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I am submitting herewith a thesis written by Lorena Villao entitled “Modern frequency and the significance of acromial shape in the etiological debate of os acromiale.” I have examined the final electronic copy of this thesis for form and content and recommended that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

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Modern frequency and the significance of acromial shape in the etiological debate of os acromiale

A Thesis presented for
the Master of Arts
Degree
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Lorena Villao
May 2007

Dedication

Quisiera dedicar este tesis a mis padres, Esther y Francisco Villao. Sus apoyos durante los ultimos veinteyseite años me han traido a lugares que nunca imaginaba. Gracias a uds. yo podía superar todos los obstaculos que la vida puede traer. Madre, gracias por empujarme siempre teniendo fé, que yo tenia la capacidad de ser cualquier cosa que intentaba. Padre, muchisimas gracias por lo humilde sacrificos que has hecho por mi durante toda mi vida. Desde el principio, cuando dejaste tus estudios, para trabajar y apoyar tu nueva familia. Ahora, disfruten que tu hija sigue adelante.

I would like to dedicate my thesis to my parents, Esther and Francisco Villao. Your support during the last twenty seven years has brought me to places I never could have imagined. Thanks to both of you, I was able to overcome all the obstacles that life has brought me. Mother, thanks for encouraging me, and for always having faith, that I had the ability to do whatever I sent my heart and mind too. Father, thank you so much for the humble sacrifices you made throughout my life. From the very beginning you put us first, and sacrificed many times. Now, life has brought me full circle to the place where you left off.

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Abstract

Os acromiale was first described by the anatomist Grüber in 1859. In later anthropological studies, os acromiale has subsequently been referred to as a genetic marker among African-American populations. However, Blakey (2000) and Rankin-Hill (1997) point out that biomechanical stress should be considered as a possible cause of this trait. This population has a harsh history, which is evidenced in the skeletal remains via nutritional deficiency, disease, and markers of occupational stress. A trait interpreted as genetic, may in fact be another stress marker. Frequency rates (%) in the William M. Bass donated skeletal collection, representing a modern sample, were compared to data from African-American skeletal samples spanning the last 300+ years. A lower frequency among modern samples may support a functional argument as a result of technological advancements leading to reduced physiological stress. The comparative African-American samples, examined here, include (in chronological order): *New York African Burial Ground (7.6%), First African Baptist Church (20%), Mother United African Methodist Episcopalian Church (2.9%), Terry (11.1%), and the Hamann-Todd Collection (13.2%).* Both the New York African Burial Ground and Mother UAME are samples presented for the first time. Unlike other samples, their frequency is not high. The Bass data, collected from a sample of 420 individuals, yielded an overall frequency of os acromiale at *3.3%*. This is a decrease from the average frequency of 7% cited in the clinical literature. However, the frequency rate among the African-American component of this collection is a high os acromiale frequency, of 10.8% (n=4/37). The European-American frequency of the William M. Bass collection is quite low at 2.6% (n=10/383). In general, the African-American os acromiale frequencies are not always high as they

have been presented. Further investigation may reveal that the underlying cause of the high os acromiale frequencies may involve additional factors. One factor may be acromial shape. The shape categories as classified by Edelson and Taitz (1992), is argued to reveal the underlying genetic cause of high os acromiale frequencies. If certain acromial shapes prove to be positively correlated to specific ancestral groups, then this could illustrate the genetic cause is a result of variation. However, if acromial shape varies in spite of ancestry, other mechanical arguments should be examined. While this research is not meant to present the last word on the etiology of this trait, it is meant to examine modern os acromiale frequencies, specifically in reference to acromial shape. The former is to test a mechanical etiology and the latter to test a genetic etiology.

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I: Introduction

Os acromiale is a non-metric trait occurring in the shoulder. When this condition is present the epiphysis of the acromion has failed to unite to the scapula and remains separate throughout the individuals' life. It is not a degenerative condition, but simply present or absent. This trait can be bilateral (both shoulders) or unilateral (one shoulder). The causes of this condition are as yet unknown. It has been debated by both anthropologists and clinical professionals that the condition is genetic. At present, the current means of analyzing this condition in anthropology are through frequency rates among different populations. Such analyses illustrates that African-American groups have a significantly higher os acromiale frequency than European-American groups (Angel et. al 1987, Case et. al. 2006, Hunt 2006, Rankin-Hill 1997, Sammarco 2000).

While the genetic argument is possible, another reason has been presented for the present distributions of high os acromiale frequencies. African-American populations have been a historically marginalized group. As such, they underwent throughout this nations' history the physiological and emotional stresses of slavery, reconstruction, post-reconstruction, and the Jim Crow era. Such conditions, present a legitimate argument into the biomechanical forces influencing the presence of high frequency of os acromiale.

In modern times, the physiological stresses are expected to be less than in earlier times. As such, the current analysis of the William M. Bass Skeletal Collection is expected to result in a lower frequency for African-American groups than in earlier historical samples. Likewise, the frequency of os acromiale would be expected to be lower in European-American groups from the William M. Bass collection.

The shape of the acromion has been proposed as an explanation for a genetic etiology. The three shape classifications for the acromion are based on the position of the acromioclavicular facet in relation to the anterior edge of the acromion. When the distance is small (0-2.5 mm), the acromion has a square shape. As the distance between the anterior edge and the acromioclavicular facet increases, the acromion becomes increasingly curved. It is the most curved shape that is proposed as being positively correlated with os acromiale. Radiographic studies have supported this argument (Gumina et. al. 2003), however this has yet to be tested on a skeletal sample set.

Therefore, the aims of thesis are twofold. The first aim is to address the current data on os acromiale frequency and second, to test the relevance of shape to the etiological discussion. The information gathered at this juncture will then be applied to previous research on the subject and elaborate on the patterns and recommend future endeavors in addressing this subject.

II: Anatomy

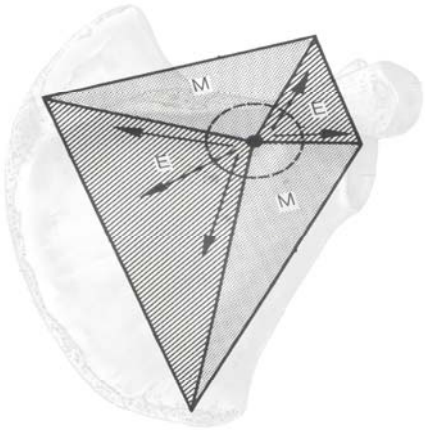
Prior to exploring the many 'facets' of this non-metric trait an anatomical summary of the scapula serves as an orientation for the reader. This synopsis will summarize the ontological development as well as the skeletal and muscular aspects of the scapula. This background is for the purpose of understanding the skeletal morphology of the acromion, presenting a context for understanding the details of os acromiale, which will be referred to as (OA) throughout the remainder of this study.

Growth and Development

The scapula begins to form in utero approximately 4-5 weeks after conception. This bone begins chondrification during the 6th week, which is followed by initial ossification around the 8th week in utero (Scheuer and Black 2000). In the scapula there are two primary ossification centers which form the body of the scapula and the coracoid process.

The primary center for the coracoid appears during the first year of post natal life, but will not be recognizable until the 3rd year. The primary ossification center of the body ossifies in an endochondral fashion forming in two opposite directions (See Figure 2.1). By the 9th week, the bone has ossified the base of the scapular spine. During the 12th week the ossification centers reach the glenoid region. At birth, the acromion, coracoid, medial border, inferior angle, and glenoid surface are still cartilaginous (Scheuer and Black 2000).

Eventually, secondary centers of ossification modify the cartilaginous epiphyses into bone. The seven secondary ossification centers include: subcoracoid, glenoid, angle



M=Membranous ossification
E=Endochondral ossification

Figure 2.1 Ossification pattern of juvenile scapula (*modified after Ogden and Philips 1983, and Scheuer and Black 2000*)

of coracoid, apical, acromial, medial border, and the inferior angle. The centers appear during the adolescent and pubescent years and fuse several years later (See Table 2.1). This ossification and fusion of the scapula epiphyses is normally complete by the ages of 18-25.

The secondary centers of ossification begin to appear in the coracoid region at 8-10 years, which articulates and fuses the coracoid to the scapula approximately eight years later. The angle of the coracoid forms around 14-15 years and then fuses at approximately 20 years. Likewise, the apical epiphysis is also specific to the coracoid process and forms the apex of the coracoid process with this center appearing at 13-16 years and fusing around the age of 20 years (Scheuer and Black 2000).

The other areas of ossification include the glenoid and the acromial epiphyses, the

Table 2.1 Secondary Ossification Centers of the Scapula

Centers	**Age of 1st appearance**	**Age of Fusion**
Subcoracoid	8-10 yrs	16-17yrs
Glenoid epiphysis	14-15yrs	17-18 yrs
Acromial Epiphysis	**8-10; 14-16 yrs**	**18-20 yrs**
Apical Epiphysis	13-16 yrs	20 yrs
Angle of Coracoid	14-15 yrs	20 yrs
Inferior Angle	15-17 yrs	23 yrs
Medial Border	15-17 yrs	23 yrs

(Modified from Scheuer and Black 2000)

medial border, and inferior angle. The glenoid epiphysis forms the bony rim around the margin of the glenoid cavity. There are small nuclei ossifying along the border that begin to form at 14-15 years, with completion around the age of 17-18 years (See Figure 2.2). The medial border and inferior angle are also formed by nuclei (islands of bone) which are formed simultaneously. These first appear between 15-17 years and fuse completely by the age of 23 years. Currently, it should be noted that there is not sufficient data regarding sexual differences in age of epiphyseal development or fusion of the scapula. This can prove to be an area of interest for future research. There are two to four ossification centers for the acromial epiphysis that first appear between 8-10 or 14-16 years, according to different sources (Renfree 2003; Scheuer and Black 2000).

More specifically, the centers begin to form along the lateral border of the acromial epiphysis and proceed to coalesce and ossify medially until the entire epiphysis is complete (See Figure 2.3). Once the epiphysis is fully formed it proceeds to fuse to the scapula. According to Scheuer (2000) the age of this last fusion is highly varied. In both

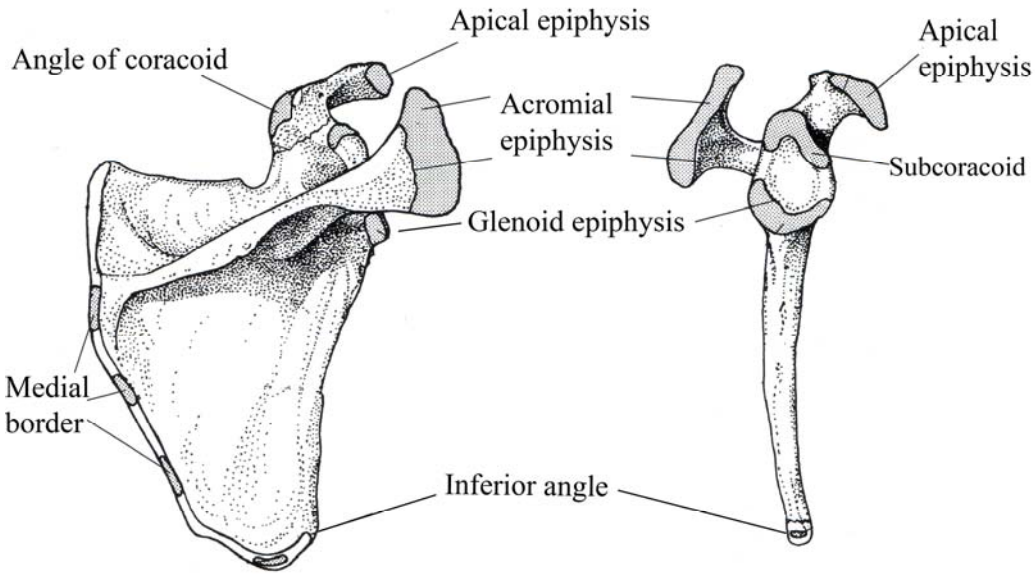


Figure 2.2 Secondary centers of ossification of the scapula (*modified from Scheuer and Black 2000*)

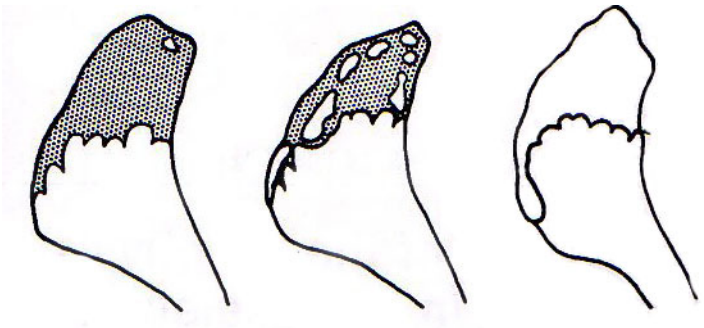


Figure 2.3 Secondary centers of ossification of the acromion *(modified from Miles 1994)*

the anthropological and orthopedic literature there are discrepancies concerning the age range in which the acromial epiphysis is considered permanently fused.

In Macalister's (1893) study of museum specimens he observed three ossification centers which begin fusing along the lateral margin of the epiphysis at fifteen years. These three centers formed the acromial epiphysis and had ossified medially and by the age of eighteen years. According to Macalister, the epiphysis was fully formed by the age of 18. However, Macalister noted that the fusion of the epiphysis to the basi-acromial center occurred after the 18th year. This later age range for final fusion of the acromial epiphysis was supported by Pick and Howden (1977), Liberson (1937), and Mann (1990). The epiphysis would continue to fuse to the scapula at the basi-acromial center up until the age range of 22-25 years. It has also been consistently noted that the formation of the acromion is extremely variable as to the age and sequence of ossification (Macalister 1893; Miles 1994; Nicholson 1996; Scheuer and Black 2000; Symington 1900). Despite the variability of the developing acromion, anthropologists and orthopedic surgeons alike have noted that OA is distinctive and could not be confused for a normal fusing epiphysis or a fracture (Case et. al. 2006; Sammarco 2000; Sterling 1995). Due to this fact, adults between the ages of 18-25 years will not be excluded from the research sample. However, it is noted that the final age of fusion is as variable as the acromion itself.

Developmental anomalies do occur among the various secondary centers, including non-fusion of the coracoid, glenoid dysplasia (non-ossification of inferior glenoid epipysis), and non fusion of the inferior angle (Pick and Howden1977). For the purpose of this research, I will focus on the non fusion of the acromial epiphysis referred

to as an os acromiale, or bipartite acromion, which has been cited as a marker of occupational stress (Kennedy 1989, 1998).

The scapula itself is a paired bone, which comprises the posterior portion of the proximal pectoral limb. The bone itself is a flat, triangular shape formed by three borders: lateral, medial and superior (See Figure 2.4). The medial border, closest to the vertebral column is angled and shorter than the lateral border, which is relatively straight. The superior border is a more complex region which connects the medial and lateral borders. These borders form three angles; lateral, inferior, and superior. The juncture where the medial and the lateral borders meet is referred to as the inferior angle. The superior angle is the junction where the superior and medial borders join and the lateral angle is formed by the head and neck of the scapula which contains the glenoid fossa. The glenoid fossa is where the humeral head articulates to form part of the pectoral girdle.

Along the superior margin is a variable notch termed the suprascapular notch where the suprascapular nerve is housed. Medial to it is a rounded, blunt projection of bone called the coracoid process. The coracoid process there are several muscle attachments, first is the coracobrachialis which aids in the stabilization of the humerus. This is followed by the short head of the biceps brachii which acts to supinate and flex the forearm. Lastly, the pectoralis minor muscle aligns the scapula against the chest wall (Agur and Dalley 2005, Pick and Howden 1977).

The scapula has both a ventral and dorsal surface. The ventral surface is the subscapular fossa where the subscapularis muscle originates. This muscle inserts at the

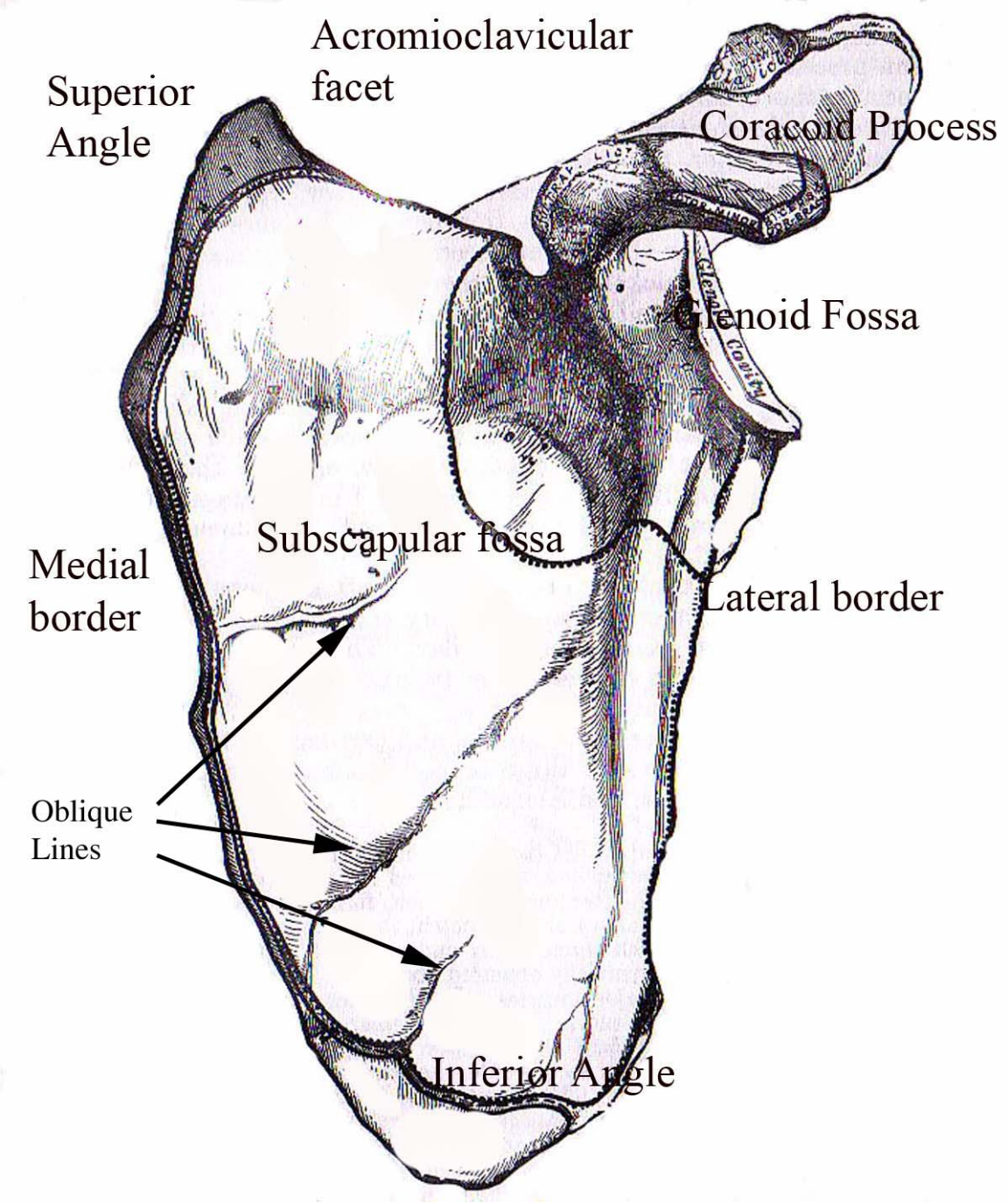


Figure 2.4 Ventral view of left scapula showing location of acromion and some landmarks *(modified from Pick and Howden 1977)*

lesser tubercule of the humerus. This muscle aids in the medial rotation and adduction of the forearm and stabilizes the humeral head within the glenoid cavity. The marked ridges on the ventral surface are the oblique ridges which anchor muscle tendons of the subscapularis muscle. Along the dorsal surface of the scapula is a raised bony projection which divides the upper and lower portions of the bone called the spine (Figure 2.5). The scapular spine is angled in a superiolateral direction along the dorsal portion of the bone. Above the scapular spine is a hollow groove called the supraspinous fossa, where the supraspinatus muscle originates. This muscle continues from the supraspinous fossa under the acromion and articulates with the uppermost portion of the greater tuberosity on the humeral head. The supraspinatus acts as an abductor of the humerus and also prevents the humeral head from dislocating (Agur and Dalley 2005, Pick and Howden 1977).

