SAMPLING BIASES AND NEW WAYS OF ADDRESSING THE SIGNIFICANCE OF TRAUMA IN NEANDERTALS

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Anthropology)
in The University of Michigan
2009

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To my father
who read to me my first stories of prehistory

ACKNOWLEDGEMENTS

There are so many people whose generosity and inspiration made this dissertation possible. Chief among them is my husband, George Estabrook, who has been my constant cheerleader throughout this process.

I would like to thank my committee for all of their help, insight, and time. I am truly fortunate in my extraordinary advisor and committee chair, Milford Wolpoff, who has guided me throughout my time here at Michigan with support, advice, and encouragement (and nudging). I am deeply indebted to Tom Gest, not only for being a cognate *par excellence,* but also for all of his help and attention in teaching me gross anatomy. Rachel Caspari, Roberto Frisancho, and John Speth gave me their attention for this dissertation and also offered me wonderful examples of academic competence, graciousness, and wit when I had the opportunity to take their classes and/or teach with them as their GSI.

All photographs of the Krapina material, regardless of photographer, are presented with the permission of J. Radovčić and the Croatian Natural History Museum.

My research would not have been possible without generous grants from Rackham, the International Institute, and the Department of Anthropology. Nor would it

have been possible without the local hosting of Jakov and Davorka Radovčić in Zagreb and Eugenia Cunha and Paulo Gama Mota in Coimbra.

Like every other Anthropology graduate student, I have accepted Laurie Marx as my personal savior and many very bad things would have happened were it not for her help.

Finally, I would not have ever been involved in the field of Anthropology were it not for the inspiration and support of many people throughout my life. These include my grandfather with whom I collected "artifacts" from our beach before I ever set foot in a classroom, my parents who constantly provided me with opportunities to explore my interests, amazing high school teachers like Peter Perhonis and Charlie Flanagan who took me seriously, wonderful professors at Bryn Mawr like Rick Davis who convinced me that Anthropology was the most wonderful and fascinating major a person could have, Douglas Ubelaker who taught me osteology and pointed me towards issues of preservation and sampling biases in the analysis of trauma, Janet Monge whose mentorship and generosity has been incredibly important to me throughout my time as her student (which I will always be), my professors and fellow graduate students at Michigan who have been some of the smartest people I have ever met and whose company I have enjoyed and been constantly inspired by, especially Steve Pastner, whose wonderful drawing graces the frontispiece, Beverly Strassmann, Loring Brace, Andy Merriwether, Meghan Howey, Liz Bridges, Daphne Gallagher, Steven Dueppen, Kay Grennan, Anna Williams, and Theo Morrow, and, finally, my dear daughter, Elizabeth, whose smiles are my sunshine on the dark, cold and dreary Ann Arbor days.

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ABSTRACT

SAMPLING BIASES AND NEW WAYS OF ADDRESSING THE SIGNIFICANCE OF TRAUMA IN NEANDERTALS

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There is a popular perception that trauma was quite frequent in Neandertals because of harsh environmental conditions and their strenuous lifestyle. Many well-known individual Neandertals exhibit injuries, but they are mostly well-preserved, male and old. In previous examinations of patterns of trauma in Neandertals, frequencies of trauma by element were not addressed and the samples of Neandertals used represented neither a specific Neandertal population nor a demographically representative sample. The hypothesis that trauma in Neandertals occurs more frequently than in other groups has never been systematically tested. This thesis reports the development and results of new methods designed to address this question in a statistically valid manner.

The small number of mostly poorly preserved Neandertal remains is vulnerable to sampling biases. How such biases prevent trauma frequency data from representing the sampled population, and provoke misinterpretation in subsequent comparisons to other populations, is addressed. Ways to limit the influence of some of these biases in testing hypotheses about the significance of trauma are described.

The distribution and frequency of trauma among Neandertals is approached by asking three questions: 1) How is trauma distributed among individual Neandertals? 2) What is the frequency of trauma by skeletal element and are frequencies significantly different from those observed in modern populations? 3) Do trauma frequencies for two collections from single sites where the data were collected by identical methods significantly differ, and if so, in what ways? The significance of differences within these aspects of Neandertal trauma is determined by analyzing two-way contingency tables using simulations (ACTUS2).

