A Study Of Neandertal Scapular Shape
With Special Reference To
Kebara Mousterian Hominid 2

by

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B.A. (Hons.), University of Winnipeg, 1990

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Title of Thesis/Project/Extended Essay

A STUDY OF NEANDERTAL SCAPULAR SHAPE WITH SPECIAL REFERENCE TO KEBARA MOUSTERIAN HOMINID 2

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Abstract

The purpose of this thesis is to examine Neandertal scapular morphology through morphometric analysis of three anatomical regions of the scapula: (1) the glenoid fossa, (2) the scapular body, and (3) the axillary border. The study utilises published and unpublished data from Neandertal and a range of subsequent modern human samples. The glenoid fossa and axillary border analyses incorporate data from various Neandertal samples, whereas the scapular body analysis focuses on a single Neandertal (right) scapula, Kehara Mousterian Hominid 2. This scapula has not been characterised in detail prior to this study. In contrast to previous research, this study emphasises evaluating Neandertal scapulae by comparison to populations whose skeletons evidence high levels of physical activity and occupational stress, as they more closely approximate Neandertal morphology than do more sedentary populations.

Each of the analyses yielded several observations. First, the glenoid fossa in Neandertals and its relationship to humeral joint surfaces was found to be strikingly similar to one sample of modern humans, and very similar to another, negating that Neandertals were distinct from modern humans in these regards. These congruences reflect similarities in shoulder and arm use, and activity stress. Second, the right scapula of Kehara 2 proved to be similar to other Neandertals, in that it is large and preserves markings of formidable musculature, reflecting the life history of the individual and that of Neandertals, in general. And third, the axillary border analysis identified an association between border shape (type) and thickness, and introduces the concept of robusticity as reflected in the thickness of the border, and not merely in its shape. The dominant type of border found in Neandertals (dorsal) was found to be less robust, in terms of thickness, than the type (bisulcate) found in a large number of the modern humans.

The overall results emphasise the importance of choosing appropriate comparative samples. In particular, they illustrate the value of assembling a wide morphological range of comparative populations, ones which are notably robust and engaged in high levels of physical activity, especially in the anatomical regions under consideration. Thus, consideration of the relationship between lifeways of an individual, or a population, and bone shape is a critical component in reconstructing hominid phylogeny.

The results of this research de-emphasise the uniqueness that has been attributed to the scapulae of Neandertals by other researchers. This does not in any way discount that their shoulders were powerful and heavily muscled, but rather dispels the notion that these type of changes are not visible in modern humans.
Dedication

For my father, Hersz Odwak

whose freedom gave me
the courage to
believe.
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Chapter 1: Introduction and Neandertal Lifeways

(A) Introduction

The natural history of the Neandertals has been a consistently contentious and intriguing paleoanthropological issue since the discovery of the Neander Valley calotte in 1856. In the past ten years study into their place in human ancestry has intensified, fueled in part by increased research on the appearance of anatomically-modern humans, and new evidence suggesting a more recent origin for Homo sapiens, both behaviorally and anatomically (e.g. Aiello, 1993; Cann et al., 1987; Frayer et al., 1993; Kidder et al., 1992; Stringer, 1989b; Stringer and Andrews, 1988; Stringer et al., 1999; Vigilant et al., 1991; Lahr, 1994).

Although the significance of Neandertal skeletal morphology was grossly misrepresented by erroneous conclusions reached from initial studies of the La Chapelle-aux-saints individual, the fact still remains that, in albeit different regards, they are a unique and puzzling group. Where before they were regarded as primitive brutes, we now recognize that they were as culturally developed as any of their contemporaries (Bar-Yosef et al., 1992; Clark, 1992; Shea, 1989). However, whereas their peculiar shared morphology was previously taken as indicative of a deficient mental capacity, it is now acknowledged that, like all other organisms, their anatomy is a reflection of the way they were living - a mirror of their culture. Thus, in recent years paleoanthropologists have turned to defining Neandertal anatomy within the context of, and with respect to, the activities and anatomical movements that shaped their bodies (e.g. Churchill and Trinkaus, 1990; Rak, 1990; Trinkaus 1983a, 1983b, 1986, 1989).

The nature of Neandertal anatomy is noticeably unique to even non-specialists, although perhaps less so in their postcranial skeleton. It has been well established that they display morphological characteristics which, whether in
combination or singularly, lie at the periphery of modern human variation (e.g. Spencer & Demes, 1993; Trinkaus, 1983a, 1983b, 1986; Trinkaus & Smith, 1985). Thus, the question most commonly asked is where in human ancestry do we place them? Are the Neandertals genetic contributors to living human gene pools, and if so to what degree? At the other paradigmatic polarity is the possibility that Neandertals differed at the specific level and therefore did not contribute to modern gene pools.

However, understanding the taxonomic or phyletic status of the Neandertals, or any hominin group, requires a characterisation of their anatomy and how it compares to both present and past human populations. Thus, the first step, anatomically and morphologically, is to compare the elements of their skeletons against a broad range of contemporaneous, subsequent, and modern humans and determine whether or not they fit within accepted limits of anatomical variation. Many researchers have attempted this for Neandertals (e.g. Endo and Kimura, 1970; Trinkaus, 1976; Trinkaus, 1983b; Trinkaus, 1983b; Churchill and Trinkaus, 1990), and concluded that they are exceptional in many morphological regards. However, I believe that in some cases the recent human samples are unsuitable or insufficiently broad, and thus overemphasise how unique Neandertals are. Hence, the implicit conclusion reached by these researchers is that these various perceived Neandertal morphological anomalies, in either simple expression (i.e. non-metric) or extent (i.e. metric), are unattainable by recent humans, because they have not been observed. Given that Neandertals, by virtue of their skeletal morphology, robusticity, muscular hypertrophy, and technology, were facing unique environmental stresses, then expecting to find a morphological equivalent modern population would be a rather challenging task.
**Thesis Goals**

This research is a study of Neandertal scapular architecture, covering three anatomical regions of the bone, by way of comparison between Neandertals and three samples of recent humans. The comparative populations engaged in physically rigorous lifestyles and should, I believe, show closer scapular resemblance to Neandertals than would less active groups for reasons of shared general biomechanics and loading of the shoulder girdle. The goal is to determine if, and how, Neandertal scapulae differ from those of subsequent human groups in the biological regions analysed. It should be stated here that any similarities uncovered would likely reflect phenotypic resemblance, based on the inherent plasticity of osseous tissue. Thus, any similarities uncovered in this research should not be taken as indicative of anything more than osseous responses to similar biomechanical stresses, rather than genetic relatedness.

The manipulative nature of the upper limb makes it a critical region of study in human evolution. The shoulder girdle is the juncture between the upper arm and the torso, specifically the glenohumeral joint where the humeral head articulates with the glenoid fossa of the scapula. Thus, the scapula, in essence, attaches the arm to the body and, with the clavicle, defines the range and types of humeral movement. Habitual movements involving loading of the shoulder, as in throwing, lifting, paddling, carrying, thrusting, digging, carving, etc., will leave impressions in the way of muscular, ligamental, and osseous changes which can be used to distinguish and characterise individuals or populations. Thus, the shape and nature of the scapula is a critical issue to understand in the evolution of human manipulative behaviours.

Neandertal scapulae have consistently been described as distinct from modern humans, in several measures lying at the periphery of modern human variation. In particular, their glenoid fossae are narrow (Vallois, 1928-46; Stewart,
1962; Trinkaus, 1983; Churchill and Trinkaus, 1990; Trinkaus et al., 1991); their axillary borders commonly show, on the posterior edge, a well-developed groove (dorsal sulcus) for a muscle that runs to the upper arm (Endo and Kimura, 1970; McCown and Keith, 1939; Stewart, 1962; Trinkaus, 1977, 1983b); and their scapular bodies are wide and large (Trinkaus 1983a, 1983b, 1986, 1989; Vallois, 1928–46). These are likely indicators of osseous and muscular hypertrophy of the shoulder. It should be noted that most of these studies are focused on sub-regions of the bone, or specific functional areas such as the glenoid fossa (e.g. Churchill and Trinkaus, 1990; Trinkaus, 1977).

While works such as these illustrate peculiarities of Neandertal scapulae, some studies clearly make use of poorly suited comparative samples, those representing sedentary, less active populations which could erroneously distance Neandertals to the tips of the branches of modern human variation. In other words, and perhaps less critically, studies should incorporate both highly active and less active comparative samples. Knowing that bones, as tissue, are highly plastic and respond by modeling as an adaptation to their use, or lack thereof, there is a need in paleoanthropology to understand the range of human morphological variation before we can confidently conclude that a certain morphological state is extreme or unattainable in living humans.

Research Design

The present study is concerned with discerning the scapular architecture of Neandertals, and will achieve this through examining a combination of unique and more traditional measurements. The entire study, divided into three parts, utilises three recent human samples and various Neandertal data. The comparative sample is comprised of Pacific Northwest Coast natives, a late 19th century collection of
North American pioneers from Golden, British Columbia, and the Chonos, a South American coastal group who are no longer a distinct biological entity.

The first analysis looks at the shape of the glenoid fossa, in what is effectively a reconsideration of data and results published by Trinkaus and Churchill (1990). Their conclusions on the uniqueness and function of Neandertal glenoid fossae will be evaluated in light of data collected from the three recent human samples. The second comparison is a very specific analysis of the shape of the right scapular body of Kebara 2, one of the most recently recovered and most complete of any Neandertal. Discovered as part of a nearly complete male skeleton in 1993, the scapula has only been described briefly, by Vandermeersch (1991). Additionally, both Kebara scapulae will be described in detail in a section separate from the analysis. Reference will be made to comparable data published on selected Neandertal scapular bodies, with the ultimate goal in this analysis to determine whether or not the scapula is characteristically Neandertal. The final analysis is concerned with the most persistent and pervasive anomaly of Neandertal scapulae, that of the shape of their axillary borders. The axillary borders of Kebara 2 and Tabun C1 will be the focus of this section, in which the problem will be approached from a somewhat different perspective than has been typical.

Although these three aspects will be analysed separately, their relatedness will be addressed. The development and mechanical effectiveness of each scapular region is contingent upon the others, just as any architectural structure benefits from the shape and support of neighbouring structures. The nature, and significance, of this will be discussed at the end of the study after each area is considered independently.

While it would be most beneficial to include data from all known Neandertal scapulae, this situation is unrealistic. The various elements are scattered across Europe, Asia, the Near East, and North America and the economic and time
constraints would clearly be insurmountable. As well, some of the measurements used in the second and third analyses have not been published (or performed) for most other Neandertal scapulae. It is for these reasons that the Neandertal sample will be so quantitatively limited.

Ideally, comparison of the Neandertal sample to a complete range of modern humans would be the most appropriate research design. However, this scenario is unrealistic for an obvious reason, that being the sheer magnitude of such a task. With the realisation that the sample must be limited in size, I felt that the best recent comparative skeletal samples would be ones which are, whether previously described or not, known to be robust, and ones which show relatively high degrees of muscular hypertrophy and rugosity. As the morphology of Neandertal skeletons reflect unusually high levels of activity stress (e.g. Ben-Itzhak et al., 1988; Trinkaus, 1983a, 1983b, 1986, 1989; Trinkaus et al., 1994), we should expect that modern populations experiencing similar stresses should have closer morphological (but not necessarily genetic) affinities to Neandertals. We may assume that morphological and architectural changes in the scapula are concurrent with lifestyle, and that such populations are arguably more comparable than less active populations.

**Comparative Samples**

**Pacific Northwest Coast Natives**

The comparative populations included in this study contain individuals which show a high amount of occupational hypertrophy, rugosity, and robusticity. One of these samples, the prehistoric Pacific Northwest Coast native skeletal collection at the Department of Archaeology, Simon Fraser University, piqued my interest in, and heightened my awareness of, skeletal plasticity and remodeling. Upon initial survey of the collections I was drawn to the occupational morphology and activity induced osseous changes in the elements of many of the individuals. In
comparison to gracile skeletons and samples I have studied in past years the NW Coast skeletons display greater hypertrophy and robusticity, changes elicited by their physical lifeways. It is likely that these changes are developmental in nature, rather than congenital (discussed in greater detail in Chapter III).

The morphology of prehistoric NW Coast skeletons suggest that they were living a very active, occupationally stressed lifestyle. Degenerative joint disease (DJD) is marked both temporally and spatially (Beattie, 1980; Conaty & Curtin, 1984; Cybulski, 1990; Cybulski, 1992). In a comprehensive study of the Gulf of Georgia region Beattie (1980) noted marked DJD in the shoulder girdles of his samples, and found no significant differences in DJD in any of the bodies' joints between sexes or sides of the body, and comments that "A rigorous and demanding lifestyle is well indicated by the occurrence of vertebral collapse and intervertebral disc herniation" (Beattie, 1980: 168). Commenting on their general physique, Boas (1899, in Cybulski, 1990) described the recent indigenous populations on the NW Coast as having short and broad trunks, long and muscular arms, less strongly developed legs, and as being of medium stature.

My study of the NW Coast sample (scapulae and humeri) generally corroborates these interpretations, although I did not study DJD specifically. While I did observe DJD, my observations reflect signs of occupation stress beyond joint degeneration or other pathologies. Their scapulae, in general, are rugose and show clear signs of muscular hypertrophy. Although variable from individual to individual, there were several scapulae with thick and bisulcate axillary borders, and many with expansive and marked major origins, rugose supraacromial deltoid origins, and deep and pitted triceps origins. In general, I would describe their scapulae as being moderately robust.

General robusticity and specific hypertrophy was even more evident on the humeri. The most striking aspect of the humeri was the insertional area of deltoid
which, in nearly all individuals, displays a large rectangular insertional area, raised off the midshaft so as to create a sulcus between it and the adjacent posterior humeral shaft. Despite their apparent upper limb strength, deltoid is not commonly as developed in Neandertals as it is in the NW Coast sample. Kebara 2, Tabun C1, and Amud 1 show much smoother and less rugose deltoid insertions, although Trinkaus (1983b) has stated that Shanidar 3 has a marked deltoid insertion.

Examination of photographs of Shanidar 3 (in Trinkaus, 1983b) reveal that the many of the individuals from the NW Coast sample exceed Shanidar 3 in development of this particular muscular insertion. The reasons for this are unclear, and will not be investigated here. As many of the humeri of the NW Coast individuals were broken near midshaft I was able to observe the cortices of several of the individuals. Although my observations are purely qualitative, the cortical bone was generally very thick. As well, on many of the NW Coast individuals pectoralis and latissimus dorsi were marked and hypertrophied, as were insertions of the other rotators.

Based on these observations and past comments, the NW Coast sample seems an appropriate comparative group for the present study. Although researchers have commented that prehistoric NW Coast groups led rigorous and active lifestyles, based on observed DJD and other pathologies, comments on muscularity are clearly lacking. The muscularity and robusticity exhibited in their skeletons clearly reflect a physically active lifestyle, particularly of consistent loading of the shoulder and upper limb.

Dorsey (1897) has made passing comments on the robusticity of Northwest Coast Native scapulae based on his study of scapular variation. He observed evidence of considerable muscularity in the shape of the vertebral border, in the development of teres major and the subsequent enlargement of the inferior angle.
Research on Pacific Northwest Coast Scapulae

The collection of Northwest Coast scapulae utilised will only be treated as a comparative sample, and no attempt will be made to describe or characterise them in any detail. The only study of Northwest Coast scapulae to date was published in 1897 by G.A. Dorsey (Dorsey, 1897). Dorsey studied 20 Kwakiutl and Songish individuals at the Field Columbian Museum. His primary concern was with the shape and variation of vertebral border and the body of the scapula, and with overall variation between the two groups and the sexes. He made passing notes on the robusticity of the scapulae based on variation, and observed evidence of considerable muscularity in the shape of the vertebral border, in the development of t. major and the subsequent enlargement of the inferior angle. He measured the dimensions of the glenoid fossa, but limited his examination to a comparison of size differences between the sexes and did not examine indices nor comment on the glenoid's structure. He did arrive at an index for a certain aspect (scapular index) of the scapular body which he called "a trustworthy index for Northwest Coast Indians" (Dorsey, 1897: 743).

Despite the decision to restrict the use of the Northwest Coast data to comparison, an attempt may be made in the future to use this information to characterise their scapulae and lifeways. The sites from which the NW Coast samples are derived will be outlined in chapter IV.

The Golden Pioneer Cemetery (NA Pioneer) sample

The NA Pioneer sample is from the Golden cemetery in British Columbia, used from 1882 to 1894. The majority (eight) are described as Caucasoid, while two show Caucasoid/Mongoloid admixture (Oliver, 1992). Golden emerged as a railway community late in the 1800s, located along the Canadian Pacific Railway. Most of the early settlers came to Golden from Europe as railway workers, miners, and
construction tradesman. The muscular hypertrophy, degenerative changes, and overall morphology apparent in their skeletons suggest that several of the individuals engaged in physically demanding occupations (i.e. labourers) (Oliver, 1992).

**Chonos**

The Chonos were a nomadic population who lived along the Southern Chilean Archipelago at the time of initial European contact in 1553 AD, and spent a great deal of time in canoes. They are no longer considered a distinct biological entity, although some believe they may have merged back with a closely related tribe. I obtained data on their scapulae from Dr. Israel Hershkovitz, who recently studied them in Chile, where they are housed. There are certain limitations to the use of the dataset, which will be outlined in Chapters IV and V. I examined photographs of Chonos scapulae and humeri in Israel, which revealed evidence of striking musculature, no doubt related to habitual canoeing, their dominant mode of travel. As well, the morphology of their upper limbs has previously been described as particularly robust (Fontaine, pers. comm, 1992; Hershkovitz, pers. comm., 1992).

**Research Organisation**

The study is divided into six chapters. The remainder of Chapter I provides a biocultural perspective on Neandertals. Chapter II details the osteology and muscularity of the scapula, as well as presents a discussion on osseous plasticity. In Chapter III the nature of Neandertal scapular morphology, as determined by past research, is considered. Additionally, the chapter outlines Kehara 2, with a detailed description of the scapulae. In Chapter IV the materials and methods of this project are detailed. The data, analysis, and results of this study are presented in three
sections in Chapter V. And finally, Chapter VI, the concluding chapter, discusses and synthesises the results of the analyses, as well as provides suggestions for future research.

(B) Neandertal Lifeways

The Neandertals emerged in the late Middle to early Upper Pleistocene, survived until approximately 36,000 yBP (Mercier et al., 1991), and were distributed across Europe, south of approximately 52° north latitude, at least as far east as central Asia, and in the Near East. The Neandertal "grade" of evolution was not seen world-wide, as their contemporaries outside of these areas were morphologically distinct (Santa Luca, 1978), and form a separate clade. Other archaic humans lived in eastern Asia, Africa, and Australasia during this period, members of the same grade of human evolution but of different geographical clades. One region, the Near East, appears to have witnessed the co-existence of Neandertals with a different population of *H. sapiens* (from the sites of Skhul and Qafzeh) (Klein, 1994; Schwarz et al., 1988; Stringer et al., 1989; Valladas et al., 1988). These two apparently separate lineages in the Near East may be distinct at the specific or subspecific level. It is best to consider Neandertals as a geographical subspecies of *Homo sapiens* (*i.e.* *H. sapiens neanderthalensis*) (Trinkaus and Smith, 1985), although some researchers discriminate between them at the species level (*e.g.* Tattersall, 1986 - *Homo neanderthalensis*).

Neandertals are associated with the Mousterian tradition, and more generally with the Middle Paleolithic. Based on aspects of their technology, economy, subsistence, population density, and social structure Hayden (1993) suggests that they were generalised hunter/gatherers and that, like the majority of contemporary groups of this type, Neandertals populations were sparse and highly mobile.
Neandertals show a mosaic of features shared with both more archaic members of Homo (plesiomorphies) and modern humans (apomorphies), as well as possessing unique features (autapomorphies) whether singularly or in combination. They most closely resemble the other late archaic humans (i.e. those in eastern Asia, Africa, and Australasia), but are sufficiently different to allow for morphological distinction. However, postcranial remains from the other archaic members of Homo sapiens are surprisingly rare, especially relative to the Neandertal sample, which creates difficulties for characterising other archaic H. sapiens.

The Biocultural Perspective

A comprehensive understanding of the lifeways of Neandertals must include both physical and cultural characteristics, and resolve how they related to one another. This section begins with an overview of the skeletal features which distinguish and define Neandertals, and concludes with evidence from the archaeological record which reflects and relates to their anatomy.

Neandertal Morphology: Cranial

Certain morphological characteristics, primarily in the cranium, distinguish Neandertals from other archaic members of the genus Homo, as well as from modern humans. In discussing these features the focus is on the presence of the traits, rather than on whether or not they are exclusively Neandertal in nature. As the concern in this section is to comprehend the behaviours reflected by their anatomy, the debate over whether or not certain ones are cladistically justified will be avoided. It should be kept in mind that this morphotype, although characterising Neandertals in general, obscures considerable variation within the sample, only some of which is ordered temporally.
Neandertal crania possess an overall appearance which is the sum of a set of traits which characterise them well as a group. These traits are more significant in combination than singularly, particularly as they reflect functional complexes. In contrast to modern humans as traditionally characterised, Neandertal crania are platycephalic, large, low, and are rounded in profile in posterior view. The mid-facial region, including the anterior dentition, is prognathic, and the mandible usually lacks a chin. They have large and thick supraorbital tori, as well as generally thick vaults (Trinkaus, 1988).

The most likely autapomorphies on Neandertal crania are aspects of their cranial base, specifically in the temporal and occipito-mastoid regions. The clearest are in the latter, and include their distinct, oval suprainiac fossae, their large juxta-mastoid crests which usually project below the level of the mastoids, their tapering mastoid processes poorly separated form the petrous portion, and the presence of an anterior mastoid tubercle, or protuberance. In the temporal region, the TMJ commonly has a mandibular fossa that is usually large, relatively shallow, and poorly delimited anteriorly given their relatively flat and broad articular eminences. As well, the external auditory meatus (EAM) usually lies above the roof of the mandibular fossa, in the same horizontal plane as the zygomatic process of the temporal bone (Trinkaus, 1988).

As with many other morphological conditions, evidence from the fossil record and recent human variation suggests caution in utilising some of these traits as highly diagnostic of the Neandertals. For example, the shape of the TMJ can be altered by even modest changes in levels of dental occlusal attrition, and the elevated level of attrition seen in Neandertals suggest that a high percentage of the observed morphology may be the result of remodeling (Trinkaus, 1988). Nonetheless, within the context of this project the behavioral and mechanical
significance of such features is of importance, rather than their phylogenetic implications.

The facial structure of Neandertals is most distinctive in terms of their mid-facial prognathism and overall configuration. The complex is comprised of an anterior projection of the dentition and nasal aperture relative to their lateral zygomatic facial skeleton. The spatial and biomechanical consequence of this configuration comes in the form of secondary characteristics, including large retromolar spaces, posteriorly located (M2-M3) anterior zygomatic roots and mental foramina, antero-lateral flattened zygomatic bones, absence of zygomatico-alveolar notches and canine fossae, relatively low zygomatico-maxillary angles indicating a more parasagittal orientation of the infraorbital region, relatively horizontal and prognathic nasal bones, anteriorly projecting nasion relative to the lateral orbital or supraorbital margins, reduced supraorbital sulcus above glabella (compared to *H. erectus*), and large frontal sinuses restricted to the middle half of the supraorbital torus (Trinkaus, 1983a, 1988).

Many of these traits, although unique to the Neandertals or rare in other human groups, are largely secondary consequences of the maintenance of Middle Pleistocene total facial/dental prognathism and the posterior retreat of the masticatory muscle region, relative to both neurocranial and postcanine dimensions (Trinkaus, 1988). Interestingly, this mid-facial prognathism appears primarily with the eruption of permanent dentition, which emphasises the role of dental and masticatory regions in producing this facial configuration (Tiller, 1986, 1989 cited in Trinkaus, 1988; Trinkaus, 1988).

In posterior view, Neandertal crania are rounded (*forme en bombe*), distinct from the angled crania of both *H. erectus* and modern humans. Trinkaus (1988) proposes that this result of a combination of features including platycephaly and the
loss of parietal bosses, loss of the sagittal keel, encephalisation, cranial base reduction, neurocranial superstructure reduction, and their unique mastoid profile.

And lastly, the posterior aspect of Neandertal crania also have distinguishing features, especially notable in lateral view. They usually have occipital buns (chignons) associated with supralambdoid depressions and reduced transverse occipital tori, although this pattern appears with decreasing frequency in the late Middle Pleistocene of western Europe, and is not as common in Near Eastern individuals (Trinkaus, 1988). After examining both European and Near Eastern Neandertal crania Santa Luca (1978) established, what he believes to be, a set of four diagnostic Neandertal cranial traits. These are the rounded mastoid protuberance, the large occipitomastoid crest which extends beyond the mastoid crest, the morphology of the occipital torus (uniformly thick, horizontal, and central in the torus), and the suprainiac fossa.

**Postcranial**

While some of the above features of Neandertal crania are linked to activity, their postcrania are particularly valuable in reconstructing aspects of their cultural patterning. The levels of postcrania robusticity and muscular hypertrophy preserved in their skeletons leave no doubt that their physical strength was formidable. Their upper limbs imply that they were exerting a markedly elevated level of habitual strength in both their arms, generally, and in their grip. Their locomotor anatomy also reveals great strength, as well as an adaptation for endurance for prolonged locomotion over irregular terrain. Additionally, their locomotion may have differed somewhat, biomechanically, from modern humans (Ben-Avraham et al., 1988; Trinkaus 1983a, 1983b, 1986, 1989; Rak, 1992).

The current evidence suggests that most, if not all, of their upper limb morphology is either plesiomorphous for *Homo* or is synapomorphous with modern
humans. In general, the sizes of the muscular insertions in their shoulder, arm, and hand skeleton were large, and their humeral cortices were thick. The articular size and orientation in the elbow and possibly some of the joints of the hand were shaped so as to handle high habitual peak forces through these joints, but did not affect mobility. Neandertals, as well, appear to have employed a transverse power grip more frequently than do most modern humans (Ben-Itzhak et al., 1988; Trinkaus, 1986, 1989; Trinkaus et al., 1991). These adaptations are a reflection of habitual loading of the shoulder and arm through upper limb positioning and actions through tool use. These actions, logically, involved the torso as well as indicated by the thickness of the ribs and hypertrophy and geometry of the vertebrae in Neandertals (Trinkaus, 1983b). The development of the upper limb in Neandertals is outlined in more detail in chapter III.

The lower limbs of Neandertals exhibit such features as large femoral heads, large and cortically thick femoral diaphyses that lack pilasters and have superomedial shaft inflation, large tuberosities (insertions) for the gluteal muscles, thickened and enlarged patellae, more posteriorly placed tibial condyles, amygdaloid and cortically thick tibial shafts, tali with large trochlea, mediolaterally expanded proximal phalangeal diaphyses, and low crural indices (Endo and Kimura, 1970; Lovejoy and Trinkaus, 1980; Trinkaus, 1983a, 1986). These are reflections of locomotor strength and endurance, partaken at such remarkable levels that Trinkaus (1986) has stated that Neandertals were spending sufficiently more of their waking hours moving across the landscape than did early modern humans.

Recent research by Rak (1992) implies that the architecture seen in Neandertal pelves resulted in different locomotor biomechanics than is seen in either modern humans or in H. erectus. Based on aspects of the superior pubic ramus of the Kebbara 2 individual, Rak concluded that Neandertal gait was less efficient for long periods of walking than is the case for modern humans. On a
similar note, Trinkaus (1988) has stated that the alterations seen in the locomotor anatomy of modern humans, in contrast to Neandertals, imply a major increase in the efficiency of subsistence-related mobility patterns.