There is a similar groove beneath the scapular spine termed the infraspinous fossa where the infraspinatus muscle originates. This muscle inserts in the middle region of the greater tuberosity of the lateral humeral head ad similar to the supraspinatus and subscapularis muscles, contributes in stabilizing the glenohumeral joint. The infraspinatus muscle prevents a dorsal dislocation of the humerus at the glenoid fossa of the shoulder joint. The spine continues along the dorsal portion of the scapula, and at its most superior and lateral portion is the acromial process. The acromial process provides a superior barrier to the shoulder joint capsule over the glenoid fossa. On the medial side of this acromial process is an articular facet which articulates with the distal end of the clavicle. This facet is termed the acromioclavicular facet (AC facet) and comprises part of the acromioclavicular joint which is discussed further below (Agur and Dalley 2005,

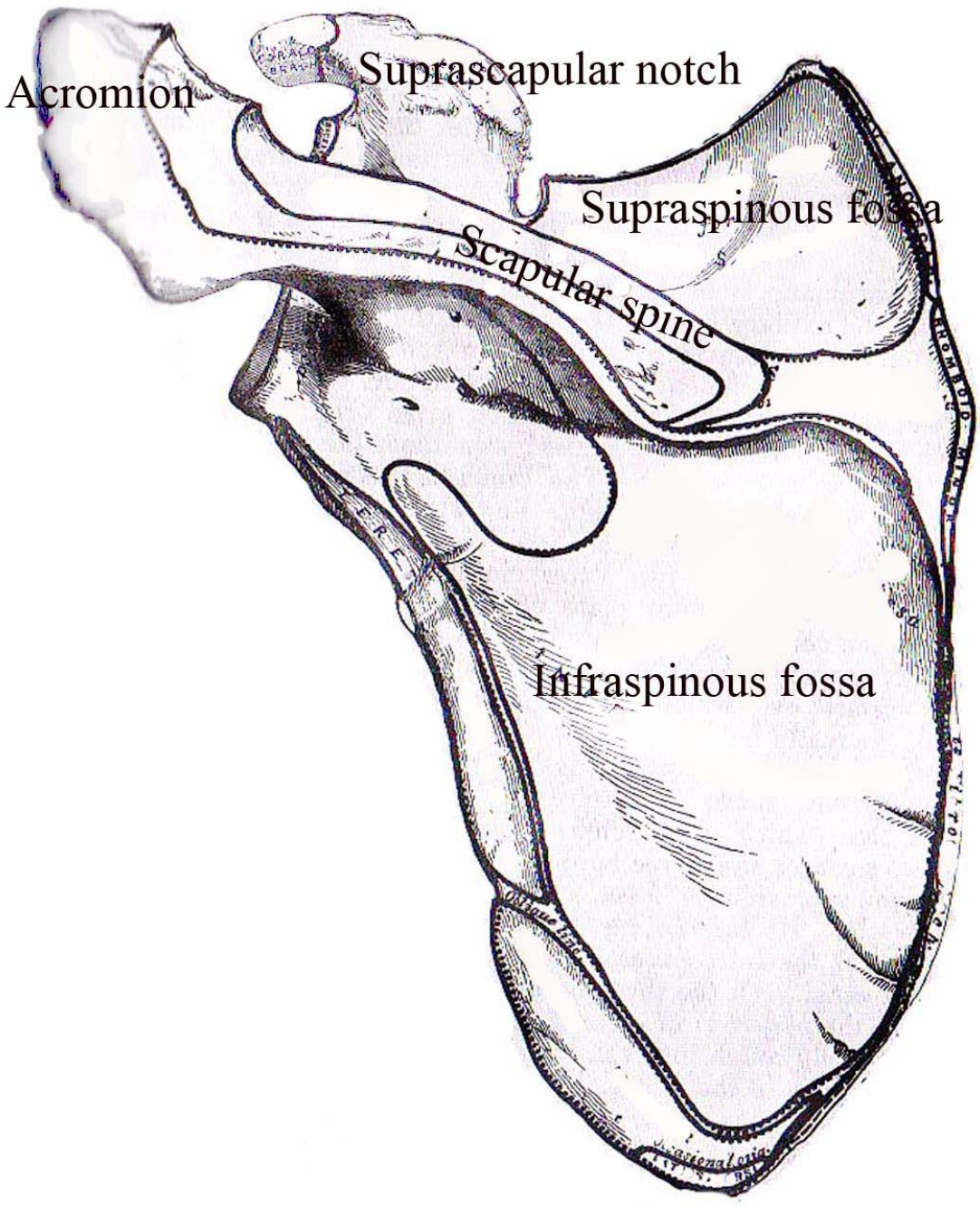


Figure 2.5 Dorsal view of left scapula **(***modified from Pick and Howden 1977***)**

Pick and Howden 1977). Beneath the acromion process and above the glenoid fossa is the supraglenoid tubercule where the long head of the biceps brachii. On the inferior portion of the glenoid fossa is a similar ridge of bone called the infraglenoid tubercule where the long head of triceps brachii muscle originates.

Muscle Attachments of the Acromion

The varying muscles which originate in the acromion are summarized in this section. This summary reflects their anatomical position and their function. On the dorsal surface of the scapular spine are two muscles: the trapezius and deltoid. The trapezius muscle consists of three regions: superior, middle and inferior. The middle trapezius articulates with the scapular spine and acromion. It originates in several places: the nuchal line on the external occipital protuberance of the occipital bone, the spinous processes of the seventh cervical verterbrae and thoracic vertebrae. The middle trapezius muscle adducts the scapula (See Figure 2.6). The middle deltoid portion originates from

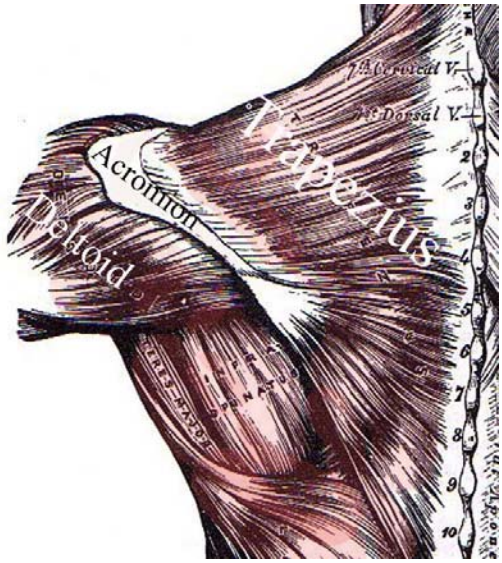


Figure 2.6 The relationship of the deltoid and trapezius to the acromion *(Modified after Pick and Howden 1977)*

the lateral border of the acromion process and inserts on the deltoid tuberosity on the lateral surface of the humeral shaft. Functionally, the deltoid abducts the arm (Agur 2005). Other muscles in the scapula are summarized in Table 2.2.

Ligaments

Ligaments are a type of connective tissue or elastic bands of fiber which contribute to the stabilization and movement of bones. The scapula has two main ligaments: the coracoacromial and the coracoclavicular (trapezoid and conoid) ligaments (See Figure 2.7). These ligaments are named after the parts which they unite. The triangular shaped coracoacromial ligament unites the coracoid and acromial processes beginning at the inferior of the anterior portion of the acromion to the acromioclavicular facet which attaches to the external border of the coracoid process. This ligament is

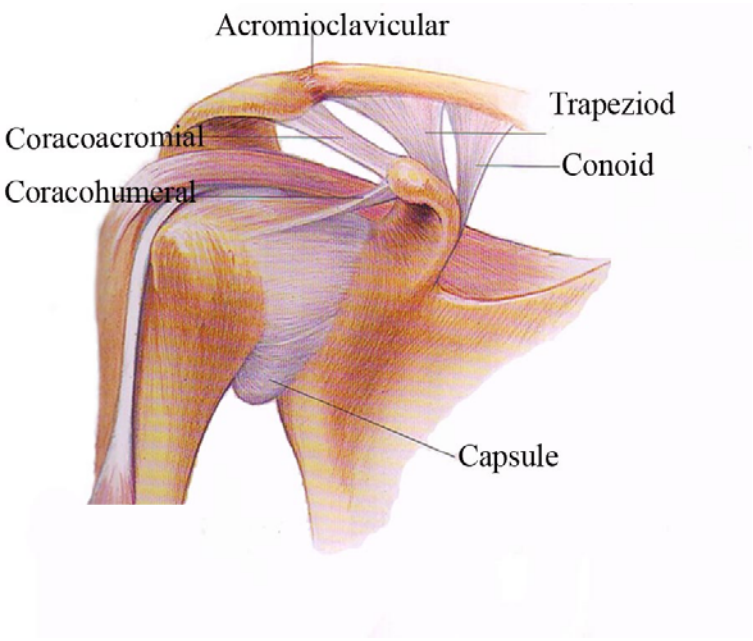


Figure 2.7 Diagram showing relationship of ligaments in the ventral right shoulder girdle (*modified from Springhouse 2001)*

Table 2.2 Muscles of the scapula

Muscle	**Origin**	**Insertion**	**Action**
Pectoralis minor	Dorsal surface of ribs 3-5	Coracoid process	Secures the scapula against the chest wall
Coracobrachialis	Apex of coracoid process	Medial surface of humerus	Aids in stabilizing the humerus
Biceps brachii	Long head-supraglenoid tubercule Short head-coracoid process	Radial tuberosity	Supinates and flexes forearm
Superior Trapezius	**Superior nuchal line, external occipital protuberance, spinous processes of 7th cervical and all thoracic verterbrae**	Posterior border of lateral third of the clavicle	Elevate the apex of the shoulder
Middle trapezius		**Acromion and spine of scapula**	**Adducts; rotates the scapula**
Inferior trapezius		Medial portion of spine of scapula	Depresses the scapula
Latissimus dorsi	Spinous processes of the lower thoracic vertebrae, lumbar vertebrae, sacral vertebrae, posterior portion of the iliac crest, inferior angle	Bicipital groove	Extensor, adductor, and rotates the arm, anchors shoulder against the chest wall
Levator scapulae	Tubercules of the transverse processes of the first four cervical vertebrae	Medial border of the scapula at and above the scapular spine	Elevates the medial border of scapula, rotates the scapula, pulls scapula medial and up, bends neck laterally
Rhomboid minor	Spinous process of the 7th cervical & 1st thoracic vertebrae	Medial border at the scapular spine	Retracts scapula, elevates medial border

Table 2.2 continued

Muscle	**Origin**	**Insertion**	**Action**
Rhomboid major	Spinous processes of the 2nd to 5th thoracic vertebrae	Medial border of the scapula below the spine	Retracts scapula, elevates medial border
Serratus anterior	Outer surface of the first 8-9 ribs	Anterior surface of the medial border of scapula	Rotates scapula for abduction and flexion of the arm
Middle deltoid	**Lateral border of the acromion process**	**Deltoid tuberosity on the lateral surface**	**Abducts arm**
Supraspinatus	Supraspinous fossa of scapula	Upper portion of the greater tuberosity of humerus, shoulder joint capsule	Helps deltoid in **abduction** of arm, prevents superior dislocation
Infraspinatus	Infraspinous fossa	Middle facet of greater tuberosity	Anchors humerus towards glenoid fossa
Teres minor	Upper portion of the lateral border of the scapula	Shoulder joint capsule, and the greater tuberosity of the humerus	Rotator, anchors humerus towards glenoid fossa
Subscapularis	Subscapular fossa	Lesser tubercule of the humerus	Rotator of the arm, stabilizes the glenohumeral joint
Teres major	Posterior surface of the lateral border of the scapula	Bicipital groove	Medial rotator, adductor, extensor of the arm
Triceps brachii	Long head-infraglenoid tubercule	Posterior part of the olecranon process	Extensor, aids in adduction of the forearm
Pectoralis minor	3rd to 5th ribs near costal cartilage	Medial border and superior surface of the coracoid process	Stabilizes scapula by anchoring it against the thoracic wall

(*modified from Agur and Dalley 2005)*

positioned above the deltoid muscle and forms a protective barrier above the humeral head to prevent a superior dislocation of the humeral head.

Above the coracoacromial ligament is the tendon of the supraspinatus muscle, a muscle of the rotator cuff. The coracoacromial ligament is therefore sandwiched between the deltoid and the supraspinatus tendon. The insertion of the coracoacromial ligament will appear as a series of longitudinal ridges and indentations (Edelson et. al 1993, Pick and Howden 1977). The coracoclavicular ligament is comprised of the trapezoid and conoid ligaments. The trapezoid ligament is the ventral most portion and forms the lateral part of the coracoclavicular ligament while the conoid ligament forms the medial portion of the coracoclavicular ligament. The coracoclavicular ligament helps to maintain the orientation of the clavicle in relationship to the rest of the scapula.

Joint Articulations

The shoulder girdle is comprised of the clavicle, scapula and humerus with the scapula centrally located. The scapula articulates with both the humerus and clavicle forming the glenohumeral and acromioclavicular (AC) joints. The clavicle, articulates with the medial portion of the acromion at the acromioclavicular facet. This type of joint is called an arthrodial or plane joint (Pick and Howden 1977). Inferiorly, the glenohumeral joint is a ball and socket joint with the head of the humerus articulating with the glenoid cavity of the scapula. The acromion projects over the humeral head and prevents upward displacement of the very mobile shoulder joint (Agur and Dalley 2005).

The scapula is essential to the function of the shoulder girdle and allows for both stability and flexibility of the upper limb. The acromion process is also important to the scapula despite its small size. As mentioned, the acromion is the insertion point for the

middle trapezius and is also the origin point of the middle region of the deltoid muscle. The acromion process along with the supraspinatus muscle and the coracoacromial ligament provide a protective boundary for the head of the humerus and prevent upward dislocation of the arm.

Os Acromiale

The specific anatomy of this condition was first described by Grüber in 1859 as an unfused ephiphysis articulated by means of a synovial joint in adults. It has also been termed bipartite acromion, met-acromion, or a lesion (Chung 1975; Mann 1990; Sammarco 2000; Sterling 1995). OA is a non-metric trait; it is scored as either present or absent. The acromial epiphyseal fusion process was studied by Macalister in the late 19th century. Most early sources on the subject have documented OA in a similar matter and the following are Macalister's descriptions of os acromiale: three large, separate ossification centers which begin to form along the peripheral edge of the acromion between the ages of 14-16 (Macalister 1893; Scheuer and Black 2000).

These centers were formed from much smaller islands of bone referred to as 'nuclei' which coalesce to form three ossification centers. These centers are referred to as: 1) pre-acromial center (PA) (apex of the acromion), 2) mes-acromial center (MSA) (intermediate between the other two centers), and 3) met-acromial center (MTA) which connects with the basi-acromial (BA) center located at the base of the scapular spine (see Figure 2.8). The met-acromial center unites with the basi-acromion, while the pre and mes-acromial centers would join together by the 18th year (Macalister 1893; Rankin-Hill 1997; Sammarco 2000). However, Macalister noted that there was an additional fusion of the epiphysis to the basi-acromial center which occurred afterwards. He did not

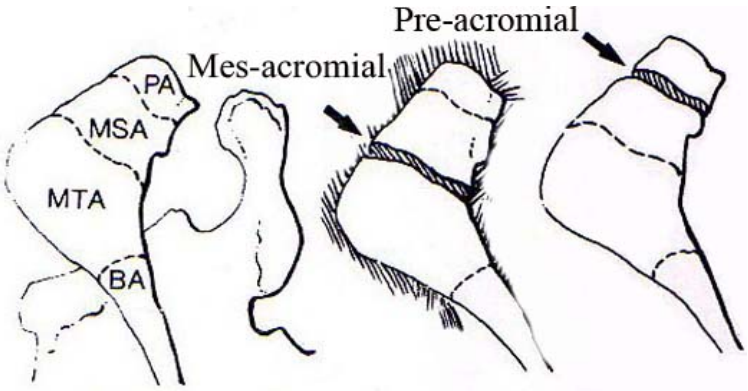


Figure 2.8 Right acromion with types of os acromial non-fusion *(modified from Mudge et. al. 1984)*

stipulate a specific age but stated that it occurred after the 18th year. Non-fusion can occur at any of these ossification centers and it can include multiple separations. The most frequent occurrence of this trait is at the juncture of the met-acromial center and the mes-acromial center, referred to as *os acromiale commune* (see Table 2.3). Miles (1994) noted that the acromioclavicular facet was commonly located on the separate epiphysis with the line of separation posterior to the facet or passing thorough the posterior half of the facet.

Another type of OA is when the pre-acromial center fails to unite with the mes-acromial center. This is termed *os acromiale terminale* (Case et. al. 2006). It is rare to see a non-union at the juncture of the met-acromial center and the basi-acromial center because the line or division between the met-acromial center is irregular and less likely to be affected by movement. However, at the mes-acromial region, the epiphyseal line is linear and can be easily affected by muscle forces (Symington 1900).

Table 2.3 Os acromiale types

Type	**Age of Normal Fusion**
Os acromiale *commune*	17-18
	22-25
Os Acromiale *terminale*	18

(*modified after Vallois 1925, in Case et. al. 2006)*

The juncture between the separate acromial epiphysis and the scapular spine is termed an interacromial joint. This area is referred to as a synchondrosis like an area united by cartilage. This juncture between the separate epiphysis has been described in a variety of ways, such as cartilaginous, fibrous, fibro-cartilaginous union (Case et. al. 2006; Jerosch 1991; Macalister 1893; Sammarco 2000). Normally, as the bone grows and develops this cartilage is gradually replaced by bone. In some cases of os acromiale, the juncture between the interacromial joint changes and can transform into a diarthrodial joint. This type of joint is a synovial joint, for moveable articulations.

The main debate in this paper centers on the "normal frequency" of this trait. The often quoted frequency of 7% is based on Grant (1972), although he never actually gave a frequency, just raw counts of occurrence (n=16/194) this sample is a cadaver sample from Canada (Albanese 2005). In this research, I will use the 7% based on Grant (1972) as a starting point for comparison since this is the frequency used by various researchers in analyzing os acromiale, although it should be noted that this frequency is not without question. Overall, the nature of the scapular and acromial anatomy serves as an overview to the topic of os acromiale and this was in order to illustrate the proper

formation of the acromion and how the subsequent non-fusion is observed, and described (See Appendix for photos).

III: Literature Review

This chapter introduces the literature from both the anthropological and clinical realm. The anthropological case studies center on frequencies found between two historic populations, European and African. The literature on the descendant groups of these respective populations is also presented. The clinical literature is brief and introduces some of the debates surrounding OA, including the idea of shape differences. While neither field has an answer for the etiology of os acromiale, each broaches the matter uniquely. The main debate in both the anthropological and the orthopedic literature is whether or not this was acquired or congenital condition. In combination, it provides a review of the literature for this research design.