Hypotheses are tested in three distinct contexts: 1) distribution of trauma among individual Neandertals with trauma; 2) distribution of trauma within a large sample of European Neandertals and in comparison to hunter-gatherer, forager and nomadic samples; and 3) comparisons between trauma in a single Neandertal sample and in a medieval sample where both samples are extremely fragmentary. Hypotheses of the independence of the presence of trauma and demographic variables, preservation status, injury severity, and area of the body injured are tested. In general, Neandertals do not show frequencies of trauma significantly greater than those in other groups.

CHAPTER I

INTRODUCTION

There is a popular perception that trauma was quite frequent in Neandertals due to the harsh environmental conditions in which they lived as well as their strenuous lifestyle (Trinkaus 1978; Geist 1981; Berger and Trinkaus 1995; Klein 1999; Pettitt 2000; Underdown 2006; Adovasio *et al.* 2007). It has also been argued that this high level of trauma shaped many aspects of the Neandertal culture (Pettitt 2000). Although many of the well-known individual Neandertals exhibit injuries, these individuals are mostly well-preserved, male and old: qualities which are not representative of the extant Neandertal sample. In previous examinations of patterns of trauma in Neandertals (Berger and Trinkaus 1995; Jurmain 2001; and Underdown 2006) prevalence frequencies of trauma by element were not addressed and the samples of Neandertals used did not represent either a specific Neandertal population or a demographically representative sample. To date, the hypothesis that trauma in Neandertals occurs significantly more frequently than in other modern groups has not been tested.

In this dissertation, I test the significance of prevalence frequencies of trauma in Neandertals by comparing a large combined sample of European Neandertals to several modern hunter-gatherer groups based on published data. I also compare prevalence

frequencies of trauma in a single Neandertal site to a comparative sample where I collected data using methods I introduce for comparisons of highly fragmentary samples.

If trauma occurred more frequently overall in Neandertals than in modern groups, this would lend support to the argument that the reduction of the risk of injury was one of the behavioral improvements which contributed to the success of anatomically modern humans. If the distribution of trauma frequencies throughout the elements of the body were significantly different in Neandertals than in modern groups, arguments could be made about different behavioral patterns of Neandertals that exposed them to special risks. If trauma does not occur more frequently and the distribution of trauma frequencies is not significantly different for Neandertals than for modern groups, arguments about the significance of Neandertal trauma are not supported by the data. In the first two cases, the relevance of the study of Neandertal trauma to the field of anthropology is that it gives us new ways of arguing Neandertals were behaviorally different from modern humans. In the latter case, the relevance of the study of Neandertals trauma is that it gives us new ways of arguing that that Neandertals were not behaviorally different from modern humans in terms of how they experienced trauma.

The biggest impediment to addressing this problem is vulnerability of the small and poorly preserved Neandertal sample to sampling biases. Such biases prevent trauma frequency data from representing the population being sampled and provoke misinterpretation in subsequent comparisons to other populations. In this dissertation, biases in the Neandertal sample will be addressed and methods will be introduced that limit the influence of some of these biases in testing hypotheses about the significance of trauma.

My approach to examining the distribution of trauma among Neandertals is three-fold: how trauma is distributed within the sample of injured Neandertals; how trauma is distributed within the context of the Neandertal population and how its frequency compares with other populations; and how trauma is distributed within the context of a fragmentary single Neandertal site compared to a fragmentary single modern site where all data is collected under the sample set of methods.

First, I address aspects of how is trauma distributed among individual injured Neandertals. I examine potentially significant demographic biases in who shows signs of injury, the degree of severity of injury, and the degree of preservation of injured individuals. However, this first perspective does not address how often injuries occur in the context of the Neandertal population in general nor is it comparable to most paleopathological approaches to determining the significance of trauma.