And finally, Neandertal distal limb segments (forearm and lower leg) were short relative to their proximal limb segments (low brachial and crural indices) compared to earlier equatorial hominids. Similar to many cold/temperate mammals, they seem to have developed a body form which favours the minimisation of body surface area and therefore heat loss. While lying at the low end of the brachial and crural indices, Neandertal values fall well within the range of modern human variation. This feature is best viewed in the context of the biogeographical patterning and thermal adaptation common to all human groups, and not exclusive to Neandertals (Trinkaus, 1983a, 1988). Most intriguing, rather, is why their indices appear so "Arctic" given their low latitudes of occupation, particularly in the Levant (Trinkaus, 1988).

The Relationship between Neandertal Anatomy and Culture

Based on the above, Neandertal anatomy clearly reflects an adaptation for a highly active lifestyle, one involving great occupational stresses and strains on their skeleton through recurrently high biomechanical loads. Within the context of this project, those aspects of Neandertal culture of primary significance are those which are intricately related to their anatomy. In essence, this involves relating aspects of their culture which left recognisable markers in their bones to behaviours inferred from analyses of their technology, in particular the effects that manipulation and mobility (locomotion) had upon their skeletons. This final chapter section discusses what is loosely termed as the biology of Neandertal culture, much of which relates to the previous discussion.
The artifacts associated with European and Western Asian Neandertals comprise a predominantly flake technology known as the Mousterian Industrial Complex. The Mousterian and the "Middle Paleolithic" are effectively synonymous in these regions, although the latter is sometimes applied to any artifacts temporally equivalent to the Mousterian. The dominant Mousterian tool types are sidescrapers and bifacial scrapers, and there is evidence for blade production as well (e.g., Boeda, 1990). The oldest Mousterian artifacts are from western Europe, dating to about 200,000 yBP. In the Near East the Mousterian terminates between 47,000 and 45,000 yBP, in Western Europe it ends slightly later at about 35,000 yBP. It is critical to note that it is not entirely correct to equate Neandertals with the Mousterian, as there were other archaic members of Homo in North Africa utilising Mousterian tools, as well as more modern-looking humans with the same Mousterian technology as Neandertals in the Near East. Additionally the latest surviving Neandertals, in western Europe, are associated with the earliest Upper Paleolithic (Chatelperronnean) assemblages at 34,000 yBP (Bar-Yosef, 1994; Farizy, 1994; Klein, 1989).

Neandertals also made frequent and forceful use of another type of tool, this one of the physiological variety. Perhaps the most pervasive culturally modified feature in Neandertal physiology is the extreme level of dental attrition seen in their anterior teeth. They almost certainly used their incisors and canines extensively for manipulation of materials. Neandertal dentition show extreme occlusal attrition, in general, but most especially on the anterior teeth. This has been attributed to the use of the anterior teeth for paramasticatory purposes involving frequent loading of the teeth nonaxially (horizontally or obliquely) while using them as a vice, a behaviour observed in many present and recent traditional societies. This behaviour is further supported by the presence of transverse scratches on the labial surface of many Neandertal maxillary incisors (Trinkaus, 1983a). It is likely that other aspects
of their craniofacial morphology were adapted to, and in turn a product of, this
behavior, particularly their degree of midfacial prognathism and the presence of the
occipital bun (see Knusel, 1991).

Manipulation

The traditional approach to understanding human manipulatory evolution
lies in the assumption that as technology became increasingly mechanically efficient,
manipulation became more precise and relied less upon overall strength, eventually
reaching modern human levels of gracilisation. Trinkaus (1989) suggests that
modern human manipulation, with its emphasis on composite tools and the
precision grip, emerged after the Neandertals in the later Upper Pleistocene. He
based this on the relative robusticity and hypertrophy seen in the upper limbs of
Neandertals. However, in reality this assumption, while offering a convenient
temporal ordering, may prove to be too simple and misleading. It implies that no
recent or living human population should display the levels of upper limb
hypertrophy and robusticity seen in the Neandertals.

Nonetheless, as part of the same research Trinkaus (1989) cogently states that
our potential knowledge of hominid manipulative capabilities is limited by the fact
that the ultimate determinants are neurological, factors which are paleontologically
invisible. However, we may be able to understand the nature of Neandertal
manipulative behaviour and evolution through a combination of evidence from
analyses of skeletal morphology, and non-typological, mechanical and use oriented
analyses of archaeologically documented technology (Trinkaus, 1989). An overview
of some of the latter types of analyses is now presented.
**Woodworking**

One activity which seems to have been carried out with notable frequency by Neandertals is woodworking (Anderson-Gerfaud, 1990; Hayden, 1993; Shea, 1989), which could in part explain for the morphology of their upper limb. As pre-Neandertal populations were already working with wood, it is logical that as an evolving clade the Neandertals would have continued this behaviour. Woodworking (and, incidentally, not hide preparation) has been demonstrated to be the most common use of both retouched and unretouched tools in French Middle Paleolithic samples, as well as at sites in Western Asia (Anderson-Gerfaud, 1990), most notably among the collections from Kebbara and Qafzeh caves (Shea, 1989). The edges of the tools display a pattern concomitant with transverse motions, and intensive woodworking has been shown to involve frequent re-sharpening of stone tools. Precisely what was being shaped from the wood is not clear, although wooden spears have been found at a number of Paleolithic locales (Anderson-Gerfaud, 1990).

There is now unequivocal evidence that Neandertals were hafting lithics into wood. Patterning of traces on convergent, side, and end scrapers and points correspond clearly to those made by split or tied hafts. These identifiable traces are caused by the motion of the tool as it jams into the haft during use. This implies that the prehension of the tool was altered significantly by attaching it to a handle, and not merely a covering. The exact shape of the handle is as yet unknown, but experimental reconstructions indicate that a right-angle or lever effect would be created by a straight simple haft and the arm and hand of the user (Anderson-Gerfaud, 1990). The existence of hafting among Neandertals has profound implications for their level and type of manipulation, and (Anderson-Gerfaud, 1990: 411) has stated that it "provides an example of deliberate use of the fulcrum principle in the Mousterian of Southwest France".
Combining the evidence for hafting together with that for woodworking implies a useful and sophisticated way to adapt certain types of stone tools to woodworking functions (Anderson-Gerfaud, 1990). In addition, this lends support to the growing realisation that Neandertal behaviour was one which was marked by prepared and planned actions, and went beyond pure survival and the need to meet only immediate demands.

**Hunting or Scavenging?**

One of the most controversial and conflicting debates surrounding Neandertal subsistence strategies concerns how they procured their animal foodstuffs. Binford (1981) is the most vocal in stating that hunting appears with the Upper Paleolithic, and that Neandertals only scavenged animal products. In contrast, there are researchers (Chase, 1989; David and Poulin, 1990; Hayden, 1993; Jelinek et al., 1988; Kubiak, 1988) who observe clear evidence that Neandertals competently and purposefully hunted animals, including large mammals.

And finally, there are those who turn to evidence of absence, that hunting and butchering tools are lacking among certain Mousterian assemblages (Beyries 1987, 1988 cited in Anderson-Gerfaud, 1990), although this may be more an effect of preservation (Anderson-Gerfaud, 1990) than anything else. As mentioned above, pointed wooden sticks have been found in Paleolithic contexts, allowing for the possibility that the preservational bias masks the solution to this debate.

Despite the contentiousness of this issue the evidence suggests that Neandertals hunted at some level, whether opportunistically or in a more focused and complex fashion. Perhaps the most compelling support for the predatory capabilities of Neandertals comes from Kebara cave in the form of impact-damaged Mousterian projectiles (Levallois points and pointed flakes) which Shea (1989) has identified. It has been well established that the use of projectiles, such as spears,
atlatls, and similar weapons, leave clear traces of muscular and skeletal hypertrophy, as well as osteoarthritis (Angel, 1966; Haney, 1974; Kennedy, 1983; Ortner 1968), and that, in general, there is a correlation between physique and hunting activities (Brues, 1959). This is not surprising, as the motions involved in cocking and throwing, and thrusting, embark exceptional forces through the upper limb and would lead to an increase in musculature and strength, as well to enhanced architectural efficiency and rigidity of the involved bones. In turn, these changes imply that hunting was physically taxing and required a high level of energy expenditure.

As outlined above, Neandertal upper limbs, from the shoulder to the hand, are striking in their levels of osseous and inferred muscular development. If we can assume that this was due at least in part to the occupational stresses of some form of hunting then the issue turns to one of method -- how were they killing their prey? This could have been accomplished, conceivably, at a distance through either the use of projectiles, such as throwing spears or stones, at close range with thrusting spears, or with traps (or through a combination of the three). A comparative study of the physical demands of throwing versus thrusting has not yet been attempted, but it has been suggested that throwing requires more laxity of the shoulder joint (Churchill and Trinkaus, 1990), while it seems intuitive that thrusting would be aided by glenohumeral stability accomplished through large and powerful musculature as well as the orientation and architecture of the joint.

The sheer number of hafted Neandertal tools in some regions suggests that they may have been used as part of a projectile, or as part of a thrusting spear. It has been suggested that Mousterian and other Middle Paleolithic projectiles were probably part of heavy throwing or thrusting weapons that could only be used at close range (Dennell, 1983; Graves, 1991). In addition, as mentioned above, Shea (1989) has identified the presence of impact-damaged Mousterian projectile
implements from Kebara and Qafzeh caves. Confronting a large mammal is obviously a daunting task, and poses considerable physical risks. This could explain the high incidence of trauma observed in Neandertal skeletons (Berger and Trinkaus, 1993; Trinkaus, 1983). as well as the overall robusticity. Berger and Trinkaus (1993) have suggested that the high degree of head/neck and upper limb injuries in Neandertals is a behavioral reflection of activity and risk incurred during foraging as well as defensive activity against competing carnivores. Further, Berger and Trinkaus observed astoundingly low survivorship or even a presence of incapacitating lower limb trauma, which they take as indicative of the extreme importance of mobility to Neandertals.

In a rather subjective study, Geist (1981) proposed that Neandertal tools, their "supreme musculature, massive joints, [and] enormous physical strength" are indicative of "violent acceleration and deceleration of the body" (Geist, 1981: 35). He states that Neandertals engaged in close quarters confrontational hunting, whereby one hunter holds the prey while another thrusted a weapon into it. In this scenario, few hunters were required, but those involved would have had extraordinary agility coupled with high speed of movement. More generally, Brues (1959) suggests that "Neandertal's heavy muscle-bound physique [was] best adapted to the use of blunt crushing implements" (Brues, 1959: 468), and concedes that their physique was a product of selection. She does not entertain the concept of osseous plasticity, but makes the point that in human populations there "has been some correlation between physique and habitual activity, resulting in a reciprocal influence between culture and body build" (Brues, 1959: 467).

The following two chapters provide the necessary background to the scapular analysis, results, and discussion presented in chapters IV, V, and VI. In chapter II the scapula and its related musculature will be described, and a discussion on the nature of bone and muscular plasticity is presented. Chapter III outlines the
present knowledge of Neandertal upper limb and scapular morphology, and includes a detailed description of the Kebara 2 individual.
Chapter II: The Scapula and Bone Plasticity

I do not know what range of variation a great series of the scapulae of the larger felidae might present, but a small one shows nothing like that of the human race... (Dwight, 1894: 23)

This chapter is comprised of two related sections. The first presents an outline of scapular architecture, musculature, and movement. The second is a discussion of muscle and osseous plasticity.

(A) The Scapula

Scapular Architecture

The scapula (fig.2.1) is a flat, inverted triangular shaped bone which lies against the thorax, and articulates with the trunk via the clavicle. It glides over the posterior of the axilla (the space between the inner surface of the arm and the chest) as the humerus moves upwards (abduction) or downwards (adduction), or backwards (extension) or forwards (flexion). The medial aspect of the scapula is molded to the posterolateral aspect of the thorax and laterally is thrust out on a tangent by the clavicle and humerus (the glenohumeral joint). The large, flat portion of the scapula, the body, is also known as the "shoulder blade". The clavicle serves a most valuable function in bracing the scapula, and thus the shoulder joint, out laterally from the thorax. The body of the scapula has an anterior (ventral) surface and a posterior (dorsal) surface, three borders, and two major processes. Both surfaces are covered by muscles attaching to them (Aiello & Dean, 1990; Gardner & Osburn, 1973).

The long medial border of the scapula lies about four to seven centimetres away from and parallel to the vertebral column, and hence is called the vertebral border. The border begins at the superior angle, the most caudal margin of the

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scapula, and ends at the inferior angle. The medial angle, occasionally referred to as the root of the spine, divides the vertebral border into two sections, the inferior one being much longer than the superior. At the inferior angle the thinner boned vertebral border meets the thicker boned axillary border which extends superolaterally to the glenoid fossa (Gardner & Osburn, 1973; Johnson et al., 1993). The axillary border frequently shows vascular marks about three to 5 cm. below the glenoid cavity, where one or both of the circumflex scapular vessels passes across its surface (Bainbridge & Tarazaga, 1956). The superior border of the scapula runs inferolaterally from the superior border to the indented scapular notch laterally, and medially to the medial angle (Gardner & Osburn, 1973).

The dorsal surface of the scapula is divided into two unequal halves by the blade's most notable feature, the spine. The raised spine widens and extends horizontally from the vertebral border, at the medial angle, and terminates above and posterior to the glenoid fossa as the acromion process (Aiello & Dean, 1990). The spine's thickening extends the area of attachment for muscles below and above it, and strengthens the thin body of bone as these muscles pull the head of the humerus to the glenoid fossa. The area above the spine is known as the superior body, or supraspinous fossa, and below as the inferior body, or infraspinous fossa. These fossae give rise to all but one (subscapularis) of the rotator cuff muscles.

The concave, ventral surface of the blade of the scapula is known as the subscapular fossa and is relatively featureless, not surprising given that it glides over the rib cage when in motion (Aiello & Dean, 1990; Gardner & Osburn, 1973).

The acromion process overhangs the shoulder joint, and anchors two of the shoulders muscles. The anterior margin of the acromion displays an articular facet for the lateral end of the clavicle. The coracoid process projects superiorly from the superior border and then is twisted sharply laterally and anteriorly like a hook. Its tip passes under the clavicle to curve over and in front of the shoulder joint. The
coracoid is the attachment site of several muscles which extend upward from the thorax and arm (Gardner & Osburn, 1973). It is bound to the acromion by the coracacromial ligament and together with the acromion forms the coracoacromial arch. This structure is unique to humans and apes and provides a protective cuff for the humeral head as well as limits its superior movement. The coracoid is attached to the clavicle by ligaments, but does not articulate with it, thus strengthening the acromioclavicular joint (Aiello & Dean, 1990).

**Ontogeny of the Scapula**

The scapula begins to ossify by the eighth post-ovulatory week, and in late fetal life there is some ossification of the acromion near its base and the chief centre of the coracoid process may appear. At birth a large portion of the scapula is osseous, but most of the acromion and coracoid, the glenoid, the medial border, and the inferior angle are cartilaginous. The adult scapula is completed by the subsequent addition of seven or more ossification nuclei. At approximately ten years of age a subcoracoid nucleus appears which takes part in forming the base of the coracoid process and the superior portion of the glenoid. By 15 years of age the first of two or more acromial nuclei appears near its tip. Soon ossification begins at the inferior angle and in the medial border. Another glenoid centre develops inferiorly three to four years later near puberty and, as it grows, deepens the glenoid cavity. A small nucleus may develop over the angle of the coracoid process and another at its free end. Most of the epiphyseal centres fuse with the body of the scapula during adolescence. Normally all have united by the age of 25 years (Chung & Nissenbaum, 1975; McClure & Raney, 1975).
The Glenoid Fossa

The neck of the scapula expands superiorly from the lateral angle into the glenoid fossa, a concavity of bone which articulates with the head of the humerus, forming the shoulder, or glenohumeral, joint. The fossa varies from tear shape to an oval pear shape. It is shallow, concave, and much smaller in size than the humeral head with which it articulates. The joint is deepened by a rim of fibrocartilage, the glenoid labrum, which, however, does not add much to the stability of the joint. Much of the joint's stability is dependent upon maintenance of intraarticular pressure (IAP) within the joint capsule which, if reduced (by venting or puncturing etc.), can contribute significantly to inferior instability (Itoi et al., 1993).

The architecture of the joint favours a wide range of movements at the expense of union and stability (Aiello & Dean, 1990; Gardner and Osburn 1973). As the latter authors have pointed out, the head of the humerus is an exemplary ball, but the glenoid is a poor socket. The glenoid is more flat than concave and presents a much smaller articular surface than the larger head of the humerus. In contrast, Poppen et al. (1978) contend that the glenohumeral joint approximates a ball-in-socket joint with the center of rotation at the center of the humeral ball (Poppen et al., 1978). The glenoid is clearly not a socket in the sense that the acetabulum is. Unlike the femoral head which is encased and seated by the acetabulum, the humeral head is held in place primarily by the surrounding ligaments, musculature, and glenoid labrum.

Nagrel et al. (1993) suggest that the shoulder does not represent a simple ball-and-socket joint with three degrees of freedom. They found that the radii of curvature of the glenoid fossa and humeral head were not equal, and that in abduction the momentary rotational axis does not meet the center of the humerus. However, these incongruities are a functional necessity of the joint. They define
the glenohumeral joint as a force-locked diatomic ball-and-socket joint as opposed to a simple ball-and-socket joint.

Research by Basmajian & De Luca (1985) has revealed that downward dislocation, or subluxation, of the humeral head (a horizontally placed structure) is actually prevented, in part, by the orientation of the fossa during normal activity. Viewed in correct orientation, the glenoid faces somewhat upward in addition to laterally and forward. This slope, particularly the inferior portion, is important to the prevention of dislocation. As the humeral head is pulled downward, it is forced laterally. Thus, the lateral movement must be stopped and this is exactly what supraspinatus (discussed below) does. It, as well as the posterior fibres of deltoid (also discussed below), tighten to prevent downward dislocation. In addition, the superior capsule of the joint becomes taut. Downward dislocation of the normal shoulder joint is in fact very rare, perhaps confirming the effectiveness of this observation. It should be noted that this locking mechanism does not operate when the humerus is abducted (Basmajian & De Luca, 1985). Additionally, as discussed above, inferior stability is also contingent upon adequate intraarticular pressure. Itoi et al. (1993) compared inferior stability of the glenoid in several cadaveric specimens and observed a considerable degree of variation in joint stability between individuals under the same loads (e.g. some shoulders dislocated and some did not with the same load applied). This variation may be due to material properties of the joint capsule as well as the initial volume of the cavity and the laxity of the joint. Stability of the joint is so sensitive to changes in IAP that, in fact, researchers suggest that something as simple as the assessment of instability in a living person using arthroscopy can affect IAP and may be erroneous. This is owing to the fact that during this procedure IAP has already been eliminated and thus the stability significantly altered due to the absence of IAP in addition to the muscle relaxation under anesthesia.
Scapular Musculature

The muscles located on the scapula are illustrated in figure 2.1, and can be divided into four categories: (1) The Omohyoid muscle; 2) Muscles acting primarily upon the scapula; (3) Muscles moving the arm at the scapulohumeral joint; (4) Muscles acting across the elbow joint on the radius and ulna.

Omohyoid

The omohyoid muscle has little, if any, relevance to this study but is included to complete the list of scapular musculature. It has two bellies, a superior and an inferior, the latter originating on the superior border from just lateral to the superior angle to the scapular notch. It inserts on the hyoid and is involved in anchoring the hyoid by drawing it upwards (Gardner & Osburn, 1973).

Muscles Acting Primarily Upon the Scapula

The scapula performs two functions in relation to the upper limb. It anchors and allows the articulation of the upper limb with the trunk, and extends the range of mobility of the arm. Therefore, arm movement requires muscles that move the humerus as well as muscles that rotate the scapula (Aiello & Dean, 1990). To anchor the upper limb the scapula must be fixed in a number of positions relative to the actual position of the limb. However, it must also allow mobility and extend the range of movement of the arm. The functional duality of the scapula is enabled by the action of a series of muscles acting upon it (Gardner & Osburn, 1973).

Trapezius is a triangular muscle which originates on the nuchal line, external occipital protuberance, ligamentum nuchae, and all thoracic spinous processes. It fans out laterally to insert onto the lateral third of the clavicle, the acromion, and crest of the scapular spine. Trapezius elevates the scapula and suspends the pectoral girdle, especially during abduction of the upper limb (Gardner & Osburn,
1973). It does not support the shoulder girdle in relaxed upright position. It acts with increased vigor through arm elevation, and is most active during abduction as the arm reaches horizontal. As well, trapezius prevents dislocation of the humerus by helping adjust the scapula during elevation of the humerus (Basmajian & De Luca, 1985). Serratus anterior is a broad, flat muscle with finger-like origins on the lateral surfaces of the first eight ribs. It passes between the rib cage and the scapula and inserts along the entire length of the vertebral border, from superior to inferior angles (Aiello & Dean, 1990; Gardner & Osburn, 1973). Serratus anterior acts to protract and support the scapula (Gardner & Osburn, 1973) and, along with trapezius, rotates it and the glenoid fossa upwards (Aiello & Dean, 1990; Basmajian & De Luca, 1985). Trapezius and serratus anterior together are the two primary muscles that act to upwardly rotate the scapula. Lateral scapular rotation by these two muscles prevents the acromion from blocking upward humeral movement, thus allowing for the full range of humeral elevation (Gardner & Osburn, 1973). This rotation is a component of abduction and flexion of the arm, and their greatest activity is at 180° elevation of the humerus (Aiello & Dean, 1990).

Levator scapulae is a narrow and thick band of muscle which originates on the posterior tubercles of the transverse processes of cervical vertebrae 1-4, and then run inferolaterally to insert on the vertebral border of the scapula from superior to inferior angles. Its main role is in elevating the scapula, and in turning the glenoid fossa downwards. As well, if the scapula is fixed it acts as a neck rotator to the same side (Basmajian & De Luca, 1985; Gardner & Osburn, 1973).

Rhomboid minor is a narrow banded muscle originating on the lower ligamentum nuchae and the spinous processes of C7 and T1. It passes inferolaterally and inserts on the vertebral border of the scapula at the root of the spine (medial angle). Rhomboid major is a flat and wide muscle originating on the
Figure 2.1. Muscular origins and insertions on the scapula. Right Scapula.
spinous processes of T2 to T5. It passes inferolaterally and inserts on the scapula's vertebral border from the root of the spine (medial angle) to the inferior angle. Basmajian and De Luca (1985) have stated that the rhomboids essentially imitate the middle portion of trapezius. They are essential for drawing the scapula to the vertebral border, scapular elevation, as well as for anchoring the scapula for movement of the upper extremity. In addition the rhomboids have the capacity to turn the glenoid downward (Gardner & Osburn, 1973).

Muscles Moving the Arm at the Scapulohumeral Joint

The muscles extending from the scapula to the proximal humerus are individually capable of producing more than a single movement of the scapulohumeral joint and collectively are involved in many coordinated movements.

Deltoid is the thick triangular muscle which encapsulates the shoulder. It has three portions, the anterior of which originates on the lateral third of the clavicle, the medial on the acromion, and the posterior on the crest of the scapular spine. The three portions then pass inferolaterally over the humeral head and collectively insert on the deltid tuberosity of the humerus (lateral surface of the shaft). The three parts can act separately or together, depending on the plane in which the humerus is abducted (Toldt, 1904; Gardner & Osburn, 1973).

The anterior head, along with pectoralis major, is a primary flexor of the humerus, and participates only slightly in abduction. The middle head is the primary abductor of the humerus, participating with supraspinatus in this action. The anterior and middle deltoids become increasingly effective as elevators as the angle of abduction increases. The posterior head is a primary humeral extensor, along with latissimus dorsi, as well a secondary humeral rotator. However, it does not contribute as a humeral abductor. When deltoid is active, the rotator cuff
muscles aid its efficiency by effectively holding the humeral head in place. Apart from moving the humerus, deltoid stabilises it for such actions as throwing or writing on a blackboard. As an antagonist to humeral adductors (pectoralis major, latissimus dorsi, teres major, triceps brachii, and coracobrachialis) the deltoid regulates and smooths their actions (Basmajian & De Luca, 1985; Poppen et al., 1978).

In fact, deltoid is active during all movements of the arm. It is believed that while one part of deltoid may act as the prime mover, the other two contract to stabilise the glenohumeral joint (Scheving & Pauling, 1959). Given this, Scheving & Pauling (1959) recommended inclusion of deltoid with the four rotator cuff muscles (described below) as stabilisers of the joint. However, this has not been endorsed by other researchers (Basmajian & De Luca, 1985).

The rotator cuff muscles are four short muscles which individually or in combination are involved with either abduction or rotation of the humerus, and together provide stability to the shoulder joint during movement of the arm. They include supraspinatus, infraspinatus, teres minor, and subscapularis. Originating on the scapula, they all have their insertions around the humeral head (Aiello & Dean, 1990; Basmajian & De Luca, 1985; Itoi et al., 1993; Toldt, 1904).

Supraspinatus originates on the medial third of the supraspinous fossa and crosses the shoulder joint superiorly to insert on the highest of three attachments on the greater tuberosity of the humerus. It acts with middle head of deltoid to abduct the arm. Additionally, it holds the humeral head in place during deltoid activity. While it does participate with deltoid in abduction, on its own it is a poor abductor. During paralysis of deltoid, for example, it cannot accomplish, even weakly, a full range of abduction (Gardner & Osburn, 1973). Supraspinatus' most vital role, as discussed above, may be in its ability to lock the shoulder joint by compressing the humeral ball into the centre of the glenoid. This prevents downward dislocation of
the humeral head which is caused when the arm is being elevated (Basmajian & De Luca, 1985; Poppen et al., 1978).

**Infraspinatus** is a thick muscle which occupies most of the infraspinous fossa. It originates on the medial three-quarters of the fossa and then continues superolaterally across the posterior surface of the glenohumeral joint and inserts on the middle of three attachments on the greater tuberosity. It and teres minor are the primary lateral rotators of the humerus (Gardner & Osburn, 1973).

Teres minor is a narrow band of muscle which originates on the lateral portion of the infraspinous fossa, adjacent to the axillary border. It follows the same path as infraspinatus and inserts on the lowest of three attachments of the greater tuberosity. Teres minor works in close association with infraspinatus as primary lateral humeral rotators (Toldt, 1904; Gardner & Osburn, 1973).

**Subscapularis** is a flat fleshy band of muscle which originates on the medial two-thirds of the subscapular fossa, then passes laterally in front of the capsule of the shoulder joint and inserts on the lesser tuberosity of the humerus. In contrast to the actions of infraspinatus and teres minor which rotates the humerus laterally, subscapularis is the primary medial rotator of the upper arm (Gardner & Osburn, 1973).

Subscapularis, infraspinatus, and teres minor also form a functional group which acts as a second or inferior group of the force couple during humeral abduction. They are continuously active during both flexion and abduction. In abduction, activity in infraspinatus and teres minor rise linearly while in subscapularis reaches a zenith beyond ninety degrees and then falls off (Basmajian & De Luca, 1985).

Teres major is a thick muscle originating on an oval area on the dorsal surface of the infraspinous fossa immediately superior to the inferior angle. It passes laterally across the axillary border and inserts on the crest of the lesser
tuberosity. The muscle is a secondary humeral extensor, and contributes as well to both medial rotation and minorly to adduction (Gardner & Osburn, 1973). Teres major is not considered a true rotator cuff muscle because it does not fuse with the capsule of the shoulder joint (Aiello & Dean, 1990). An interesting study by Broome and Basmajian (1971) has shown that teres major is not recruited in free movements of the shoulder unless resistance to these movements (medial rotation, adduction, and extension) is added.

Coracobrachialis is a short muscle originating on the tip and lateral surface of the coracoid process and passes inferolaterally along the lateral wall of the axilla and inserts on the middle third of the humerus along its medial surface. It acts as a secondary humeral flexor, and plays a minor role in adduction as well (Gardner & Osburn, 1973).