Anthropological Literature

The focus here is on African-American descendant groups in the United States. To set the background for the debate between a genetic, and a stress-related etiology, it is helpful to see the contrast and comparison between African and European ancestral groups. While the data here is from relatively few sources, this topic has only begun to be explored in recent years.

Os acromiale in Africa and Europe

Case et. al.(2006), looked at the OA frequencies of a European sample from Medieval Denmark and compared it to a Bantu sample from South Africa. That analysis thus far is the only one to compare ancestral groups for OA. The Danish sample came from several church cemetery sites located in Odense, Svendborg, Viborg, Bygholom Aarhus consisting of 532 specimens (M=264, F=230) curated at the University of South Denmark. The dates for these specimens are approximately 1000 to 1536 AD. The

African sample is comprised of 494 (M=229, F=187) cadaver specimens from the Raymond Dart Anatomical Collection housed at the University of Witwatersrand. These individuals are comprised of remains from various tribes whose language could be traced to the "Bantu language family".

Case and coworkers results show an above average frequency of OA for the South African sample of 18.2% while the Medieval Danish sample had a frequency of 7.7%. Therefore, a genetic argument seems to be more favorable in this situation. However, the question of chronology is a factor. The time period for the South African sample could have shown differences in culture and subsistence strategies which were quite different between the two groups.

The researchers did point out that for the mechanical argument to stand, a side bias, showing asymmetric use, was good evidence. The analysis of a side bias concluded that there was a significant left side bias for the South African sample (*p=0.013, two tailed test, n=50*). However, since the majority of the world is right handed, the left side bias was more of a puzzle than expected. For the Danish sample there was also a left side bias of 75%, although it was not found to be statistically significant (*p=0.105)*. The sample size was small (n=19) and may have affected the outcome. Oddly enough in both cases, the unilateral frequency was higher than the bilateral frequency. This is the opposite of what most researchers find, usually the bilateral frequency is higher (Liberson 1937; Sammarco 2000; Symington 1900).

This mechanical argument was analyzed by Case et. al (2006) further as the cemetery sites of the Danish sample were divided into high versus low socioeconomic status. The cemeteries of parish churches and leper hospitals were categorized as those

of the lower class, while the monastery and cathedral cemeteries were classified as those of the upper class. There were apparent differences in frequency higher socioeconomic status-6.3% vs. lower socioeconomic status-9.6%, though the differences between the two were not statistically significant.

Sex bias in OA frequency was also considered as a potential factor supporting a mechanical hypothesis. It would be evidence of labor divisions with more strenuous activity done by males. However, the genetic argument can still apply in this scenario, through sex-linked traits despite the fact that such traits are considered rare. In the South African and Danish sample, the sex bias was not statistically significant (See Table 3.1). The higher female frequency in both samples is not what would be expected to see since males in modern samples exhibit the higher OA frequencies. Case et. al. point out that a confounding factor is that many of these skeletal samples do not have a large enough representation for women in their sample to accurately test a sex bias. The sex bias has neither confirmed nor refuted the argument of a genetic etiology since samples with an equal proportion of females have seldom been tested until the work of Hunt and Bullen (2006) (See below).

In summarizing, Case et. al (2006) argued that the a genetic etiology had a stronger foundation than the argument of a mechanical etiology. The evidence of a higher frequency in South Africans reinforced that genetics was the primary cause due additional samples of African descendant groups (See Ch. IV). Ultimately, they propose that a combined etiological argument be considered for future studies. While the genetic argument is favored in this study, there was a side bias present in both the South African and Danish samples. A combined argument for OA acknowledges that there are genetic

Table 3.1 South African sample vs. Medieval Danish sample

Sample	Total	Males	Females	Unknown	Total Freq.	Male Freq.	Female Freq.	P-Value
South African	494	264	230	0	18.2%	17.4%	19.1%	0.559
Medieval Danish	532	229	187	126	7.7%	6.6%	7.0%	0.847

(Modified from Case et. al, 2006)

predispositions which can be manifested when specific types of mechanical stress (i.e. heavy lifting, and repetitive overhead activity) are present, especially during the adolescent phases of growth. By examining OA from this combination perspective, such a possibility can be tested here.

Miles (1994) examined the frequency of OA amongst a European population, from a burial ground from the isle of Ensay in Outer Hebrides, Scotland dating to ca. 1700. There are four time periods for this site covering a wide time range (1500 AD to recent), corroborated by carbon-dating and historical records. The total frequency is 8.18% (n=9/110 pairs) is close to the normal frequency range, according to the Grant (1972) frequency. It was bilateral in only 22% of the cases and in both cases affecting women. Interestingly, women were the majority of those affected by OA in this sample, representing 67% of those affected. However, the significance of this is difficult to test since their sample size is small (See Table 3.2 for details).

Miles was not focusing on the differences of population frequencies. Rather the focus of his research was on an older debate focused on the nature of OA. Earlier, in the anatomical literature, the argument was centered on whether OA was the result of a developmental non-union or if it was an unfused fracture (Symington 1900). That debate and its conclusions will be briefly elaborated upon, as it brings up a point which many

Table 3.2 Early Christian Burial Ground, *Isle of Ensay, Scotland*

Total	**Bilateral**	**Unilateral**		**Sex distribution**	
8.18% (n=9)	22% (n=2)	Left	Right	Female	Male
		85.7% (n=6)	14.2% (n=1)	66% (n=6)	33% (n=3)

(*Modified from Miles 1994)*

would consider pertinent to the topic of os acromiale: was this condition developmental or a fracture?

In the early twentieth century, there were two conflicting schools of thought. One the one side was Symington who was an anatomist that observed OA as bilateral in 67% of cases. He stated that OA was the result of an unfused epiphysis as opposed to a fracture. This was based on the fact that the juncture between the epiphysis and the scapular spine was too congruent to be the result of a fracture. Alternatively, Struthers interpreted OA as the result of a fracture of the acromion which failed to fuse properly (Miles 1994; Symington 1900). The variation of the epiphyseal line was taken as further support of the fracture theory. If the non-union was developmental, Struthers argued that the line would angle backwards instead of being a line across the acromion. The types of os acromiale non-fusion, vary according to the site of non-fusion, therefore the proposed "fracture" line is most similar to the site of mes-acromial non-union (see Figure 3.1). The Struthers school was not widely accepted, as most anatomists treated this as a developmental phenomenon. Clinical teaching implies that if the condition is bilateral it is reasonable to assume that it is developmental non-union (Symington 1900). Possible misinterpretations of this trait could have been due to the fact that many of the cadaver specimens studied were of older individuals. As a result, the physical appearance of how

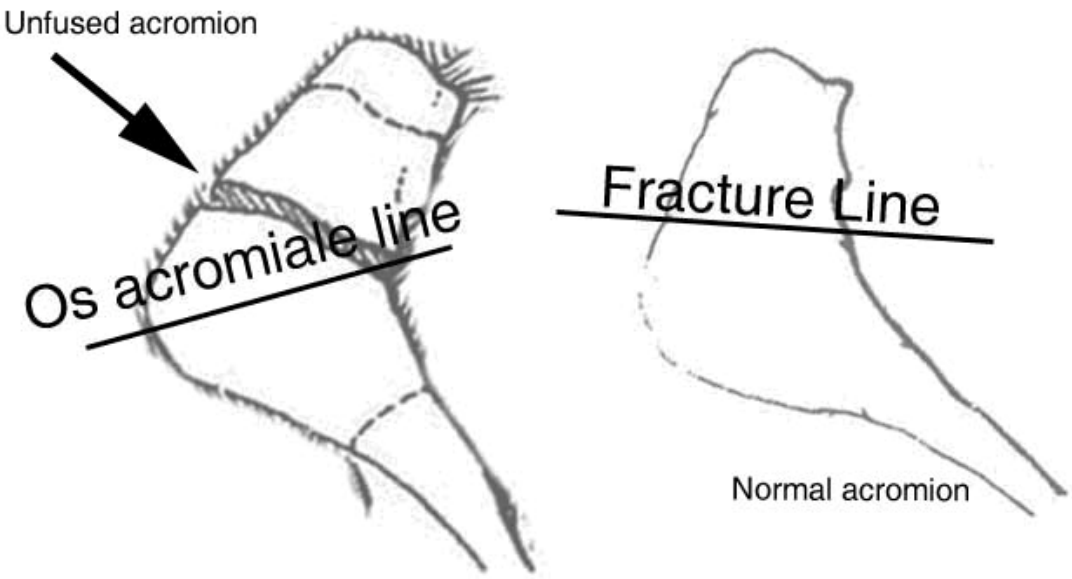


Figure 3.1 Side by side comparison of acromion with hypothesized fracture and OA lines

a developing acromion appeared was unknown and could have been interpreted as a fracture (Miles 1994). The etiological discussions regarding os acromiale have been through a long history which is thus continuing along the lines of the present discussion.

In addition to the Medieval Danish sample presented earlier, another European sample includes the Mary Rose sample from England (Stirland 1988, 2000). The interesting aspect about this site is that the author interpreted os acromiale as the result of a mechanical etiology, not a genetic, due to the high frequency of OA at this site. It is the only sample with an OA frequency of high levels. It shows that high OA can occur amongst other ancestral groups.

This sample was the result of an English flagship which sank in 1545 during a battle against a French fleet. The ship remained buried at sea until 1982 with the remains subsequently well preserved. The skeletal sample from the Mary Rose is predominantly

male. The majority of males in the Mary Rose sample fall into the 15-25 age range. The occupational specializations of the crew were known through the ship's manifest which contains the details of crew and occupations. Stirland (1988, 2000) uses this to argue that the occupation of archer on the ship could have led to the high frequency of OA.

The details surrounding the trait frequency for in this group was first reported as 12.5% (n=26/ 207 scapulae). However, due to the nature of the site, there was a great deal of commingling. Yet despite this commingling, the researchers were able to match 52 scapulae. When the commingling is taken into account, the corrected frequency based on Stirland's (2000) data is 19% (10/52 pairs). This is the highest frequency in a European sample to this date. The bilateral frequency is 60% and the unilateral frequency is 40%. Of the unilateral occurrences of OA, the left side is the most frequent side (75%) of OA. This left side occurrence is one of the most common side biases in the literature although not all have been tested for significance.

Stirland (1988) attributes the high frequency of OA to the use of long-bows by professional archers on the ship. Archers were regularly deployed on such ships and in 1512, English law required that every able bodied male individual was trained to use the long bow (See Ch.V). Male children began training with bows and arrows between the ages of 7-17 yrs. In 1542, another act was passed stating that at the age of 24, one had to be able to shoot accurately at a target a distance of 200 meters (Rule 1982).

In addition to the Mary Rose sample, the Towton site is another English sample with high OA rates (Fiorato 2000). Towton is located in the North Yorkshire region of England. This was the scene of the battle of Towton in 1461 AD. This battle was part of the War of the Roses, a feud between the Houses of York and Lancaster, which were

vying for the throne of England. This site predates the Mary Rose site and like the Mary Rose, this population is primarily male. The ages of those recovered were predominantly between the ages of 26-35 and were employed as soldiers for their respective houses.

From this site, approximately 29 individuals analyzed for the trait of OA. This sample size does not accurately reflect the number of individuals which participated in the battle which was estimated to be ca. 28,000. The analysis of OA depends on the completeness of scapulae recovered and the ability to match them as a set. The OA frequency was 9.2% and bilateral 67% of the time. This rate is higher than that seen at the Isle of Ensay, but not as frequent as high as the OA frequency in the Mary Rose sample (Fiorato 2000). The actual OA frequency in such cases expected to be higher than what is recovered, due to the likeliness of recovery (Vallois 1925 in Miles 1994).

Knüsel (2000), like Stirland, interpreted a mechanical etiology for the Towton individuals citing the evidence at the Mary Rose. It is not difficult to see the reason beyond such interpretations, especially considering that they are all male samples and the profession in which these men were employed. These represent individuals employed in physically tasking occupations of archer and soldier.

Knüsel proposed, largely from data in the clinical literature, that having OA provided greater mobility in the shoulder area due to the nature of the interacromial joint between the base of the acromion and the separate acromial epiphysis. This would lend to an increased range of movement, in regards to the external rotation and elevation of the arm. This would also allow for the easier passage of the supraspinatus muscle tendons which move under the acromion. The need for greater laxity in the dominant arm of such individuals develops out of the necessity to protect the shoulder from injury during

forceful overhead movements. While Knüsel does not necessarily propose archery as the cause, he acknowledges that it could be considered the source of mechanical stress along with projectile throwing activities performed during war conflicts of that period.

All of the above mentioned research focuses on available Old World samples, including one from Africa, and three from Europe. These have been the two ancestral regions which have been focused on the most. It would be interesting to see the patterns present in other ancestral groups, however that data is not available at the present time. The following section focuses on samples from the descendant groups of these two regions. The summary of OA frequencies presented in this section can be seen in Table 3.3.

Os acromiale in African and European-American descendant groups

The earliest sample of an African-American population is from the African Burial Ground in New York City (NYABG) (Blakey et. al 2001). Enslaved Africans were brought to New York City from West Africa via the Trans-Atlantic slave trade (Mcmanus 1966). Slavery largely associated with Southern plantations, did exist in northern regions as well. The NYABG sample represents a highly stressed community that survived the highly stressful Trans-Atlantic passage. The 'Negro Burial Ground', as it had been referred to, was in use ca. 1712-1794. However, it may have been in use even earlier.

Table 3.3 Summary of OA frequencies (Europe and Africa)

Sample	**OA Frequency Rate**	**Ancestry**	**Citation**
Medieval Danish	7.7%	European	Case et. al., 2006
Isle of Ensay (Scottish)	8.18%	European	Miles, 1994
Towton (English)	9.2%	European	Fiorato, 2000
Bantu	18.2%	African	Case et. al., 2006
Mary Rose (English)	19%	European	Stirland, 2000

Local churches had prohibited the burial of African descendants in their church cemeteries as early as 1697 (Blakey et. al 2001).

NYABG contained the remains of 419 buried individuals, only 301 of which were preserved well enough to be studied (M=102, F=69, 130 subadults) (Blakey 2004). Rankin-Hill (pers. comm.) supplied the raw data regarding OA frequency rates at NYABG, which are presented here for the first time. The results show a low frequency of OA (7.6%). This frequency could have been affected by taphonomic factors limiting the recovery of the scapula placing the frequency well below the normal frequency range. The problem with this low frequency is that it does not support a genetic argument or a mechanical argument.

It should not be doubted that NYABG is a stressed population. There are three main conditions which typify African-American skeletal samples, 1) high infant mortality, 2) malnourishment, and 3) high levels of work stress (Blakey 2004). The paleodemography of the NYABG group, (n=301), indicates that adult mortality rates were highest in the 30-50 age range. Females tended to have the higher mortality rate peaking at 30-39 years while men had a higher mortality rate peaked in between 40-49 years. In general, females tend to have a higher mortality rate, again due to the effects of childbirth. In the NYABG data, the adult mortality rates were affecting males and females in a similar manner up until their fourth decade. The similarity in high mortality rates for both males and females can be due to the fact that this population had suffered as a result of the traumatic transport experience amongst first generation slaves.

Signs of nutritional deficiency were also present at NYABG. Porotic hyperostosis occurred in 50.5% of the adult population and 39.8% of sub-adults. Rickets, shown by

bowing of the lower limb bones, affected 14.4% of adults and 6.5% of children. Rates of scurvy are not available for this population at this time (Blakey 2004). In the NYABG sample, the dentition is a further source of information concerning access to proper care and hygiene, or lack thereof. Dental pathology includes caries and abscessing as well as enamel hypoplasias which reflects developmental stress, diet, and living conditions. A diet high in carbohydrates can lead to more frequent caries lesions and when left untreated, caries can develop into abscesses, which may eventually lead to tooth loss and bone resorption. The frequency of enamel hypoplasias in sample from NYABG was 70% (62.5% of F, 74.3% of M) and is lower than seen at FABC (Blakey 2004).

In a slave population such as NYABG, there were also signs of musculoskeletal stress markers (MSM). This includes hypertrophy of muscles attachments, facets, and degenerative joint disorders. The types of labor performed by slaves in New York City, ca. 18th century, included working in the cities ships and ports, manufacturing, road and building construction, and domestic labor. In the NYABG, only 187 out of 301 adults were suitable for analysis for MSM. Specimens were excluded due to their poor state of preservation, mold contamination, or their young age (<15). One of the individuals, burial 97, demonstrates a very physically stressed person. His MSM scores were moderate to severe for 56% of all his muscle attachment sites which was twice the average amount. This individual expressed signs of physical stress due to slave labor, and had os acromiale. It would be this suite of characters that would make a strong case for the mechanical etiology. It would be interesting if all those affected with OA from NYABG could be examined for this type of stress level to see Burial 97 is the exception

or the rule. From frequency data alone, NYABG does not fit the model for the mechanical argument and neither does it fit the model of the genetic perspective.

All this evidence of nutritional deficiency, occupational stress markers, mortality rates is present in the NYABG sample (Blakey 2004). The only argument which is shows the most plausibility is the combined hypothesis. In the case of NYABG, this could be proposed to be the reason which os acromiale was not as high as expected. The genetic potential of a non-union of the acromion would only occur if the mechanical stress affected that particular region during adolescence.

The next site is one which was the initial basis for the genetic argument of os acromiale. J. Lawrence Angel at the Smithsonian Institution studied a free African American skeletal population from the inner city of Philadelphia (Angel 1987; Parrington 1990). He examined the remains of the First African Baptist Church (FABC) which dated from ca. 1822 to 1841 for the non-metric trait OA. Despite the status of a freeborn community in FABC, certain older individuals in the population exhibit healed fractures associated with the harsher conditions associated with enslavement. Angel (1987) stated that, based on the high frequency of os-acromiale among African-Americans, it was a genetic trait. The OA frequency he was referring to was the initially reported frequency of 30%, much higher than the frequency of 7% reported (Grant 1972). This was in the early estimate of FABC data based on an initial sample size of 25 individuals.

There are other factors to consider when assessing the etiology of os acromiale. While this may be a freed African-American population, the population could still be subject to mechanical stress. If, the FABC population had been involved in strenuous activity at a young age, it could have affected the bone fusion process (Rankin-Hill

1997). Rankin-Hill (1997) adjusted the frequency down to 20% as the final sample size for the FABC population (n=75) the condition was bilateral in 78.6% of the cases. The majority of individuals affected were male (25%) as opposed to female (12.8%) although there is no mention of a side bias. Most individuals (87.5%) were aged to be between 30-50+ years old and. Rankin-Hill (1997) and Blakey (2000) suggest that FABC, although a free and an ex-slave population, underwent a great deal of stress, if not more stress after slavery. The FABC skeletal population follows this model demonstrating a high incidence of infant mortality, and adults between the ages of 40-50 years. Female mortality peaked between 20-30 years that correlates with child bearing years. Male mortality rates peaked later during the 40-50 age range.

A reflection of an iron deficient diet was found in 53.3% of adults as evidence of the nutritional disease at FABC was porotic hyperostosis. Other evidence of nutritional deficiency included rickets, scurvy, and osteomalacia, although these were not as frequent as porotic hyperostosis (Rankin-Hill 1997). Periostitis, a sign of infection, was found in 25.3% of the population. It affected men (36.1%) at a higher rate than women (15.4%). In general, the men of the FABC population were highly stressed. Dental evidence of metabolic stress, as evidenced by the presence of one or more hypoplastic defect occurred in 92% of adult males, and 86% of adult females (Blakey et. al. 1994).

