mission Indians may explain increases in specific cross-sectional geometric properties. Thus, an important finding in this study is that although osteoarthritis and bone geometry reflect physical behavior, they represent responses to different types of activity. On one hand, osteoarthritis reflects impact-loading usually unrelated to running or mobility. Cross-sectional properties, on the other hand, reflect long-term habitual behaviors associated more with body movement (e.g., mobility, long-distance travel). Regarding the former, it appears that only certain types of repetitive impact-loading may cause osteoarthritis (Eichner 1989). Experimental and other evidence indicate that running is not a causal factor of osteoarthritis, but it may aggravate the condition if already present in an individual (Eichner 1989). Therefore, while running (or the degree of mobility in general) affects cross-sectional long bone geometry and the shape of the diaphysis, it does not likely play a major role in determination of prevalence of osteoarthritis (see also discussion in Ruff 1992).

The study of behavioral patterning in human skeletal remains by the investigation of long bone cross-sectional geometric properties and osteoarthritis offers important information about past lifeways. Both before and during sustained contact with Europeans and the establishment of mission centers in Spanish Florida, native populations underwent alterations in settlement patterning, diet, and mechanical behavior that resulted in modification of bone morphology (cross-sectional geometric properties) and joint pathology prevalence (osteoarthritis) reflecting those alterations. The establishment of missions, in particular, occasioned a shift to a more sedentary lifeway in native populations and a decrease in level of activity and mobility. At the same time, behaviors involving repetitive motions and heavy impact-loading of articular joints resulted in an increase in prevalence of osteoarthritis in the late seventeenth century.

Although the mechanical changes observed show the same trends generally for both males and females, it is interesting that Early Contact–period females, unlike males, show a reduction in bone strength. Because the humerus is not involved in ambulatory behavior, the changes observed can only be interpreted in relation to activities involving stresses placed on the arm. This finding suggests males increased the use of their upper arms while females did not, at least in the earlier mission era. Based on these findings, we argue that females and males engaged in very different behaviors during this time. What the differences in behaviors were remains unclear.

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