Muscles Acting Across the Elbow Joint on the Radius and Ulna

Two muscles acting on the forearm originate on the scapula. Biceps brachii and triceps brachii both have small origins on the scapula. By virtue of the placement and function they are natural antagonists, regulating and smoothening the action of the other.

Biceps brachii has two heads, the short originating on the medial area of the tip of the coracoid, the long on the supraglenoid tubercle. The two heads pass distally and unite to form a fusiform muscle on the anterior side of the humerus before inserting on the radial (bicipital) tuberosity (Toldt, 1904; Gardner & Osburn, 1973). Biceps brachii is a primary flexor (along with brachialis and brachioradialis) and supinator of the forearm. It also works with the rotators to facilitate retention of the humeral head in the glenoid fossa (Gardner & Osburn, 1973).

Triceps brachii has three heads, the long one originating on the infraglenoid tubercle of the scapula. The lateral and medial heads originate on the posterior
surface of the humerus above and below the radial groove, respectively. All three heads then travel distally on the posterior humerus and unite midway along the humerus and insert on the upper part of the posterior surface of the olecranon process of the ulna. Triceps brachii is the primary extensor of the forearm (Gardner & Osburn, 1973).

It can be seen, and should be noted, that there are no prime humeral adductors originating on the scapula. Teres major, triceps brachii and coracobrachialis play minor roles in comparison to pectoralis major and latissimus dorsi, the prime of humeral adductors (Gardner & Osburn, 1973). The posterior fibres of deltoid are quite active during humeral adduction, however only to resist the medial rotation that the main adductors would produce if unresisted (Basmajian and De Luca, 1985).

Poppen et al. (1978) have sectioned some of the shoulder muscles from two individuals and calculated the cross-sectional area for each. The calculations provide a sense of the relative size of the musculature, as well as the strength of the muscle, as the maximum force a muscle generates depends upon its cross-sectional area (Morris, 1948; Poppen et al., 1978). The results are based on a supraspinatus of area 10 units (actually 621 mm²): supraspinatus, 10; anterior deltoid, 16.0; middle deltoid, 23.8; posterior deltoid, 20.9; infraspinatus, 18.3; subscapularis, 22.3; latissimus dorsi, 11.9 (Poppen et al., 1978).

In light of this discussion of scapular musculature and movement of the upper extremity functional correlations should be seen. A muscle on its own is not as efficient without its neighbouring muscles and structures, and often is one of several which share a common location and reasonably similar points of origin and insertion. Thus, such muscles may have a shared group function. For example, the shoulder is capped anteriorly by the middle deltoid and supraspinatus which in conjunction produce humeral abduction. Another example is the rotators, which
share common morphological and functional relationships. In fact, they are loosely encased in a regional fascia separating them from other regional muscles which have different planes and actions (Gardner & Osburn, 1973; Aiello & Dean, 1990). The efficiency of a muscle can also be enhanced by changes in the underlying bone, and by the shape of an element in general, as will be discussed in the following section.

(B) Bone and Muscle Plasticity

The plasticity of, and influence of activity upon, bone and muscle must be considered in the present research, particularly as the differences between individuals or groups in scapular morphology may conceivably be the result of distinctive cultural or occupational histories. The present understanding of osseous plasticity is examined in this section.

Bone is a living tissue which, much to the benefit of the organism, is highly plastic and undergoes shape and density changes in response to stresses such as nutrition, disease, injury and activity. It is a solid tissue constantly subject to stresses which condition its development and architectural structure. It adapts to mechanical needs by atrophy and hypertrophy (Chamay & Tschantz, 1972), and the development of the shape and irregularities of osseous tissues may occur under circumstances of prolonged and continued stress imposed by some habitual, or occupational, activity (Kennedy, 1989).

The Anatomy of Bone

Bone constitutes most of the skeleton of the human body, and is the hardest of the connective tissues. At the gross level all bones in an adult skeleton have two typical forms: spongy and compact bone. Compact, or cortical, bone is the solid, dense bone that forms the outer surface of all elements. At joints, compact bone
covered by cartilage during life is called subchondral bone. It is recognisable by its smoother and shinier appearance than non-articular compact bone. Spongy (cancellous) bone is lighter, more porous than, and is located within, compact bone. It is observed in the ends of long bones, in short bones, in the vertebral bodies, sandwiched between flat bones, and under the protuberances where tendons attach (Hollinshead, 1976; White and Folkens, 1991).

With the exception of joint surfaces, the outer surface of bones are covered by periosteum in life. Some of the periosteal fibres penetrate the bone, while others connect tendon to bone. The endosteum lines the inner surface of bones during life, but is less defined, and more membranous, than the fibrous periosteum. Both the periosteum and endosteum are osteogenic tissues, containing bone forming cells. These cells are more numerous and active during youth, and less numerous, but potentially active, in adulthood. They may be stimulated to deposit bone when the periosteum is traumatised (White & Folkens, 1991).

Similar to cartilage, bone is comprised of a fibrous connective tissue imbedded in more solid matrix, essentially a collagen framework packed with calcium phosphate mineral. Bone is a highly vascular, constantly changing, mineralised tissue whose hardness and resilience are exceptional. Collagen molecules intertwine to form flexible, slightly elastic fibres in bone. This allows for the flexibility of bone. The collagen of mature bones is stiffened by a matrix (hydroxyapatite) of minerals, primarily in the form of tiny crystals of a complex calcium and phosphorous compound which give bone its characteristic strength and hardness (Aiello & Dean, 1990; Hollinshead, 1976; White and Folkens, 1991). Normal human cortical bone is comprised of 5-10% water, 25-30% organic, and 65-70% inorganic (minerals) matter. By weight, collagen makes up 90-95% of the dry, fat-free organic content of bone. The inorganics are dominated by calcium, phosphate, and carbonate, with lesser amounts of hydroxyl, chloride, citrate,
fluoride, magnesium, potassium, sodium. Other elements occur in trace amounts, such as lead and strontium (Jaffe, 1972).

Three basic types of cells are involved in bone tissue formation and maintenance. Below the periosteum are where osteoblasts, cells involved with bone material synthesis and deposition, are located. They make large amounts of osteoid, an uncalcified organic pre-bone tissue plentiful in collagen. Calcification of bone occurs as crystals of hydroxyapatite are deposited into the osteoid matrix. Once surrounded by bony matrix, the osteoblast are called osteocytes. Osteocytes are cells which reside in the lacunae and are responsible for maintaining bone tissue. And lastly, osteoclasts are responsible for the resorption of bone tissue (White & Folkens, 1991).

Bone modeling and remodeling takes place at the cellular level as osteoclasts remove bone and osteoblasts build bone tissue. Opposing processes of bone formation and resorption allow bones to maintain or change their shape and size during growth, maintenance, and repair. In immature individuals, in whom the deposition of calcium has not gone on to completion, the fibrous tissue of bones exceeds the mineral content and the bone thus has toughness without full hardness. Hence, the bones of a young child are more easily affected by plastic deformation than those of an adult. Thus the bones of a young child are relatively easily deformed by weight-bearing, and when young bones are broken they tend to break irregularly and splinter. The disproportion between crystalline minerals and fibres allows this splintering. In a young adult the balance between fibrous content of the bone is usually well maintained, so that the bone possesses both maximum hardness and resistance to stress. As an individual reaches old age calcium slowly replaces water in the bone, and the balance is thus in favour of the calcium compound. At this age the bone, although remaining hard, is no longer tough, so that if strained will easily result in fracture (Hollinshead, 1976).
Osseous Plasticity

Studies of human skeletal variation and skeletal plasticity have increased most recently (Kennedy, 1989), but have been recognised for some time, as evidenced, for example, by the comments of W.M. Turner (1887):

To some extent undoubtedly the habits of a race will affect the configuration of the skeleton. Within certain limits the forms of bones are without question influenced by the muscular apparatus which is attached to them. Compare, for example, the skeleton of a child with that of an adult, and you will at once see how in the progress to maturity the bones assume a precision of form such as they did not possess in the infantile condition, the ridges and processes become accentuated, and the articular surfaces become moulded into shape. To some extent this is due to the traction exercised on the bones when in a relatively soft and plastic condition, by the groups of muscles which act upon them. If then the habits of one race call into play some special groups of muscles, which are not, through a difference in habit, so constantly employed in another race, then I have no doubt that the form of the bone, not merely as it regards the prominence of the processes to which the muscles are attached, but the relative area of the surfaces of attachment, would undergo a corresponding modification. One would expect to find, for example, in a race unprovided with beasts of burden, whose habits required much walking exercise in search of food, a development of the muscles of the lower limbs and a consequent modification of their bones, such as would not arise in a race of more sedentary habits. It is in this way, I believe, that the prismatic form of femur, which the French anthropologists have named *femur à colonne*, in which the linea aspera forms a strong ridge, and the surfaces of attachments for the other muscles of the thigh are strongly marked, has been produced. Similarly a race, which like certain of the aboriginal Australians requires to climb trees in search of food, or another race, like some of the tribes of the Papuans, who build houses in the top of lofty trees, would acquire a development of the muscles and bones of the shoulder and upper limb, such as would not take place in those people who seldom raise their arms above the head. (Turner, 1887: 486-487)

Turner (1887: 492) adds that skeletal plasticity "has not, I think, received sufficient attention in its anthropological bearings".

By the late 19th century, from the study of working-class people whose bodies had been shaped by years of physical labour, there was a growing
awareness among European surgeons and anatomists that the skeleton could display a broad spectrum of morphological and size variation that could be related to life habits. It was not until Hrdlicka's era that occupational morphology was given serious consideration in North America, especially with reference to prehistoric remains. During this century anthropologists and medical practitioners have continued to note occupational markers, but have done so largely unaware of one another (Kennedy, 1989). As Kennedy (1989: 132) has so aptly written, "Synthetic studies of the subject, which combine research data of industrial medicine and anthropological skeletal biology, do not exist, and a historical review reveals that sources appear sporadically and are written according to a wide range of scientific standards of observation and publication."

Anthropological research into osseous markers of occupational stress has been concentrated in three fields: paleoanthropology, paleodemography, and forensic anthropology (Kennedy, 1989). Apart from a study of squatting facets among Neandertals (Trinkaus, 1975) and an excellent series of recent papers analysing postcranial robusticity in Homo (Ruff et al., 1993; Ruff et al., 1994; Trinkaus et al., 1994) significant paleoanthropological research into the subject has been surprisingly absent (Kennedy, 1989). Thus, despite the apparent value of this topic the paleoanthropological community has only recently begun to consider its reconstructive value as a tool for interpreting human activity patterns.

The paleodemographic literature primarily talks of mortality and disease as skeletal stressors, although Cohen and Armelagos (1984) have edited an excellent volume on the nutritional stresses involved with the transition from hunting-foraging to agriculture and pastoralism. As well, forensic anthropologists, contrary to the fact that they, perhaps, have the most to gain from recognising markers of occupation stress, have published very little on the topic (Kennedy, 1989).
There has been, however, some excellent research into the subject, from studies of both living persons and skeletal material. There is a considerable amount of research by clinicians into occupationally induced skeletal changes amongst living persons. For example, Claussen (1982) discovered striking hypertrophy of the active-side ulnae of professional bareback rodeo riders. King et al. (1969) describe a similar degree of hypertrophy in the throwing-side shoulders and arms of professional baseball pitchers. And Buskirk et al.'s (1956) study of the racket arm of tennis players revealed considerable hypertrophy as well lengthening of the radius and ulna in the athletes.

Research on prehistoric skeletal remains are fewer in number. However, there have been a number of exceptional studies published, most of which are more recent, indicating a growing interest in, and understanding of, osseous plasticity and occupational markers. For example, Kennedy (1983) has demonstrated hypertrophy of the ulnar crest (attachment of supinator) along with pronounced depth of the adjacent supinator fossa, among prehistoric peoples (especially in males) known to have used spears, atlats, and similar projectile weapons for hunting and warfare. Kennedy noted that similar features occur in the right ulnae of living persons of both sexes who are habitually engaged in certain occupational and athletic activities involving angular displacement of the forearm as a result of medial rotation of the arm and shoulder, rapid extension of the shoulder and arm, and abrupt shifts from forearm pronation to supination. Morimoto (1959) has determined that the formation of squatting facets in the Japanese is caused by constant dorsiflexion, medial rotation (or abduction) and eversion of the subtalar joint in squatting posture, which aids in stabilising of the foot. Haney (1974) has demonstrated a correlation between subsistence type and the degree and type of osteoarthritis in the elbow ("anatal elbow") through three major temporal periods in prehistoric Central California. Haney's work built on that
done previously by Angel (1966) and Ortner (1988), who outlined changes in the
ebrow from individuals practicing strenuous hunting with spears and atlatls. With
reference to the shift to agriculture in the southeastern United States, Bridges (1989)
oberved greater size and strength in the long bones of Mississippian agriculturalists
from northwestern Alabama when compared with Archaic hunter-gatherers from
the same region. She relates this to the alterations in both levels and type of activity
accompanying the transition to maize agriculture. As well, Bridges noted that
females took over a greater proportion of subsistence activities associated with
agriculture as reflected in their skeletal anatomy. And finally, in an excellent paper
Wells (1967) identified an 18th or 19th century interred male skeleton as that of a
weaver or tailor based on the degree of kyphosis, enlargement of the ischial
uberosities, and pronounced bowing of the fibulae in the individual.

Kennedy (1989) has pointed out that recent textbooks in forensics, human
osteology, and human skeletal pathology and paleopathology omit discussions of
occupational makers and that overall descriptions are few. However, as evidenced
by the above examples interest in understanding skeletal markers of occupational
stress seems to be growing. Increased research and publication on the subject is
apparent in the academic journals. For example, the recently founded International
Journal of Osteoarchaeology (IJO) has published a number of research reports and
comments on the subject, including the identification of three male voyageurs
from the Fur Trade Period, based, in part, on skeletal stress markers (i.e. presence of
vertebral osteophytosis and osteoarthritis, Schmorl's nodes, hyperdevelopment of
muscle and ligament attachments in the trunk and limbs, new bone formation at
entheses and syndesmose, and osteoarthritis in the elbow and shoulder - changes
concomitant with habitual carrying, lifting, and paddling or rowing, as well as
developmental accessory facets on the metatarsals and proximal pedal phalanges
indicating possible activity-induced stress from hyperdorsiflexion of the toes in
habitual kneeling, such as when river canoeing (Lai and Lovell, 1992); a study of asymmetry and activity-related change in male humeri of individuals from two medieval sites and from Henry VIII's flagship, the Mary Rose, where the researcher was able to demonstrate patterns of activity-related changes in the groups, but not individual occupations (Stirland, 1993); and attribution of the skeletal remains of a medieval leper as that of a "cripple" based on the presence of osseous alterations in possible response to altered posture and crutch-aided locomotion (Knüsel and Göggel, 1993). Thus, it appears that the IJO is proving to be a good forum for the discussion and development of the subject.

The most difficult aspect of studying osseous plasticity is ironically fundamental, that being how do we determine if the shape of a given bone is acquired or inherited? With individuals known to have partaken in repetitive tasks, such as some of those discussed above, the plastic responses are more easily visible, particularly where the changes are asymmetrical or marked. However, with populations the problem is more difficult.

One way to discern between the forces behind the morphology of a bone is to study closely related populations engaged in disparate activities. If we assume that a considerable amount of time is required for selective changes to appear in skeletal anatomy, then differences observed between such groups are likely plastic in nature. In a series of papers outlining the reduction of sexual dimorphism from the Upper Paleolithic to the Neolithic, Frayer (1980, 1981) demonstrated that male body size decreased more than did female size, thus causing an overall reduction in sexual dimorphism. Frayer proposed that these changes were a selective (not plastic) response to the shift from big-game hunting in the Upper Paleolithic to the adoption of new technology in the Mesolithic. He sees Upper Paleolithic males hunting large megafauna with hand-propelled spears, an activity requiring great strength, and one which selected for large body size. In contrast, the Mesolithic
witnesses the advent of the spear thrower and subsequently the bow and arrow, which removed the selection for strength and size in males.

Subsequent research by Collier (1994) supports the notion that robusticity is associated with big-game hunting, but that sexual dimorphism is not so simply explained. Collier illustrated that the degree of dimorphism can vary in different skeletal regions, and that the total set of activities of both sexes contribute to an overall pattern. He studied two recent Alaskan Eskimo populations and noted that the two populations had different relative sexual dimorphism levels for different body parts.

Collier (1994) does not discuss the source of these phenotypic differences. However, his study offers an insight into the issue of the origins of skeletal anatomy. Given that the two populations are closely related in both time and space, it is likely that the osteological differences between them are plastic responses to the forces involved with their particular lifestyles. Cases such as this, where two closely related groups are available for study, allow inquiry into the inherited/acquired issue.

The Effect of Biomechanical and Muscular Stress Upon Skeletal Structure

Phenotypic changes in bone occurs in response to three primary causal factors: (1) biomechanical loading (2) muscles directly increasing the amount the bone at the location of a muscular attachment, and (3) direct muscle pull causing cortical recession.

Modeling describes the organismic growth of bone, whereas remodeling distinguishes bone turnover occurring after the skeleton has matured (Frost, 1985). In the present research the term remodeling will be favoured, except in certain cases requiring discrimination.
Biomechanical Loading

A force is anything that tends to change the state of a body with respect to motion or the relative position of the molecules composing the body. More simply stated, a force is a push or pull (Evans, 1973). Load refers to the forces which normally act on a bone causing elastic deformation. Bone reacts to loads by slow remodeling. This constant remodeling consists of resorption and concurrent lamellar bone apposition, taking place in the periosteum, the endosteum, and the intracortical lacunae. It evolves more rapidly in the young, more slowly in adults. Remodeling is profoundly modified, either constructively or destructively, by the orientation of mechanical stresses (Chamay & Tschantz, 1972; Currey, 1984).

There are three types of pure force: tension, compression, and shear. Tension lengthens bones, while compression shortens them. Shearing forces slide one part of a bone in a direction opposite to an immediately adjacent portion. Torsion is a combination of compression and shear, and twists bone such that one part rotates with respect to the remainder. The muscular actions pulling at the patella (cranially on the anterior surface, and caudally on the inferior) is an example of tension (Kennedy, 1989; Currey, 1984). Tension is more dangerous than compression, as bones are somewhat weaker when subject to this force (Currey, 1989).

Each of these forces is a type of strain, a force which changes the linear dimensions of a body as the result of the application of the force (Evans, 1957; 1973). Each of these comes in the form of an external force (i.e. weight, muscle pull) which causes intramolecular and structural changes in the bone in order to resist the force. Strain refers to these forces and describes the alteration to the linear dimensions of a bone as the result of them. For example, if a bone were 1.2 cm
long before tension and 1.4 cm inches afterwards it would have a total strain of 0.2 cm (Evans, 1957, 1973; Kennedy, 1989).

Biomechanically speaking stress has an altogether different meaning than has been given to it in the above discussion of occupational markers. The tendency of a body to be deformed by the application of a force is resisted by an internal force among the molecules composing the body. The ratio of this internal force to the area upon which the force is assumed to act is stress. As a ratio (force per unit area) it cannot be seen, and can only be computed in terms of force (load). The kind of force (tensile, compressive, shearing, torsion) applied to a body produces the same kind of stress within the body. An example of this is the internal resistance produced within the leg bones as the result of the compressive forces applied to them when walking and standing erect. In fact, stress is sometimes referred to simply as the intermolecular resistance within an object to the action of an outside force which is applied to it (Currey, 1984; Evans, 1957, 1973).

The markers of occupational stress resulting from these forces manifest macroscopically if an area of a bone's elastic limit is exceeded and the area of stress does not return to its original shape (Kennedy, 1989). It is in this way that a bone is strengthened and is able to resist greater forces in the future, and withstand them without injury. In certain pathological conditions bone is "overloaded", that is to say submitted to a force causing plastic deformation which produces internal lesions without fracture. Bone can react to this type of overload by rapid and massive hypertrophy (Chamay & Tschantz, 1972).

**Muscle Attachments**

The biological function of skeletal muscle is movement, of either the organism or of objects relative to the organism. The bones of the skeleton are the levers which move the organism, in directions determined by the muscles. The size
of skeletal muscle i.e. its total protein content, and the morphology of its osteological attachments, are not fixed after birth, and skeletal muscle undergoes a greater post-natal growth than most other body tissues. Dramatic growth of skeletal muscle occurs during postnatal development in response to a variety of hormonal signals. Among these are quality and amount of food intake, alterations in endocrine status (e.g. diabetes), and increased use or disuse of the muscle (Goldberg, 1980). While each of these has profound effects on skeletal and muscular development, the last is the most readily recognisable in fossil hominids.

Tendons are the link between muscle and bone, and are defined as a bundle of heavy collagenous fibres which attach muscle to bone or, occasionally, to some other structure. Muscle and tendon fibres blend at one end, and at the other they enter the bone and blend both with the connective tissue surrounding the bone (periosteum) and with the collagenous fibres making up the matrix of the bone itself (Hollinshead, 1976). Despite their rigid connection, the tendon-bone link is weaker than either the tendon or the bone itself. Apart from cases of extreme stress resulting in avulsion or direct trauma to the tendon, therefore, overstressing a particular tendon-bone attachment will result in microtrauma at the point of attachment itself. Fortunately, both systemic and isolated pathologies are typically readily distinguished from activity induced causes by their distribution and degree of development. Repeated microtrauma at insertional locations can result in the formation of bony enthesopathies (Robb, 1994).

The maximum force a muscle can generate is, logically, related to its size. Studies of cross-sectional muscular area have established that the relative force in a given muscle is proportional to its cross-sectional area (Morris, 1948; Poppen et al., 1978). Once ossifications related to metabolism, trauma, and inheritance (e.g. Capasso, 1986; Ortner and Putschar, 1981; Rogers et al., 1987) are discounted, surficial markings and tendonal ossifications are due primarily to aging and activity
Muscular insertions and origins make use of bone's inherent plasticity to increase musculoskeletal efficiency in three possible ways. First, bone can remodel to support functional stress and provide adequate areas of muscular attachment as traction and biomechanical forces stimulate bone growth. Second, accumulated microtrauma at the site of a muscle attachment leave traces in the form of surface markings. And third, bone can react to extreme muscle contractions in the form of stress fractures. These fractures are not evident at the attachment locales, and are similar to stress factors resulting from other causes (Robb, 1994). Due to the fact that greater force is placed on areas of muscular insertion than on areas of muscle origin, the former are characteristically more marked (Kennedy, 1989).

Prolonged physical activity elicits changes in bone mineral levels (i.e. bone density) as well. In a comparison of bone mineral content between 15 cross-country runners and a control group of 31 individuals, Dalén and Olsson (1974) discovered that levels were significantly greater in the runners. This would seem in accordance with the necessity for remodeling to involve concomitant changes in the required mineralisation. The researchers measured mineral content in a variety of elements and found that levels were greater in the appendicular skeleton than for the axial. Of particular interest is that mineral content in elements not seemingly as involved with running (the head of the humerus and the distal radius and ulna) as those that are (femur and calcaneus) both groups displayed similarly elevated mineral levels (Dalén and Olsson, 1974). Bone mineral content seems to be innate to a some extent, as researchers have shown significant differences between adults of different populations (e.g. Reid et al., 1986).
Scapular Plasticity

Studies of variation in the form of the scapula have a long history in physical anthropology. For the most part the earliest studies were concerned with racial and evolutionary differences in scapular shape (Dorsey, 1897; Dwight, 1894; Frey, 1924; Graves, 1921; Kuhns, 1945; Sun & Chi, 1986). However, Wolffson (1950) was the first researcher to investigate in any great depth the relationship between the muscles of the scapula and its form. He was interested in determining if scapula shape could be influenced during post-natal growth by one or more of the attaching muscles. Using rats as his experimental sample, which he believed have a shoulder girdle approximating that of humans, Wolffson devised a series of experiments whereby he either severed a muscle at its attachment or removed it completely to see the developmental effect on the rat scapula. The animals were sacrificed between 77 and 82 days later and their scapulae examined (Wolffson, 1950). Wolffson's study clearly showed that scapular shape is heavily influenced by muscle function. The muscles involved were "rhomboid" (it is not clear whether this refers to r. minor, r. major, or both), s. anterior, trapezius, supraspinatus, infraspinatus, and subscapularis. Additionally, in certain tested individuals Wolffson severed the brachial plexus which served to paralyse the forelimb entirely.

The results of his study were both logical and conclusive. Severing of "rhomboid", s. anterior, and the brachial plexus is associated with straightening of the vertebral border. Kuhns (1945) had previously noted a correlation between persistent concave borders and general muscle relaxation in humans. Concave bordered scapulae are occasionally referred to as scaphoid scapulae (McClure & Raney, 1975). The vertebral border is the last epiphysis to ossify on the human scapula, and thus its relatively slow development likely allows for it to be the subject of considerable extrinsic factors (Wolffson, 1950). In contrast to the
persuasive elegance of this correlation, Vallois (1928–46) had earlier proposed that a convex or concave border usually signifies a male scapula, a straight one a female. Bainbridge & Tarazaga's (1956) study of recent British scapulae does not confirm this, and in their sample only one individual (female) out of 58 possessed a concave border. This, in fact, strengthens Wolffson's conclusions on the correlation between muscle inactivity and concave vertebral borders.

Removal in the rat of trapezius, infraspinatus and supraspinatus together, and of supraspinatus alone, and paralysis of the forelimb are associated with reduction of the spine and decrease in size of the supraspinous fossa. Severing of s. anterior and removal of trapezius, infraspinatus and supraspinatus together correlate with reduction of the infraspinous fossa. In one case where trapezius, infraspinatus and supraspinatus and subscapularis were removed all the scapular fossae were reduced in size, the supraspinous being the most effected (Wolffson, 1950).

Wolffson's (1950) experiments illustrate that muscle function and development directly affects the shape of the vertebral border, the size of the scapular spine, and the size of the scapular fossae. Thus, the persistence of these formations into post-natal life depends on the presence of functioning muscles, and further that the musculature plays a critical role in shaping these features. In humans muscles such as infraspinatus and subscapularis would be expected to affect the shape of the vertebral border, as they have longer attachments along it. As well, humans have a larger infraspinous fossa (relative to breadth) than do rats (Wolffson, 1950). As the study was only concerned with the spine, vertebral border, and fossae Wolffson, unfortunately, neglected to report any changes to the axillary border or the glenoid fossa.
Chapter III: The Neandertal Shoulder Girdle and Kebara 2

The current chapter begins with a detailed description of the present understanding of upper limb and shoulder girdle of Neandertals, with primary emphasis on the scapula. The chapter concludes with a description of the Kebara Mousterian Hominid 2 scapulae.

(A) The Neandertal Shoulder Girdle

Before describing the shoulder girdle of Neandertals, a brief overview of their postcranial and upper limb anatomy is presented.

Neandertal Postcranial Anatomy

The evolution of modern-looking humans from archaic members of Homo sapiens involved many cultural and anatomical changes. Among these was a general trend towards postcranial gracilisation (Kennedy, 1984; Ruff et al., 1993, 1994; Trinkaus, 1983a; Trinkaus et al., 1994). Much recent work has demonstrated that interesting and significant postcranial changes occur with the transition to anatomically modern humans, most of which reflect overall robusticity, but others related to patterns of manipulation, locomotion, and cold adaptation (Rak, 1992; Trinkaus, 1983a; Trinkaus, 1986; Trinkaus et al., 1994).

The level of robusticity in Neandertals is pervasive because it is notable in all skeletal regions, and in most of their bones (Trinkaus, 1983a). None of these changes, however, suggest patterns of movement different from modern humans, except perhaps in their gait (Rak, 1992). Before discussing the scapular architecture of Neandertals a brief overview of the notable aspects of their upper body is presented.
Neandertal Upper Body Robusticity

The upper skeleton of Neandertals present a suite of morphological and morphometric characteristics that leave no doubt that their lifestyles involved high levels of activity which were carried out throughout the duration of their lives. Their cultural adaptation was one which involved powerful and habitual loading of the upper limb, as reflected by impressive markers of muscular hypertrophy, mechanically enhancing linear bone dimensions, and marked humeral cortical density.