An 1838 census from the Pennsylvania Abolition Society, surveyed the variety of occupations held by head of the household. The majority of males were employed as laborers, waiters, and porters. The majority of women were employed as washerwomen (laundresses), domestics, and cotton mill workers. The majority of these occupations involved strenuous physical labor. For the mechanical argument to apply, such strenuous

labor would have occurred during adolescence when unfused areas were the most susceptible.

A later (1855-1920) African-American sample in this paper from Wilmington, Delaware is the Mother Union American Methodist Episcopal (UAME) Church cemetery site (Thomas, et. al 2000). This sample was comprised of 128 adults (60=M, 43=F, 25=undetermined). For the Mother UAME site, the frequency rates were constructed based on the reported observations of OA in the archaeological reports. The Mother UAME church had a total frequency of 2.9% (n=3/103). This sample shows a decreasing trend in OA frequency from FABC population. Bilateral frequency of OA was 50%, lower than the average rate.

This next sample is one of two cadaver collections which contain large numbers of both African-American and European-Americans analyzed for OA. The Hamann-Todd collection was studied radiographically by a clinician, Sammarco (2000). He examined 1198 skeletons comprises indigent individuals from the Cleveland, Ohio region. This collection ranges from the 1900's until the 1930s (Kern and Latimer 1996). This sample consists of 1033 males, and only 165 females. This creates a problem when it comes to interpretation of a sex bias, since the sample is overwhelmingly male. Sammarco (2000) concentrates on the within-population differences within populations, simply the differences between populations. At this time, an analysis on the biohistory of the African-American population of Hamann-Todd has not been done.

The OA frequency for the entire Hamann-Todd collection is 8%, and is bilateral in 33% of the sample. The OA frequency for the African-American portion of the sample is 13.2%, while for the European-American subset it is 5.8% these differences were

found to be statistically significant, $p<0.001$. The same pattern of African-Americans having a higher frequency is again reaffirmed. Sammarco also notes that the male (8.5%) versus female (4.9%) frequency is higher, and these results were also significant $p<0.09$, this is similar to the results obtained by Hunt and Bullen (2006) in their examination of the Terry collection. However, Case et. al. (2006) criticized Sammarco for his claims of a sex bias as the Hamann-Todd female sample is made up of 165 individuals out of 1198 (Case et. al. 2006). Hunt and Bullen (2006) were able to show that there was still a sex bias with a larger and proportionate representative sample size of females.

Sammarco also noted the presence of a fused OA which has not been noted in the anatomical literature. The specimens which appeared to have a fused OA had a thin depression line around the acromion. This is a condition in which the acromial epiphysis has fused although the line of depression is still visible in the bone. While it is unclear how frequently it is occurs in the normal population, in this research it will be considered as a variant of the type of os acromiale. This should not adversely increase the rate of OA significantly, as it is extremely rare version of OA (See Ch. VIII).

In an analysis of the OA frequency in the Terry collection which dates to 1920-1967. Hunt and Bullen (2006) examined the possible correlations between OA, sex, and ancestry. The Terry collection is from St. Louis, Missouri, and contains remains of cadaver specimens from hospitals, morgues, and the medical schools. They examined 1594 individuals, 828 were African-American, and 766 were European-American. These groups were divided further into four groups, 481 African-American males, 347 African-American females, 456 European-American males, 310 European-American females. Their study differed from previous studies in that they only included adults

aged 25+ and older, while previous research included individuals between the ages of 18-25. This is due to the differing views as to possible misdiagnosis of os acromiale versus a subadult acromion. However, that is not a concern if one can discern between a juvenile and unfused epiphysis (Sammarco 2000).

The total OA frequency in the Terry collection was 8.34% and the bilateral frequency was 57%. Among the European-American subset of the Terry sample, 5.35% were affected with OA, and bilateral in 22.8% of cases. While among African-American subset, the OA frequency was 11.11%, and the bilateral frequency was 44%. They found that there were statistically significant differences between ancestral groups, ($p<0.0001$). Their results mirror previous research in reflecting a higher frequency of OA in African-Americans.

However, the frequency of OA is also higher according to sex; there was also a significant difference between the sexes at the alpha level of 0.5, ($p=0.0295$). The male frequency of OA is 9.7% as opposed to the female frequency of 6.4%. A two-way contingency test examined the interaction of both ancestry and sex together, and showed there was a significant difference (p=0.004) between ancestral groups within each sex (ex. European males and African-American males). No significance was found between the sexes within ancestral groups of African-American individuals ($p=0.1877$). Yet, there was a significant difference between European-American females and males ($p=0.0403$).

In summary, this showed that African American males were at one end of the extreme with European-American females at the other. This pattern could also follow a stress related argument with those same extremes correlated with the physical workloads

of each respective group. Further, European-American males in the Terry had the highest occurrence of a side bias, with 54.8% had an OA on the right side. While, in African-American males there was no side bias, bilateral occurrences were the most frequent, at 48.3%.

All of the above mentioned literature focused on samples of descendant groups from both Africa and Europe. While in the previous section the sample with the highest OA frequency was European, among the descendant groups the highest OA, was found among an African-American sample (Table 3.4). A total summary of OA frequencies in all the descendant groups in this section, are in Table 3.5. From an overview of the anthropological literature a case for the mechanical etiology has been made, despite the difficulties of accurately assessing it from skeletal data is difficult, but not impossible. One approach to examine a mechanical argument is to examine a modern sample for a decrease in OA frequency. If present, this would reflect that OA has been decreasing in a directional fashion, instead of fluctuating randomly. This is based on the assumption that the modern sample of the William M. Bass donated skeletal collection is less active than earlier samples.

Table 3.4 Frequency of OA among African-American populations

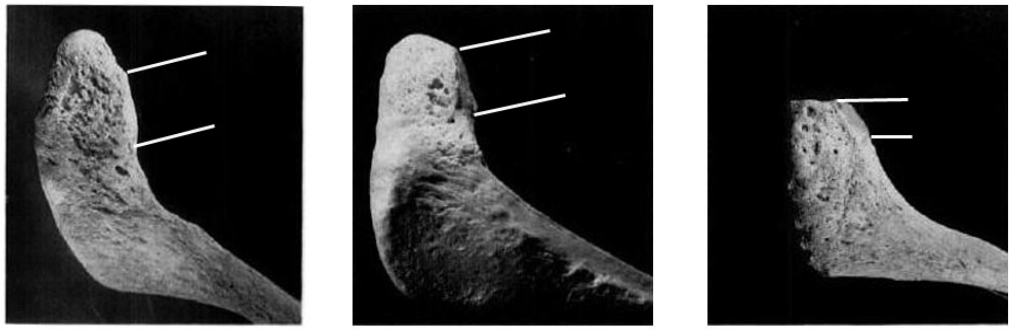
Skeletal Sample	No. of Ind.	Total Freq. of OA	Bilateral freq.
UAME	103	2.9%	50%
NYABG	171	7.6%	42.8%
TERRY	828	11.1%	44%
HAMANN-TODD	355	13.2%	44.7%
FABC	75	20%	78.6%

Table 3.5 Summary of OA frequencies (European and African descendant groups)

Sample	OA Frequency Rate	Ancestry
UAME	2.9%	African-American
Terry Collection	5.35%	European-American
Hamann-Todd	5.8%	European-American
NYABG	7.6%	African; African-American
Terry Collection	11.11%	African-American
Hamann-Todd	13.2%	African-American
FABC	20%	African-American

Acromial shape

In this paper, the combined hypothesis seems worthy of further examination. One possible genetic explanation, shape, can be tested by while simultaneously studying the modern frequency. The background on studies of the acromial shape comes from the clinical literature where varying researchers have expanded upon this subject and OA. Edelson and Taitz (1992) conducted a study on the acromion by which they divided the acromion into three categories based on shape. These shapes are based on the position of the acromioclavicular facet and its distance from the anteriormost edge of the acromion. These categories are: 1) cobra, 2) intermediate, and 3) square-tip (See Figure 3.2). The cobra is the shape which has the longest distance (5-10 mm) between the AC facet and the acromion. In this particular shape the position of the acromioclavicular facet is the furthest from the anterior acromial edge. The square tip is the opposite extreme, which occurs when the acromioclavicular facet is at the anterior edge of the acromion, and the anterior portion of the acromion forms a straight edge. The intermediate shape is between the other two categories and the acromioclavicular facet is medially located between the square tip and the cobra.



Cobra **Intermediate** **Square Tip**

Fig 3.2 Acromion shapes with respective acromioclavicular facets highlighted between the white lines (*Modified from Edelson and Taitz 1992*)

Gumina et. al. (2003) applied the categories set forth by Edelson and Taitz (1992) towards the genetic argument for OA. It was emphasized that the morphological condition of the acromion maybe what is genetically transmitted instead of the condition os acromiale. These researchers examined the acromioclavicular shape and joint position radiographically to examine if there was a specific acromial shape that occurred most frequently in association with OA. Within a group of 244 volunteers there were 211 (86%) individual without os-acromiale, along with 33 (14%) individuals who had cases of os-acromiale. Those unaffected by OA represented the control group in this study. The results showed that for the control group (without OA) 52.13% had a square tip acromion, 30.8% had an intermediate, 14.69% had cobra shaped acromion. Only 18% had a square tip shaped acromion, 36-40% had an intermediate shaped acromion and 40-45% had a cobra shaped acromion. In this radiographic study, individuals with OA were more likely to have an acromion in the shape of cobra, or intermediate as opposed to that

of a square-tip. There results were found to be statistically significant (*p=.0002).* This data has yet to be tested on a skeletal sample. In the present study of the William M. Bass skeletal collection, this combined hypothesis will be tested along with a decrease in OA frequency. In this manner, both a genetic etiology and mechanical etiology will be further tested.

IV: Os acromiale and the case for a genetic etiology

Genetics refers to the hereditable biological composition of an individual, or on the broader scale; population groups. Ancestry refers to the shared evolutionary history such that can be evidenced by heritable traits present in the genotype, and/or phenotype. A great deal of variation can be manifested within a single ancestral group for any given trait. Shared evolutionary histories at times parallel specific geographic regions of evolution. However, as populations move and evolve so shall ancestral groups continue to change.

There are two main possibilities regarding the etiology of OA. The first possibility is that the main shape influencing the presence of os acromiale is a genetic etiology (Angel et. al 1987, Case et. al 2006, Sammarco 2000). A second possibility is that the main force shaping the manifestation of the trait is stress during developmental stages of growth (Stirland 2000, Knüsel 2000, Hershkovitz, et. al 1996). The first possibility will be explored further in detail in this section, while the last two shall be explored further in the next section.

One issue with the interpretation of any trait is that the numbers of genes operating on it are not known. Therefore it is possible that non-metric traits, which appear to have discrete phenotypes (presence or absence) are in fact polygenic (Berry and Berry 1968). That nature of the genetic components of this condition can only be assessed through familial studies, or the discovery of the gene(s) that affects this trait specifically. Frequency rates that have been supplied are in fact only indirect support of the genetic argument (Case et. al. 2006).

Angel (1987) first mentioned OA as a genetic marker in his article on the FABC population. The developmental anomaly was present at a higher frequency (20%) at FABC, than the 7% documented from anatomical literature (Grant 1972). However, the applications of one sample frequency as the norm for interpreting the other, is debatable. Berry (1968) cautions against generalizations based on one sample, since frequencies are sample specific and should not be used to make assessments on other samples

According to Angel (1987), if OA is a reliable genetic marker then it would reflect the inter-relatedness between family groups within the FABC cemetery. Angel (1987) examined the spatial relationship between the OA affected individuals, and found several interred in shared grave plots. From this he deduced that these individuals were from family groups, because family members would be most likely buried in the same plot. Of the 19 affected individuals, 12 of these were found in five separate cluster groups of shared grave plots (see Figure 4.1).

Angel (1987) further theorized the type of kinship relationships at FABC based on these temporal-spatial distributions. He stated, "Note that many of the families were probably interrelated by marriage if this trait; is a reliable genetic marker." He is implying that if OA is indeed a genetic trait, then the five clusters of groups represent five families, who were not only related by blood but perhaps by marriage as well. The interpretations and implications this trait was an attempt at reconstructing a pedigree of the FABC individuals based on this trait.

Case et. al. (2006) argued that the evolutionary force with the most of the effect on OA would be genetic drift. Under this argument closely related groups would exhibit similar

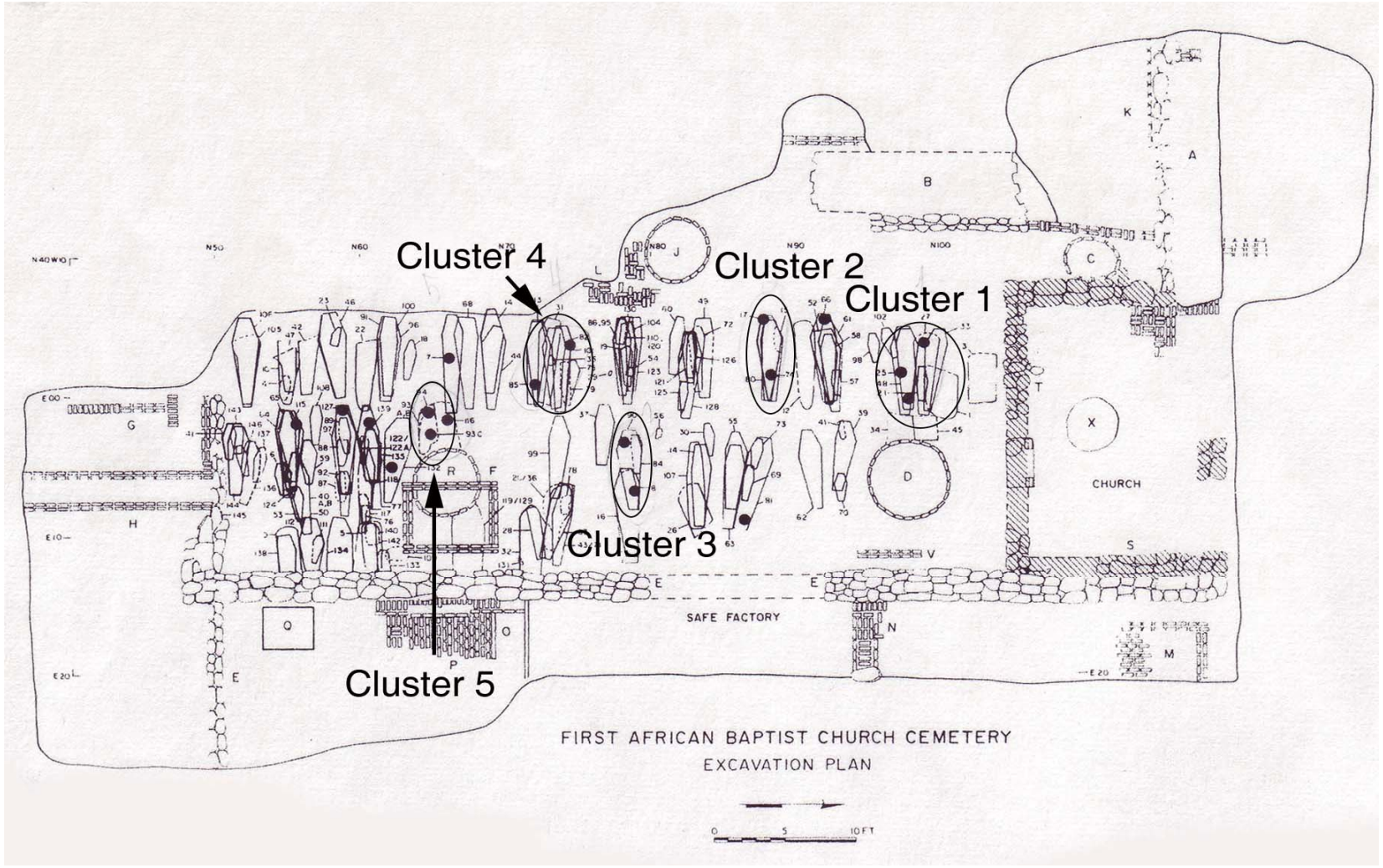


Figure 4.1 First African Baptist Church Excavation Plan *(modified from Parrington and Roberts 1990)*

frequencies as opposed to distantly related groups. Genetic drift is also random as the fluctuations of the OA frequencies appear to be. Mutation seems to be unlikely candidate for influencing this trait on a genetic level, since this would have to be a recurring mutation in the gametes. Gene flow is dependent on the degree of admixture of population groups. He argued that for this to significantly influence frequency rates, large scale admixture would have taken place. Natural selection is also not viewed as the main evolutionary mechanism acting on OA. This is based on the logic that OA by itself would not affect reproductive success.

Of those advocating a genetic perspective, Sammarco (2000) deduced from his study (see Literature Review) that the high frequency among African-Americans (13.2%) was correlated with a genetic factor associated with ancestry. Gumina (2003) also advocated the argument of a genetic predisposition, but in regards to the shape of the acromion overall, not regarding ancestry. In fact the shape argument was advocated as the connection between genes and os acromiale instead of ancestry. Logically proponents of a genetic argument would stipulate that the three shape categories could also correlate with specific ancestry. This hypothesis will be tested for any interactions in the logistical regression model.

Os-acromiale is to some degree shaped by our genes. The real question is to what extent is the trait a result of ancestry, or a result of additional factors? No gene functions in isolation it is a part of the individual, who, is affected by all that surrounds him. Therefore, the underlying mechanical conditions which shape those frequencies, including the daily lives of affected individuals should be explored further before final conclusions are reached.

V: Os acromiale and the case for a stress etiology

The second possible argument for OA is a stress etiology. To prove such a mechanical stress etiology, first the source of stress must be identified. That stress would have to occur during the developmental stages when secondary ossification centers first appear until the age when these centers fused together 14-25 yrs (Case et. al. 2006; Liberson 1937; Macalister 1893). In Kennedy (1989), os acromiale is described as being the result of a tearing of the rotator cuff due to continual and heavy loading of the upper limb.

Case et. al. (2006) presented the elements, which should be present for a mechanical etiology to be plausible. First, that in groups with similar frequencies, the activity levels of adolescent youths would have to be of a similar type of stress level affecting the upper girdle of the body. However, this author commented that it was "…unlikely that all these groups shared a lifestyle that placed similar stresses on their shoulders during adolescence" (Case et. al. 2006). While it may be difficult to examine such activities, as not all skeletal samples come with complete records regarding the work histories for that place or time, this could be another approach applied in future studies.

Aside from looking at the sociohistorical evidence, mechanical stress can be deduced from the OA data itself based on the presence of 1) a side bias, or 2) a sex bias (Case et. al. 2006). Another method to examine a mechanical etiology is to deduce work stress based on the class of sample. Under the assumption that even in death class distinctions can be made, and that said class difference reflects a difference in work opportunities mechanical support could be attained. The logical argument follows that a lower class individual is more likely to have a stressful workload at an early age. In

previous applications, differences between the two classes within the Medieval Danish population were not statistically significant (*p=0.105).*

There are several critiques regarding this interpretation of sex biases. These are due to the fact that proportionate sample sizes are not substantial enough for sex biases to be concluded. In the South African and Danish samples, the sample sizes included a larger number of females, in an attempt to alleviate this problem. Case et. al. (2006) tested the South African and Danish sample, for a sex bias and the results were also not found to be statistically significant (*p=. 847, p=. 559, respectively*). However, in the South African Bantu, Medieval Danish, and NYABG samples, the female frequency of OA was always higher than the male frequency (see Table 5.1). Chronologically speaking, those samples with a higher female sex bias tend to be the earliest samples. A male sex bias was present in later samples, though not found to be significant in previous research.

However, Hunt and Bullen, 2006 did find a significant sex bias.

A critique of a side bias, is that in several studies which examined side biases of non-metric traits, it was very rare that a consistent side bias was present (Case et. al. 2006). In most cases, the heritability of such traits is not yet known. Furthermore, the difficulty in ascertaining a side bias depends on the condition of the sample. Some samples may be commingled, fragmentary, missing, leaving an incomplete data set which cannot be examined for side bias in an individual let alone a population. Such analyses should be limited to those samples which paired data is available.

Recall, that in the South African sample analyzed by Case et. al. (2006), there was a side bias present on the left side, which was found to be statistically significant

Table 5.1 OA frequency according to sex

Sample	Total No.	Males No.	Females No.	Male Frequency (OAM/TM)	Female Frequency (OAF/TF)	Overall OA Frequency
South African Bantu	494	264	230	17.4%	19.1%	18.2%
Medieval Danish	532	229	187	6.6%	7.0%	7.7%
NYABG	171	102	69	6.86%	8.69%	7.6%
FABC	75	36	39	25%	12.8%	20%
Mother UAME	103	60	43	5%	2.32%	2.9%
Hamann-Todd	1198	1033	165	8.5%	4.9%	8%
Terry Collection	1594	937	657	9.7%	6.39%	8.34%

(*p=.013*). Therefore, the presence of a consistent, non-random side bias in a large OA affected sample would support a mechanical stress etiology. There was no combined analysis done which would have taken into account how a side bias might further reveal differential distribution amongst the sexes. Nevertheless, a side bias, which is statistically significant among the South African sample, was present and supports a mechanical etiology.

There was also a side bias, again favoring the left side in the Mary Rose sample. In this sample, Stirland (1988, 2000) argued that the occupational activity of an archer, could explain the high frequency of OA. Archers training in the 16th century England began at an early age (7-17 yrs.). This is exactly during the formative years which would affect the developing acromion. The draw weight of a longbow, as was tested using computer modeling reconstructions, was 100-172 lbs. (Stirland 2000). Archers were employed on battle ships in this period, and heavy longbows with draw weight of this magnitude, would have had a considerable impact on the developing acromion, especially through repetitive use.

Stirland (2000) even offers an explanation as to the tendency to see a higher unilateral OA frequency on the left side. In archery, there are different styles of firing a bow, one of which is termed “laying the body”. Instead of using the drawing arm as a pulling force, the person leans into the bow with their full weight. The force is then on the left arm which is holding the bow, and thus places more strain on the left shoulder (See Figure 5.1). This would be a plausible explanation for the side bias in this situation.

Despite Stirland’s mechanical argument, arguments from the genetic camp have raised the point that if mechanical stress is the sole cause of OA, than there should be more examples of European sites reflecting those high levels (Hunt 2006). Stirland (2000) offers the conclusion, that perhaps the Mary Rose represents a rare sample. While, there are no historical documents stating the presence of archers on the Anthony Roll (an inventory of English ships), 185 soldiers were listed as part of the crew of the Mary Rose. This along with the archaeological remains of 172 longbows, and 3969 arrows later recovered from the ship point to soldiers with a specialization in archery (Stirland 2000).

Many of these soldiers could have been trained in the use of longbow, even than the average medieval European male would have been required to have this skill. It is not a huge stretch that soldiers, would be specialists in this regard. In this way, the Mary Rose, is a military sample, not a typical European sample. Nevertheless, Stirland’s interpretation of the Mary Rose sample is critiqued, as being too commingled for analysis (Hunt 2006). However, as was illustrated in the Literature review, Stirland (2000). revised her sample size to reflect bones, which could be paired to one another.



Figure 5.1 "Laying the Bow" firing position (*from Stirland 2000*)

Lastly, it has been argued that the age of fusion could potentially be a factor, however that is not the case as the differences between OA and a developing epiphysis are distinguishable from each other as well (See Ch. II).

In summary, the Mary Rose reflects a unique type of sample, that of a military population, which is more likely to reflect specific parameters, yielding a higher frequency of OA. Those parameters are 1) a specialized population, 2) a mechanical stress which affects the shoulder region, 3) stress which occurred between the ages of secondary ossification center formation and normal fusion (14-25).

To further this example, the Towton site, (see Literature Review) is another English military site. There is a frequency of OA (9.2%) present though not as high as the frequency seen in the Mary Rose. However, this illustrates that there are other English sites reflecting a high OA. Again, the context surrounding this site seems to suggest, that the more specialized the population is, and the more they are stressed in the shoulder region, the more likely they will reflect OA at a higher rate (Knüsel 2000). In the European sites, there appears to be a connection between a higher frequency of OA and military populations. However, with African, or African-American populations, no particular activity has yet been identified.

One of the puzzles regarding this fact is the NYABG sample whose OA frequency was 7.6%. This frequency is within the "normal" range based on modern Euro-American samples. Yet, the knowledge that NYABG represents one of the earliest slave samples in this paper should cause one to pause. How is it possible, that such a stressed population has a relatively "normal" frequency? One argument is that in an urban slave environment, signs of stress in the skeleton are highly variable, given the

wider range of work activities. In the colony of New York, slaves were occupied in a wide range of employments ranging from coopers, tailors, bakers, tanners, goldsmiths, naval carpenters, blacksmiths, weavers, bolters, sailmakers, millers, masons, candlemakers, tobacconists, caulkers, carpenters, shoemakers, brushmakers, glaziers (Mcmanus 1966). Studies into the occupational parallels between the African-American sites could be a potential future topic of research. At this point, clinical data also yields interesting data on current patterns of stress and os acromiale.

Os Acromiale & Sports

The evidence for a mechanical etiology can also be obtained from the clinical record. The following illustrates case studies of several athletes who required medical attention. There are various modern sports in which athletes develop shoulder pain, which in turn lead to a discovery of an os acromiale. The relevance between os acromiale and certain shoulder diseases is still unknown. It has been discussed in conjunction with rotator cuff tears, and impingement syndrome. The orthopedic community has not yet discerned what role os acromiale plays in relation to these illnesses. For further information see (Edelson and Taitz, 1992, Jerosch 1991, Neer II 1983, Nicholson 1996, Miles 1994, Mudge et. al. 1984, Sammarco 2000). While these are clinical scenarios, they present contextual information about activities, which lead to shoulder stress.

The first case involves the shoulder injury of a 19-year-old injured basketball player. He sustained “a direct blow to the right shoulder” during a Division I collegiate level men’s game. Previously, this individual had a history of shoulder pain in this area when using him arm in an overhead motion. Eventually, it was discovered that in

addition to the injury, he also had an os acromiale in that shoulder. In another incident, this same athlete fell on his left shoulder, and an os acromiale was discovered there as well. In this scenario, discovery of os acromiale occurred after a direct trauma. This individual had prior to injury and experienced pain during overhead activities. The age of this basketball player would indicate that he should be in phase when fusion is to take place. However, this example should not be excluded from analysis, as the epiphysis would appear different from a fusing OA (Davlin 2003).

The next case, involves a 17-year-old baseball catcher. This athlete experienced pain while throwing with his right arm. Similar to the previous case there were initial symptoms of shoulder pain when performing overhead actions. This individual suffered an injury in which he was hit in the right shoulder with a baseball. This arm is under strain of repetitive use, and is the individuals throwing arm. This individual experienced pain when his arm was in multiple positions, including abduction (Sterling 1995). He was diagnosed with impingement syndrome, along with the os acromiale and treated. The left shoulder also had an os-acromiale, but since there were no symptoms of pain and it was not treated.

A 29-year-old professional tennis player, who had begun playing tennis at 14 yrs., had no previous history of shoulder pain. This player was engaged in repetitive overhead play for 15 years without any symptoms. In this scenario, direct trauma had not occurred to the shoulder region. The main source of immediate strain was a long and exhausting match the day before pain started. X-rays of the right shoulder revealed an os acromiale. This example demonstrated that direct trauma is not always the source of shoulder problems. This athlete, unlike the previous two cases, had full range of motion and was

not diagnosed with any additional shoulder afflictions. This example also illustrates that long term- overhead activity is also a source of shoulder problems in the modern athlete (Burkhart 1992).

This case is not from a clinical background. It is the analysis of the remains of two individuals of known occupations. These skeletons are part of the Hamann-Todd collection, and belonged to two boxers, ages 45, and 42. Both individuals had a suite of occupational markers, fractures, and degenerative changes on their entire skeleton. While, the researchers had *a priori* knowledge of work activity, Hershkovitz, et. al (1996) did not focus solely on one marker, but rather the whole pattern of mechanical stress present in the entire skeleton.

One of the traits presented as mechanical stress marker was, os acromiale. This is based simply on it's presence in both individuals who happen to be boxers. In one individual the trait was bilateral, while it occurred only on the left side in the other. Hershkovtiz et. al (1996), interpret the non-fusion of the acromion due an early onset of training, involving weights bearing exercises affecting the deltoid muscle which would anchor at the acromion. Additionally, in the first individual, the secondary ossifications of the lumbar vertebrae and the last six thoracic vertebrae failed to fuse as well. Increased instances of lack of bony fusion would seem to reflect a genetic etiology. Then again, from a stress perspective, the lack of fusion only occurred in the lower back. Such regional variation might be a sign of increases stress in the lower back.

It would be presumptive to say that those afflicted with OA in the Bass collection were athletes. However, the argument for mechanical stress being a factor in the presence of OA must definitely be considered. The primary evidence supporting it would

be that the individuals 1) affected while young 2) performed a specialized activity, which aggravated bony fusion. Since that data is not always available the secondary support for a mechanical etiology of OA is the presence of 1) a sex bias, 2) a non-random side bias. Furthermore, for these biases to be accurately interpreted, they should be tested in samples, which are large, proportionate amongst ancestral and sex subgroups to examine. The Bass collection will be analyzed to determine whether in the Bass collection 1) the frequency rate is significantly lower than earlier populations, 2) a sex bias is present, or 3) a side bias is present.

VI: Materials & Methods

To address these two research questions, 1) modern frequency analysis of OA, and 2) significance of OA shape, two samples would be utilized. The William M. Bass skeletal collection contains the remains of 900+ individuals and dates from the years 1981 to the present. The purpose of examining this sample was to examine the modern os acromiale frequency. This is under the assumption that a modern population from a sample such as the William M. Bass collection is inherently less stressed than an earlier sample. Advances in technology and an increasingly sedentary lifestyle would lend itself to a decreased OA frequency, if OA is only influenced by mechanical stress.

A comparative sample of 542 scapulae from the Robert F. Terry collection curated at the Smithsonian Institution was also examined. The purpose is to ascertain whether there is a difference between early vs. late twentieth century samples as a result of modern technological advancements. This sample is different from the published sample of Hunt and Bullen (2006) in two ways. First, this research will examine the acromial shape in conjunction with acromial (presence or absence). Second, the age of their sample is 25+ and those studied in this research will include a broader range of individuals aged 18+.

OA frequency methods

Only individuals with a known age and ancestry were included in the research sample due to this trait being manifested after the age of normal fusion (18-25). Since OA is dependent on the individual being a skeletally mature adult, then it was not expected to have a statistically significant difference in different age ranges. Therefore the only age factor was whether the individual was past the age of normal fusion.

Individuals, whose scapulae were incomplete, fragmentary, or missing, were excluded from the assessment of OA. OA was scored in a binary fashion, with 1=present and 0=absent (See appendix). As long as the condition was present (including a fused OA) the individual was denoted as affected. The data was scored per side, in case of asymmetry present in individuals. All scores were presented per side instead of per individual due to this reason.

Several frequency rates were recorded: *total frequency,* which represents the total number of individuals with OA in the sample population; *bilateral frequency* represents the number of individuals with OA in both shoulders. Total frequency shows how many individuals are affected by OA, while bilateral frequency reflects how severely each individual was affected. It was also noted where the acromial epiphysis had failed to fuse, such as the met- and mes-acromial junction or the pre-acromial junction (Mann 1990). It was critical to have a pair of scapulae, with the acromion region intact, and observable. As a result of these selective criteria the final sample size from the Bass collection includes 420 individuals. This includes 383 individuals of European-American descendants, and 37 individuals of African-American ancestry. Sex and ancestry distribution of the sample is illustrated in Table 6.1.

Table 6.1 Ancestry and sex distribution of William M. Bass collection

Ancestral Groups	**Sex**	**No.**	**Percentage of Sample**
African-American	F	4	.9%
	M	33	7.8%
European-American	F	97	23%
	M	286	68%

Shape methods

In order to test the argument put forth by Gumina (2003), the acromioclavicular facet position was observed in the William M. Bass collection and the Robert F. Terry collection, in conjunction with the acromial condition. All specimens were assessed visually and metrically for this classification. Although the measurement for cobra was provided as ranging between 5 and 10 mm, no measurement was specified in Edelson & Taitz (1992) or in Gumina (2003) for the intermediate acromial shape.

For the purpose of consistent classification, the measurements distinguishing between the intermediate category was set between 2.5 mm to 4.99 mm from the acromion tip to the anterior border of the AC facet. This is based on dividing 0-5 mm range equally between the square tip and intermediate range. The measurement was taken by placing one end of the sliding caliper against the anterior AC facet edge, and moving the other end towards the anteriormost projection of the acromion (See Figure 6.1). Each individual was examined at least twice on separate random occasions, with an adequate interval between recordings to insure accuracy (Merbs 1983). By, the beginning of the data collection process it was clear that shape varied not only between individuals, but between sides. Rather than a specific person being given a shape type category, each shoulder was examined individually and classified asymmetrically.

When degenerative changes were present on the acromion, i.e. osteophyte growth, lipping, enthesophytes, degeneration of the facet border, irregularity of the facet border, etc. the acromion became difficult to classify. Any specimens with degenerative changes which mitigated an acromial shape categorization were excluded from this section of the analysis. There are several studies which support the correlation between

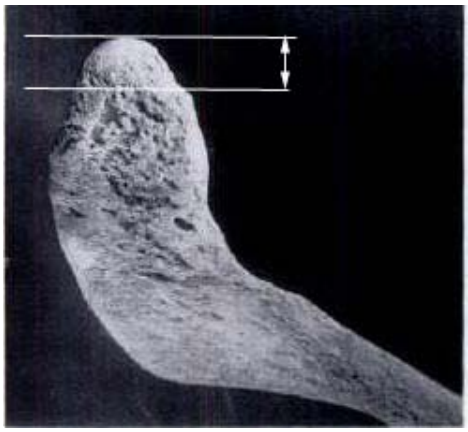


Figure 6.1 Measurement of acromioclavicular facet distance (*modified from Edelson and Taitz, 1992)*

osteophytic growth and rotator cuff tears, however that is not explored further here (Tuite 1995).

Acromial Shape Analysis

The shape analysis of os acromiale presented a more complex analysis of the data. In the Bass sample, many of the acromions which were examined were degenerated in older individuals. Some individuals, had enthesophytes along the anterior edge of the acromion. Other individuals, had osteophytes along the border of the acromioclavicular facet, and some individuals had both. While acromion shape could still be ascertained non-metrically, the ability to quantify this metrically would be at best an estimate. With applying a visual estimate was doable this implied the assumption that these older individuals had the same shape type at an earlier age. Therefore, individuals with degenerated acromions were left out of the shape analysis. In the Bass sample out of 840 acromions, only 262 were classifiable by shape. The Terry collection sample was less

degenerated and 353, out of 542 scapulae were observable. Both reduced samples were not a concern, however, since Gumina et. al (2003) had a sample of 244 individuals these samples appeared large enough to detect the significance of shape. The data, once collected, was reviewed for errors, and was statistically analyzed using the statistical software package SAS 9.1.3 Copyright © 2000-2004.

The frequency rates of each sample (see Figure 6.2) were analyzed for differences in time (Early vs. Late 20th century), for a sex bias, ancestry bias, sex and ancestry bias, and side bias. These were tested using a Chi Square test with large sample sizes. When sample sizes were small, than a different test, the Fisher's Exact test was used instead of the Chi Square. The logistical regression was used to analyze shape due to sparseness of the data set (See Appendix).

T I M E	19th century African-Americans (Terry Collection)	19th century European-Americans (Terry Collection)
	20th century African-Americans (Bass Collection)	20th century European-Americans (Bass Collection)

Figure 6.2 Statistical cross comparisons between sample groups

VII: Results

The first research question was whether the os acromiale frequency decreases in modern times, in comparison to an earlier sample. This was tested by comparing the frequencies from the Bass and Terry samples. This hypothesis would provide probable support for a mechanical etiology for OA. In addition, the frequencies in respect to ancestry, sex, and side were compared and analyzed within each sample by using a Chi-square, or a Fisher's Exact Test when necessary. The second question addresses whether acromial shape has an influence on the presence or absence of OA, as seen in previous radiographic studies. Acromial shape has been proposed as a genetic explanation for the presence of OA, instead of strict ancestral influences. Shape was analyzed through a log linear regression due to the sparseness of the data.

Also excluded from shape analysis were those OA affected individuals whose acromial epiphyses were not recovered. The final number of OA affected individuals from the Bass which could be analyzed by shape was n=8 out of 14. For the Terry sample this number was slightly improved: n=23 out of 29. The robusticity of a chi-square test was suspect, and the ability of chi-square to detect any relationship between the variables was not likely. As a result of the sparse distribution of acromial shape, a log-linear regression was conducted on the shape data to better detect if shape, sex, ancestry and acromial condition were related. The results of this analysis showed that the only significant variable was the acromial condition itself (*Left:* $X^2=8.70, p=.0032$; *Right:* $X^2=10.15, p=.0014$). In both samples, the log linear regression was only able to detect the difference between the absence and presence of this condition in each shoulder. The same was true for the Terry sample, and the log linear regression was also only able

to detect that the acromial condition varied significantly between presence and absence *(Left: X^2=10.79, p=.0010; Right: X^2=11.59, p=.0007).*

Shape was therefore removed from the data set and the regression was run again to see if new variables appeared to be significant in log-linear regression. Once shape was removed from the analysis, the log-linear regression found ancestry to be a significant variable (See Table 7.1). Furthermore, the chi-square tests were now robust enough to ascertain relationships between the variables. The chi-square yielded the same results as the above analysis (see below).

Modern os acromiale frequency analysis

The next phase of the analysis compared the most current total OA frequency from the Bass sample (1986-2006), to a sample from the Terry Collection (1920-1960). The total OA frequency for Bass was 3.3% which was lower than the overall OA frequency of 10.7% from Terry (See Table 7.2). The decrease in total os acromiale frequency, was present and significant according to the chi-square tests for each shoulder: *Left: X^2=9.8152, p=.0017; Right: X^2=13.7246, p=.0002.* The following chi-square analyses looked at four main variables and their relationship with os acromiale: 1) ancestry 2) sex, 3) sex and ancestry, and 4) side.