The ribs of Neandertal display a pronounced thickening of the shafts, indicating hypertrophy of the shoulder (pectoralis major, pectoralis minor, and serratus anterior) and back (erector spinae) musculature which attach to the ribs. The anatomy of their vertebrae is consistent with this development. Their lower cervical spines are consistently long, straight, horizontal, and robust indicating hyper-development of the nuchal musculature. This correlates well with the frequent paramasticatory (nondietary) use of their anterior dentition, as mirrored by their facial morphology and the high levels of anterior tooth attrition visible in older individuals (Jelinek, 1994; Stewart, 1962; Trinkaus, 1983a, 1983b) (as outlined in Chapter I).

Neandertal humeri are exceptionally robust, concomitant with the development seen in their scapulae (discussed below), and in general are relatively short, thick, and stout, with large articular surfaces. Their humeral heads appear to be relatively and absolutely large, and the greater tubercle is prominent laterally. The insertions of p. major, latissimus dorsi, teres major, and t. minor are commonly hypertrophied at their insertions on the proximal humeral shaft, in contrast to recent humans who are said by Trinkaus (1983a, 1983b) to be less pronounced in this respect.
Trinkaus (1983a) has stated that most Neandertals have deltoid tuberosities sufficiently enlarged so as to create a sulcus between them and the posterior margin of the shaft, whereas such sulci are rare on more recent humans. Diaphyseal cortical thickness in Neandertal and recent human humeri has been studied and quantified by several authors (Ben-Itzhak et al., 1988; Churchill, 1993; Ruff et al., 1993; Trinkaus et al., 1994) who conclude that Neandertals show significantly thicker cortices. This indicates a marked difference in the level of related muscle mass between the two groups, as well as increased resistance to flexural stress and overall greater strength in the humeri of Neandertals (Ben-Itzhak et al., 1988). Additionally, strong development of the hand flexors is apparent in the lateral expansion of the medial epicondyle; also the overall biepicondylar width in Neandertal humeri widens more suddenly than in modern humans (Senut, 1985).

Neandertal forearms are particularly robust in features associated with pronation and supination. Supination of the forearm is performed primarily by biceps brachii, its insertion located on the radial tuberosity of the radius. In Neandertals the tuberosity tends to be directed medially rather than anteromedially in recent humans. The more posterior positioning of the tuberosity implies the maintenance of a more effective moment arm for biceps brachii through the full range of supination (Trinkaus, 1983a; Trinkaus & Churchill, 1988). As well, many Neandertal radial shafts have accentuated curvature, which would increase the moment arm for the pronator muscles by increasing their interosseous space (between the radial and ulnar shafts) (Trinkaus, 1983a). Pronation of the forearm is carried out by two small muscles, pronator teres and p. quadratus, the origin of the latter of which in Neandertals forms a discrete ridge on the distal ulnar shaft, and is more weakly developed in recent humans (Trinkaus, 1983a).

If Neandertals habitually performed activities requiring pronation and supination of the forearm it is likely that the hands were involved in the action as
well. There are, in fact, many indications of this in their hand morphology. Their carpals display large areas on the palmar tuberosities of the scaphoid, trapezium, and hamate bones. They are robust and extend medially from the bodies of the bones, providing a deep carpal tunnel through which likely passed the large tendons of the long digital flexors (Trinkaus, 1983a). Their proximal and medial phalanges were short and robust, and had wide bases and heads, relative to Upper Paleolithic populations (Musgrave, 1973). The apical tufts of Neandertal distal phalanges reflect manual hypertrophy as well. In comparison to recent humans, Neandertal tufts are large and circular, a feature which Trinkaus (1983a) suggests implies that they were habitually exerting considerable force through their fingertips (i.e. grip).

Neandertal thumbs, in particular, present a suite of features clearly indicative of significant loading of the thumb in flexion. On the pollical metacarpal there is a large crest for the insertion of opponens pollicis, compared to recent humans, which would have served to increase the moment arm relative to the long axis of the bone. The thumb flexors are well marked in Neandertals, forming large insertional areas at the bases of their proximal phalanges and more so on the distal phalanges. Pits formed by flexor pollicis longus on the palmar surface of the distal phalanges are large, deep, and consistently more pronounced than those evident on more recent human thumbs. As well, as noted above, the tuberosities on the distal thumb phalanges are notably large (Trinkaus, 1983a).

And finally Neandertal proximal pollical phalanges are relatively shorter than their distal pollical phalanges in comparison to recent humans (Trinkaus, 1983a; Trinkaus and Villemeur, 1991). Trinkaus and Villemeur (1991) found that these dimensions provide a mechanical advantage for the flexor muscles across the interphalangeal and metacarpophalangeal joints in Neandertals compared to recent humans, again, emphasising the strength of their thumbs.
Taking into consideration the unique metrical and morphological aspects of the entire hand, Musgrave (1971) concluded that Neandertals may not have been as dextrous as living H. sapiens. Each of these features can be found in modern hands, he adds, but that they rarely occur combined in one hand.

**The Neandertal Upper Limb and Shoulder Girdle**

Neandertal scapular architecture is unique in several regards. The three primary differences are found in the unique shape of their axillary borders, the narrowness of their glenoid fossae, and in the hypertrophy of the rotator cuff musculature as reflected by the breadth of their scapulae (on occasion referred to as morphological length) and in the height of their scapular spines.

To date there have been no anomalies reported for the superior scapular borders of Neandertals, except that perhaps they have large scapular notches (Boule, 1912). This has since been called into question by Stewart (1962) who concluded that they may be no different than the Skhul and Qafzeh hominids in this regard.

**The Axillary Border**

The most peculiar aspect of Neandertal scapulae, and the one which has received the most attention, is the configuration of their axillary borders (e.g. Boule, 1911-1913; Endo and Kimura, 1970; Gorenovć-Kramberger, 1914, 1927 in Stewart, 1962; McCown and Keith, 1959; Schwabl, 1914; Stewart, 1962; Trinkaus, 1977, 1983b). While most other morphological features of their scapulae are within the modern human range, their axillary borders are more anomalous.

The axillary border is the thickest section of bone on the inferior body of the scapula, running inferomedially between the infraglenoid tubercle and the protuberantia marginis axillaris. Axillary borders are described as exhibiting one of
three axillary sulcus (sulcus axillaris) patterns which grade into one another: a single ventral sulcus, a single dorsal sulcus, or a bisulcate border (ventral and dorsal sulci) (Figure 3.1). It has been noted that the majority of Neandertals are unique in their axillary morphology, in that they show a marked sulcus on the dorsal side of the border, whereas the majority of modern humans have a sulcus on the ventral side. The intermediate condition, a bisulcate axillary border, is present in some Neandertal and modern human individuals (Stewart, 1962; Trinkaus, 1977, 1983b).

Both ventral and dorsal sulci have a labium on either side of the sulcus, one dorsal and the other ventral. In either case the labium running lateral to the sulcus is usually crest- or margin-like (similar to the interosseous crest of the radius) in morphology, whereas the medial one is torus-like in shape. For example, a dorsal sulcus usually displays a marked oblique craniocaudal thickening on the dorsal side of the scapula, medial to and adjacent to the sulcus, with a thinner crest more ventrally along the axillary border. Thus, the sulcus is located between the two labia. In the case of a bisulcate form there is a central crest along the axillary border dividing the two sulci, and generally a torus-like ridge on the other side of each, one ventral and the other dorsal.

Testut (1889, in Stewart, 1962) was among the first to comment on the structure of the axillary border, describing in detail the first bisulcate, represented by the Chancelade skeleton. In contrast to the case of most modern humans whom he stated have a deep longitudinal sulcus on the ventral side of the axillary border, the Chancelade male has two shallow longitudinal sulci, one on each side of the border and facing laterally. Testut, however, did not introduce any names to the sulci (Stewart, 1962). Thus, the bisulcate condition is sometimes referred to as the Chancelade type of axillary border.
Marcellin Boule (1912) brought attention to the dorsal type of sulcus, using the scapulae of La Ferrassie I and the Neandertal skeleton as examples. He referred to the pattern as the Neandertal-type. Two years later Schwalbe (1914, in Stewart, 1962) introduced the term sulcus axillaris, but did not discriminate between types. In describing several of the scapulae from Krapina Gorjanovic-Kramberger (1925, in Stewart, 1962) introduced the terms sulcus dorso-axillaris and sulcus ventro-axillaris and concluded that Neandertals and modern humans have distinctive border types of axillary borders.

Von Eckstedt (1925, in Stewart, 1962) significantly revised the axillary border terminology from observations he made on a variety of modern human scapulae. He was the first to look at a significantly large sample (409 individuals), as well as place the Chancelade type in the intermediate position between Neandertals and modern humans. He substituted sulcus axillaris teretis for sulcus dorso-axillaris, sulcus axillaris subscapularis for sulcus ventro-axillaris, and facies axillaris bisukata for the Chancelade type. He noted variation within each type, and
provided a more detailed classification system. Von Eickstedt was able to identify dorsal sulci in a small percentage of his sample (6.4% were clearly dorsal and 15.6% were suggestive of a dorsal sulcus), with the majority ventral (44.7%) as well as a large number of bisulcates (31.4%). Fifteen years later, in their classic description of the Mount Carmel scapulae from Tabun and Skhul, McCown and Keith (1939) were somehow unaware of the extent of literature on axillary borders, including the Latin names proposed for Neandertal and other scapulae. Instead, they referred to the dorsal sulcus as "Bole's sulcus" or "marginal sulcus."

In describing the Shanidar scapulae Stewart (1962) chose Gorjanovic-Kramberger's terminology (sulcus dorso-axillaris, sulcus ventro-axillaris) except for retaining use of the Chancelade category for bisulcates. Interestingly, at the time of Stewart's publication the Skhul hominids were considered to be of the same population as the individuals from Krapina, Neandertal, La Ferrassie, Shanidar, and Tabun i.e. they were grouped as Neandertals. Stewart divided the axillary borders of the known Neandertals at the time into two groups: (1) Dorsal - La Ferrassie I and II, Neandertal, Shanidar I, and Tabun; (2) Bisulcates - Skhul IV, V, and Shanidar III. Presently, however, most researchers discriminate between the Skhul (and Qafzeh) remains and the others, and do not refer to them as Neandertals.

Interpretation of Axillary Border Morphology

While the above studies were concerned with variation in, and the phylogenetic implications of, the axillary border, the first analysis of its functional implications was performed by Trinkaus (1977). By tabulating the frequency and distribution of axillary types among Neandertals, the Skhul hominids, European Upper Paleolithic hominids, and recent Homo sapiens (Europeans and Amerindians) (Table 3.1) he demonstrated that the frequency distribution of sulcus types from the Middle Paleolithic to present follows a consistent pattern, effectively
a decrease in dorsal type and an increase in ventral type. Neandertals exhibit all three axillary types in varying percentages, but the ventral type is rare, while the dorsal type is predominant. A temporal anomaly is presented by the Skhul hominids who, in contrast to their Neandertal contemporaries, do not display dorsal sulci. Rather, they all (n=3) have bisulcated axillary borders, the same pattern seen in the Upper Paleolithic sample (n=12). However, more recently Trinkaus (1983b) described one Upper Paleolithic individual, Predmostí 14, as exhibiting dorsal sulci. The only non-Neandertals that Trinkaus (1977) found the dorsal pattern in was one recent European, while the remaining recent humans were predominantly of the ventral type, with a percentage of each subgroup exhibiting the bisulcate form.

Trinkaus' (1977) analysis of the functional significance of the axillary border is based on his interpretation of the related musculature of each border type. The lateral fibres of subscapularis and teres minor attach along the mid-axillary border. In modern humans with the ventral type, Trinkaus proposed that most of the axillary border is occupied by subscapularis, whereas t.minor is limited to the dorsal surface. In this type there is commonly a clear crest separating the extent of t.minor along the dorsally placed axillary margin. When the axillary margin is more

<table>
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<tr>
<th>Group</th>
<th>N</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
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</thead>
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<tr>
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<td>11</td>
<td>36.8%</td>
<td>7</td>
<td>5.3%</td>
<td>1</td>
</tr>
<tr>
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<td>3</td>
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<tr>
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<td>0</td>
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<tr>
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<td>1</td>
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<td>28</td>
<td>75.8%</td>
<td>91</td>
</tr>
<tr>
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<td>0</td>
<td>13.4%</td>
<td>16</td>
<td>86.6%</td>
<td>103</td>
</tr>
</tbody>
</table>

Table 3.1 - Frequency of axillary border types in samples of fossil and recent humans. Table compiled from data in Trinkaus (1977), and does not include Kebara 2.

61
ventrally placed, as in the dorsal type, the lateral extent of t.minor increases. Thus, in the Neandertal dorsal types most of the axillary border is occupied by t.minor. Trinkaus proposes that the relative increase in the attachment area for t.minor with the bisulcate pattern and the full dorsal sulcus strongly implies a larger, more powerful t.minor. He adds that it does not imply a concomitant relative decrease in the development of subscapularis, since its dimensions are related to factors other than the configuration of the axillary border.

As outlined in Chapter II, t.minor, along with infraspinatus, is a primary lateral rotator of the humerus. Besides serving this function, during abduction of the humerus (by deltoid and supraspinatus) it aids in retaining the humeral head in the glenoid fossa. However, Trinkaus suggests that this alone cannot account for the pronounced development of t.minor in the dorsal border type. Rather, he proposes that its hypertrophy is due to stabilisation of the arm during adduction. The primary adductors, latissimus dorsi, pectoralis major, and teres major are also strong medial rotators of the humerus. Thus, if the humerus is powerfully adducted, the medial rotation of these muscles must be counterbalanced, and this is precisely what Trinkaus suggests t.minor does, explaining its strong development in the shape of a dorsal sulcus. Additionally, as the humeral adductors of Neandertals were quite powerful as suggested by their strong humeral attachments, an extra development of t.minor (as well as infraspinatus and the posterior fibres of deltoid) may have been necessary for precise manual dexterity.

Thus, the morphology of the axillary border, as interpreted by Trinkaus, appears to be related to robusticity of the individual, the dorsal type being the most robust of the three, followed by the bisulcate type, and finally the ventral (Trinkaus, 1977, 1983b, 1989). Initially, Trinkaus (1977, 1983a, 1983b) proposed that the strong dorsal sulci represent strong M. teres minor attachments (Trinkaus, 1983b; 220) which existed to provide rotational stability of the shoulder during humeral
adduction, as these adductors also rotate the humerus medially: "The presence of a dorsal sulcus on the scapular border is a direct reflection of an enlargement of the teres minor muscle." [Trinkaus, 1983a: 170]. Most recently, however, Trinkaus (1986, 1989) has revised his interpretation somewhat, stating that most appropriately it is the dorsal sulcus axillary border "probably reflects a structural reinforcement of the axillary border in response to dorso-ventral oriented bending stress, particularly when the humerus was in an abducted position" (Trinkaus, 1989: 334). He adds that this stress was created by the apparently hypertrophied rotator cuff musculature (discussed previously), as well as the major, and that the transition to early modern humans involved a decrease in the frequency of the dorsal sulcus (Trinkaus, 1986, 1989).

At the cultural level, Trinkaus (1977, 1983b) asserts that the evolution of the border to the bisulcate pattern of the Skhul and Upper Paleolithic hominids (Trinkaus, 1977) and the ventral sulcus pattern characteristic of recent humans indicated a steady decrease in the levels of biomechanical stress of the shoulder in accordance with the corresponding increases in the level of cultural efficiency during the Upper Pleistocene.

The Glenoid Fossa

As outlined in chapter II, the glenoid fossa articulates with the humeral head, and together these form the glenohumeral joint. It is teardrop to pear-like in shape, with the longer axis oriented craniocaudally. Several authors (Vallois, 1928-46; Stewart, 1962; Trinkaus, 1983b; Churchill and Trinkaus, 1990; Trinkaus et al., 1991) have noted that Neandertal glenoid fossae are relatively narrower than those of more recent humans, and recently researchers have attempted to interpret its mechanical significance (Churchill and Trinkaus, 1990; Trinkaus et al., 1991).
The shape of the glenoid fossae is commonly described with the glenoid index (named GLE by Churchill and Trinkaus (1990)), which is simply the dorsoventral breadth of the fossa divided by its craniocaudal height multiplied by 100, providing a percentage width of height value. Most Neandertals have low glenoid indices relative to more recent humans. For example, Stewart (1962) presented a sample of nine Neandertals (including Skhul V which, at the time, was considered to be a Neandertal by most researchers) averaging 67.4 compared to modern human samples ranging between roughly 70.0 and 80.0 (data on the latter from Vallois (1932)). More recently, Churchill and Trinkaus (1991) compared 16 Neandertals which averaged 66.5 to an early Upper Paleolithic sample (n=5) averaging 73.1, and a modern human group (n=99) averaging 73.4, and concluded that the Neandertals were significantly narrower than the other groups.

Churchill and Trinkaus (1990) were the first study the fossa within the greater context of the upper limb and interpret the significance of its morphology upon the movement of the upper limb. As noted above they found significant differences between the Neandertals and more recent humans in relative glenoid width. However, they discovered three interesting differences beyond simply the glenoid index itself.

First, after scaling glenoid length and width against humeral length (to control for body size) they found that the two groups differed significantly in glenoid length, Neandertals being longer, but not in width, and concluded that the transition to the morphology found in modern humans involved a decrease in glenoid fossa length relative to other aspects of upper limb morphology. Second, it was found that the glenoid of Neandertals is narrower relative to the size of the humeral head, and third, to the distal articular surface of the humerus as well. Thus, the authors concluded that "... for any given humeral joint surface,
Neandertals exhibit a narrower fossa than would an anatomically modern human." (Churchill and Trinkaus, 1990: 154).

In interpreting the biomechanical significance of Neandertal glenoid fossae Churchill and Trinkaus (1990) remark that their apparent narrowness is striking given the numerous features (described above) of their upper limbs establishing their adaptation for exerting great force on the environment and resisting resultant reaction forces and stresses from powerful muscle contraction. As well, relative to their stature Neandertals had large upper limb joint surfaces, perhaps an adaptation to large joint reaction forces, a response to increased resistance to joint degeneration by spreading forces across a greater surface area. In this respect, the relative narrowness of their scapular fossae seem all the more puzzling.

Churchill and Trinkaus (1990) suggest that the habitual behaviour patterns of Neandertals loaded the shoulder within a dorsoventrally narrower range than modern humans, but that their actual range of motion was not necessarily different. They propose that the increase use of projectile technology in the Upper Paleolithic altered the nature and direction of joint reaction forces acting on the glenoid and produced selective pressures favouring more posterior movement of the humeral head. During the cocking phase of throwing external rotation and maximum extension occurs, and the internal rotation and flexion of the humerus produces shearing stress on the dorsal and ventral areas of the glenoid labrum. Thus, the authors propose that a wider joint is more efficient for throwing than a narrower one and that in the Upper Paleolithic there was selection for wider fossae, and this simple morphological change indicates a significant shift in human throwing behaviour and projectile use at this time.

A second commonly noted anomaly of Neandertal glenoid fossae is their apparent shallowness (Churchill and Trinkaus, 1990; Gorjanovic-Kramberger, 1906, in Churchill and Trinkaus, 1990). The articular surface appears somewhat flattened
craniocaudally compared to modern humans. The significance of this feature has never been explored prior to Churchill and Trinkaus' (1991) study. By dividing the length of the glenoid fossa by its depth and comparing it between populations the authors confirmed that Neandertals have a significantly flatter articular surface than do modern humans. However, when joint size was taken into consideration the apparent differences disappeared. The articular surface of the average Neandertal humeral head represents a portion of a sphere larger than those of the mean humeral heads in their modern human samples. When they plotted glenoid fossa and humeral head radii of curvature against each other for both groups no significant differences were seen between Neandertals and modern humans. Thus, Neandertal scapular fossae are flatter, but only because they represent arc segments from larger circles than do the fossae of modern humans. The flatness of their fossae is then, effectively, a by-product of articular enlargement and therefore of robusticity (Trinkaus et al., 1990).

Churchill and Trinkaus' (1990) research will be outlined and analysed in greater detail in Chapters V and VI. As their work is the only interpretation of the morphology of Neandertal glenoid fossae to date it serves as a benchmark against which to draw comparisons and reconsiderations.

The Scapular Body

The most distinctive features of Neandertal scapular bodies (apart from the axillary border) are their mediolateral expansion (BRE measurement, defined in Chapter IV), especially relative to humeral length (Trinkaus 1983b, 1986, 1989; Vallois, 1928-46), the general enlargement of the infraspinous fossa (Trinkaus, 1983b), and the raised height of their scapular spines (Trinkaus, 1983a).

Neandertal scapulae are mediolaterally enlarged, even more so relative to humeral length, compared to modern humans (Trinkaus, 1983b, 1986, 1989). Their
values are high relative to modern human, especially when scaled against humeral length, but the upper limits of modern variation do overlap with the Neandertal values for both and scaled and unscaled width. This marked width does not correlate to the overall proportions of the scapulae. For example, the ratio of infraspinous fossa height to scapular breadth (1-SP/BRE*100, defined in Chapter IV) in the Shanidar Neandertals is similar to those of a recent human sample (Trinkaus, 1983b). As well as having relatively large scapulae, Neandertals tend to have high axillospinal angles. This is the angle between the axillary border and spine, and the wider angle facilitates an enlargement of the subscapular fossa (Trinkaus, 1983b).

Trinkaus (1983b, 1989) suggests that the combination of large scapular breadth and axillospinal angles suggests an enlargement of three of the rotator cuff muscles, supraspinatus, infraspinatus, and subscapularis. While all three are affected by changes in breadth of the scapula, only infraspinatus and subscapularis relate to the axillospinal angle. The wider scapular breadth of Neandertal scapulae would increase the muscle attachment areas of all three along the spine, and in general increase the surface area of the scapular body. The greater axillospinal angle effectively moves the inferior angle laterally relative to the vertebral border, which in turn increases the surface areas of the infraspinatus and subscapular fossae. Trinkaus (1986) has also suggested that this mediolateral enlargement would have facilitated greater moment arms of trapezius for scapular rotation.

Neandertals also have wide angles between their glenoid fossae and axillary borders. Their axilloglenoid angle reflects both the orientation of the glenoid fossa and the lateral positioning of the glenoid fossa, and relates in part to their high axillospinal angles (Trinkaus, 1983b). A greater axilloglenoid angle also reflects an expansion of the subscapular and infraspinous fossae.

The enlargement of the surface areas of the rotator cuff muscles is further illustrated by the heights of their scapular spines, which tend to be relatively high
off the plane defined by the supraspinatus and infraspinatus surfaces. This would have the effect of increasing the volume of muscle fibres contained on the dorsal scapular surface. As well, the increased height moves the acromion, and hence deltoid, further away from the axis of rotation of the shoulder joint and increases the moment arm of deltoid (Trinkaus, 1983a, 1983b).

With reference to these features of Neandertal scapular bodies, Trinkaus (1983b) states that "Because the scapula is primarily an attachment area for muscles and is responsive to atrophy and hypertrophy of those muscles, these aspects of the Shanidar and other Neandertal scapulae indicate a hypertrophy of their shoulder musculature" (Trinkaus, 1983b: 222).

The study of these three anatomical areas has prompted researchers to conclude, most relevantly, that with the origins of modern humans there is reduction in scapular breadth (Trinkaus, 1986), a decrease in the frequency of the dorsal sulcus (Trinkaus, 1977, 1989), and an relative increase in glenoid fossa width (Churchill and Trinkaus, 1990; Trinkaus et al., 1991). These all, in turn, reflect a general reduction of robusticity form the Middle Paleolithic to present. Therefore, for these contentions to be correct all modern human populations should conform to this pattern.

(B) Kebara Mousterian Hominid 2

Kebara Cave (Mugharet el-Kebara) is located on the western escarpment of Mt. Carmel in Israel (fig. 3.2), 13 km south of Tabun cave, and facing the Mediterranean sea two km to the west. Recent, Bronze Age, Natufian, Kebaran, Aurignacian, Early Upper Paleolithic, and Mousterian deposits have been excavated since initial excavations began in 1930. Research at Kebara was undertaken from 1930 to 1931, from 1951 to 1965, in 1968, and most recently from 1982 to 1990 (Bar-Yosef, 1991; Bar-Yosef & Vandermeersch, 1991; Bar-Yosef et al., 1992). The most
Figure 3.2. Map of the Near East (Levantine region) showing the location of Kebara as well as other Middle Paleolithic sites. Map adapted from Bar-Yosef et al. (1992) with permission.
recent French-Israeli organised excavations (1982 to 1990) were, in part, undertaken to address the previous disagreements over the chronological place of the Levantine fossils and their relationship to the observable industrial variability (Bar-Yosef & Vandermeersch, 1991). The project was an international and multidisciplinary effort which has since gained considerable academic acclaim (e.g. Clark, 1992; Garrad, 1992; Henry, 1992). Aside from increasing our understanding of the Levantine chronology, the systematic studies of lithic industries, and the studies of the human skeletal remains, the project succeeded in enlarging the body of knowledge which can attained from a Middle Paleolithic cave excavation (Bar-Yosef, 1991). It is for this reason that the work at Kebara has been described as "one of the most important late-20th-century excavations and analyses of a Middle Paleolithic site at a major crossroads of the Old World" (Trinkaus, 1992: 511). The data from Kebara Cave, and the various analyses of lithics, fauna, human remains, and features of the site have contributed significantly to our understanding of the behaviour of Mousterian peoples in the Levant, and in general (Smith, 1992).

The Mousterian burial Kebara 2 (Fig 3.3), also referred to as Kebara Mousterian Hominid 2 or KMH 2, was discovered in 1983, dated by ESR to between 64,000 and 60,000 yBP (Schwarcz et al., 1989), and by TL to between 61,000 and 59,000 yBP (Valladas et al., 1987). It should be noted that dating was not done directly on the skeletal remains. The individual is an excellently preserved 25-35 year old adult male, lacking only the cranium, right lower limb, and most of the left lower limb. Its morphological affinities lie with the Mousterian hominids from Amud, Tabun, and Shanidar rather that with the Skhul-Qafzeh group commonly labeled more modern (Bar-Yosef et al., 1992). Kebara 2 is most commonly referred to as a Neandertal, although Arensburg. (1991; 1992, pers. comm.) maintains that none of the Mousterian Levantine hominids should be referred to as Neandertals.
Figure 3.5: Burial position of Kebara Mousterian Hominid 2. Adapted from Bar-Yosef et al. (1988), with permission.
and that the Amud, Tabun, Shanidar, and Kehbara Mousterian hominids are morphologically distinct from European Neandertals.

Kehbara 2 was discovered in a burial pit lying on his back with arms crossed, the right forearm across the thoracic cavity, right hand at the level of the left scapula, and the left forearm and hand a little lower at lumbar level (Fig. 3.4). The cause of death is unknown. Interestingly, there is rather convincing evidence that the cranium was removed during the Mousterian some time after interment (Bar-Yosef et al., 1992).

The Mousterian in Light of Kehbara 2

From analysis of the entire body of archaeological evidence from Kehbara Cave comes, perhaps, the most enlightening suggestion by Bar-Yosef et al. (1992:530) that "In sum, the commonly Eurocentric summaries which attempt to show major archaeological differences between Neandertals and Cro-Magnons are not supported by the evidence exposed in Kehbara Cave." Clark (1992:531), on a similar note, concluded that "The essentially "modern" behaviors in which the Kehbara Neandertals engaged also tend to discredit Lewis Binford's widely publicized portrayal of them as little more than animals."