Table 7.1 P-values for ancestry and condition from log-linear regression

	Bass		**Terry**	
	Left	*Right*	*Left*	*Right*
With shape	*X^2=1.82* p=.1772	*X^2=1.22* p=.2684	*X^2=.28* p=.5936	*X^2=.81* p=.3675
Without shape	*X^2=8.59* p=.0034	*X^2=8.59* p=.0034	*X^2=7.03* p=.0080	*X^2=7.55* p= .0062

Table 7.2 Bass and Terry os acromiale frequency distributions

	TERRY			BASS		
Frequency Type	**Overall**	**African-American**	**European-American**	**Overall**	**African-American**	**European-American**
Total	10.7% (n=29)	17.4% (n=23)	4.3% (n=6)	3.3% (n=14)	10.8% (n=4)	2.6% (n=10)
Bilateral	48.2% (n=14)	52.1% (n=12)	33.3% (n=2)	42.8% (n=6)	100% (n=4)	20% (n=2)
Unilateral	51.7% (n=15)	47.8% (n=11)	66.6% (n=4)	57.1% (n=8)	0	80% (n=8)
Left	46.6% (n=7)	45.4% (n=5)	50% (n=2)	62.5% (n=5)	-	62.5% (n=5)
Right	53.3% (n=8)	54.5% (n=6)	50% (n=2)	37.5% (n=3)	-	37.5% (n=3)

Ancestry

When the OA frequency was divided according to ancestry, African-American individuals continued to demonstrate a higher os acromiale frequency, while European-American sub-sample demonstrated a low frequency in modern samples. In the Terry collection, the OA trait occurred at a rate of 17.4% among African-Americans, and 4.3% of European-American populations. This frequency rate is following the same pattern as previous researchers have reported. African-American groups continue to reflect an above average rate of this condition in comparison to European-American groups.

OA frequency in the Bass were lower than in the Terry, as 11.4% of African-Americans had this trait while only 2.6% of European-Americans are affected by this trait. While there were more European-Americans affected by this trait in the Bass (n=10) the trait itself occurred more frequently among African-American individuals still in the present day. The decrease in OA frequency, as expected for modern times did occur for both ancestral groups, however, the African-American portion of the Bass is still above 7%.

As for the significance between OA and ancestry; in the both the Bass and Terry samples there was a significant difference between individuals of African-American and European-American subgroups in regards to the presence of this trait. This difference between the ancestral groups is statistically significant in both the Terry and Bass at the alpha level of .05 (See Table 7.3). A Fisher's exact test was used instead of the chi square test due to the small sample sizes.

The results show that in both the Bass and Terry samples, OA frequencies were significantly different between African-American and European-American groups. This confirms the data previously seen in the literature. It is interesting to note that while the overall frequency of OA has decreased in modern times, the African-American sub sample of both the Bass and Terry were still more affected than European-American sub-sample.

Sex

From looking at the OA frequencies alone, there appeared to be higher occurrences among females in the Terry collection and a higher frequency among men in the Bass collection. In the end there were only a small number of women which had OA. In the Bass there was n= 2, (all European-American) and in the Terry was n= 9 (all African-American). In a way, because of the nature of the data, this is already combining

Table 7.3 P-values for ancestral differences between samples (Fisher's Exact)

Sample	**Left Shoulder**	**Right Shoulder**
Terry African-American vs. Terry European-American	p=.0025	p=.0014
Bass African-American vs. Bass European-American	p=.0108	p=.0047

sex and ancestry, on the female side, as opposed to comparing sex alone. In the Bass collection, for both the left and right shoulders, the differences between the sexes were not statistically significant (*p=1.00; p=.1220, respectively*) using the Fisher's exact test. In the Terry collection, the results for the left (X^2*=2.8180, p=.0932*) and right (X^2*=3.4967, p=.0615*) shoulder were the same as the Chi square tests demonstrated p-values higher than the alpha of .05. In such a situation, the statistical analyses indicated that OA frequency did not differ significantly between the sexes in either sample.

Sex and Ancestry

While sex was not a significant difference, ancestry was and therefore the two factors were combined to detect if there was any significant difference in OA frequency. Each sample was analyzed individually, and by side. African-American males had the highest frequencies for both Terry and Bass (*22.7%, 12.1%, respectively*). The lowest frequencies were the Terry and Bass sample of European-American females (*1.3%, 2%, respectively*).

It should be noted that there were no African-American females from the Bass collection with this condition, leaving that sub-sample from comparison in this analysis. The data from the Terry collection was tested through Fisher's exact test, and there was not significant difference between the four sub-groups divided according to both sex and ancestry, both shoulders in a p-value of 1. While this scenario cannot be concluded from the Bass without data from African-American females, the frequency patterns have mirrored each other up to this point, and with additional data could illustrate whether these results are indeed the same in the Bass.

Side

This analysis examined the presence of a side bias within either sample for those individuals which were affected by OA in a unilateral fashion. The acromial conditions were again examined by side and in each sample separately. Following Case et. al 2006, the unilateral cases were tested against a proxy sample of equal number of bilateral occurrences. The test indicated that there was no significance according to side for both the Bass and Terry samples (*p=.5089; .1434, respectively*). The Terry sample, the unilateral condition was divided up pretty equally: L=46.6%; R=53.3%, so the results were expected. However, in the Bass there was a 62.5% of incidence on the left side (all Euro-American) but the sample was perhaps too small (n=8) to detect any significance.

Partial OA

An uncommon condition which Sammarco (2000) came across when studying OA in the Hamann-Todd collection is that of a partial or fused acromion. Radiograpically, a fused OA is indistinguishable from OA, but visually the acromion has a distinct depressed radiolucent line where the bone is fused. The acromial epiphysis is visibly distinct from the rest of the acromion. In the Terry sample this type of OA occurs 8.6% (n=5/58 scapulae) affecting four individuals. In the Bass sample it occurred 10.7% (n=3/28 scapulae) affecting two individuals.

The results of the two main research questions, demonstrated that in a general sense the OA decreased since 1850 to the present, supporting a stress argument. However, no other biases indicating mechanical arguments were present according to sex, sex and ancestry, or side. Shape, as a possible genetic explanation, was not proven through these tests. Of all the variables examined, there was only a significant difference

in the Terry and Bass total OA frequency and between ancestry and OA. None of the other biases which would support a mechanical argument were found to be significantly different within the Bass or the Terry. Only, ancestry alone was found to vary significantly between the Terry and Bass samples. The significance of an ancestral correlation confirms the data previously presented in the literature regarding a possible genetic correlation.

VIII: Discussion

After the results seen in the previous chapter, certain issues must be elaborated upon. The first addressing the acromial condition itself, and why shape was not detected as a significant factor. Also, the significance of the modern OA frequency, along with the four variables tested and why some yielded significant results while others did not.

Asymmetry & shape

Initially in this investigation, data on acromial condition was analyzed per individual, and not per side. However, it became quickly apparent that the shape categories varied not only between individuals but within individuals. There are varying reasons behind asymmetry, due to handedness as well as simple variation in the formation of the acromion. The straight one to one correlation between an individual's acromial condition and shape was not possible by grouping them by individual. The most direct comparison came from a one to one examination of each respective side. This form of comparison was more effective especially when only one side was available for analysis.

The shape analysis was not able to detect a correlation, unlike Gumina et. al (2000) study. While, the Bass sample had a large amount of missing data due to degenerated acromions, the Terry sample with more complete shape comparisons also yielded a non-significant result. There are several variables which could have lead to differing results between these two studies. First, in Gumina et. al, 2003 the shape type was classified per individual and not per side. The problem with this method is that implies symmetric conditions in the shoulder when that is not always the case. By ignoring asymmetry, the significance of shape could give a false result of being

significant when it was not. While there are individuals with the same acromial shape in each shoulder, that type of 1:1 relationship between shape and acromial condition would not apply to asymmetric individuals. Second, the difference between radiographic studies and anatomical is that their analysis was based on a two dimensional image, rather than the actual acromion. Third, the difference in results could be due to inter-observer error, and the different ways acromial shape was classified.

Modern OA Frequency in the William M. Bass collection

The current data reveal that os acromiale is not as frequent as it was in earlier in times. This trait is increasing in rarity in the general population. Although gene frequencies also shift over time, the stress link between a decreasing frequency is still possible. One way of interpreting this data is stating that the overall frequency decline is driven by the European-American samples which decline from 4.3% to 2.6%. In the Bass since the sample size is heavily European-American, this portion of the sample could influence the overall frequency driving it lower. Nevertheless, the Bass African-American frequency declined the most from 17.4% to 10.8% during this time.

As to the African-American trait frequency itself, the Bass frequency of (10.8%) does remain high, consistent with earlier reported frequencies among African-Americans. While initially it appeared that frequencies would have shifted over time and space, they have not declined among the African-American samples in the Bass collection. The question remains, as to why. From a genetic perspective, the parsimonious answer is that genes frequencies shift in unpredictable ways. As to the mechanical perspective, a modern frequency can only illustrate what is occurring, and it does not answer why. The high frequencies are not misrepresentations, but rather only part of the picture. The

question as to the causation of this trait remains, and frequency data, while informative, do not reveal much about causation.

As towards the absence of a sex bias, the paucity of females which are in the sample is part of the problem. Furthermore, the rarity of the trait further minimizes the chance of having a large enough sample to test. When combining sex and ancestry, previous research has illustrated that the trend of OA frequencies, is that African-American males are the most significantly affected group, while European-American females were the least affected (Hunt and Bullen 2006). In this study, that pattern was similar. However, since no African-American females were affected by this trait the comparison was insignificant, because of this missing group.

Historical sample comparison

In comparison to the os acromiale frequencies presented from African-American samples, there is continual fluctuation in the frequencies. Most notably, the frequencies of NYABG (7.6%) and UAME (3.1%) are low compared to the other samples. The African-American samples each represent different historical periods, regional variations, and varying levels of status. Future studies could examine what the sociohistorical scenarios, specifically which could have shaped the fluctuations that are present in this data. The lowest frequency is from the Mother UAME Church site in Wilmington and represents a rural sample (See Figure 8.1). The highest frequency remains FABC, which comes from the second smallest sample (n=75) and represents an urban sample, dating to

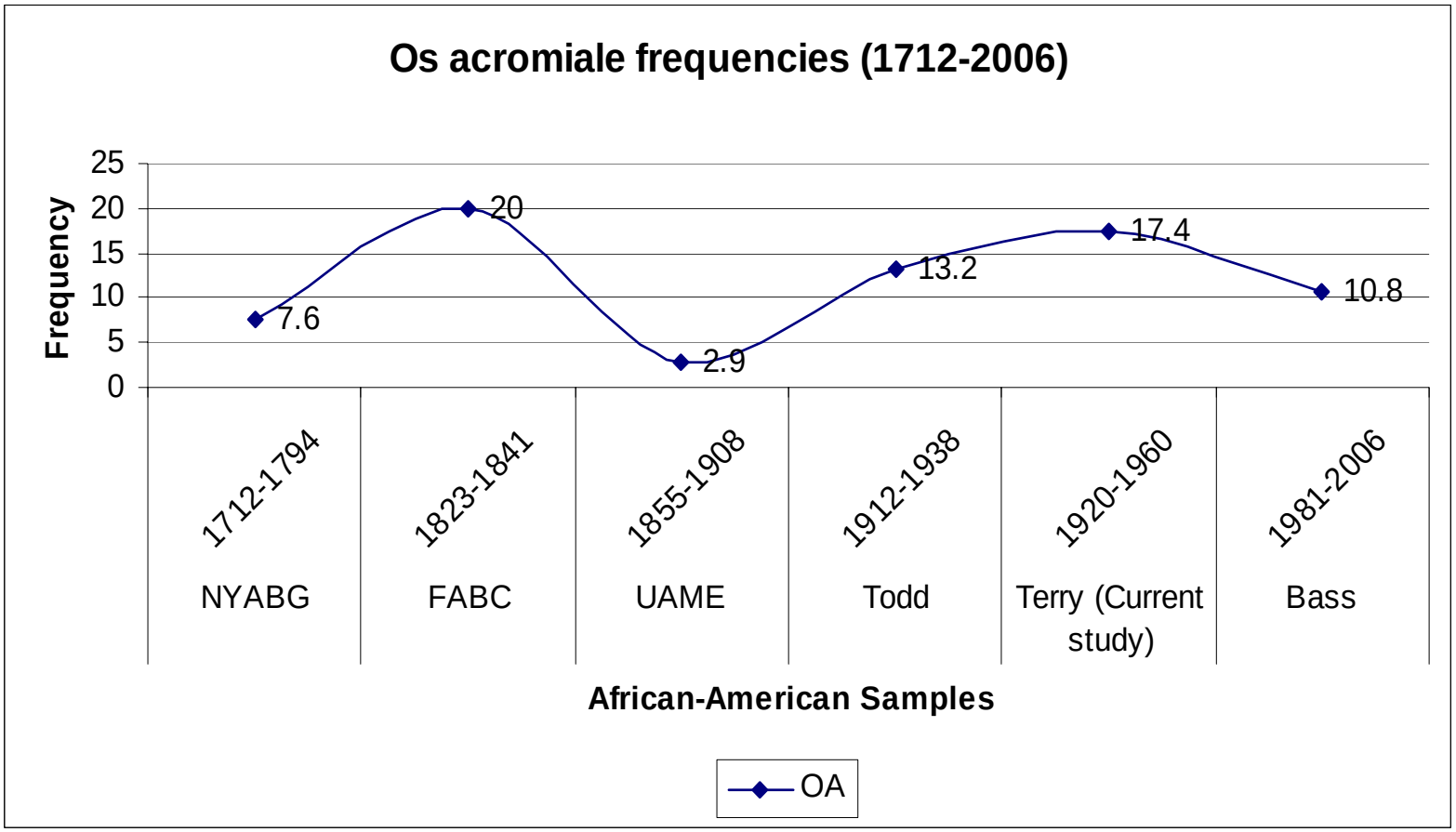


Figure 8.1 **Os acromiale frequency for African-American skeletal series**

the period prior to UAME. It would seem odd that two samples which occur sequentially in time would differ so greatly. Examinations into specific, temporal and regional variations present between Philadelphia and Wilmington could shed some light on this.

NYABG has not been analyzed previously for OA frequency, although early analyses estimated that OA rates in NYABG were potentially as high as FABC (Blakey et. al. 2004). Although, when the raw data was actually examined, the actual count was lower than expected (Rankin-Hill pers.comm.). Aside from the UAME sample, it represents the second lowest occurrence of OA. It is the sample with the most "normal" frequency among African-American samples. This significance of this sample is that it represents the only sample from an enslaved group. For this reason, NYABG was expected to yield a higher frequency, correlating with a mechanical etiology. The argument could be proposed that NYABG represents a sample which consisted of enslaved individuals, although young, but older than the age of acromial fusion (18+). If this case, then it is possible that this lower rate reflects a pre-slavery lifestyle. In both the Mother UAME and NYABG samples their frequency is lower than previously seen patterns. It would be interesting if any other correlations between these two sites. It is still difficult to argue a mechanical etiology in light of high frequencies in modern populations, but there are questions as to sampling.

Sampling Issues

The Bass sample is an attempt to reflect a modern frequency among African-Americans, contains the smallest sample of this group (n=37) in this study. There are problems with using data from small sample sizes. For example, let us examine the Terry

frequencies derived from two sources: this study and Hunt and Bullen (2006). Hunt and Bullen (2006) published comprehensive results on OA in the Terry collection recently. Their sample size for African-Americans was large, numbering eight hundred and twenty eight. This was equally proportionate to their sample size of European-Americans, which numbered seven hundred and sixty six. As to the research from this analysis, a smaller sample of African-Americans from the Terry collection was examined (n=132). It was proportionate to a sample size of n=139, for the European-Americans sample. Both of our frequency results showed that African-Americans had a high frequency. However, the smaller sample from this study produced a frequency that was higher by 6.3%. Hunt and Bullen's frequency is certainly the more accurate frequency, since it is based on a larger sample, despite their age of assessment beginning at 25 yrs.

A similar scenario occurred when Rankin-Hill examined the OA frequency at FABC. When the total sample size was increased from n=25 to n=75, then the trait frequency decreased from 30 to 20%. In the Bass sample of n=37, this would imply that the OA frequency of 10.8% could be different as a result of the small sample size. Additionally, the Bass sample contains a small number of African-American females (n=4), none of which had OA, and therefore a sex bias test was a moot point. With a much larger sample, and equally proportionate distribution of sexes, significant results can be found. For example, Hunt and Bullen (2006), were able to detect a significant sex bias within their analysis of the Terry collection ($X^2=4.733, p=0.0295$). This is why these researchers advocated larger samples, with proportionate distributions between ancestry, as well as sex. As the results from the smaller Terry sample (n=270) in this paper, which were equally proportionate between the sexes, the result was not significant

at the $p<.05$ level. Sample sizes would have to be much larger to detect such a sex bias, ranging on the magnitude of <400+. The current demography and rate of OA in the Bass collection limits the scope of such extensive comparisons at this time between the ancestral and sex sub-categories.

Reassessment of the normal frequency

The often quoted 7% is based on Grant (1972) although he never actually gave a frequency of that number. Instead he gave counts of incidence and number of subjects. (n=16/194). When re-evaluating this frequency the result was not the often cited 7%, but rather a frequency of 8.2%. Although, it still remains questionable that the frequency which is considered "normal" is based on one cadaver sample. The range of frequencies cited in both clinical and anthropological studies ranges from between 1-15% (Liberson 1937) to 7-15% (Sammarco 2000). While the FABC frequency is still higher than this range, it still shows that there is more variation in the frequency of OA than previously considered. Perhaps, a separate frequency should be applied to different populations to assess normalcy. It would be incorrect to compare the 8.2% (corrected) frequency to African-American samples. The interesting thing to note about the African-American and European-American frequencies is that they appear to be mirroring each other in recent samples (See Figure 8.2). Both are declining over time and it appears that the European-American samples are approaching zero. This would be an area to explore in the future to follow the OA frequency and examine if it does approach zero.

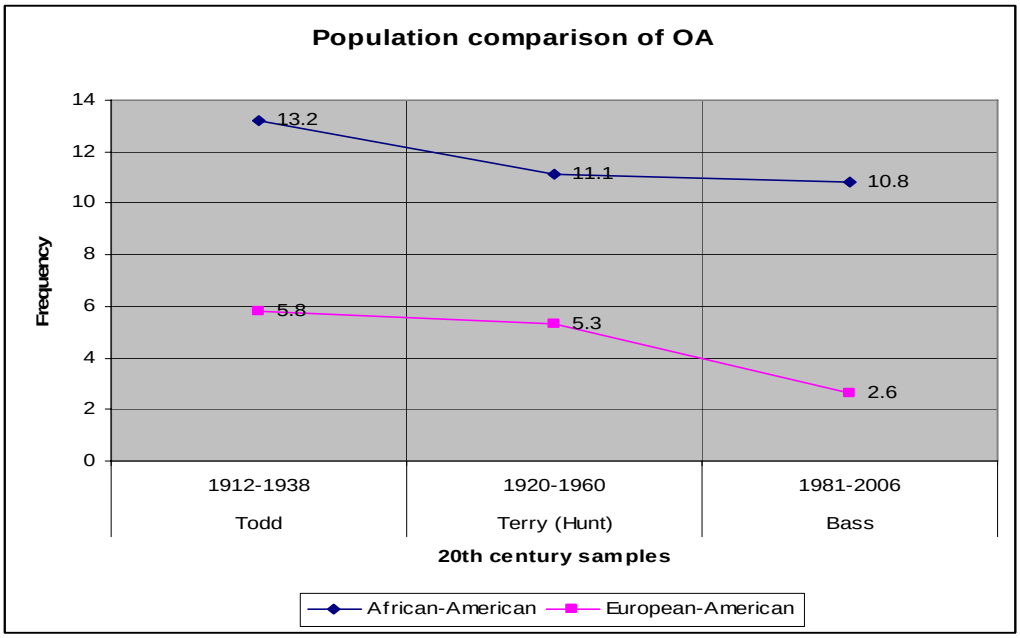


Figure 8.2 Recent OA frequencies (European-American vs. African-American)

Recovery Rate

A predominant factor in analyzing acromial shape was the recovery rate for the acromial epiphysis. In the Bass donated skeletal collection, only 35.7% (n=10/28 scapulae) of acromial epiphyses were recovered. This is due to taphonomic factors which include the outdoor location of the facility, the small size of the epiphysis coupled with the lack of recognition of the epiphysis in the recovery phase. While it may not be possible to recover all small bones, educational awareness of what this condition looks like could potentially improve the recovery rate of os acromiale epiphyses.

Definition of OA

The definition of OA is referred to as the persistent non union of the acromial epiphysis, past the normal age of normal fusion (Macalister 1893). However, there is not a definition regarding the partial or fused condition. Since it is "fused" it does not

technically fit the definition as stated above. The definition of OA should be amended to include this rare type of OA. It is most likely, that since OA, in life is a cartilaginous joint that the cartilage fuses in some cases retaining a distinctive demarcation. It is this demarcation, which distinguishes a fused OA, from a normal acromion altogether. This type of OA should be added to the definition, such that: OA is a condition in which the acromial epiphysis remains persistently separate; demonstrated by an actual separate epiphysis, or a depressed demarcation at the juncture of epiphyseal fusion.

Forensic applications

The often posed question to this topic is whether or not OA could be used in assessing ancestry in forensic identifications. Being that it is a rare trait, in general, it is not recommended to use this trait for the purpose of assessing ancestry. While, it is more frequently seen among African-Americans in certain skeletal series, instances of European-Americans affected by OA actually outnumber the African-American occurrences in the William M. Bass collection. Therefore, it is quite possible to come across OA in a European-American individual, as it is an African-American individual. Other ancestral traits should be used to assess Euro-American or Afro-American ancestry. OA frequencies could be mentioned in concert with a suite of non-metric traits, but it should never be the tipping point of an ancestral assessment.

Occupational relationships

When considering the possible occupations, which could affect the shoulder in an adverse manner, one has to consider the motion correlated with the activity. In the shoulder area, such harm is caused by the repeated abduction and overhead elevation of the arm (See Ch. V). The field of occupational medicine denotes repetitive movement as

affecting a broad variety of occupations. While the force of heavy workloads tends to attract the most attention, it is often the repetition of the activity which can cause harm as well (Messing 2000, Baxter et. al 2000). Ethnographic data can illuminate possible activities which affected African-Americans in the scapular region.

17th-18th century

Enslaved people held a variety of occupations and employments. In New York, during the 17th century, occupations included coopers, tailors, bakers, tanners, goldsmiths, naval carpenters, blacksmiths, weavers, bolters, sailmakers, millers, masons, candlemakers, tobacconists, carpenters, shoemakers (Mcmanus 1966). Certain occupations definitely come to the forefront as far as shoulder strain is concerned. Blacksmiths pounding at the anvil, lifting a hammer over head to pound metal into various shapes. Naval carpenters working with tools, sawing or hammering repeatedly (Armstrong and Fleischman 2003). Coopers, whose occupation was to construct barrels, combined both carpentry and blacksmith work. Similarly, African-American enslaved women did agricultural or domestic work. This would include tending small farms, livestock. Domestic work included cooking, cleaning, butchering and caring for the children of their master (Hine 2005). A task such as doing the wash could entail various aspects of shoulder strain. This includes carrying the loads of laundry, sometimes carried on the head. Also, the fetching of water, and the motions of washing and wringing clothes, manually would be strain on the shoulder as well.

19th century

Philadelphia saw a population surge during the early 19th century, which increased competition for work (Dubois 1967). Occupations were varied but the work which was

mainly available to African-Americans entailed general labor. The presence of a port in Philadelphia was a source for maritime labor for African-Americans employed as stevedores. Stevedores, also known as longshoremen, would load and unload ship cargo. This can present shoulder strain in carrying heavy sacks of cargo over the shoulders. In addition, another occupation was that of a hod carrier. They work in collaboration with bricklayers and carry the materials (bricks, plaster) across, or over the shoulders (See Figure 8.3). Hostlers worked in the stables, maintaining and feeding horses (Dubois 1967, Laurie 1980).

Women were employed as domestics, at times working a second job in addition to their work in the home, with jobs as cooks, seamstresses, laundresses or janitresses (Dubois 1967). Laundresses, was an occupation in which women would carry loads of



Figure 8.3 Hod Carrier, August Sander (photographer), 1928

laundry bundled on top of their heads, taking in laundry from other locations (Hine 2005). The majority of women's occupation in 1838 in Philadelphia was that of washerwomen or laundresses (Hines 2005).

Between the years, 1830-1880, the Wilmington area of Delaware was in the midst of industrial development. Some of the industries located there included, shipyards, rolling mills, foundries, machine shops, railroad car works, chemical works, textile factories, tanneries and brickyards (Thomas, et. al 2000). The majority of African-Americans were employed as laborers, some digging drainage ditches for the city marsh areas. Others were employed as brick makers, bricklayers, blacksmiths, masons and carpenters. As, was the case in Philadelphia, women in Delaware were employed mainly in the domestic arena as maids, washer women, or cooks (Essah 1996). These occupations involve the continual and heavy loading of the arms that is associated with os acromiale (Kennedy 1989).

20th century

The Hamann-Todd and Terry collection originated from the indigent poor of the Midwest, Cleveland and St. Louis, respectively. This period corresponds to the late 19th century and to the early 20th century in this region. The Great Migration brought African-Americans to the North and Midwest regions, to escape harsh conditions in the Jim Crow South. The majority of African-Americans were employed as common laborers (Bigham 2006). Such work included ditch digging, railroad workers for L&N railroad, and demolition crews. This type of manual labor could have considerable strain on the shoulder involving the shoveling of heavy loads of dirt, repairing or laying down

track, loading or unloading freight cars, feeding and caring for horses and the stables, as well as demolishing roads and buildings using African-American work crews. For women, domestic work was still a primary arena although factory work (munitions, meatpacking, metalwork) was open to African-American women during World War I.

When considering the ethnographic context surrounding the William M Bass collection, machines had already entered into the work place. However, when it comes to shoulder stress, repetitious movements still can affect the shoulder in certain occupations. This would include: assembly line workers, tradespeople, crop production workers, and workers using mechanical or power tools (Rosenstock and Cullen 1986). Even in modern populations the occupations that are affected in the shoulder region still include shipyard workers, and industrial workers (Baxter et. al 2000). The domestic trade, although improved by the arrival of technology, is an occupation where African-American women are employed, and could potentially be afflicted by shoulder stress. (Hines 2005).

IX: Conclusion

This etiological analysis, although not comprehensive, is informative on the genius of os acromiale. Yet, the answer to the etiology of this condition remains unclear. This trait has mainly been supported through frequency data and has not yet expanded directly into genetic or biomechanical realms. While frequency data is available, easily attainable, there are limitations. Samples with individuals of unknown ancestry, sex, or incomplete scapulae are obviously not useful in computing frequency assessments. When possible, samples should be equally proportionate in the quantity of males and females as well as between ancestral groups. Any unbalance in proportion yields different results in the computation of biases in the record.

A sex or side bias would be a good indicator of a mechanical etiology and occurs in the literature. Evidence of a significant sex bias was found in Terry collection males (Hunt and Bullen 2006) and a significant "left" side bias in a South African sample (Case et. al 2006). One problem is that for the analysis of sex bias, a large sample size is required. In the comparison of the Terry sample analyzed here (n=270), in comparison to the Terry sample in Hunt and Bullen (2006) reached an insignificant sex result. The key difference was their sample size was much larger and equally balanced by sex. The sample size needed to assess side bias requires approximately 50 unilateral cases of os acromiale. While evidence of mechanical etiology does exist in the literature, it is rare and not easily to tease apart due to the parameters needed.

Ancestral bias is seen more repeatedly in cases of os acromiale, especially in smaller samples. This bias was the only significant bias detected in the Bass and Terry samples in this research, which are smaller in comparison (n=43). Ancestry is a more

sensitive correlate than either sex, or side. The significance of ancestry is the strongest point for the argument of a genetic etiology. It is not direct support and until cross-generational, or genetic studies are applied to this question, it is what is present. Contrary to what was expected acromial shape in the Bass and Terry samples, it was not correlated with os acromiale, as radiographic research has suggested. In this way, the genetic factors are not explained by the morphology of the acromion, and other explanations should be examined.

The combined hypothesis, suggesting a genetic predisposition, which is exacerbated by the presence of a mechanical stressor, does fit with the data summarized by this research. A genetic explanation alone does not explain the presence of a side bias or a sex bias in the literature. Granted these samples are isolated incidences, however, such biases appear to be sensitive to sample size and proportion in the case of this rare trait. On the other hand, a mechanical explanation has not been analyzed directly through markers of occupational stress among these African-American samples. That is why the hybrid argument is the most plausible explanation at this point. Still, the modern frequency data from the Bass collection indicates that this condition is decreasing in both populations, and approaching a very low frequency in European-Americans. Such a pattern, if mirrored in other modern-day populations suggests that this trait is becoming increasingly rare and might disappear altogether. The frequency, among Afro-Americans is also decreasing, though still remains high. However, more complete assessments would need larger samples than those currently available in modern skeletal collections. Additional frequency data collection, along with alternative data analyses of genetic data

or biomechanical data are recommended in the continuation of the etiological discussion on os acromiale.

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APPENDIX

Photographs of Os acromiale



Figure A Example of Mes -acromial non fusion on the right scapula (male, approximately 70 yrs. from William M. Bass skeletal collection)

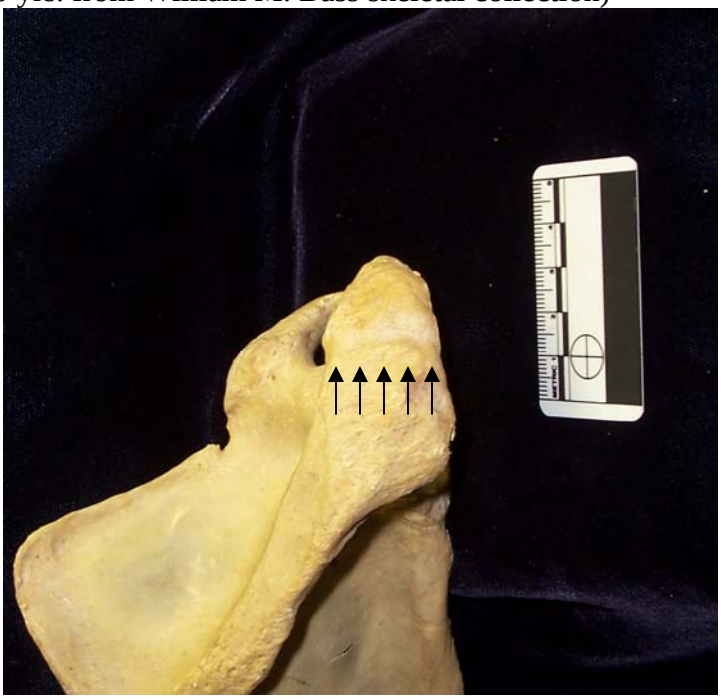


Figure B Example of a fused os acromiale on right scapula (male, 42 yrs. from the Robert F. Terry Collection at the Smithsonian National Museum of Natural History.)



Figure C Bilateral os acromiale non fusion (male, 45 yrs. from Robert F. Terry collection at Smithsonian National Museum of Natural History.)



Figure D Lateral view of os acromiale on right scapula (male, 70 yrs. from William M. Bass skeletal collection.)

William M. Bass os acromiale data

AC_L=Acromial condition (left) AC_R=Acromial condition (right)
0=trait absent 1=trait present
AS_L=Acromial shape (left) AS_R=Acromial shape (right)
1=square tip 2=intermediate 3=cobra

ID	Sex	Ancestry	AC_L	AC_R	AS_L	AS_R
1-81D	M	E-A	0	0	1	1
4-81D	F	E-A	0	0	2	2
1-83D	F	E-A	0	0	.	.
2-83D	M	E-A	0	0	2	3
3-83D	M	E-A	0	0	.	.
5-83D	M	E-A	0	0	2	.
1-84D	M	E-A	0	0	.	.
2-84D	M	E-A	0	0	.	.
1-85D	F	E-A	0	0	.	.
2-85D	M	E-A	0	1	3	3
2-86D	F	A-A	0	0	1	1
7-86D	M	E-A	0	0	.	.
1-87D	M	E-A	0	0	1	2
2-87D	M	E-A	0	0	.	.
3-87D	M	E-A	0	0	2	1
4-87D	M	E-A	0	0	1	1
5-87D	F	E-A	0	0	.	.
6-87D	M	A-A	0	0	.	.
7-87D	M	E-A	0	0	.	.
8-87D	M	E-A	0	0	3	3
10-87D	M	E-A	0	0	.	.
12-87D	M	E-A	0	0	.	.
14-87D	M	E-A	0	0	.	.
15-87D	F	E-A	0	0	1	1
1-88D	F	E-A	0	0	1	2
2-88D	M	E-A	0	0	.	.
9-88D	M	E-A	0	0	1	1
10-88D	M	E-A	0	0	.	.
12-88D	M	E-A	0	0	1	1
13-88D	M	E-A	0	0	3	3
14-88D	M	E-A	0	0	2	2
16-88D	M	E-A	0	0	1	1
19-88D	M	E-A	0	0	2	3
23-88D	F	E-A	0	0	3	3
24-88D	M	E-A	0	0	.	1
2-89D	M	E-A	0	0	2	.
3-89D	M	A-A	0	0	.	.
4-89D	M	E-A	0	0	.	.

6-89D	M	A-A	0	0	.		.	
7-89D	M	E-A	0	0	.		.	
8-89D	M	E-A	0	0		3	.	
9-89D	M	A-A	0	0		2	.	
10-89D	M	E-A	0	0		1		1
11-89D	M	E-A	0	0		3		3
12-89D	M	E-A	0	0	.		.	
15-89D	M	A-A	0	0	.		.	
16-89D	M	E-A	0	0	.		.	
3-90D	M	E-A	0	0		2	.	
4-90D	M	E-A	0	0		3		2
10-90D	M	E-A	0	0	.		.	
11-90D	F	E-A	0	0	.		.	
12-90D	M	E-A	0	0		2	.	
14-90D	M	E-A	0	0		2		1
15-90D	M	A-A	0	0	.		.	
18-90D	M	A-A	0	0		2		3
19-90D	M	E-A	0	0	.		.	
20-90D	M	E-A	0	0	.		.	
21-90D	M	E-A	0	0		1		1
22-90D	M	E-A	0	0	.		.	
27-90D	M	E-A	1	1		3	.	
28-90d	F	E-A	0	0		2		2
2-91D	M	A-A	0	0	.		.	
3-91D	M	E-A	0	0	.		.	
6-91D	M	E-A	0	0	.		.	
7-91D	M	E-A	0	0	.			3
8-91D	M	A-A	1	1		2	.	
10-91D	M	E-A	0	0		3	.	
12-91D	M	E-A	0	0		1		1
13-91D	M	E-A	0	0		1		1
14-91D	M	E-A	0	0	.			3
15-91D	M	A-A	0	0	.		.	
16-91D	M	E-A	0	0		1		1
17-91D	M	E-A	0	0		1		1
18-91D	M	E-A	0	0	.		.	
19-91D	M	E-A	0	0		3		3
20-91D	F	E-A	0	0	.		.	
25-91D	M	E-A	1	0		2		3
26-91D	M	E-A	0	0		2		2
27-91D	F	E-A	0	0		2		3
1-92D	M	A-A	0	0		1		1
2-92D	F	E-A	0	0	.		.	
3-92D	M	E-A	0	0	.			2
6-92D	F	E-A	0	0		2		3

7-92D	F	E-A	0	0	.		.	
10-92D	M	E-A	0	0	.		.	
14-92D	M	E-A	0	0		3	.	
16-92D	M	E-A	0	0	.		.	
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21-92D	M	A-A	1	1	.		.	
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3-93D	M	E-A	0	0		2	.	
4-93D	M	E-A	0	0		2	.	
5-93D	M	E-A	0	0		1		2
6-93D	F	E-A	0	0	.		.	
7-93D	M	E-A	0	0	.		.	
8-93D	M	E-A	0	0	.		.	
9-93D	M	E-A	0	0		1		3
14-93D	M	E-A	0	0		3		3
15-93D	M	A-A	1	1		1	.	
18-93D	M	E-A	0	0		3		3
20-93D	F	E-A	0	0	.		.	
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23-93D	M	E-A	0	0	.		.	
26-93D	F	E-A	0	0	.			1
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8-94D	M	E-A	0	0		3		3
9-94D	M	E-A	0	0	.		.	
10-94D	M	E-A	0	0	.		.	
11-94D	M	E-A	0	0	.		.	