The discovery and analyses of Kehbara 2 have contributed immensely to our knowledge of Neandertal anatomy and behaviour. Portions of some of its elements (and related morphologies) are uniquely preserved in Kehbara 2 and cannot be compared to any other Middle Paleolithic hominids. These include aspects of the hyoid, the ribs, and the vertebrae (Bar-Yosef et al., 1992). From the discovery and examination of the hyoid bone, which is morphologically identical to modern humans, and cervical region it is now believed that Middle Paleolithic hominids
were likely capable of speech (Arensburg et al., 1988; Arensburg et al., 1990), a topic which has for many years been highly contentious.

Arensburg (1991: 124) has stated that the vertebrae, sternum, and hyoid of Kebara 2 are "virtually impossible to separate from modern man". He found an absence of archaic features in the ribs of Kebara 2, and noted that they are quite similar metrically and morphologically to "present" human populations. He also observed great variability in shape and size of the ribs, a feature noted in Neandertals by other researchers (e.g. Endo and Kimura, 1970). All of the vertebrae are preserved, and appear to be nearly identical those of modern humans. Kebara 2 may have had a slightly shorter neck segment relative to thoracic length.

However, this cannot be generalised for other Mousterian hominids as no others preserve comparable elements (Arensburg, 1991). Unique gait and posture related biomechanics in Neandertals have been suggested by some researchers (Rak and Arensburg, 1987; Rak, 1990; Rak, 1992) based on the morphology of the pelvis, with its virtually complete, and long, superior pubic ramus. As well, the shape of the pelvic inlet does not support the previous hypothesis that Neandertals differed in gestation length (Trinkaus, 1984b) from modern humans (Bar-Yosef et al., 1992).

In fact, Kebara 2 differs from other Levantine Mousterian skeletons, such as in overall robusticity of the mandible (high), dimensions of the sacrum, and the cotylo-sciatic breadth (Bar-Yosef et al., 1992). On the other hand, despite its Neandertal affinities morphometrics of the hyoid, the ribs, and the vertebral column fall within the range of variability of modern humans. In final general analysis of the individual Bar-Yosef et al. (1992: 530) emphasised that "With regard to many features it is the most robust individual known from the Levant.". It is interesting that such a robust individual yields from so recent in the Levantine Mousterian. It is possible, as one author (Schepartz, 1992) has suggested, that the current vogue of using the terms Neandertal (Amud-Kebara-Shanidar-Tabun) and early modern
(Skhul-Qafzeh) in the Levant may serve only as a temporal rather than as a
taxonomic categorisation. However, more precise dating of Amud, Tabun, and
perhaps Shanidar is required before this can be considered.

The Shoulder Girdle and Upper Limb of Kebara 2

I studied Kebara 2 at the Department of Anatomy and Anthropology, Sackler
School of Medicine, Tel Aviv University. My observational analysis of the overall
skeleton confirms that features of its mandible and postcranial skeleton indicate
that it is either a Neandertal, or lies in close phylogenetic proximity to them. The
mandible lacks a chin and its corpus is very robust and high, with a clear retromolar
gap and a considerable amount of anterior tooth wear. The vertebral spinous
processes appear to be relatively horizontal, and the ribs are thick and show a type
of curvature common in other Neandertals. I am not suggesting that they are
unique among humans in these areas of development, but rather, that they are
distinguishable from the conditions commonly described in modern humans
(contra Arensburg (1991), described above). The better preserved ilium displays a
very long superior pubic ramus, and what remains of the left femur appears to be
moderately robust.

The scapulae both have marked dorsal sulci, and are classified as exhibiting
a bisulcate type of border, with the remainder of the bone preserving evidence of
impressive musculature. The arm bones are well muscled, and the hands shows
significant hypertrophy, especially of the thumbs (as described above, the thumbs
are consistently hypertrophied in other Neandertals). The hypertrophy and
robusticity of the three thumb elements are highly reminiscent of those of Tabun C1
and Amud 1 (see Chapter IV). This overall anatomy is concomitant with that
described as characteristic of Neandertals. Thus, while the specimen lacks cranial
remains there is strong evidence to cluster it with the Mousterian hominids from the sites of Amud, Tabun, and Shanidar, as well as those from European locales.

Description of the Scapulae of Kebara 2

The architecture of Kebara 2's scapulae attests to the musculature and strength of the individual. The elements have been described only once previously, by Vandermeersch (1991), in what is primarily a brief outline of the scapula. A detailed description of each element is now presented, in preparation for the analysis in the following chapter, with reference made to Vandermeersch (1991) where appropriate.

Scapulae

Both scapulae are exceptionally well preserved, although the left has suffered from considerable post-mortem crushing and distortion. The thickness and robusticity of the bones is immediately apparent, as is the large overall size of their bodies. The right scapula (fig. 3.4 - 3.6) lacks only the acromion, the extremity of the coracoid, and a central portion of the body measuring about 4cm². The caudal and dorsal margins of the glenoid also have been eroded and prevent accurate measurement of the fossae. The left scapula (fig. 3.7) is missing only the coracoid and the supraspinous fossa. However, the spine, and superomedial half of the body is distorted due to post-mortem crushing. As a result nearly all of the scapular body measurements required in this study are unobtainable on the left scapula. Additionally, the ventral half of the glenoid is damaged and dimensions in this region are impossible to obtain. Thus, while Vandermeersch (1991) has published glenoid length and width estimates for both Kebara scapulae they could well be inaccurate given the lack of preservation of portions of the glenoid articular surfaces. The analysis, in this study, of the glenoid fossa is sensitive to minor
deviations in glenoid dimensions (discussed in more detail in the "methods" section of Chapter IV) which cannot be calculated unequivocally in the Kebara 2 scapulae.

As the scapular notch is imperfectly preserved in both Kebara scapulae no conclusive comments can be made on their shape and they will not be examined here.

**Right Scapula**

The right scapula is shown in figures 3.4 - 3.6. As stated previously, it lacks only the acromion, the lateral tip of the coracoid, and a very small central portion of the infraspinous fossa. Two small sections, one approximately at the 70% level from the top of the vertebral border and the other immediately adjacent the spine, are also missing. Fortunately, the form of each is easily reconstructable. The cranial-most tip of the superior angle is also absent, but can be accurately estimated with a high degree of confidence. The dorsal margin of the glenoid (required for measuring scapular breadth) is similarly broken, but its location is equally estimable. It should be noted that there is a small (3 cm in diameter) round concavity on the dorsal body (and thus a convexity on the ventral body) just inferior to the spine and lateral to the medial angle. This irregularity appears to be due to post-mortem processes, although Vandermeersch (1991) noted this depression, without commenting on its origin. This feature is absent on the left scapulae, but the region is damaged, thus leaving the certainty of this anomaly in question.

Nevertheless, the landmarks necessary for analysing the shape of the body on the right element are available. As mentioned earlier, the preservation of the glenoid surface is insufficient to allow reliable measurements of glenoid dimensions.
Figure 3.4. Dorsal view of the Kebara 2 Right scapula. Photograph by author. Scale in CM.
The body is relatively large, especially the infraspinous fossa (fig. 3.4). Most noticeable is that the superior body is short compared to the voluminous surface of the inferior body, a characteristic noted also by Vandermeersch (1991).

The axillary border is clearly bisulcate (fig. 3.5), with a markedly thick pillar of bone (referred to as *crista axillaris* by Vandermeersch (1991)) running medially adjacent to each sulcus. As discussed in the first section of this chapter, a bisulcate axillary border consists of a dorsal *and* a ventral ridge or pillar (Vandermeersch's (1991) *crista dorso-axillaris* and *crista ventro-axillaris*, respectively). Each sulcus is divided by an interosseous-like crest of bone (the axillary margin). While both Kebara scapulae are bisulcate, the dorsal sulcus is larger on the right side.

The infraspinous surface (fig. 3.4) preserves evidence of considerable musculature, especially along and adjacent the axillary border, as well as in the overall fossa. Most notable is the ridge of bone next to the dorsal sulcus, which is in roughly the same dorso-ventral plane as the ventral pillar described below. It is raised higher off of the scapular body than the ventral pillar, and its sulcus is wider and deeper. The dorsal pillar and sulcus on the right side are larger, as well as higher and deeper, respectively, than on the left. The dorsal pillar extends 60.0 mm inferiorly from a point immediately inferomedial to the caudal margin of the glenoid. It is more strongly developed than the ventral pillar, as is its accompanying sulcus. It is likely that the ventral and dorsal pillars are reflect common morphological and biomechanical influences. This will be addressed in more detail in Chapters V and VI. The area medial to the dorsal pillar is concave, due in part to the raised nature of the pillar. This concavity is deeper on the left scapula and is more central.
Figure 3.5. Lateral view of the Kebara 2 Right scapula. Photograph by author. Scale in CM.
There is a second, and less conspicuous, pillar of bone (Vandermeersch's (1991) *crista medioaxillaris*) just below and parallel to the dorsal pillar (fig. 3.4). This second pillar begins right at the axillary border and runs diagonally over the area of *t*.major. It is thickest in the middle of the blade just above the depression for *t*.major. *T*.major appears to have been well developed in Kebbara 2, as its origin at the inferior angle shows a large oval depression, capped superomedially by the second dorsal pillar. The depth of the *t*.major depression is emphasised, in part, by the development of the second dorsal pillar. The lateral margin of the *t*.major depression extends to a crest along the axillary border just superolateral to the inferior angle. The full extent of the crest cannot be determined, as its lateral extremity is fragmented.

After arching gently ventrally, the superior angle bends abruptly dorsally, possibly as a plastic response to an enhanced supraspinatus or levator scapulae. Again, the cranial extremity of the superior angle is broken, but its extent can be estimated very reliably. A 27.0 mm section of bone is missing between the superior angle and scapular notch. However, the latter is perfectly preserved, being broad and bluntly curved at its base.

The spine is complete, but broken at the junction of the acromion, which is the only major portion of the scapula missing. The central portion of the spine is moderately large, this being the area of the scapular origins of trapezius cranially, and deltoid inferiorly. The lateral root the spine appears thick and at this point the spine itself is high off the body of the scapula.

The caudal and dorsal margins of the glenoid fossa are damaged (fig. 3.5). Estimates of the glenoid dimensions would be highly equivocal as the glenoid labrum is not visible in these areas. The glenoid does not appear to be particularly narrow, although Vandermeersch's (1992) estimations of glenoid length (35.5 mm
Figure 3.6. Ventral view of the Kebara 2 Right scapula. Photograph by author. Scale in CM.
and breadth (22.7 mm) yield a relative glenoid width of 63.9, narrow compared to published data (Churchill and Trinkaus, 1990) for recent humans and Neandertals. My estimations of glenoid length and breadth are 34.8 mm and 23.3 mm, respectively. This produces a glenoid index of 66.9. However, given the preservational state of the glenoid fossa these estimates should be considered tentative and only used with caution, if at all, in a comparison of glenoid fossae, although they have been in the past (Churchill and Trinkaus, 1990) who measured Kebara 2 independently. If these values are accepted as metrically sound, they may misrepresent the true nature of the shape of the glenoid in this individual specifically, and the range of variation expected in Neandertals generally. The left glenoid fossa, described below, is equally damaged and unmeasurable.

The subscapular fossa is highly concave, as the blade sweeps dorsally from the outer margins of the bone. This, as well as strong intermuscular ridges on the subscapular surface, suggest that subscapularis was well developed. Along the border from superior to medial angle, there is a sharp, raised crest for the insertion of serratus anterior. Continuing inferiorly to the inferior angle, the margin of the border is thickened and raised, but is more thin than above. Adjacent the axillary border, from just medial and inferior of the glenoid fossa to mid-way down the axillary border, the bone is noticeably thickened, forming the ventral ridge of the ventral sulcus. Medially there is a shallow and narrow sulcus. Neither the ventral ridge or sulcus is as thick or deep, respectively, as those on the dorsal side. The coracoid is thick, with a large pectoralis minor tuberosity, and is lacking only its extremity.

There is an unusual groove along the medial face of vertebral border adjacent the medial angle, where rhomboid minor inserts. This is likely a marking
of the muscle’s origin. The shape of the vertebral border is best described as slightly concave.

**Left Scapula**

The left scapula (fig. 3.7) appears to be generally more robust than the right. This is unfortunate, as most of the superomedial body and the spine are crushed and the acromion displaced. Post-mortem damage to the supraspinous fossa, vertebral border and general distortion of the blade does not allow for measurement of the body shape. It is in fact, possible, that the altered nature of the bone causes it to appear to be more robust. Nearly the entire supraspinous fossa is missing, and all that remains of the coracoid is its root. The entire superomedial half of the scapula is crushed and lightly encrusted with matrix. As well, the glenoid fossa has been marred by flattening and crushing. The inferolateral half of the body, including the entire length of the axillary border to the inferior angle, and the acromion, in contrast, are beautifully preserved and display clear signs of muscular hypertrophy.

The infraspinous fossa is large, and appears to be wider than the right side. The breadth of the scapula is impossible to measure however Vandermeersch (1991) has estimated it (Left = ~115.5 mm, Right = 107.0 mm) and suggests that it is the measurement which differs the most between the sides. The axillary border is clearly bisected, and the dorsal sulcus appears to be closer in size to the ventral sulcus than is the case for the right side. The dorsal pillar is thick, but is not as thick or high as on the right. Similarly, the dorsal sulcus is evident, but not as broad or deep as on the right. The central portion of the body, adjacent the axillary border, is noticeably concave, due in part to the convexity that is the dorsal ridge. The concavity is deeper than on the right side.
Figure 3.7. Dorsal view of the Kebara 2 Left scapula. Photograph by author. Scale in CM.
The second dorsal pillar (Vandermeersch’s (1991) *crista mediauxillaris*) is sharp and continues above the area for t. major. As on the right side, the origin for t. major is in the form of a strongly marked depression, but the underlying bone is not as thick as on the right side. This depression causing the axillary border to curve dorsally at the inferior portion of the sulcus where the axillary border meets the inferior angle. The lateral extremity of the t. major does not appear to have projected as far as on the right side.

As noted, the supraspinous fossa is missing, except for a small central portion adjacent the scapular notch. The centre of the spine is broken at its extremities, where it thins at each end near the medial angle and the acromion, and is subsequently shifted out of its natural position in respect to the acromion and rest of the scapula. It appears to be thicker than on the right scapula.

The glenoid fossa is highly damaged. It has been flattened and its ventral half is broken into superior and inferior halves by a wide crack running laterally from the centre of the glenoid. As well, the surface is lightly encrusted with matrix and the extent of the glenoid labrum is not visible. Given these preservational shortcomings accurate measurement of the glenoid is impossible, and even estimates would be highly unreliable. The glenoid appears to be tall, but not particularly narrow. As with the right side Vandermeersch (1991) has estimated the glenoid length (45.0 mm) and breadth (27.7 mm), giving a relative glenoid width of 61.9, even more narrow than the right side. Vandermeersch’s estimates suggest that the left glenoid is roughly 25% larger than the right. Such a degree of asymmetry is highly unlikely. I have estimated glenoid length and breadth as 38.5 mm and 26.5 mm, respectively, producing a glenoid index of 68.8. As with the right side, these estimates are suitable for an analysis of glenoid fossa shape.

The subscapular fossa is concave and, like the right side, shows marked intermuscular ridges. A groove running adjacent the length of the vertebral border
likely housed the insertion of serratus anterior. The entire vertebral border is thickened, more so than on the right side, and is slightly concave. The ventral ridge is almost as thick as on the right side, and its accompanying sulcus is slightly more vast and deeper. Most importantly, the ventral and dorsal pillars and sulci on the left side are closer in size to each other than is the case on the right side, where the dorsal structure are dominant. The crest of bone between the two sulci along the axillary border is somewhat larger on this side, whereas the overall thickness of the axillary border is less than on the right side. It is impossible to assess whether there is a groove similar to that on the right side along the medial face of vertebral border adjacent the medial angle, as the area is obscured by matrix.

One of the three objectives of the present research is to assess the shape and significance of the Kebara scapulae and how they compare to more recent humans, as well as to Neandertals for which there is comparable data. To achieve this, chapter V will include an analysis of the architecture of the right scapula through morphometric comparisons to three recent human samples, with the results considered in the final chapter.
Chapter IV: Materials and Methods

This chapter begins with a presentation of the comparative samples, including temporal, geographical, and behavioural backgrounds for each, with the exception of Kebara 2, described in the previous chapter, and the behavioural aspects of Neandertals, discussed in the first two chapters. The chapter concludes with a section on the analytical methods, in which the osteological measurements, data preparation, and statistical methods are outlined.

Three morphological regions of the scapula were analysed: (1) The Glenoid Fossa, (2) The Scapular Body, and (3) The Axillary Border. The comparative data for each analysis varied, with the three groups for which I collected data - Pacific Northwest (NW) Coast natives, North American (NA) Pioneers, and Chonos natives - forming the core of the comparative samples. The NW Coast and NA Pioneer groups were utilised in all three analyses, and the Chonos in two. Reference is made to other Neandertals where referential data was available and applicable.

The (1) glenoid section encompasses a large body of published data (from Churchill and Trinkaus, 1990) which groups Kebara 2 with other Neandertal scapulae, as well as including a large sample of "modern humans" and an Early Upper Paleolithic group. In contrast, the (2) scapular body analysis compares only Kebara 2 to my three groups. It would have been interesting to include scapulae from other Neandertals and non-Neandertals in this analysis but, unfortunately, such data on the body is unavailable at this time, either because it is unpublished or because some of the scapular measurements are unique to this study. As well, the Kebara 2 right scapula has the most complete body of any Neandertal scapula, and thus presents a unique study opportunity. Some reference to other Neandertal scapulae - those preserving pertinent comparative regions - is made in this section, but emphasis is on the shape of the Kebara individual. In section (3) the axillary
border issue is examined by studying concomitant changes in sulcus morphology in Kebara 2, Tabun C1, and the NW Coast and NA Pioneer groups. Some reference is made to other datasets but, as in section 2, paucity of measurements restricts the analysis to these groups and individuals.

(A) Materials

Sample choice for this study was contingent upon the suitability and availability of appropriate skeletal material. As outlined earlier, populations or individuals which, historically or prehistorically, are believed to have engaged in physically (osteologically) demanding lifestyles were chosen as most suitable. For the scope of this research, availability was primarily determined by the proximity of collections - i.e. skeletal collections presently housed in the Department of Archaeology, Simon Fraser University or nearby. The exception to this is the Middle Paleolithic material which I studied in Israel. As discussed earlier, many of the measurements taken on the included scapulae have not been performed in previously published sources, thus making published comparable samples scarce.

Kebara 2

Described previously in chapter III.

Tabun C1

Tabun C1 is an adult female Levantine Neandertal, approximately 30 years old at death, (McCown and Keith, 1939; Day, 1986) discovered during excavations in the Mount Carmel range between 1929 and 1934 (McCown & Keith, 1939). I studied Tabun C1 at The Department of Palaeontology at the British Museum (Natural History). Data from Tabun C1 are utilised in sections one & three, but I was
Figure 4.1. Tabun C1 left scapula. Dorsal view. Scale in cm. Photo by the Author.
Figure 4.2. Tabun C1 left scapula. Lateral view. Scale in cm. Photo by the Author.
unable to include it in the body analysis due to the fact that I included only males in this section.

Until recently the skeleton was believed to date to 50,000 yBP (Farrand, 1979; Masters, 1982). Recent, however, ESR dates have been calculated from bovid dentition from layer C at Tabun (Grun et al., 1991). These new dates are between 102,00 ± 17,000 and 119,000 ± 11,000 yBP, dates which have been well received (Mercier et al., 1993), although there is some concern that the skeleton may actually have been positioned in the more recent layer B and intrusive to layer C (Garrod & Bate, 1937). If these dates are correct Tabun C1 represents the oldest Neandertal yet discovered in the Levant. As detailed in Chapters I and III this presents the possibility of contemporaneity of Neandertals with the "more modern" grades of H. sapiens in the region. Only the left scapula (fig. 4.1 and 4.2) was recovered. It preserves the glenoid fossa, acromion, coracoid, and axillary border to the inferior angle (all attached). Lacking are the proximal 90% of the vertebral border, the spine from the medial angle to the area adjacent the scapular notch, the superior border, and the majority of the body.

The Golden Pioneer Cemetery (NA Pioneer)

A sample of ten adults from the Golden Pioneer cemetery in British Columbia was studied at the Department of Archaeology, Simon Fraser University. The collection is temporarily housed at SFU, and is expected to be reburied in the very near future.

The Golden cemetary was used from 1882 to 1894, confidently dating this population to between 99 to 111 years ago. As determined by Oliver (1992) the age range of the individuals is 18 to 64 years, while one of ten range from 18 to 38 years. Only two individuals are identified as female by Oliver, and the sex of one of them
is equivocal. The remainder are designated male with a high degree of confidence. The majority (eight) are described as caucasoid, while two (one of each sex) show caucasoid/mongoloid admixture (Oliver, 1992).

The remains were not washed prior to study due to the existence of desiccated tissues and body fluids which may have attracted mold and bacteria if dampened. Despite this situation hindering a few measurements, the data from this sample is remarkably complete, owing to the excellent preservation of the remains, and the careful excavation of their graves.

Golden came into existence in the late 1800s as a railway community, situated along the Canadian Pacific Railway. Many of the early settlers, primarily of European descent, came to Golden as railway workers, miners, and construction tradesmen. The occupations of the recovered individuals appear to have been physically demanding, as attested to by their skeletal morphology, muscular hypertrophy, and degenerative changes, suggesting that several of the individuals were labourers (Oliver, 1992).

Northwest Coast Natives

I studied the NW Coast samples at Simon Fraser University. This required, perhaps, more time than would be anticipated, particularly as the scapulae of most of the individuals were fragmented and required reconstruction ranging from simple to extensive. The humeri and femora, albeit to a lesser extent, required reconstruction as well. Fortunately, none of the elements required washing, and very few more than simple surface brushing. Despite the reconstructive aspect, as well as the relative scarcity of appreciably complete scapular remains, I was able to assemble an adequate sample (Table 4.1). The sample includes adults of both sexes. Age and sex were assessed with the help of Department of Archaeology skeletal catalogues, student skeletal reports, and site reports. Where these aids were
<table>
<thead>
<tr>
<th>Site</th>
<th>Borden</th>
<th>M</th>
<th>F</th>
<th>Total</th>
<th>Date</th>
<th>Date Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach Grove</td>
<td>DgRs1</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>400 B.C. - 400 A.D.</td>
<td>Beattie, 1980</td>
</tr>
<tr>
<td>Crescent Beach</td>
<td>DgRt1</td>
<td>8</td>
<td>3</td>
<td>11</td>
<td>3000 B.C. - 400 A.D.</td>
<td>Beattie, 1980</td>
</tr>
<tr>
<td>Helen Point</td>
<td>DFRa8</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3000 B.C. - 1000 B.C.</td>
<td>Beattie, 1980</td>
</tr>
<tr>
<td>Marpole</td>
<td>DHRs1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>400 B.C. - 400 A.D.</td>
<td>Beattie, 1980</td>
</tr>
<tr>
<td>Namu</td>
<td>ElSx1</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>1000 B.C. - 1000 A.D</td>
<td>Curtin, 1984</td>
</tr>
<tr>
<td>Pender Island</td>
<td>DeRt2</td>
<td>7</td>
<td>6</td>
<td>13</td>
<td>5170 B.C. - 810 B.C.</td>
<td>Carlson, 1980</td>
</tr>
</tbody>
</table>

| Totals       | 24   | 20  | 44  |       |                    |             |

Table 4.1. Sex distribution of NW Coast skeleton sample, and date ranges of the respective sites. All individuals are adults.

unavailable, or if assessment was equivocal, I assessed the sex and age of individuals using traditional pelvic and cranial markers (Bass, 1987; Shipman et al., 1985; White & Folkens, 1991).

The samples utilised here originate from coastal sites within the Gulf of Georgia region and Fitz Hugh Sound (Figure 4.3). Namu is the only site sampled which is outside of the Gulf of Georgia area, located in Fitz Hugh Sound approximately 275 miles northwest of the Gulf of Georgia sites. The Gulf of Georgia region has considerable geological, topographical, and climatic variation, incorporating areas of rising oceanic mountains, an archipelago of islands and reefs, and the Fraser River lowland valley. Their economy - based predominantly on fish, mollusca, and wood - is visible both archaeologically and ethnographically (Burley, 1980). The archaeological samples range in cultural sequences from the Mayne Phase (circa 5500 yBP - 3200 yBP) to the Locarno Beach Phase (circa 3200 to 2500 yBP) to the Marpole Phase (circa 2500 yBP to 400 yAD) to the Coast Salish Phase (circa 400 yAD to contact) (Burley, 1980; Fladmark, 1986; Carlson, 1990). Mitchell (1971) has commented that the Gulf of Georgia's regional prehistory displays cultural, physical, linguistic, and mythological continuity. Burley (1980)
has argued that coterminous cultural complexes within the region share similarities through the prehistoric period. As well, he infers that ethnographic records suggest a considerably lengthy interaction between subregions of the Gulf of Georgia region. For the purpose of this study, therefore, grouping the skeletons as

Figure 4.5. Strait of Georgia region and locations of sites yielding Northwest Coast native skeletal remains utilised in this study.
a prehistoric Northwest Coast sample was deemed valid. Had sample sizes of the individual NW Coast sites, or cultural periods, been large enough it would have been possible to compare sub-samples of the NW Coast group.

Chonos

I obtained data of a Chonos (also referred to as the Chono) skeletal collection from Dr. Israel Hershkovitz, who had studied them in Chile. He studied the shape of both their scapulae and humeri, focusing on somewhat different aspects than I have. Nonetheless, I was able to use some of his data for my comparative analyses. Photographs of Chonos scapulae and humeri reveal evidence of striking musculature, attesting to their lifestyle. As well, the morphology of their upper limbs has been described as particularly robust (Eugenio A. Fontaine, pers. comm.; Hershkovitz, pers. comm.). The sample is comprised of 39 adults of both sexes.

The Chonos are described as a distinctively nomadic canoe people who, at the time of initial European contact in 1553 AD, lived along a 300 mile strip of the Southern Chilean Archipelago (Figure 4.4 - 45°30' to 48° S latitude), the territory between the Guaitecas Islands, the Taito Peninsula, and the Gulf of Penas or the Guinonecus Islands (Cooper, 1917). Travel in this region is accomplished almost exclusively by water, and the island- and mainland coast are covered with dense, extremely wet, temperate rainforests (Cooper, 1963), reminiscent of the environment of the Pacific Northwest Coast of North America.

Ethnographic descriptions of the Chonos are meager, especially details of their material culture (Fontaine, n.d.). Cooper (1967) has stated that nothing has been added to our knowledge of them since 1767. Unfortunately, their population
dwindled after European contact, and they were almost entirely displaced by the actions of missionaries by 1795. The last Chonos sighted were a single family in 1875 (Cooper, 1917). Members of this group have not survived as a distinct biological entity, although some believe they may have merged back with the nearby Alacaluf, a closely related tribe. There are aspects of their culture and somatology which suggest close affinity to the Alacaluf (Cooper, 1963; Fontaine, n.d.).

It is possible that much of the occupational morphology of the Chonos skeletal sample can be explained by their dominant mode of transport. They traveled extensively by water, in earlier times in bark canoes, and subsequently in plank boats. These watercraft aided in their subsistence, as their basic diet is described as consisting of fish, shellfish, seals, and sea lions. Chonos women were
apparently accustomed to diving for shellfish. In addition, they reportedly ate birds, eggs, and stranded whales. Ethnographies describe the Chonos as practicing occasional herding more recently, keeping a few sheep and goats on their islands. Agriculture was sporadic as well, with potatoes, maize, and barley contributing somewhat to their diet. Shaggy dogs were raised and their hair utilised to make short mantles to cover the Chonos' shoulders, as well as to weave blankets. As mentioned earlier, their material culture was poorly described, although there is regular mention of their use of the stone ax.