18-94D	F	E-A	0	0	.		.	
19-94D	M	A-A	0	0	.		.	
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4-97D	M	E-A	0	0	.			2
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9-97D	M	E-A	0	0		3	.	
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3-98D	M	E-A	0	0	.		.	
4-98D	M	E-A	0	0	.		.	
5-98D	M	E-A	0	0	.		.	
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5-00D	M	E-A	0	0	.		.	
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19-00D	F	E-A	0	0	.		.	
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21-00D	M	E-A	0	0	.		.	
22-00D	M	E-A	0	0		3		2
23-00D	F	E-A	0	0	.		.	
24-00D	F	E-A	0	0	.		.	
29-00D	M	E-A	0	0		3		3
01-01D	M	E-A	0	0	.		.	
03-01D	F	E-A	0	0		1		1
04-01D	M	E-A	0	0	.		.	
05-01D	M	A-A	0	0	.			3
06-01D	M	E-A	0	0	.		.	
07-01D	M	E-A	0	0		2		2
08-01D	M	E-A	1	0	.			3
09-01D	M	E-A	0	0	.			2
10-01D	F	E-A	0	0		3	.	
11-01D	F	E-A	0	0		2		3
12-01D	M	E-A	0	0		3		3
13-01D	M	E-A	0	0		3		2
14-01D	F	E-A	0	0		1	.	
15-01D	F	E-A	0	0	.		.	
16-01D	M	E-A	0	0		2		2
17-01D	M	E-A	0	0		1		1
18-01D	M	E-A	0	0		3	.	
19-01D	M	E-A	0	0	.		.	
21-01D	M	E-A	0	0	.		.	
22-01D	M	E-A	0	0		3		3
23-01D	M	E-A	1	0	.			1
25-01D	M	E-A	0	0		3		2
26-01D	M	E-A	0	0		3		3
27-01D	F	E-A	0	0	.		.	
28-01D	F	E-A	0	0	.		.	
29-01D	M	E-A	0	0	.		.	
30-01D	M	A-A	0	0		3		3
31-01D	M	E-A	0	0	.		.	
32-01D	M	E-A	0	0		2		2
33-01D	F	E-A	0	0	.		.	
34-01D	M	E-A	0	0	.		.	
36-01D	M	E-A	0	0	.			1
37-01D	M	E-A	0	0	.		.	
38-01D	M	E-A	0	0	.		.	
39-01D	F	E-A	0	0		1		1

40-01D	M	E-A	0	0	.		.	
42-01D	M	E-A	0	0	.		.	
43-01D	M	E-A	0	0	.		.	
44-01D	M	E-A	0	0	.			1
45-01D	m	E-A	0	0	.		.	
48-01D	M	E-A	0	0	.		.	
49-01D	F	E-A	0	0	.		.	
01-02D	M	E-A	0	0	.		.	
02-02D	M	E-A	0	0	.		.	
03-02D	M	E-A	0	0	.		.	
04-02D	F	E-A	0	0		3		2
06-02D	M	A-A	1	1		1		3
07-02D	M	E-A	0	0		1		1
08-02D	F	E-A	0	0	.		.	
09-02D	M	E-A	0	0	.		.	
10-02D	M	E-A	0	0	.		.	
11-02D	M	E-A	0	0	.		.	
12-02D	F	E-A	1	0	.			2
13-02D	F	E-A	0	0	.		.	
14-02D	M	E-A	0	0	.		.	
16-02D	M	E-A	0	0	.		.	
17-02D	F	E-A	0	0		2		3
19-02D	f	E-A	0	0	.		.	
20-02D	M	E-A	0	0	.		.	
21-02D	F	E-A	0	0	.		.	
23-02D	F	E-A	0	0		3	.	
25-02D	M	E-A	0	0		2	.	
26-02D	M	E-A	0	0	.		.	
27-02D	F	E-A	0	0	.		.	
30-02D	M	E-A	0	0	.		.	
31-02D	M	E-A	0	0	.		.	
32-02D	M	E-A	0	0	.		.	
33-02D	M	E-A	0	0		3		3
34-02D	M	E-A	0	0	.		.	
35-02D	F	E-A	0	0	.		.	
42-02D	M	E-A	0	0	.		.	
43-02D	M	E-A	0	0	.		.	
44-02D	M	E-A	0	0	.		.	
01-03D	M	E-A	0	0		1		1
02-03D	M	E-A	0	0	.		.	
03-03D	M	E-A	0	0		1		1
04-03D	M	E-A	0	0	.		.	
05-03D	M	E-A	0	0	.		.	
06-03D	M	E-A	0	0	.		.	
07-03D	M	E-A	0	0	.			3

08-03D	M	E-A	0	0		1	1
09-03D	M	E-A	0	0	.	.	
10-03D	M	E-A	0	0		1	1
11-03D	F	E-A	0	0		2	.
17-03D	F	E-A	0	0		2	.
18-03D	F	E-A	0	0		2	2
19-03D	M	E-A	0	0	.	.	
20-03D	F	E-A	0	0		3	2
21-03D	M	E-A	0	0	.	.	
22-03D	M	E-A	0	0		1	1
23-03D	M	A-A	0	0	.	.	
24-03D	M	E-A	0	0		1	.
25-03D	M	E-A	0	0	.	.	
26-03D	M	E-A	0	0		1	1
27-03D	M	E-A	0	0	.		2
28-03D	M	E-A	0	0		2	3
29-03D	F	E-A	0	0	.	.	
30-03D	M	E-A	0	0	.	.	
31-03D	M	E-A	0	0	.	.	
32-03D	F	E-A	0	0	.	.	
33-03D	F	E-A	0	0		2	.
34-03D	M	E-A	0	0	.	.	
36-03D	M	E-A	0	0	.	.	
37-03D	M	E-A	0	0		3	.
38-03D	M	E-A	0	0	.	.	
39-03D	F	E-A	0	0		3	.
41-03D	F	E-A	0	0		2	.
42-03D	M	E-A	0	0	.	.	
43-03D	F	E-A	0	0		2	.
44-03D	M	E-A	0	0	.	.	
45-03D	F	E-A	0	0	.	.	
46-03D	M	E-A	0	0		2	2
47-03D	M	E-A	0	0	.	.	
48-03D	M	E-A	0	0	.	.	
49-03D	M	E-A	0	0	.	.	
50-03D	M	E-A	0	0	.	.	
51-03D	M	E-A	0	0	.	.	
52-03D	M	E-A	0	0	.	.	
53-03D	F	E-A	0	0	.	.	
54-03D	M	E-A	0	0	.	.	
60-03D	M	E-A	0	0	.	.	
61-03D	F	E-A	0	0	.		3
63-03D	F	E-A	0	0	.	.	
03-04D	M	E-A	0	0	.	.	
08-04D	M	E-A	0	0	.	.	

09-04D	M	E-A	1	1	.		.	
11-04D	F	E-A	0	0	.		.	
12-04D	F	E-A	0	0	.		.	
13-04D	M	E-A	0	0	.		.	
16-04D	M	E-A	0	0	.		.	
17-04D	F	E-A	0	0	.		.	
18-04D	F	E-A	0	0		2	.	
19-04D	F	E-A	0	0		3		1
21-04D	M	E-A	0	0		2	.	
24-04D	M	E-A	0	0	.		.	
46-03D	M	A-A	0	0	.		.	
25-04D	M	A-A	0	0		2	.	
26-04D	F	E-A	0	0	.		.	
27-04D	M	E-A	0	0	.		.	
28-04D	M	E-A	0	0	.		.	
29-04D	M	E-A	0	0		1		1
32-04D	F	E-A	0	0	.		.	
34-04D	F	E-A	1	0	.			3
35-04D	F	E-A	0	0	.		.	
36-04D	M	E-A	0	0	.		.	
38-04D	M	E-A	0	0	.		.	
39-04D	M	E-A	0	0	.			3
43-04D	M	E-A	0	0	.		.	
44-04D	M	E-A	0	0	.		.	
47-04D	M	E-A	0	0	.		.	
48-04D	M	A-A	0	0	.		.	
49-04D	M	E-A	0	0	.		.	
50-04D	M	E-A	0	0	.		.	
52-04D	M	E-A	0	0		3		3
53-04D	M	E-A	0	0	.		.	
57-04D	F	E-A	0	0	.		.	
58-04D	M	E-A	0	0		3		3
59-04D	M	E-A	0	0		1		3
60-04D	M	E-A	0	0		2		2
61-04D	M	E-A	0	0	.		.	
62-04D	F	E-A	0	0		1		2
64-04D	M	E-A	0	0	.		.	
66-04D	M	E-A	0	0	.		.	
68-04D	M	E-A	0	0	.		.	
69-04D	F	E-A	0	0		1		1
02-05D	F	E-A	0	0		2	.	
03-05D	M	E-A	0	0	.		.	
05-05D	M	E-A	0	0		1	.	
08-05D	M	E-A	0	0		2		3
12-05D	M	A-A	0	0	.		.	

13-05D	F	E-A	0	0	.		.	
14-05D	M	E-A	0	0		3	.	
15-05D	M	E-A	0	0		3	.	
18-05D	F	A-A	0	0	.		.	
19-05D	F	E-A	0	0	.		.	
20-05D	M	E-A	0	0	.		.	
23-05D	M	E-A	0	0	.		.	
24-05D	M	E-A	0	0		3	.	
25-05D	F	E-A	0	0	.		.	
27-05D	F	E-A	0	0	.		.	
29-05D	F	E-A	0	0	.		.	
34-05D	M	E-A	0	0		2		2
41-05D	F	E-A	0	0	.		.	
42-05D	M	E-A	0	0		3	.	
46-05D	M	E-A	0	0		1	.	
47-05D	M	E-A	0	0	.		.	
48-05D	M	E-A	0	0	.		.	
51-05D	M	E-A	0	0		1		1
52-05D	M	E-A	0	0	.		.	
53-05D	M	A-A	0	0		3	.	
60-05D	M	E-A	0	0	.		.	
61-05D	M	E-A	0	0		3	.	

Terry os acromiale data

AC_L=Acromial condition (left) AC_R=Acromial condition (right)
0=trait absent 1=trait present
AS_L=Acromial shape (left) AS_R=Acromial shape (right)
1=square tip 2=intermediate 3=cobra

id	sex	ancestry	AC_L	AC_R	AS_L	AS_R
39	F	A-A	0	0	.	.
109	M	E-A	0	1	3	.
195	M	E-A	0	0	3	2
196	M	E-A	0	0	3	3
201	M	E-A	0	0	2	2
202	M	E-A	1	1	2	3
203	M	A-A	0	0	3	2
204	M	A-A	0	0	3	3
207	M	E-A	0	0	2	2
210	M	A-A	1	1	3	2
216	M	E-A	0	0	1	1
221	M	E-A	1	0	.	3
222	M	A-A	0	0	2	.
229	M	E-A	0	0	3	3
230	M	E-A	0	0	3	3
233	M	E-A	1	0	3	2
234	M	E-A	0	0	3	.
246	M	E-A	0	0	2	3
250	M	E-A	0	0	.	3
259	M	E-A	0	0	2	1
260	M	E-A	0	0	1	2
261	M	E-A	0	0	2	2
263	M	E-A	0	0	3	3
272	F	A-A	0	0	2	.
273	M	E-A	0	0	2	2
274	M	E-A	0	0	2	.
275	F	E-A	0	0	1	2
277	M	E-A	0	0	3	.
279	M	E-A	0	0	2	3
285	M	E-A	0	0	3	3
304	F	A-A	1	1	3	2
305	M	E-A	0	0	.	3
315	M	E-A	0	0	.	.
316	M	E-A	0	0	3	3
318	M	E-A	0	0	3	3
320	M	E-A	0	1	2	2
377	M	A-A	1	0	3	2
385	M	A-A	0	0	2	3

400	M	A-A	0	0	3	3
402	M	A-A	0	1	.	2
409	M	E-A	0	0	.	.
411	M	E-A	0	0	3	3
414	M	E-A	0	0	1	1
431	M	E-A	0	0	3	2
434	M	E-A	0	0	1	1
440	M	E-A	0	0	3	3
441	M	A-A	0	0	.	.
443	M	A-A	0	0	.	.
444	M	A-A	0	0	3	3
445	M	A-A	0	0	.	.
447	M	A-A	0	0	.	.
450	M	A-A	0	0	1	1
452	M	A-A	1	1	3	3
457	F	A-A	0	0	2	2
458	M	A-A	0	1	2	.
459	M	E-A	0	0	.	.
461	M	A-A	0	0	1	1
462	M	A-A	0	1	.	3
465	M	A-A	0	0	3	3
466	M	A-A	0	0	3	3
467	M	A-A	0	0	1	2
468	M	A-A	0	0	.	3
469	M	A-A	0	0	.	.
470	M	A-A	1	1	2	.
471	M	A-A	0	0	3	.
488	F	A-A	0	0	.	.
496	M	E-A	0	0	3	3
503	M	A-A	1	1	3	3
504	M	A-A	0	0	3	3
506	M	E-A	0	0	.	.
507	M	A-A	0	0	3	3
515	M	A-A	1	0	.	.
516	M	A-A	0	1	3	.
517	M	E-A	0	0	2	2
518	M	A-A	1	1	.	.
519	M	A-A	0	0	1	1
520	F	A-A	0	0	3	3
522	M	A-A	0	0	1	2
523	M	A-A	0	0	1	1
524	M	A-A	0	0	1	.
530	F	A-A	0	0	.	.
532	F	A-A	0	0	.	.
535	F	A-A	1	0	.	.

545	M	E-A	0	0	.	.	
546	M	E-A	0	0	2	1	
548	M	E-A	0	0	.	3	
557	M	E-A	0	0	2	1	
559	F	A-A	0	0	.	.	
561	F	A-A	0	0	2	3	
563	M	E-A	0	0	3	.	
564	M	E-A	0	0	2	2	
567	F	A-A	0	0	.	.	
568	F	A-A	0	0	2	3	
583	F	A-A	0	0	1	1	
584	F	A-A	0	0	.	.	
586	F	A-A	0	0	.	.	
587	F	A-A	0	0	.	.	
591	M	E-A	0	0	3	2	
592	M	A-A	0	0	2	2	
594	M	A-A	0	0	3	.	
595	M	A-A	0	0	2	2	
599	M	E-A	0	0	2	2	
601	F	E-A	0	0	2	1	
603	F	A-A	0	0	3	.	
610	F	A-A	0	1	2	.	
611	F	E-A	0	0	2	2	
615	F	A-A	0	0	3	3	
639	F	E-A	0	0	3	.	
640	F	A-A	0	0	3	.	
641	M	E-A	0	0	2	2	
653	F	A-A	0	0	3	3	
654	M	A-A	0	0	3	.	
655	F	A-A	0	0	1	1	
661	F	A-A	1	1	.	3	
666	F	A-A	0	0	3	3	
674	M	E-A	0	0	.	.	
679	F	A-A	0	0	2	2	
692	F	E-A	0	0	3	2	
703	M	A-A	0	0	1	1	
718	M	A-A	0	0	2	.	
719	M	A-A	0	0	1	1	
723	F	A-A	0	0	.	3	
738	F	A-A	0	1	2	3	
742	M	A-A	0	0	.	.	
743	M	E-A	0	0	3	2	
745	F	A-A	0	0	.	.	
747	M	E-A	0	0	3	2	
751	M	E-A	0	0	3	3	

753	M	A-A	1	1	.	.	
755	M	E-A	0	0	1	2	
760	M	A-A	0	0	3	2	
761	F	A-A	0	0	.	.	
763	M	E-A	0	0	3	3	
772	M	E-A	0	0	3	3	
775	F	A-A	0	0	.	.	
795	M	E-A	0	0	1	1	
802	M	E-A	0	0	3	.	
811	M	A-A	0	0	.	.	
815	F	A-A	0	0	3	3	
816	M	A-A	0	0	3	2	
817	M	A-A	0	0	.	.	
821	M	A-A	0	0	3	3	
823	M	A-A	0	0	.	2	
824	F	A-A	0	0	3	3	
825	M	A-A	0	0	1	1	
826	M	A-A	0	0	3	2	
829	M	A-A	0	0	3	.	
830	M	A-A	0	0	3	3	
831	F	A-A	0	0	.	.	
836	M	A-A	0	0	.	.	
850	M	A-A	0	0	1	1	
854	F	E-A	0	0	2	2	
859	M	A-A	0	0	3	3	
862	M	A-A	0	0	2	2	
864	M	A-A	1	0	3	3	
867	M	E-A	0	0	.	.	
875	M	A-A	1	1	.	.	
876	M	A-A	0	0	2	2	
880	F	E-A	0	0	3	3	
882	M	A-A	0	0	3	3	
885	M	A-A	0	0	3	3	
886	F	A-A	0	0	1	1	
887	F	A-A	0	0	.	3	
897	M	E-A	0	0	1	2	
1602	M	E-A	0	0	1	1	
103R	F	E-A	0	0	3	.	
104R	F	A-A	0	0	.	.	
105R	F	A-A	0	0	1	1	
106R	F	A-A	0	0	2	.	
107R	F	E-A	0	0	3	.	
108R	F	E-A	0	0	.	.	
111R	M	E-A	0	0	3	2	
112R	F	E-A	0	0	1	1	

117R	F	E-A	0	0	.	.	
11R	F	A-A	0	0	3		2
120R	F	A-A	0	0	3		3
126R	M	E-A	0	0	.		1
12R	F	E-A	0	0	3		3
131R	M	E-A	0	0	3		3
133R	F	E-A	0	0	.	.	
135R	F	E-A	0	0	1		3
139R	F	E-A	0	0	1		1
144R	F	E-A	0	0	.		1
146R	F	A-A	0	0	1		1
148RR	F	E-A	0	0	2		2
149R	F	E-A	0	0	.	.	
14R	M	E-A	0	0	3		3
150R	F	E-A	0	0	.	.	
154R	F	E-A	0	0	2		2
159R	F	E-A	1	1	2	.	
161R	F	E-A	0	0	2		1
162R	F	E-A	0	0	2		2
164R	F	E-A	0	0	1		3
166R	F	E-A	0	0	.		2
174R	F	E-A	0	0	3	.	
175R	F	E-A	0	0	.	.	
187R	M	E-A	0	0	3		2
188R	F	E-A	0	0	1		2
189R	F	E-A	0	0	1	.	
190R	F	E-A	0	0	1		3
191R	F	E-A	0	0	2	.	
206R	F	E-A	0	0	3		3
20R	F	E-A	0	0	.	.	
217R	F	E-A	0	0	.	.	
22RR	F	E-A	0	0	3	.	
232R	F	A-A	0	0	.		1
236R	F	E-A	0	0	2	.	
238R	F	E-A	0	0	.	.	
23R	F	A-A	0	0	1		2
243R	F	E-A	0	0	.	.	
247R	F	E-A	0	0	.	.	
248R	F	E-A	0	0	1		3
249R	F	E-A	0	0	2		3
24R	F	A-A	0	0	.	.	
252R	F	E-A	0	0	.	.	
253R	F	A-A	0	0	1		1
256R	F	E-A	0	0	.	.	
25R	F	A-A	1	0	.		3

26R	F	A-A	0	0	.		.	
275RR	F	E-A	0	0		2		3
27R	F	A-A	0	0	.			1
28R	F	E-A	0	0	.		.	
293R	F	E-A	0	0		1		1
294R	F	A-A	0	0		3		2
301R	M	E-A	0	0		3		3
306R	F	E-A	0	0		2		3
311R	M	E-A	0	0		1		1
312R	F	E-A	0	0		2	.	
319R	F	E-A	0	0	.			3
348R	F	A-A	0	0		3		2
37R	F	E-A	0	0		3	.	
38R	F	A-A	0	0		2		2
39R	F	E-A	0	0	.		.	
41R	F	E-A	0	0		1		2
42R	F	A-A	0	0		3		3
47R	F	E-A	0	0		2		1
53R	F	E-A	0	0		2		3
543R	F	E-A	0	0		2	.	
55R	F	E-A	0	0		1		1
56R	F	A-A	0	0		1	.	
605R	M	E-A	0	0		1	.	
637R	F	A-A	0	0	.			2
63RR	F	A-A	0	0	.		.	
658R	F	A-A	1	1				
659R?	F	E-A	0	0		1	.	
65R	F	A-A	0	0	.		.	
66RR	F	E-A	0	0	.		.	
67R	F	A-A	0	0	.		.	
68R	F	A-A	0	0		2		3
69R	F	E-A	0	0		3		3
6RR	F	E-A	0	0	.			3
729R	F	A-A	0	0	.			3
741R	F	E-A	0	0		2		2
745R	F	E-A	0	0		2		2
749R	F	E-A	0	0	.		.	
75R	F	E-A	0	0	.		.	
76r	F	E-A	0	0	.			1
77R	F	A-A	0	0	.		.	
78R	F	A-A	0	0	.		.	
809R	M	A-A	1	1		1		3
80RR	F	E-A	0	0		1		2
818R	F	E-A	0	0		2		1
81R	F	A-A	0	0	.		.	

833R	M	A-A	0	0	1		1
883R	M	A-A	0	0	2	.	
91R	F	E-A	0	0	1		1
92R	F	E-A	0	0	2	.	
94R	F	A-A	0	0	2	.	
96R	F	E-A	0	0	.	.	
97R	F	E-A	0	0	1	.	
98R	F	A-A	1	1	2	.	

Vita

Lorena Lucía Villao Crúz was born May 18, 1980 on the island of Manhattan to Esther Villao Crúz, and Francisco Antonio Villao Brúcell. She graduated from Benjamin N. Cardozo High School with a concentration in modern dance. She decided to pursue a major in the realm of classical studies at Hunter College (CUNY), with a concentration in classical archaeology. After graduation from Hunter in 2002, she returned to pursue a Masters, studying anthropology at the University of Tennessee, with a concentration in biological anthropology.