The Chonos dataset does not include adequate humeral or femoral data. Hershkovitz was unable to pair (by individual) any of the elements, or to match scapulae, humeri, and femora to individuals, as they were found in separate, unmarked boxes (Hershkovitz, personal communication). Thus, of his data I have chosen only the scapulae, as I cannot confidently match them to either the humeri or femora. The scapulae originate from eleven archaeological sites, and individuals are not identified to their right-left pairs. Therefore, it was decided to choose either all right scapulae or all left scapulae for each site, to avoid including both sides of an individual.

Other Material Studied

**Amud 1**

I studied the Amud 1 skeleton at the Rockefeller Museum, Jerusalem. Amud 1 was discovered in 1961 in the Wadi Amud, Israel (Suzuki and Takai, 1970). This middle adult male has been grouped with the Shanidar and Tabun hominids (Trinkaus, 1984) and Kebara 2 (Bar-Yosef et al., 1992) as Near Eastern Neandertals. It is equivocally dated to about 60,000 yBP (Tchernev, 1988).

The Amud left scapular fragment (Figure 4.5), the better preserved of the two sides, consists of a partial glenoid fossa, 70% of the superior axillary border, and the
Figure 4.5. Amud 1 Left Scapula. Dorsal view. Scale in cm. Photo by the Author.
root of the spine. As there are no remains of either scapular bodies, Amud 1 is only included in the glenoid and axillary border sections, as part of grouped Neandertal datasets, and not specifically as I measured it. It is too fragmented and incomplete to be compared extensively in this study.

**Shanidar**

The Shanidar Neandertals, together with the fossils from Amud, Tabun, and Kebbara, complete the sample of Neandertal skeletons discovered to date in the Levant. Unfortunately, political barriers made the Shanidar (Iraq) collection inaccessible to this study. This is unfortunate, as they represent the largest collection of Neandertals from any Near Eastern site. Where possible, the Shanidar scapulae will be referred to by means data published in the excellent volume published by Trinkaus' (1983). However, not all of the variables (measurements) utilised in the present study have been collected from the Shanidar scapulae.

**(B) Methods**

Scapulae are among the more poorly preserved elements archaeologically, even in cases where a skeleton is fairly well preserved (Dwight, 1997). This is to be expected given the thinness and fragility of the scapular body on either side of the spine. Most of the NW Coast scapulae and many of the humeri and femora that I encountered were fragmented, incomplete, and required refitting. This was performed by refitting clean breaks with white glue. If breaks did not join completely they were not reconstructed, and the affected measurements not taken.

The most common preservational state of the scapulae from the NW Coast collection is of a glenoid fossa with the roots of both the acromion and coracoid and the proximal 60% of the axillary border attached. The spine and medial angle
were the next most commonly preserved portions. Recovery of the superior angle was rare, and inferior angle exceedingly rare. The effect of preservational bias is reflected in the comparative sample sizes among the three analyses, with sample sizes for the glenoid fossa section the highest, those involving the medial angle the next highest, and measurements utilising the superior and inferior borders the rarest. Fortunately, the NA Pioneer sample was remarkably well preserved, not surprising given their relatively recent date of burial. As mentioned earlier, for the measurements required Kebara 2's right scapula is lacking only a fraction of the superior angle, which can be confidently estimated.

Study of the NW Coast sample, the largest of the groups, was hindered by fragmentation of many of the scapulae, humeri, and femora. Reconstruction of the elements, primarily the scapulae, was required in most individuals.

**Variables**

All linear measurements were recorded with sliding calipers to an accuracy of one-tenth of a millimetre, with the exception of humeral and femoral lengths which were measured on an osteometric board to an accuracy of one millimetre. Glenoid Fossa Maximum Depth (GFD) was taken by measuring the depth below a line (using string) connecting the most laterally projecting cranio-caudal points on the glenoid. All angular measurements were taken with a contact goniometer on light-shadow traced images (for AX/SP and AX/GL) or directly on the scapula (for SP/MGL) to an accuracy of one degree.

Care was taken to include only those individuals who were unaffected by pathological changes or degenerative joint disease in the shoulder. Individuals showing compensatory (i.e. pathology-induced) use of one arm, and thus a high degree of asymmetry, were excluded. Very few of the values in the dataset are estimates. These were attempted only in cases where a small fragment or margin of
bone was missing, and are considered reliable. Estimated values in the datasets are indicated by brackets around the values.

**Measurements**

**Scapula** (Figure 4.6)

**AX** (Axillary Border Type): The axillary border sulcus was scored as one of three types (discussed and defined in Chapter III): 1 = Ventral, 2 = Bisulcate, 3 = Dorsal.

**GAL** (Glenoid Articular Length): The craniocaudal distance between the outermost edges of attachment of the glenoid labrum of the glenoid fossa (Churchill et al., 1990).

**GAR** (Glenoid Articular Breadth): The dorso-ventral distance between the outermost edges of the attachment of the glenoid labrum of the glenoid fossa (Churchill et al., 1990).

**GPL** (Glenoid Physiological Length): The maximum distance between the two most laterally projecting points of the glenoid fossa (Churchill et al., 1990).

**GPD** (Glenoid Fossa Maximum Depth): The deepest point below a line connecting the two most laterally projecting points used in the GPL measurement. Some fossae have a nearly-central to central pit, which was not included in the depth measurement.

**LEN** (Scapular Length (Martin 1: Morphological Breadth)): Craniocaudal length of the scapula from the superior to the inferior angle.

**BRE** (Scapular Breadth (Martin 2: Morphological Length)): Mediolateral length of the scapula from the medial angle to the middle of the dorsal border of the glenoid fossa.

**S-GL**: Length from superior angle (S) to the center of the glenoid fossa (GL). The center was determined by the intersection of the vertical and horizontal axes of the glenoid.

**L-GL**: Length from inferior angle (I) to the center of the glenoid fossa (GL).

**S-SP** (similar to Martin 6): Length from the superior angle (S) to the mid-point on the dorsal border of the spine (SP), taken along the line used for LEN.

**LSP** (similar to Martin 5): Length from the inferior angle (I) to the craniocaudal mid-point on the dorsal border of the spine (SP), taken along the line used for LEN.
Figure 4.6 Scapular measurements and landmarks utilised in this study.
**SPHT** (Spine Height): "Distance from the line connecting the supraspinatus and infraspinatus surfaces at the lateral margin of the spine to the dorsal most point on the adjacent spine." (Trinkaus, 1983a: 220).

**M-Ax**: Medial Angle(M) (occasionally referred to as the root of the scapular spine (RS) e.g. Johnson et al., (1993)) to the mid-point (Ax) along the axillary border between trigonum infraglenoidale and protractor marginis axillaris.

**S-M** (Martin 6a): length from superior angle (S) to medial angle (M).

**L-M** (Martin 5a): length from inferior angle (L) to medial angle (M).

**SPTK** (Spine Thickness): maximum cranio-caudal thickness at mid-point of the lateral margin of the spine (just medial to the scapular neck), usually taken slightly medially where it normally reaches its minimum thickness.

**AXTK** (Axillary Border Thickness): thickest anteroposterior point on the axillary border, taken perpendicular to the face of the glenoid fossa, not including the infraglenoid tubercle (lateral view).

**AX/SP** (Axillospinal Angle): The measured angle at the caudal end of the glenoid fossa when connecting lines between it and the medial angle (M) and the inferior angle (L). This provides a measure of the mediolateral position of the inferior angle relative to the scapular spine, as well as reflects the distance between the medial and inferior angles (Dorsal view).

**AX/GL** (Axilloglenoid Angle (Martin 16): The measured angle at the most caudal tip of the glenoid fossa when connecting lines from it to the inferior angle (L) and to the most cranial point of the glenoid fossa. This provides an angular measure of the position of the inferior angle (L) relative to the position of the glenoid fossa (Dorsal view).

**SP/MGL** (Spino-MidGlenoid angle): In lateral view, this is measure of the angle of the spine (and the related Acromion process) relative to the glenoid fossa. It is measured at the point at which a line bisecting the spine intersects with a line dividing the glenoid fossa cranio-caudally (commonly the same line used in measuring GAL) (Lateral view).

**Humerus**

**HL** (Maximum Humeral Length - Martin 1)

**HHD** (Humeral head diameter - Martin 10): Maximum Anteroposterior Head Diameter.

**HDB** (Distal articular breadth)
Femur

FL (Maximum femoral length)

FemAP: Maximum anteroposterior diameter of the femur at mid-shaft.

Data Preparation

The first stage of data preparation was side-selection, or, the reduction of measurements (i.e. two) taken from both sides of an individual to a single, usable measurement. It is contingent upon the fact that redundancy of measuring both sides of an individual has to be eliminated by choosing only one value per individual (for those individuals with both scapulae present). This can be done in a number of ways: (1) Average the right and left side measurements in each individual. (2) Choose to use one side for the entire sample, with the possibility of plugging in any missing values from the opposite side (if present on the opposite side - either as measured, or corrected for missing values by prediction equation). (3) Choose either side per individual. This can be done by either selecting the best preserved side, or randomly picking sides if equally preserved, with the possibility (as in #2) of plugging in missing values from the opposite side (if present on the opposite side - either as measured, or corrected).

In choosing a suitable method, the relatedness of measurements within each scapula was deemed a primary criterion. By related I mean to suggest that as a bone (or element) is architecturally structured with its points mechanically and developmentally interrelated, it is probably most sensible to keep as many measurements from each side together as possible. For example, considering that the length and breadth of the glenoid fossa are linked to its function as a joint, it seems more appropriate to keep the measurements together, rather than averaging sides and creating a hypothetical glenoid fossa. Furthermore, the most critical
measurement in the glenoid section, the glenoid index (GLE=GAB/GAL*100), like other indices, is highly sensitive to even a difference of a few millimetres. Thus, averaging sides could produce quite different results than was actually the case in either shoulder of a chosen individual. For the humerus, as well, it is functionally appropriate to keep individual sides together with their respective scapulae. This is especially pertinent for consideration of the relationships between humeral head diameter, glenoid dimensions, and glenoid flattening, as there is an inherent assumption that there must exist a biomechanical relationship between the humeral head and the glenoid fossa.

Method #3 was chosen as the most adequate for this study, primarily for the reasons that (a) it will recover the most related variables (more than method #2), and (b) it does not create the sort of hypothetical element that method #1 does.

In summary, the method for side-selection for the scapular data was as follows: (1) The best preserved side was chosen. If the sides were equally preserved then one side was randomly picked. (2) Plugging in missing values from the opposite side, if present, and corrected for asymmetry if higher than 5.0%.

Asymmetry was assessed in the sample (for scapulae, humeri, and femora) by averaging Right minus Left scores (for each sex) for each measurement, and it was determined that asymmetry was very low for most of the variables, with most values lying between +1% to +3% (+ = right side asymmetry, - = left side asymmetry). As well, some variables displayed very low left side (-) asymmetry. A few variables displayed higher asymmetry, with 4 variables scoring between 5.2% and 6.6% (either + or - ). It is for these values, those showing higher than 5% asymmetry in either direction, that prediction equations were calculated and used (if the unchosen side preserved the missing measurement).

Side selection for the humeri used the same criterion as for the scapulae, but priority was given to choosing the same side as that chosen for the matching
Thus, for example, if a right scapula were chosen for a given individual priority was given to the right humerus. This seems most reasonable considering that there is shared musculature, as well as articular and biomechanical forces between each paired scapula and humerus. On the occasion that sides could not be matched, the opposite side humerus was chosen. Asymmetry was low for all the humeral measurements (all less than 0.8%). Because of its relationship to the glenoid fossa, HHD is central to this study. Fortunately, asymmetry was low in this measure (+0.8 in males, +0.2 in females) and thus using head diameters from the opposite side should realistically reflect the true case. However, for the majority of the sample, sides were matchable.

Side-selection for the femora was done by simply matching sides to the humeri if possible, or using the opposite side if necessary. Femoral length showed minimal asymmetry (-0.1% in males, -0.3 in females). As the femur does not share a direct mechanical relationship with the scapula or humerus there was no concern about its influence on the scapular data if the opposite side femur had to be utilised.

Data from a comprehensive study by Churchill and Trinkaus (1990) was incorporated into the glenoid analysis. It is important to note that, in contrast to the present work, they averaged their right and left side measurements. To allow comparison to Churchill and Trinkaus' results, all indices in the glenoid section were multiplied by 100 (*100) (allowing for ease of interpretation). Thus, the value for a given index is transformed into a percentage (%). As discussed in Chapter II, and defined in this chapter, all indices apart from GLE (the relative width of the glenoid fossa) were created by Churchill and Trinkaus (1990). Vallois (1928-46) was the first to calculate the relative width of the glenoid in Neandertals.
Size Standardisation

In morphological comparisons size differentiation between individuals (and populations as well) can often reflect what are essentially concomitant differences in bone dimensions. One example of this is the positive correlation between limb lengths and height - i.e. that taller individuals, in general, have longer humeri and femora than do shorter individuals (Huber, 1968; White & Folkens, 1991). In general, most elements of the skeleton correlate to overall body size, and thus for some analyses measurement correction, or standardisation, is desirable in order to make measurements for individuals of different size comparable.

For the present study all variables in the body and axillary border analyses, except angular measurements and the axillary sulcus type, were scaled for size against humeral length. This was done to give a more realistic measure of shape differences, accounting for differences in body size between individuals. To transform, the respective scapular measurement was divided by Humeral Length and multiplied by 100 (i.e. [scapular measurement/HL]*100). This provides a percentage scapular measurement of humeral length. Angular measurements and indices (those not utilising HL) were not transformed. Both non-scaled and scaled data were analysed, and are presented together. In anticipation of size standardisation humeral and femoral lengths were measured (as detailed above) in individuals preserving these elements. As the humerus is not weight-bearing (Ruff et. al., 1993), and thus less suspect to curvature, it was chosen as the better element of the two for standardisation. In a study of paired male humeri from crew of the Mary Rose, Sturiland (1993) observed a number of ride-side asymmetries, and that of these only maximum humeral length appears to be congenital in origin. She concluded that humeral length appears to be unaffected by activity, being congenital in origin, but adds that "congenital asymmetry in humeral length may be enhanced by preferential use of the right arm" (1993, 109).
Humeral length was not available for all individuals. Fortunately, humeral length correlates highly with femoral length (fig. 4.7) so that it can be calculated with reasonable confidence for those individuals lacking measurable humeri. As well, plotted residuals displayed a constant width (random) pattern and attest to the linearity of humeral and femoral lengths.

Unfortunately, humeral and femoral lengths were unavailable for some individuals, and for the entire Chonos sample. For the Chonos it was impossible to match individual scapulae, humeri, and femora with the cataloguing information provided (Hershkovitz, pers. comm., 1994). These individuals were not included in comparisons utilizing data scaled against humeral length. However, individuals lacking the required elements with which to standardise were included in the non-scaled tests.
Statistical Techniques

To test for statistical differences in measures between the Neandertals and the comparative groups, the following techniques were applied:

In the (1) glenoid fossa analysis two-tailed student t-tests were employed to compare means of indices between Neandertals and the other groups. As well, data was analysed using ANOVA followed up with Tukey's HSD test for pairwise comparisons. All tests were done on grouped, not raw, data, as raw data was unavailable for Churchill and Trinkaus' (1990) samples. To assess the variability of results of ANOVA on raw vs. group values, ANOVA were performed on both the raw and grouped data for the NW Coast and NA Pioneer samples. The results of these tests were extremely similar, lending to the reliability of results of ANOVA on group data.

In the (2) scapular body analysis both scaled and unscaled variables were tested with a single variate two-tailed t-test, comparing Kehara to the other groups. And finally, in the (3) axillary border section the three different types were tested for differences in border thickness with two-tailed t-tests of both scaled and unscaled variables.
Chapter V: Results

As outlined earlier the analyses were split into three sections (which correspond to anatomical regions): (1) the glenoid fossa, (2) the scapular body, and (3) the axillary border. A discussion of how these regions relate to one another, and consideration of Neandertal scapulae in general, is presented in Chapter VI.

(1) Glenoid Fossa

For this section of the analysis, comparative data from a recent comprehensive analysis of Neandertal glenoid morphology (Churchill & Trinkaus, 1990) will be included. The Kebara right scapula was grouped with other Neandertal scapulae (n=16) in Churchill and Trinkaus' (1990) analysis, and they were compared to a sample of Early Upper Paleolithic (E.U.P.) Humans (n=5) and Modern Humans (n=99). The Modern Human group consists of recent Euroamericans (n=49) and late prehistoric (Puebloan) Amerindians (n=50). Churchill & Trinkaus' (1990) results will be re-analysed with reference to the three additional groups considered here (NW Coast, NA Pioneer, and Chonos) to resolve if and how Neandertal glenoid morphology differs from these additional samples of modern humans. In data preparation of the samples added here males and females were grouped to conform to Churchill and Trinkaus' methods. The descriptive statistics for glenoid measure appear in Table 5.1, and the descriptive statistics and results of t-tests between the Neandertals and the other groups for the glenoid indices appear in Table 5.2.

The Glenoid Fossa Index (GFI)

The glenoid fossa index (GFI = GAB/GAL) is the most fundamental measure for describing the relative breadth of the glenoid fossa. It is commonly
Table 5.1. Mean scapular and humeral measurements. Mean, SD, and n for Neandertal, E. Upper Paleolithic, and Modern Human values from Churchill and Trinkaus (1990). Italicised values are estimates (see text). GAL = glenoid articular length, GPL = glenoid physiological length, GAB = glenoid articular breadth, GFD = glenoid fossa maximum depth, HL = maximum humeral length, HHD = humeral head diameter, HDB = humeral distal articular breadth.

<table>
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<tr>
<th></th>
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<th>GFD</th>
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<th>HHD</th>
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<tr>
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<tr>
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<tr>
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<td></td>
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</table>

Cited as indicative of the narrowness of Neandertal glenoid fossae (Stewart, 1962; Trinkaus, 1983b; Churchill and Trinkaus, 1990; Trinkaus et al., 1991). Figure 5.1

Plots Churchill and Trinkaus' (1990) group means for the glenoid indices of their Neandertals, E.U.P. and modern human samples, along with the three additional groups (NW Coast, NA Pioneers, and Chonos) considered here (all plotted with two standard errors (95% confidence interval)).
<table>
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<tr>
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</tr>
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<td></td>
</tr>
<tr>
<td>NW Coast</td>
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<td>16</td>
</tr>
<tr>
<td>Mean</td>
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<td>1.1(0.4)</td>
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<td>SD(SE)</td>
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<td>99</td>
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</tr>
<tr>
<td>Chonos</td>
<td>74.1</td>
<td>3.0(0.8)</td>
<td>98</td>
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</tbody>
</table>

Table 5.2. Average glenoid indices for 6 groups. Mean, SD, and n for Neandertal, modern human and E.U.P. groups from Churchill and Trinkaus (1990). All indices are multiplied by 100. Asterisks and refer to results of t-tests. Significantly different (t-test) from Neandertals at: *p<.05 **p<.01 ***p<.001

Although significantly different, GAB is narrower relative to HDB than in Neandertals.
Churchill and Trinkaus (1990) have shown their E.U.P. and modern human samples to be significantly different from both comparative groups (P<.001). It is clearly observable in figure 5.1 and table 5.2 that the Neandertal and NW Coast means are identical, while the E.U.P., Modern Human, and Chonos are very similar to each other and do overlap, but are all considerably different than the Neandertal and NW Coast groups. The NA Pioneer mean is intermediate, their upper and lower limits overlapping the other groups. The results of t-tests (table 5.2) corroborate this

![Graph showing relative glenoid breadth for different groups](image)

Figure 5.1. Glenoid fossa indices (GLE) for six groups (error bars = two standard errors). Neandertal, E.U.P. Paleolithic, and modern human data from Churchill and Trinkaus (1990).

- that there is no significant difference between the Neandertals and NW Coast groups in relative glenoid breadth. The t-test for the NA Pioneer–Neandertal comparison suggests that the two groups differ significantly in GLE (p<.05), but
Tukey's HSD value (4.26) implies the contrary, that the NA Pioneers and Neandertals do not differ as tested. The Chonos, Modern Human, and E.U.P groups are markedly distinct from the Neandertals (p<.001). The results for the Early Upper Paleolithic sample should be considered with caution, however, given the small sample size (n=5).

In light of the above, the suggestion by other workers (e.g. Stewart, 1962; Churchill and Trinkaus, 1990) that Neandertals exhibit relatively narrower glenoid fossae than modern humans may be questioned. As GLE in the NW Coast and Neandertal samples do not differ significantly, their value in fact identical, a relatively narrower glenoid fossa cannot be distinguished as a condition exclusive to Neandertals. Clearly all of the comparative samples included here are modern humans, and thus Neandertals and at least one modern human group (NWC) are identical in the relative width of their glenoid fossae. Additionally, the NA Pioneers do not differ as tested with Tukey's HSD statistic, and as well deemphasise the uniqueness of Neandertal glenoid morphology.

Churchill and Trinkaus (1990) have presented other morphological anomalies of Neandertal glenoid fossae. Some of these will now be addressed. It should be noted that the measurements for the remainder of the glenoid fossa analysis were not obtainable for the Chonos. Only glenoid articular measures were available from the Chonos scapulae, and as a result this group was not included in the remaining glenoid analyses.

**The Glenoid Fossa and Humeral Joint Surfaces**

The degree of curvature (Depth = GFD/GPL) of the glenoid fossa is distinct in Neandertals compared to the other 4 groups (fig. 5.2, table 5.2). As others have noted (Stewart, 1962; Churchill and Trinkaus, 1990) Neandertals possess flatter
glenoid fossae. However, Churchill and Trinkaus (1990) have recently shown that the flattening of the glenoid in Neandertals is simply a by-product of a larger humeral head, in that they represent arc segments from larger circles than do the fossae of the modern humans (whose humeral heads possess smaller circles).

Therefore, the size of the humeral head must be considered in interpreting the curvature of the fossa. Comparison of glenoid fossa and humeral head radii of curvature (HHRC/GFRC, Table 5.2) indices indicates that, as tested by t-test, only the NA Pioneer group differs from Neandertals (p<.05) in the shape relationship between humeral head and glenoid depth. In contrast to the results of the t-test, Tukey's HSD value (9.88) negates that the NA Pioneers are different in this index. Caution should be taken in accepting any of the results of this comparison, as the Neandertal sample may be biased (n=4): the standard deviation (0.8) and variance (0.4) are quite low compared to the other groups. As well, t-tests require homogeneity of variance between the samples and this is not the case for the groups in this measure.

Depth aside, the scaling of the glenoid fossa to proximal and distal humeral joint surfaces was measured with 4 indices: (1) GAL/HHD; (2) GAB/HHD; (3) GAL/HDB; and (4) GAB/HDB. These allow direct comparison to Churchill and Trinkaus' (1990) study which, with use of these measurements, showed that Neandertals glenoid fossae are not only narrow relative to their lengths, but are also narrow relative to humeral joint surfaces. Table 5.2 and figures 5.3 - 5.6 present the results of these comparisons, with the NA Pioneer and NW Coast Groups added.

The present research confirms the observation (Churchill & Trinkaus, 1990) that glenoid length relative to humeral head diameter (GAL/HHD) does not differ between Neandertal and more recent human groups (table 5.2, fig. 5.3). However, glenoid length relative to humeral distal articular breadth (GAL/HDB) in the NA Pioneer and E.U.P. groups does differ significantly (p<.05) from Neandertals, the
length of their fossae relative to HDB being shorter and longer, respectively, compared to the Neandertal group (fig. 5.5). Neandertals do not differ from the NW Coast and modern Human groups in this measure.

With respect to the breadth of the glenoid fossa and humeral joint surfaces, the results of the GAB/HHD and GAB/HDB comparisons are of particular significance (Figures 5.4 and 5.6, table 5.2). Churchill and Trinkaus (1990)

![Graph showing Glenoid depth indices](image)

Figure 5.2 Glenoid depth indices (Depth) for five groups (error bars = two standard errors). Neandertal, E.U. Paleolithic, and modern human data from Churchill and Trinkaus (1990).

illustrated the narrowness of the glenoid fossa relative to humeral joint surfaces in Neandertals, being significantly different from the condition in modern humans. However, addition of the NA Pioneer and NW Coast samples does not confirm these observations, and in fact falsifies the hypothesis of Neandertal uniqueness in this regard.
Firstly, it can be seen (Figure 5.4, table 5.2) that there is no difference in the relative breadth of the glenoid fossa compared to humeral head diameter (GAB/HHD) between the Neandertal, NW Coast, and NA Pioneer groups. These 3 groups have relatively narrower fossae when compared to the E.U.P. and Modern Human samples. The t-tests performed here confirm that Neandertals do differ significantly from the Modern Human (p<.001) and E.U.P. (p<.05) groups (as Churchill and Trinkaus (1990) indicated).

![Figure 5.3: GAL/HHD Indices for five groups (errors bars = two standard errors). Neandertal, E.U. Paleolithic, and modern human data from Churchill and Trinkaus (1990).](image1)

![Figure 5.4: GAB/HHD Indices for five groups (errors bars = two standard errors). Neandertal, E.U. Paleolithic, and modern human data from Churchill and Trinkaus (1990).](image2)

![Figure 5.5: GAL/HDB Indices for five groups (errors bars = two standard errors). Neandertal, E.U. Paleolithic, and modern human data from Churchill and Trinkaus (1990).](image3)

![Figure 5.6: GAB/HDB Indices for five groups (errors bars = two standard errors). Neandertal, E.U. Paleolithic, and modern human data from Churchill and Trinkaus (1990).](image4)
Secondly, comparison here of GAB relative to the humeral distal articular breadth (GAB/HDB; table 5.2, fig. 5.6) corroborates that Neandertals have significantly narrower fossae than do Churchill and Trinkaus' Modern Human and E.U.P. groups (p<.001). However, the NA Pioneer sample is indistinguishable from Neandertals in this index while the NW Coast group, although differing significantly (p<.05) from the Neandertals, possess relatively narrower fossae relative to HDB than do the Neandertal and NA Pioneer samples. It should be noted that Tukey's HSD value (4.26) implies, in contrast to the t-test results, that the NW Coast and Neandertal means are not significantly different. Despite the discrepancies of these two tests, the fact remains, most importantly, that the glenoid fossae of the NW Coast natives are either as narrow (Tukey's HSD test) or narrower (t-test) than the Neandertals' relative to the distal articular breadth of their respective humeri.

These similarities negate the conclusion that "... for any given humeral joint surface, Neandertals exhibit a narrower fossa than would an anatomically modern human" (Churchill & Trinkaus, 1990: 154). It has been shown here that at least two groups of anatomically modern humans possess fossae as narrow as Neandertals (relative to humeral joint surfaces), and in one group it is in fact narrower (NW Coast: GAB/HDB).

The Glenoid Fossa and Humeral Length

Churchill & Trinkaus (1990) have shown that glenoid length and breadth respond more dramatically to changes in humeral length in Neandertals than in their sample of Modern Humans and Early Upper Paleolithic Humans. By regressing glenoid length and breadth on humeral length and noting marked differences in slopes, intercepts, and coefficients of determination (R^2) between groups they determined that there is a tighter relationship between body size (i.e.
humeral length as an indicator of body size) and these glenoid dimensions in the Neandertal sample.

Figure 5.7 displays the regression plots for glenoid dimensions on maximum humeral length for the NW Coast and NA Pioneer samples. For reason stated earlier, Churchill and Trinkaus' samples could not be included in these plots as, their individual values were not available. For both glenoid dimensions the NW Coast sample shows low correlations \( r^2 = 0.25 \) and \( r^2 = 0.40 \), respectively) with maximum humeral length. The NA Pioneer group's humeral length, while showing a low correlative relationship with glenoid length \( r^2 = 0.28 \), proves to be a relatively good predictor of glenoid breadth \( r^2 = 0.78 \), just as in the Neandertal group \( r^2 = 0.86 \). It appears that humeral length and glenoid articular dimensions do have a considerably tighter relationship than the recent human groups considered here. However, inferences drawn from small sample regression analysis should be approached cautiously.

(2) The Right Scapular Body of Kebara 2

Neandertal scapular bodies have been shown to be wide, to have high axillospinal and axilloglenoid angles, and to have elevated spine heights (Stewart, 1962; Trinkaus, 1983a, 1983b, 1989) relative to various modern human samples. These changes are suggestive of hypertrophy and enlargement of the attachment area of scapular musculature, especially of the rotator cuff muscles (which relate to the axillary border discussed next in section (3) of this chapter). The Kebara 2 scapular body was compared to the NW Coast, NA Pioneer, and Chonos groups to see if it is distinguishable in these areas as well. Reference and comparison is made to other Neandertal scapulae where possible.

Although in the past sexes have been mixed in comparisons of this nature (e.g. Stewart, 1962, Trinkaus, 1983b) I chose to compare the Kebara scapula to
For comparison:

\[
\begin{align*}
\text{GAL} & = -42.168 + 0.256 \times \text{HL}; R^2 = 0.84 \text{ (Neandertals)} . \\
\text{GAL} & = 7.725 + 0.085 \times \text{HL}; R^2 = 0.40 \text{ (Recent Humans)} . \\
\text{GAB} & = -31.621 + 0.181 \times \text{HL}; R^2 = 0.86 \text{ (Neandertals)} . \\
\text{GAB} & = 7.656 + 0.056 \times \text{HL}; R^2 = 0.35 \text{ (Recent Humans)} .
\end{align*}
\]

Figure 5.7. Regression plots of glenoid fossa dimensions (GAL = glenoid articular length, GAB = glenoid articular breadth) on maximum humeral length (HL). Prediction equations and coefficients of determination for Neandertals and recent humans from Churchill & Trinkaus (1990).
males only of the above groups. Analysis of the three groups revealed significant between-sex differences in most measures, and thus warranted exclusion of females. Given that females, in general, will have smaller scapulae inclusion of female variables would tend to overstate size differences between the Kebara scapula, that of a male, and the other groups.

Restricting the analysis to males reduced group sample sizes considerably. In some group comparisons this would leave as low as 3 individuals for a given group, with most retaining 6 to 7 individuals. Testing for significant differences between Kebara 2 and samples of such low sizes would not allow for confident results. To alleviate this dilemma I clustered the NW Coast, NA Pioneer, and Chonos males into a recent human group, which was then compared to Kebara 2. Reference is made to the original groups where appropriate, particularly in cases where one group is more similar or dissimilar to the Neandertal scapula.

As detailed in Chapter IV the variables for the body were examined, and are presented, as both raw and scaled. Although emphasis is on comparison of Kebara to the recent human group, the individual sub-groups were also compared to Kebara. They are referred to where necessary i.e. when there is significant recent human sub-group variation.

The body was divided into four study areas: (a) the overall Body, (b) the supraspinous fossa (c) the infraspinous fossa, and (d) the spine. As discussed previously, the Chonos dataset is incomplete. Scaling was not possible for the latter, as there are no humeri available. As well, only LEN, BRE, S-M, and I-M were available from their dataset. Thus, raw data of only their overall body size and the medial portion of their scapular body could be examined.
(A) The Overall Shape of the Scapular Body

The overall shape and size of the scapular body was analysed to determine if the right scapula of Kebara 2 is diagnostically Neandertal in nature. In order to study the shape of the body LEN, BRE, M-AX, and Scapular Index (ScapIndx = BRE/LEN) were compared. These measurements describe the morphological length and breadth of the scapula, as well as the breadth from the medial angle to the midpoint along the axillary border. The results are presented in table 5.3.

In overall shape tests Kebara 2 differed significantly (p<.05) only in M-AX/HL. This measurement is a diagonal (inferolateral) breadth, as opposed to a horizontal (mediolateral) breadth such as BRE. As the scapula lengthens, the point AX moves further away from the medial angle, so that a high M-AX value may not necessarily indicate a wide scapula. It may indicate that the infraspinous fossa was enlarged in Kebara, relative to humeral length, affecting the insertional area of the located rotator cuff musculature.

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<th>BRE/HL</th>
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<td>15</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Kebara 2</td>
<td>167.0</td>
<td>52.7</td>
<td>107.0</td>
<td>33.8</td>
<td>101.0</td>
<td>31.9*</td>
<td>64.1</td>
</tr>
</tbody>
</table>

Table 5.3. Overall Body Measures and Indices (ScapIndx = LEN/BRE). All indices multiplied by 100. Recent humans = NW Coast, NA Pioneer, and Chonos groups combined.
* Significantly different from Recent Humans at: P<.05

Although LEN & BRE were not significantly different as tested, Kebara's values lie at the upper end of the sampled variation of the comparative groups (fig. 5.8), especially for BRE. In fact, scaling of these measures (/HL) consistently distanced Kebara from the recent humans (i.e., lower p-values in tests of scaled...
variables), suggesting that Kebara is relatively large in overall scapular body shape (fig. 5.8). As can be seen in table 5.3, however, there are no differences in scapular breadth to length ratios ($\text{ScapIndx}$), suggesting perhaps a critical relationship between scapular height and breadth for humans, although the correlation coefficient ($R^2 = 0.32$) for scapular length regressed on breadth is lower than would be expected for a tight relationship. Splitting the recent humans by group showed no statistically significant difference in Scapular Index between the NA Pioneer, NW Coast, and Chonos groups.

For comparison, scapular breadths of other Neandertals are as follows: Shanidar 2, 3, and 4 - 116.0, 115.0, and ca. 115.0 mm, respectively; La Ferrassie 1 - 121.5 mm; Krapina 125, 127, 130, and 132 - ca. 115.0, 100.0, ca. 107.0, and ca. 107.0 mm, respectively (Trinkaus, 1983b). At 107.0 mm, The Kebara 2 is at the lower end of the range of values for these individuals, and fits within this pattern of relatively wide Neandertal scapulae. It should be noted that these values are unscaled.
(B) The Supraspinous Fossa

The shape of the supraspinous fossa was examined with specific reference to the superior angle. It should be noted that the upper most margin of the superior angle is missing on the Kebara right scapula. However, in my experience its point can be estimated with a high degree of accuracy. The three measurements used were S-GL, S-SP, and S-M, all distances involving the superior angle. BRE, discussed previously, gives a vague sense of how wide the base of the supraspinous fossa is, but is not accurate enough to be considered as informative in this section. Ideally one might measure from the floor of the scapular notch to the medial angle to determine the breadth of the border, but this measurement is not possible in either Kebara scapulae.

Table 5.4 presents the results of the supraspinous fossa comparison.

<table>
<thead>
<tr>
<th></th>
<th>S-GL</th>
<th>S-GL/HL</th>
<th>S-SP</th>
<th>S-SP/HL</th>
<th>S-M</th>
<th>S-M/HL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recent Humans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>86.0</td>
<td>26.1</td>
<td>38.8</td>
<td>11.4</td>
<td>53.3</td>
<td>15.6</td>
</tr>
<tr>
<td>SD(SE)</td>
<td>7.1(2.0)</td>
<td>1.8(51)</td>
<td>4.8(1.4)</td>
<td>.86(26)</td>
<td>5.8(1.2)</td>
<td>1.9(55)</td>
</tr>
<tr>
<td>n</td>
<td>13</td>
<td>12</td>
<td>12</td>
<td>11</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td><strong>Kebara 2</strong></td>
<td>89.5</td>
<td>28.2</td>
<td>31.4</td>
<td>9.9</td>
<td>48.1</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Table 5.4. Supraspinous fossa measures and indices. All indices multiplied by 100. Recent humans = NW Coast, NA Pioneer, and Chonos groups combined. No significant differences as tested.

There were no significant differences between Kebara and the recent humans. As well, there were no significant differences among the sub-groups of the recent humans. What can be gleaned from the data, and will be referred to in the next section, is that in scaled measures the superior angle of Kebara lies somewhat closer to the spine than in the recent humans (Fig. 5.9). This is particularly apparent when S-SP is scaled against humeral length.
(C) The Infraspinous Fossa

The morphological and mechanical importance of the inferior body lies in its role as the cradle of the rotator cuff musculature. The rotators of Neandertals have always been considered formidable (Trinkaus, 1983a, 1983b, Churchill and Trinkaus, 1990; Trinkaus et al., 1991), and this section will attempt to interpret the musculature of Kebara 2 in this regard.

<table>
<thead>
<tr>
<th></th>
<th>L-GL</th>
<th>L-G°/HL</th>
<th>L-SP</th>
<th>L-SP/HL</th>
<th>L-M</th>
<th>L-M/HL</th>
<th>Infrspin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent Humans</td>
<td>144.0</td>
<td>43.9</td>
<td>122.8</td>
<td>37.3</td>
<td>119.0</td>
<td>37.2</td>
<td>76.5</td>
</tr>
<tr>
<td>Mean (SD/SE)</td>
<td>8.58 (2.43)</td>
<td>6.30 (1.81)</td>
<td>2.66 (0.74)</td>
<td>7.80 (1.60)</td>
<td>2.70 (0.60)</td>
<td>1.70 (0.50)</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>13</td>
<td>13</td>
<td>12</td>
<td>12</td>
<td>24</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Kebara 2</td>
<td>146.6</td>
<td>46.2*</td>
<td>137.3*</td>
<td>43.3*</td>
<td>137.3*</td>
<td>43.3*</td>
<td>81.4*</td>
</tr>
</tbody>
</table>

Table 5.5. Infraspinous (Infraspinous fossa) Measures and Indices. All Indices multiplied by 100. Recent Humans = NW Coast, NA Pioneer, and Chonos groups combined.

* Significantly different from Recent Humans at: P<.05
The results of the infraspinous fossa tests are shown in tables 5.5. For every linear measurement, both scaled and unscaled, except unscaled I-GL, Kebara is significantly larger than the recent humans (P<.05). As well, the infraspinous index is significantly higher (P<.05) in Kebara, with 81.4% of its scapular length accounted for by the length of the infraspinous fossa. Interestingly, as shown in the supraspinous fossa analysis, the low height of supraspinous fossa in Kebara may relate to this. The superior angle in the recent humans appears to be further away from the spine than Kebara 2, whereas the inferior angles are more distant from the spine in Kebara 2. Among all individuals Kebara 2, in fact, has the highest values for each of the scaled and unscaled linear measurements, except unscaled I-GL. As well, Kebara 2 has the largest Infrasp1n value of any of the individuals. This suggests that the infraspinous fossa was enlarged in Kebara 2, as illustrated by the increased distance of the inferior angle from the medial

<table>
<thead>
<tr>
<th></th>
<th>AX/SP</th>
<th>AX/GL</th>
<th>I-SP/BRE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recent Humans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>56.8</td>
<td>134.2</td>
<td>118.4</td>
</tr>
<tr>
<td>SD/SE</td>
<td>4.6(1.5)</td>
<td>4.9(1.5)</td>
<td>10.1(3.0)</td>
</tr>
<tr>
<td>n</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Kebara 2</strong></td>
<td>67.0</td>
<td>145.0</td>
<td>128.3</td>
</tr>
</tbody>
</table>

Table 5.6. Infraspinous Angles & Indices. All Indices multiplied by 100. Recent Humans= NW Coast & NA Pioneer groups combined. AX/SP & AX/GL are measured in degrees. No significant differences as tested.

angle, the spine, and the glenoid fossa. Enlargement of the lower scapular body suggests a size and strength increase in the related musculature, that of the rotators. The surface areas of the infraspinatus and subscapularis attachments would be particularly affected.

The angular measurements AX/SP and AX/GL describe how large the infraspinous fossa is. AX/SP is the angle between the inferior and medial angles
taken at the inferior glenoid fossa margin, and AX GI, the angle between the inferior angle and the superior glenoid border taken at the inferior glenoid fossa margin as well. A more obtuse angle has been taken to represent a larger infraspinous fossa (see, for example, Trinkaus, 1983b).

Although Kebara 2 does not differ significantly from the recent humans as tested in these angles, it lies at the upper end of both the recent human sample’s variation (fig. 5.10 & table 5.6), and the Neandertal range. Kebara’s high AX/SP angle is similar to Shanidar 1 & 3 (67.0° and ca. 60.0°, respectively). However, not all Neandertals have high axillospinal angles. Tabun C1 (55.0°), as L, as well as Trinkaus (1983b) have measured it, and a sample of European Neandertals (56.7° ± 1.5°, n=6) (Trinkaus, 1983b) lie well within the range of the recent humans. A range of the mean axillospinal angles of 16 recent human samples has been reported by Vallois (1928-1946, in Trinkaus, 1983b) to be 40.5–47.8°, and are all

![Figure 5.10. Scapular angular measurements. Error bars = two standard deviations. Recent human group includes NA Pioneer and NW Coast samples.](image)

below the mean for the modern human sample studied here. Compared to other Neandertals Kebara’s axilloglenoid angle is also high (145°), slightly above the
mean of a European Neandertal sample (145.6° +/- 5.3°, n=7) and greater than that of Amud 1 (140°) and Tabun CI (132°). La Ferrassie1's estimated value (ca 145.0° (Trinkaus, 1983b)) is identical to Kebara 2. Trinkaus (1983b) reports that the total range of Neandertal axilloglenoid variation is 132°-150° (n=9), into which Kebara 2 fits comfortably at the upper end.

The axillospinal and axilloglenoid angles represent angular placement of the inferior angle and axillary border relative to the medial angle, and the glenoid fossa, respectively. This suggests an enlargement of the rotator cuff musculature, as Trinkaus (1983b) has proposed for the Shanidar Neandertals. It would suggest that the higher angles may also mean that the orientation of the axillary border relative to the humerus was different, perhaps enhancing the use of t. minor, a major humeral lateral rotator. Each of these angles suggest that Kebara 2 had a more expansive infraspinous fossa than the recent human group. Although this is not

![Figure 5.11 Infraspinous length relative to scapular breadth. Error bars = two standard deviations. Recent humans include both NW Coast and NA Pioneer groups. Index is multiplied by 100.](image-url)
discernible as statistically tested for angular measures, it is suggested that the observation is meaningful.

Trinkaus (1983b) has reported the I-SP/BRE (Infraspinous length / Scapular Breadth * 100) indices for Shanidar 3 (110.4), a recent human sample (112.0 +/− 1.1, n=30), and La Ferrassie 1 (123.5). From this he concluded that La Ferrassie had very wide and high scapulae. If this interpretation is correct the value of Kehara 2 (128.3), greater than La Ferrassie 1, suggests that it also had very wide and high scapulae. However, given that Kehara 2 does not differ significantly from this recent human sample (table 5.6, fig. 5.11) this conclusion is highly equivocal. It fits well within the recent human range, although above the group mean.

The wide scapular breadth, enlarged infraspinous fossa, and increased axillospinal and axilloglenoid angles of Kehara 2 lead to the conclusion that the individual, like other Neandertals, had heavily muscled upper limb. The enlargement of the infraspinous fossa, observable through high angles and increased linear measurements, facilitated concomitant changes to the rotators, especially supraspinatus, infraspinatus, and subscapularis. The lengthened vertebral border, as seen in a long I-M value, allows for longer origins of both rhomboideus minor and r. major. Teres minor and t. major would see more expansive origins along the axillary border, the border enabling a long area of attachment as evidenced by a high I-GL. value. The enlarged scapular breadth would have lengthened the spine, and increased the area of muscular attachment of deltoide and trapezius. Thus, the architecture of Kehara 2's lower scapular body reflect increased musculature and strength of the upper limb.

(D) The Spine

Trinkaus (1983a, 1983b) has commented that the scapular spines of Neandertals lie relatively high off the meeting point of supraspinatus and
infraspinatus, immediately adjacent the lateral margin of the spine on the dorsal surface. This would move the acromion, and deltoid, further away from the axis of rotation of the glenohumeral joint, enhancing the effectiveness of deltoid, the primary humeral abductor (supraspinatus is the other *prime* humeral abductor) (Trinkaus, 1983a). Accordingly, it would also enlarge the surface area for the rotator cuff musculature by increasing the volume of muscle fibres contained on the dorsal surface of the scapula (Trinkaus, 1983b). This section compares the spines of Kehara and the recent human group. The recent humans do not include the Chonos sample, for which spine data is presently unavailable.

As discussed earlier, this section utilises two measurements not known to have been performed elsewhere. Spine Thickness (SPTK) measures the thickness

![Graph](image.png)

**Figure 5.12. Spine Thickness regressed on Spine Height (mm) (Males only).**
of the spine at the mid-point of the lateral margin, and SP/MGL the angle between
the spine and the coronal craniocaudal plane of the glenoid fossa. For a
perspective on the relationship between spine height and thickness, spine height is
regressed on spine thickness in figure 5.12. The NW Coast group show the higher
correlation of the two, although neither is particularly strong.

The spine of the scapula anchors the primary humeral abductor, deltoïd,
and the primary scapular elevator trapezius. It should be noted that the nature of
the spine, particularly at the acromial end, is likely influenced by the orientation
and activity of the clavicle. Supraspinatus originates in the supraspinous fossa, part
of which is on the superior portion of the spine. Thus, it may also participate in
structuring the spine.

<table>
<thead>
<tr>
<th></th>
<th>SPHT</th>
<th>SPHT/HL</th>
<th>SPTK</th>
<th>SPTK/HL</th>
<th>SPTK/SPHT</th>
<th>SP/MGL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humans</td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>36.9</td>
<td>11.3</td>
<td>9.2</td>
<td>2.8</td>
<td>24.5</td>
<td>123.3</td>
</tr>
<tr>
<td></td>
<td>2.9(56)</td>
<td>81(16)</td>
<td>1.4(25)</td>
<td>0.37(72)</td>
<td>3.1(58)</td>
<td>7.9(1.5)</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>26</td>
<td>30</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>Kebara</td>
<td>40.0</td>
<td>12.6</td>
<td>10.5</td>
<td>3.3</td>
<td>26.2</td>
<td>124.0</td>
</tr>
</tbody>
</table>

Table 5.7. Spine Measures and Indices. All Indices multiplied by 100. Recent
Humans = NW Coast & NA Pioneer groups combined. No statistically significant
differences as tested.

Table 5.7 shows the results of the spine comparisons. Kebara 2, while not
significantly different as tested, lies at the upper end of the range of the recent
human range for spine height (fig. 5.13) and spine thickness. Kebara 2 becomes
more distinct from the recent humans when scaled (fig. 5.13), as judged by lower p-
values on tests of scaled measures (SPHT : SPHT/HL - 0.3029 : 0.1278; SPTK :
SPTK/HL - 0.3685 : 0.1920). Trinkaus' (1983b) published raw Spine Height values of
38.2 and ca. 40.0 for Shanidar 1 (male) and Shanidar 3 (male), respectively, are
similar to Kebara 2. I calculate scaled Spine height in Shanidar 3 (SPHT/HL,
humeral length ca. 319.0 mm) as 11.9, intermediate to the recent human mean and Kebara 2. Humeral length is unavailable for Shanidar 1.

While the suggested cause of the height of the spine is hypertrophy of the scapular musculature, as discussed above, I examined its relation to another possible factor. One determinant of the height of the spine might be the distance of the acromion from the glenoid fossa. The distance between the humeral (inferior) side of the acromion and the glenoid fossa is likely affected by the size of the humeral head, so that a larger humeral head would demand more space between the glenoid fossa and the acromion, raising the acromion and the height of the spine. However, when spine height is regressed on humeral head diameter (fig. 5.14) this argument is poorly supported. While the NW Coast sample shows a moderate correlation, the NA Pioneer sample does not. HHD is measured anteroposteriorly, and perhaps if the humeral head were measured craniocaudally, or to its maximum diameter, a tighter fit would be obtained between spine height and humeral head shape.
SPTK/SPHT (×100) measures the thickness of the spine relative to its height. Kebara 2, while above the recent human mean, is not significantly different in this index (Table 5.7). SP/MGL is a measurement created to judge the angle at which the spine lies relative to the glenoid fossa (see Chapter IV for a complete description).

As can be seen in Table 5.7 there is no significant difference between Kebara 2 and the recent humans. This measure, despite its moderate sample size, had a high amount of variation as indicated by the standard deviation.

Thus, the scapular spine of Kebara 2 appears to be structured similar to that described for Neandertals in general (Trinkaus, 1983a, 1983b). This will be interpreted and discussed in the following chapter.

(3) The Axillary Border

The most discussed, and peculiar, aspect of Neandertal scapular morphology is the structure of their axillary borders (Boule, 1912; Schwalbe, 1914;
von Eckstedt, 1925; McCown and Keith, 1939; Gorjanovic-Kramberger, 1927; Stewart, 1962; Trinkaus, 1976, 1983a, 1983b, 1989). As outlined in Chapter III, Neandertals frequently display dorsal sulci, less frequently bisulcate sulci, and least frequently ventral sulci. The work of the above researchers illustrates quite convincingly that the majority of scapulae from recent humans display ventral sulci, and the remainder possess the bisulcate pattern. Although dorsal sulci have been described (e.g. Hershkovitz, pers. comm) in recent humans they are seemingly rare. In this section sulci frequency is compared between Neandertals and the recent human samples, as well as examines the sulci of Kebara 2 and Tabun C1 more closely.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Dorsal</th>
<th></th>
<th>Bisulcate</th>
<th></th>
<th>Ventral</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Neandertals</td>
<td>22</td>
<td>59.0%</td>
<td>13</td>
<td>36.3%</td>
<td>8</td>
<td>4.5%</td>
<td>1</td>
</tr>
<tr>
<td>Skhul &amp; Qafzeh Hominids</td>
<td>4</td>
<td>0.0%</td>
<td>0</td>
<td>100.0%</td>
<td>4</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>European U. Paleolithic</td>
<td>7</td>
<td>16.7%</td>
<td>1</td>
<td>83.3%</td>
<td>6</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>Recent Europeans</td>
<td>120</td>
<td>0.4%</td>
<td>1</td>
<td>23.8%</td>
<td>28</td>
<td>75.8%</td>
<td>91</td>
</tr>
<tr>
<td>Recent Amerindians</td>
<td>119</td>
<td>0.0%</td>
<td>0</td>
<td>13.4%</td>
<td>16</td>
<td>86.6%</td>
<td>103</td>
</tr>
</tbody>
</table>

Table 5.8. Frequency of axillary border types in samples of fossil and recent humans. Table compiled from data in Trinkaus (1979 & 1983b), and does not include Kebara 2 (bisulcate).

Table 5.8 compiles data collected by Trinkaus (1976, 1983b), the most extensive studies to date, and gives an indication of the distribution of axillary border types among fossil and selected recent humans. A temporal trend is apparent, with increasing frequency of ventral sulci following the late Middle Paleolithic. The dorsal sulcus has been interpreted as evidence of scapular robusticity, specifically hypertrophy of t. minor (Trinkaus, 1976; Trinkaus, 1983b), one of two primary lateral humerus rotators (Gardner & Osburn, 1973). The
presence of a dorsal sulcus provides, Trinkaus (1983b) says, additional attachment area for t. minor. T.minor counteracts the medial rotation associated with humeral adduction, and provides rotational stability of the shoulder during these movements. As stated in Chapter III, Neandertals evidently had highly developed humeral adductors, so that the existence of a strong, counteracting t. minor is not at all surprising.

In my estimation both scapulae of Kehara 2 have bisulcate axillary borders (corroborated by Vandermeersch (1991)), while that of Tabun G1 is clearly dorsal. Table 5.9 lists the frequencies of sulcus types in my sample of recent humans (both sexes). As can be seen the majority of the scapulae in both groups are ventral. However, there is a high percentage of bisulcates, particularly among the NA Pioneers. There is a substantially higher percentage of bisulcates in these recent human groups than in Trinkaus' (1979, 1983b) recent Europeans and Amerindians.

The axillary morphology of the Chonos poses interpretive and comparative difficulties. All thirty of the sampled (i.e. choosing one side of the body only per individual, as discussed in Chapter IV) individuals possess dorsal sulci (Males - n=20; Females - n=10), and when both sides of the body are considered only one scapula is non-dorsal, exhibiting the bisulcate pattern. As I have not seen the scapulae I cannot comment on their exact morphology. Hershkovitz (personal communication) attributes their dorsal sulci to pathology and, however, considers

<table>
<thead>
<tr>
<th>Group</th>
<th>Dorsal</th>
<th>Bisulcate</th>
<th>Ventral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>NW Coast</td>
<td>41</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>NA Pioneer</td>
<td>10</td>
<td>0.0%</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5.9. Frequency of axillary border types in recent human samples (Males and Females).
the dorsal sulci in Neandertals to be a result of occupational stress. In other words, while both groups present dorsal sulci, their causes are different. Only a close examination of the Chonos elements can lead to a resolution of this. Nonetheless, the fact that they preserve dorsal sulci, regardless of the cause, is extremely interesting and deserves further investigation.

While hypertrophy of t. minor has long been cited as the cause of the dorsal sulcus Trinkaus (1989: 334) has recently stated that it is more appropriate to view the dorsal sulcus as reflecting "a structural reinforcement of the axillary border in response to dorso-ventral oriented bending stress, particularly when the humerus was in an abducted position". Although he is not explicit, I believe that Trinkaus now shifts the emphasis from the sulcus to the dorsal ridge running adjacent and medial to the sulcus (as described in chapter III), and the smaller ventral ridge on the adjacent ventral surface. If this is correct, then the dorso-ventral thickness of the axillary border (across the ridge) might be a good marker of stress tolerance of the axillary border of a given scapula. I measured maximum axillary border thickness (AXTK) in my samples to obtain a sense of this.

Table 5.10 presents a comparison of axillary border thickness by sulcus type.

<table>
<thead>
<tr>
<th>Group</th>
<th>Dorsal</th>
<th>Bisulcate</th>
<th>Ventral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>N</td>
<td>AXTK</td>
</tr>
<tr>
<td>Recent Humans</td>
<td>32</td>
<td>14.0 (1.6)</td>
<td>11</td>
</tr>
<tr>
<td>Kebara 2</td>
<td>1</td>
<td>15.6</td>
<td>-</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent Humans</td>
<td>19</td>
<td>12.4 (1.4)</td>
<td>6</td>
</tr>
<tr>
<td>Tabun C1</td>
<td>11.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 5.10. Axillary Border Thickness (AXTK) among males and females of recent humans and a fossil sample, by Axillary Border type (mm). Italicised values are single individuals.
Sexes were split because there was a significant difference (p<.0001) between them in axillary border thickness. Despite the limited sample size there is an apparent correlation between border thickness and type. In both the females (p<.0178) and male (p<.0388) bisulcate axillary thickness is significantly thicker than the ventral type's.

The thickening of the axillary border is likely a reflection of robusticity, and as such should arguably be scaled for size (Trinkaus et al., 1991). Table 5.11 presents axillary border thickness scaled against humeral length. Once again, as in the unscaled comparison above, there is a considerable difference between the border thickness of the axillary types. Among the female recent humans the bisulcates are significantly larger (p<.0279). It is likely that the male recent human bisulcates, while not significantly different from the ventral males (p<.0799), were appreciably thicker. Kebara 2 clearly lies well above the recent human mean, and had a very thick axillary border relative to its size. Among the females, Tabun C1, a dorsal type, is considerably thinner than the female recent human bisulcates.

However, the nature of the thickness of the dorsal type cannot be appreciated from observing only one individual. Measurements of axillary border

<table>
<thead>
<tr>
<th>Group</th>
<th>Dorsal</th>
<th>Bisulcate</th>
<th>Ventral</th>
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<tbody>
<tr>
<td></td>
<td>N</td>
<td>AXTK/H.L.</td>
<td>n</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent Humans</td>
<td>28</td>
<td>4.2(0.5)</td>
<td>10</td>
</tr>
<tr>
<td>Kebara 2</td>
<td>1</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent Humans</td>
<td>16</td>
<td>4.2(0.4)</td>
<td>5</td>
</tr>
<tr>
<td>Tabun C1</td>
<td>1.38</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>

Table 5.11. Size scaled Axillary Border Thickness (AXTK/H.L *100) among males and females of recent humans and a fossil sample, by Axillary Border type. Italicised values are single individuals.
thickness of other Neandertals, and other recent humans, would allow for an improved perspective on this matter. Unfortunately, this data is unavailable at this time.
Chapter VI: Discussion and Conclusions

The implications of the research results are now considered. Each study will be discussed and interpreted separately, before considering the broader relevance of this research.

Discussion

(A) Neandertal Glenoid Fossa Shape

The results of the glenoid analysis performed in this study clearly deemphasise the uniqueness suggested of Neandertal glenoid morphology by the research of Churchill and Trinkaus (1990). The two primary differences between modern humans and Neandertals in glenoid shape suggested by Churchill and Trinkaus' study are that (1) Neandertal glenoid fossae are significantly narrower than those of their modern human sample, and that (2) "Neandertals have narrower fossae than recent humans relative to humeral joint surfaces" (Churchill and Trinkaus, 1990: 156), and also state that this is the case for "any given humeral joint surface" (Churchill and Trinkaus, 1990: 154).

The results of the present study, using similar analytical techniques and, most critically, with the important addition of three recent human samples, falsifies these two conclusions. First, there is no difference in relative glenoid width between Neandertals and NW Coast natives, and their average value is remarkably identical: 66.5. As well, the average value for the NA Pioneer is much closer to that for Neandertals than any of Churchill and Trinkaus' (1990) comparative samples are, and may in fact not be significantly different (Tukey's HSD) than the Neandertals.

Second, the narrowness of the glenoid relative to humeral joint surfaces (the humeral head and the distal articular surface) seen in Neandertals, and said to be
unique by Churchill and Trinkaus, is shared with both the NA Pioneer and NW Coast native samples. Although Churchill and Trinkaus (1990) state that the relative narrowness of the glenoid to the humeral surfaces is particularly striking, the glenoid fossae of NW Coast sample on average are even narrower than Neandertals relative to the distal articular breadth of the humerus.

These results highlight the limited nature of Churchill and Trinkaus' (1990) samples for understanding the shape of Neandertal glenoid fossa relative to more recent humans. The addition of the samples in this research widen the range of morphological variability of the comparative samples, and demonstrate that the fossae varies quite widely among modern human populations. Interestingly, Mendes Correa (1919) measured an average glenoid index of 68.8 for a group of Portuguese (n=57). Whether these results can be compared to the present research is equivocal, as it is unclear if the recording techniques were similar to those in the present research.

Among Mousterian populations, as well, relatively narrow glenoid fossae are actually not a feature exclusive to Neandertals. The Levantine modern human skeletal sample from Qafzeh contains at least one individual, Qafzeh 8, whose glenoid fossa is extremely narrow relative to its height. The right glenoid fossa of Qafzeh 8 is shown in figure 6.1. I have studied the original material of this individual (housed in the Rockefeller Museum, Jerusalem). The glenoid fossa of Qafzeh 8 measures 36.9 mm (GAL) by 21.5 mm (GAB, est.) producing a glenoid fossa index of 58.3. This is a particularly narrow fossa, well below the average for Neandertals (66.5) reported in chapter V. The right humerus of Qafzeh 8 is remarkably robust. The crest for pectoralis major is very distinct, the bicipital groove is broad and deep, and, at 376 mm, the element is very long. The distal articular breadth of the humerus is 45.5 mm(est.) which yields a GAB/HHD index of 47.3 (Neandertal average = 79.6, NWC = 75.4, NA Pioneer = 74.0, E.U.P. = 87.1;
Figure 6.1. Lateral view of the right glenoid fossa of Qafzeh 8. Superior is at top, scale in cm. Photo by author.
see table 5.2 for comparison) making the glenoid fossa of this individual strikingly
narrow relative to HDB. This, again, brings to question Churchill and Trinkaus' (1990) conclusion that Neandertals have narrower fossae than do modern and recent humans relative to humeral joint surfaces.

**Biomechanical Significance**

Churchill and Trinkaus (1990) suggest that the relative narrowness of Neandertal glenoid fossae is an indication that the habitual behaviour patterns of Neandertals loaded the shoulder in a dorsoventrally narrower range than modern humans, but that their actual range of motion was not necessarily different. In the Upper Paleolithic, and in recent humans, they suggest that the nature and direction of joint reaction forces changed due to the increased use of projectile technology, and the wider fossa would handle the resulting dorsal and ventral shearing stresses more efficiently. Thus, the architectural changes in the glenoid are a simple reflection of the shift in human throwing behaviour and projectile which emerged during the Upper Paleolithic, and continued to recent times.

However, the results of the present study suggest that, if this interpretation is correct, these changes do not follow a temporal trend and that the feature is not a feature which can be used to distinguish between archaic members of *Homo* and more recent and modern humans.

The shape of the glenoid in a given population, thus, could be an indication of the technology they employed. Neandertals and NW Coast natives may have had in common features of their subsistence that required shoulder stability and less laxity of the shoulder.

The relative narrowness of the glenoid fossa relative to the humeral joint surfaces could be due to changes in the humeral surfaces rather than the glenoid.
As the humeral head and/or humeral distal articular surface get larger, the glenoid becomes narrower relative to each. Thus, in an individual whose shoulder and elbow joints are more active and subject to greater forces and attrition, the elbow surfaces may enlarge. Hence, the low values seen in Neandertals, NW Coast natives and the NA Pioneer sample imply that these groups may have shared similar motions and forces through these joints, in each group the humeral surfaces enlarging in response to activity.

Although, while this interpretation proposes that the widening humeral surfaces reflects an active shoulder joint, it does not fit well with the range and type of motion discussed for glenoid fossa width, where joint stability and narrowness of the glenoid are paramount. Thus, the narrowness of the glenoid suggest glenohumeral joint stability, while the humeral surfaces, particularly the head, imply laxity. It may have been the case that Neandertal upper limb activities required stability of the glenohumeral joint, while their elbow saw much laxity in terms of flexion and extension. Admittedly, the motions, architectural stability, and overall relationship between joint use and subsequent reaction of the osseous tissues among the glenohumeral and elbow joints are quite disparate, and difficult to compare, as one (glenohumeral joint) has a wide range of motion while the other (elbow) is restricted to movement in only one plane.

Suggestions for Future Research on Neandertal Glenoid Fossa Morphology

In general, the research methods employed here, and by Churchill and Trinkaus (1990), seem to be producing interesting results, but there are clearly limitations to both the methods and the samples involved. For example, measuring glenoid dimensions is not simply a matter of measuring the marginal extremities of the joint. Rather, as Churchill and Trinkaus (1990) have defined it, measuring GAL and GAB involves identifying the line of attachment of the glenoid labrum on the
glenoid's surface (which approximately outlines the general shape of the glenoid), and then measuring between the lateral and medial margins (GAB) and the cranial and caudal margins (GAL) of it. Prior to Churchill and Trinkaus' (1990) study researchers did not expressly state that they measured the dimensions this way, and I suspect that most simply measured the morphological extremities of the joint itself. Thus, that the techniques for measuring the fossa have differed historically implies that the data among studies employing different techniques could be incompatible. This is not a large issue, but one that should be acknowledged.

As far as samples are concerned, to provide the most comprehensive study as possible one should apply the methods presented here, and in Churchill and Trinkaus (1990), to broader and larger samples of recent humans, and especially to Neandertal contemporaries (both geographically and temporally) such as Qafzeh 8, described above. If the relative width of the glenoid fossa (to both its height and HDB) of Qafzeh 8 is any indication, the Levantine contemporaries of the Neandertals may have been more similar to Neandertals in this regards than they are presently understood to be.

While the continuing study of glenoid external morphology is clearly informative, results from a recent application of CT-Osteoabsorptiometry (CT-OAM) on the subchondral mineralisation of the glenoid fossa in living humans has profound implications for such studies of fossil hominids. Muller-Gerbl et al. (1989, 1990) have outlined a technique which uses CT-OAM for the estimation of subchondral mineralisation patterns in human joints. The distribution of subchondral mineralisation below the surface of a joint is a metrical parameter which relates quantitatively to the average effective load on that joint, and thus represents the long-term loading history of the joint in an individual. Muller-Gerbl et al. (1990, 1993) examined the density distribution patterns of the glenoid fossa in patients with various shoulder conditions, and also gymnasts and "normal" people.
The density distribution differed significantly between the groups, a result of the loading history between the groups.

Patterns of density distribution in the glenoid can be predicted from the study by Poppen et al. (1978). The researchers studied the vector of forces through the glenoid during abduction and found that at 0° of abduction the humeral head was subluxing downwards. In the 30-60° range, the resultant force was close to the superior edge of the glenoid indicating a tendency to sublux upwards. Beyond 60° however, the humeral ball was pressed directly into the center of the glenoid. With moderate weights added to the hand the forces through the ball and the glenoid increased dramatically (Poppen et al., 1978). Elaboration of the work by Poppen et al. (1978), coupled with above such studies of subchondral patterns in persons of known occupations could aid immensely in understanding similar patterns in fossil hominids.

Of particular interest would be a study of the subchondral density of both the glenoid fossa and the humeral head in Middle and Upper Paleolithic hominids. This could be related to external dimensions, or examined independently. Correlations would be expected between subsistence, tool-use, and mineralisation. If, as Churchill and Trinkaus (1990) have concluded, that Neandertal glenoid fossae indicates shoulder stabilisation for use, in contrast to the laxity seen in recent humans (for throwing), then there should be concomitant changes to the subchondral bone in the glenoid and humeral head. This method of subchondral investigation could be applied to any joint surface, such as the acetabular or auricular surfaces. However, it is possible that the processes involved with fossilisation would obscure the actual distribution pattern of an individual, and certain areas of the subchondral matrix may appear to be thinner or thicker than they actually were in life.
The glenoid tubercle, which sometimes appears in approximately the center of the glenoid fossa, has been noted by Bainbridge & Tarazaga (1956) to appear more frequently in males and in more robust scapulae. Incidentally, both Kebara scapulae possess glenoid tubercles. Unfortunately, data was not collected for the recent samples under consideration here. It is suggested that a more thorough investigation into the distribution of this feature and its relationship to scapular and glenoid architecture would be a worthy endeavor.

(B) The Kebara 2 Right Scapula

The analysis of the Kebara 2 scapula was undertaken to determine if its morphology is characteristically Neandertal. It appears that, in most measures, it fits well into the what has been characterized for Neandertal scapulae. It is wide and has high axillospinal and axilloglenoid angles. In particular its inferior body is expansive, especially when the associated measures are scaled against humeral length. However, the height of its spine is not exceptional, and the supraspinous fossa is small relative to the infraspinous fossa.

In overall body measures, Kebara 2 differed significantly from the modern human sample in only one measure, the scaled measurement from the medial angle to the midpoint along the axillary border. However, for length, breadth Kebara 2 lies at the upper end of the sampled recent human range, and is even more distanced when humeral length is taken into consideration. In unscaled scapular breadth, although wide relative to most of the recent human sample, Kebara 2 is in the low to middle range for Neandertals.

The supraspinous fossa was not distinctive in Kebara 2, except that it lies at the lower end of the range for recent humans. This may be due to developmental emphasis on the inferior body, so that the supraspinous fossa is low relative to the infraspinous fossa.
The size and orientation of the infraspinous fossa are the most notable features of the Kebara 2 right scapula. For every measurement, except unscaled inferior angle to glenoid fossa (I-GL), Kebara 2 was significantly different than the recent human sample, and in fact had the highest values among all individuals for each measurement except I-GL. Thus, in Kebara 2 the inferior angle is at a considerable distance from the medial angle, spine, and glenoid fossa compared to the recent human sample. The large percentage of scapular length accounted for by the length of the infraspinous fossa (81.9%) further emphasises the increased distance of the inferior angle from the spine and glenoid fossa. The axillospinal and axilloglenoid angles of Kebara 2 are also at the upper end of the recent human sample values, and indicate that the infraspinous fossa was large. In contrast with other Levantine Neandertals, both of the angles in Kebara 2 are high, but are similar to values for European Neandertals (elaborate). Although Kebara 2 is consistently larger in infraspinous measures than the recent human samples in this study, it is possible that other samples of recent humans may approach, or exceed, Kebara 2 in these measurements. Future research on the scapula would do well to compare Kebara 2 to additional recent human samples.

As these measurements underlay their functional relatedness, it is not surprising that they share in common such high values. The long infraspinous fossa, wide scapular breadth, and high axillospinal and axilloglenoid angles all facilitate an enlargement of the entire infraspinous fossa. This would facilitate an enlargement of the originating area of the rotator cuff musculature on the infraspinous (infraspinatus, t. minor) and subscapular (subscapularis) surfaces, and imply greater strength in the shoulder.

If the infraspinous fossa is viewed as an inverted triangular (inferior angle-glenoid fossa-medial angle-inferior angle) then it can be seen that these results indicate that each of the three sides were lengthened in Kebara 2 relative to the
recent humans. The longer vertebral border, as indicated by the length from inferior angle to medial angle, would have allowed for long insertions of the rhomboids. The more extensive axillary border, from inferior angle to glenoid fossa, lengthens the origins of t. major, t. minor, and triceps, and along the spine from the glenoid to medial angle the horizontal area for deltoid and trapezius would have been long. However, unlike the association between muscle area and strength discussed in Chapter II, it is not clear how lengthening the attachment area of a muscle affects its strength and efficiency.

In addition, I suspect that the higher angles, particularly the axilloglenoid angle, may have affected the orientation of the axillary border relative to the humerus such that the interosseous space was less between the two than is the case for the recent human sample i.e. the humeral shaft would be closer to the axillary border. Although difficult to infer, if this were the case then it is possible that t. minor and t. major would have been somewhat shorter and run at different angles to the humerus than in the recent humans. As well, the orientation of triceps may have been somewhat different in Kebara 2.

The level of discordance observed by Trinkaus (1983a, 1983b) in spine height between Neandertals and recent humans was not seen between Kebara 2 and the recent human sample. The height of the spine, however, was at the high end of the recent human range, especially when scaled against humeral length. As well, the thickness of the spine relative to its height in Kebara 2 was at the upper end of recent human variation, but was not significantly different as tested.

And finally, although some researchers (e.g. Trinkaus, 1983a) have noted that Neandertal spines are more horizontal than is the case for modern humans, this was not seen in Kebara 2. The angle of the spine relative to the craniocaudal axis of the glenoid was not different from the recent human sample. However, this method (SP/MGL) for measuring the angle of the spine may not be the most
informative, and it is suggested that other avenues be investigated for quantifying this characteristic.

As some of the scapular body measures distanced Kebara 2 further from the recent humans when scaled values were used, some might argue that this could be due to Kebara 2 having short humeri. However, this is not the case. At 317 mm, the right humerus of Kebara fits comfortably into the modern human range for male right humeri (291 mm -351 mm), which average 321 mm (SD =16.8, n = 28). This emphasizes that the size differences noted for scaled comparisons in the Kebara 2 right scapula are absolute, rather than relative.

As mentioned in chapter III, Trinkaus (1983a) has emphasised the enlarged size of Neandertal deltoid tuberosities, adding that they are so large as to create a sulcus between them and the posterior margin of the shaft. In contrast, he states that such sulci are rare on more recent humans. In contrast, my own study of Near Eastern Neandertals (Kebara 2, Amud, and Tabun C1) as well as the NW Coast and Golden samples (outlined in Chapter IV), however, does not support Trinkaus' (1983a) observation. In fact, in the majority of the recent human samples the deltoid tuberosity is marked, whereas the Neandertals are less impressive in this regard. The relative gracility of the deltoid insertion on these Neandertals is puzzling and unexpected given the apparent hypertrophy of other aspects of the arm and shoulder. The deltoid tuberosity marks the insertion of deltoid, and its relative gracility, as I observe it, may be due, in part, to a somewhat different angular placement of the muscle. The medial and posterior heads of deltoid originate on the acromion and scapular spine, respectively. If the acromion were more posterior in Neandertals, or if its fibres met the humeral shaft at a different angle than is the case in modern humans, then the biomechanical forces and overall architecture of the region may have differed and allowed for the observed differences in deltoid tuberosity shape. Nonetheless, this is a speculative
hypothesis, and it have simply been the case that Neandertals did not involve their deltoids as frequently or habitually as did the NW Coast and NA Pioneer individuals.

In discussing the paleoanthropological evidence from Kebara Cave Rosenberg (1992: 539) has stated "We can look forward to further application of these data towards resolving questions of the behavioral and morphological variability of archaic humans in the Levant and the origin of modern humans." The present study of the right scapula of Kebara 2 indicates that the shoulder of the individual, like other Neandertals, was well muscled and able to withstand strong biomechanical forces. In general, the scapular architecture of Kebara 2 is similar to other regions of Neandertal anatomy, in that it gives clear indication that they were leading physically strenuous lives. In addition, these results support Bar-Yosef et al.'s (1992) conclusion that Kebara 2 is the most robust Neandertal known from the Levant.

Suggestions for Further Research on Neandertal Scapular Body Shape

Clearly the next step for understanding scapular shape in Neandertals would be an extension of the morphometric methods employed here to a larger sample of both Neandertal fossils and a wide array of recent human skeletal samples. As well, incorporating a multivariate statistical analysis, as well as techniques of three dimensional shape modeling, would raise the resolution and interpretation of this issue to a level beyond that reached in this study.

(C) Neandertal Axillary Border Morphology

The results of the axillary border comparison suggest that robusticity of the scapula is expressed in the thickness through the border itself, and that bisulcate condition may, in fact, be more robust than the dorsal type. The axillary ridge is as
informative as the axillary border, and in fact one can not exist, or function, without the other. What can be concluded from this study is that the axillary borders of bisulcates clearly are thicker, and theoretically provide more resistance to dorso-ventral bending stress than do the ventral type. If, as Trinkaus (1989) has claimed, this is the main function of the thickened Neandertal dorsal sulcus, Neandertals are not the only populations to respond in this way to these stresses. Clearly the NW Coast and NA Pioneer groups (which make up the recent human sample) contain many individuals whose axillary borders withstood biomechanical stresses similar to those met by Neandertals.

It should be noted that in their study of the scapulae of recent British Bainbridge & Tarazaga (1956) described one 65 year old male's axillary border as "strikingly recalling the Neandertal type, having a strongly developed dorso-axillary [dorsal] crest transgressing onto the infraspinous fossa and a very light ventro-axillary [ventral] crest disappeared below the middle third of the border." The question remains as to the origin of the axillary morphology. Considering that the "Neandertal type" can be found in modern humans, and that not all Neandertals possess dorsal sulci (59%, see Chapter V) it may be the case that the shape of the axillary border in this regard is acquired by an individual based on upper limb activities and is not congenital.

**Suggestions for Future Research on the Axillary Border**

As the axillary border analysis comprised only a portion of this research the traditional method was employed, in addition to the study of the thickness of the axillary border. Above all, this allows the data collected for the present samples to be compared to that of other researchers.
The nature of previous axillary border investigations suffer from an inherent stagnancy, due primarily to the traditional three sulcus-type scoring system. This tripartite method is in need of expansion and revision. Modifying and expanding scoring would allow for discrimination of other levels of axillary development. In this study there were cases where individuals were between, for example, the bisulcate and ventral types and were scored as the type they more closely resembled, when in fact they were neither truly ventral nor bisulcate. Consideration must be made for differing degrees of development.

Despite the fact that 38 of 39 Chonos scapulae possessed dorsal sulci, they were not used in the axillary border comparison, as Hershkovitz (pers. comm.), feels that the sulci are pathologies. This morphological dilemma begs the question of how one defines a skeletal pathology, and how they are to be distinguished from (healthy) osseous changes. That the entire sample of individuals display identical pathologies is truly fascinating, and must be the result of a shared, exceedingly habitual activity. It is possible that paddling was the activity in question, and it would be interesting to assess the thickness of their borders, in the way measured in this study, to see if they are notably thick, regardless of their origin. As a speculative hypothesis (that cannot be tested in this study) I suggest the possibility that the pathology was met only after exceedingly high activity of upper limb, similar to Neandertals in stress type, but more habitual in nature.

Conclusions

Perhaps the most intriguing issue, which lay at the core of interpreting the phyletic weight of such studies, is: to what degrees are the shape differences, and variation therein, the result of developmental and inherited forces? If the studies of Muller-Gerbl et al. (1990, 1993) are any indication, the subchondral structure (internal mineralisation) of the glenoid fossa is highly plastic and responsive to
differential distribution and levels of forces in the shoulder. There is no reason to suspect that the external shape and surface of the glenoid are not similarly responsive to activity by osseous remodeling. As well, Wolfson's (1950) study of the scapula of the rat, outlined in Chapter II, illustrates the extent to which scapular shape can be modified in response to muscle presence and use. Similar changes and reactions would occur in humans. There can be no doubt that much of the template of the scapula is the product of genomic factors, but development appears to be an active contributor to scapular shape in all regions. The NW Coast and NA Pioneer scapulae were markedly variable in size and shape, including axillary border morphology. Inheritance aside, part of this must be due to occupational stresses, and possibly to torso shape in general.

The fundamental question raised by each and every study of Neandertal functional anatomy is: what were they doing to necessitate such formidable musculature and robusticity? It has been shown in this, and other, research that the humeral rotators in Neandertals are well developed, and that they thus must have been performing strenuous tasks with their arms and upper bodies. In reality, any number of activities partaken regularly and strenuously will leave recognisable markers on the skeleton, and this creates obvious interpretive difficulties. In addition muscles used as protagonists or antagonists most likely lead to similar osseous changes. For example, teres minor might leave similar osseous markers on the scapula whether it were used as a primary lateral humeral rotator, in an activity such as paddling, or as a stabiliser of the arm against medial rotation of the humerus. Our present understanding of this dilemma does not allow for resolution of the issue.

Each of the analyses of this study imply that Neandertals possessed considerable strength in their shoulders, specifically the lateral humeral rotators, and in general had the ability to stabilise their shoulders to resist considerable
forces. What was it about their lifestyle that accounts for the unusual amount of use of the medial rotators? There are intuitive causes, like those associated with their subsistence. The use of spears, both as projectiles and as thrusting weapons, would require strength and laxity of the shoulder. For this one activity to account for their shoulder architecture, however, it would have had to have been regular and repetitive, and have emitted forces through both shoulders, given that both sides seem nearly equally effected in skeletons where both sides are preserved. In modern athletes who favour the use of one arm (i.e. baseball pitchers) osseous development is markedly asymmetrical, and the same would be expected in a hunter who threw or thrust spears with one arm. Unless Neandertals were ambidextrous it seems unreasonable to assume that the use of the spear alone is responsible for the musculature of their shoulder.

Other subsistence behaviours are equally likely candidates if carried out repetitively and vigorously. Preparation of Levallois cores, for example, might require shoulder strength, although the elbow and wrist seem more crucial. Activities such as digging for tubers and roots, securing hides with one or both hands while working them with the mouth and hand, flint knapping, grinding plant matter, etc., are possible candidates as well, but it is hard to envision any of these activities being carried out in such a regular fashion so as to create such changes in the skeleton. There is no archaeological evidence to suggest the unusually frequent occurrence of any particular behaviour in the Mousterian. This is not to discount the possibility that one cultural activity accounted for much of their time and shoulder anatomy, but rather that, if so, it is at present unknown. It is more likely that the anatomy of Neandertal upper limbs are the result of a multitude of activities, some of which were highly strenuous.

Given the evidence for extensive woodworking in the Mousterian, it is possible that the actions involved with retrieving and shaping of wood and wooden
artifacts contributed significantly to Neandertal postcranial anatomy. Depending on
their procurement techniques and the artifacts they required, this could have
required considerable strength of the upper limb and torso. Unfortunately, we have
no knowledge of exactly what they were making, apart from the wooden handles
inferred by the patterning of hafting traces left on Mousterian convergent, side, and
end scrapers and points discussed on Chapter 1. A study of the muscles involved in
woodworking, using an EMG to determine muscle activation for different motions,
would be very valuable for understanding the fossil data. There are certain
confounding factors to such a study, the greatest of which is the possible
incongruency between modern and Neandertal woodworking techniques.

It would interesting, as well, to consider the association of osseous markers
on an element or between elements. For example, groups of muscles act together
during certain motions, and therefore we would expect correlative changes in
muscular insertions and origins. As well, robusticity (increased bone density and
cortex thickness) of certain sections of bone likely correlates with the development
of certain muscles. Ultimately, combining a catalogue of cultural activity and
muscle use (with the use of EMG) with patterns of muscle markings, robusticity,
and activity-type among living persons, or skeletons of individuals of known life
history, would prove to be a profound tool for interpreting skeletal morphology.

A more general issue raised by this research is the use and definition of the
terms *anatomically modern humans* and *modern humans*. Among
paleoanthropologists there is no consensus on what exactly a modern human is,
and researchers are disparate in their definition of the concept. This leads to
misuse of the term, and in some cases creates artificial boundaries between
hominids. For example, Churchill and Trinkaus (1990) maintain that Neandertals
and "modern humans" are incongruent in glenoid fossa morphology, while the
present research has shown the opposite to be true. The two modern human
samples (NW Coast and NA Pioneers) share narrow fossa shape with Neandertals, and thus "modern humans" are obviously more variable in this feature than paleoanthropologists have allowed.

For researchers to conclude that a hominid or group of hominids is different than modern humans is erroneous unless a variety of samples size is used. Unfortunately, this is not the method chosen by most researchers, who would do well to qualify their studies by making clear that their hominid data is different from the group of modern humans they have used, rather than creating an unfounded gap between hominids and modern humans. The desired scenario would be to outline the range of living and recent human variation before generalising a character state for all humans based on few samples. Admittedly, there are certain characteristics which we can safely characterise with relative ease (i.e. cranial capacity), but this is clearly not the case for the entire skeleton. I suspect that as studies of poorly known collections appear, and our set of observations on living and recent humans grows, we will recognise the ever widening range of modern human skeletal variation.

Each of the three analyses, although in separate anatomical regions on the scapula, illustrate that the scapulae of Neandertals were subject to considerable biomechanical forces, were structured to allow for a large volume of musculature, display evidence of muscular hypertrophy, and that their overall architecture favoured strength and biomechanical efficiency of scapulohumeral movements.

While these features characterise Neandertal scapulae, does it follow that they are unique in these regards? The results presented here lessen the morphological distance between recent humans and Neandertals implied by past studies. Based on the present findings, Neandertals share aspects of glenoid morphology with at least some recent humans, while having relatively larger scapular bodies. The one scapula feature which remains outstanding in Neandertals is their predominance of
dorsal sulci. There are no features of Neandertal scapulae which suggests that they had a range of scapular (shoulder) movement superior or inferior to recent humans, only that they had overall greater strength in their upper limb. The agent most likely responsible for these differences are cultural, that being that Neandertals were using their arms and upper bodies in a way as yet to be observed in modern humans, or seen in modern human skeletons. Given the shared similarities between Neandertals and more recent humans in glenoid shape and axillary border patterns, such shared resemblances cannot be used for phylogenetic purposes. They are the result of independent acquisition which are likely acquired rather than inherited, and may reflect shared or similar behaviours impinging on a malleable osseous system.

The clearest way to address this issue is to (1) gain a comprehensive understanding of the skeletal variation of recent and living humans; (2) inventory and interpret the influence of occupational activities upon skeletal morphology, and; (3) then return to the fossil hominids and, in combination with behavioural data from archaeological studies of Mousterian culture, embark upon exhaustive morphometric comparisons between Neandertals and subsequent human populations. Only when we understand the nature of osseous changes in modern humans can we begin to resolve how Neandertals lived and where precisely they fit into human prehistory.
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