My second approach to examining the distribution of trauma in Neandertals is determining the frequency of trauma by counting bones both with and without trauma. The hypotheses about the significance of the frequency of trauma can be tested for each element, as well as for demographic parameters such as age-at-death and sex, and levels of preservation. The frequency of trauma by element in Neandertals is also compared with frequencies of trauma in samples of modern hunter-gatherers, foragers and nomadic populations. These comparisons are important because they put the rates of trauma observed in Neandertals into a context where it is possible to test whether Neandertal trauma is significantly different from that observed in modern populations. However, because of the limitations of the Neandertal sample, these comparisons are based on data collected under less restrictive protocols for the Neandertal sample than for the modern

samples where fragmentary bones are excluded in the bone counts by element. It is unclear how much difference this exclusion of fragmentary bones makes in the trauma frequency counts of the comparative samples. Because excluding fragmentary bones from the Neandertal sample would leave few bones to count, comparisons of trauma frequency with a sample where fragmentary bones are also included is suggested as a way to more accurately assess the significance of frequency of trauma in Neandertals. Also, within the sample of Neandertals, data was collected by many different researchers using techniques ranging from macroscopic examination to radiographs to computer tomography. These differences in levels of observation might also influence how much trauma was observed.

My third approach to assessing the significance of trauma distribution in Neandertals is to compare frequencies for two collections from single sites, one Neandertal and one modern, where the data were collected by identical methods and most fragmentary bones were included.

The significance of potential differences within these aspects of Neandertal trauma will be determined using analysis of two-way contingency tables using simulations (ACTUS version 2). The value of using simulations rather than classical statistical methods is that smaller samples may be significantly compared and the significance of each individual cell in a table is assessed as well as the significance of the entire table.

This thesis consists of eight chapters. In the first chapter, the topic of the thesis is introduced and the contents of the dissertation are outlined.

In the second chapter, I survey the way that data about trauma has been gathered by other researchers and potential sampling biases. I describe how evidence of trauma is defined and communicated. How much trauma is reported is often influenced by how it is observed and described, as well as by the nature of the sample itself. Some of these observation and sampling biases are: how easily of types of trauma can be seen; variability in age at death; taphonomic modification; and differences in how evidence of trauma is counted by researchers. I review the effects of these factors. I will present a "wish list" of aspects that a sample should have in order for research into its trauma to have the highest resolution and be most representative of the trauma that occurs in the living population. The chapter will be concluded with a summary of the various ways "patterns of trauma" are defined and compared.

In the third chapter, I summarize the history of the discovery and interpretation of trauma in Neandertals. In the first section of the chapter, I review the primary descriptions of the injuries of individual Neandertal remains. In the second section, I summarize the history of interpretation and conclusions about trauma in Neandertals as a group.

In the fourth chapter, I test hypothesis about the distribution of trauma within the sample of individual Neandertals with trauma. These data mostly come from the primary descriptions of trauma reviewed in the third chapter. Variables include the temporal and geographical distribution of Neandertals with trauma, areas of the body with trauma, age and sex distributions of individuals with trauma, levels of preservation of individuals with trauma and degree of severity of injury.

In the fifth chapter, I examine ways of addressing the significance of trauma in the Neandertal sample as a whole and the problems inherent in this endeavor. In the first half of this chapter, I test several hypotheses about the independence of aspects of trauma and other factors in the context of a sample of Neandertals. I compiled this sample from all the European Neandertals published in the *Catalogue of Fossil Hominids* (Oakley 1971). These tests include the relationships between: preservation and how trauma is observed; age-at-death class and preservation status; age-at-death class and the presence of trauma; and the preservation of individual skeletal elements and the presence of trauma. I also compare distribution of trauma within skeletal elements of this European Neandertal sample with the distribution of trauma observed in samples from modern hunter-gatherer, forager, and nomadic populations. In the second half of this chapter, aspects of the limitations of the available material for examining trauma in Neandertals will be reviewed. These limitations include the disparate nature of the location and chronology of the samples, different levels of preservation depending on the site, possible preservation biases of some elements, potential age and sex biases in the Neandertal sample, unknown possible differences in the activities of males and females, unknown biases in the mortuary treatment of the sample, small sample size, non-standardized reporting of the Neandertal remains, and the lack of comparability of the Neandertal remains to other published samples.

In the sixth chapter, I discuss of alternate ways of addressing trauma in Neandertals. These ways include the benefits of the analysis of a sample from a single site. I outline a new methodology for observing and recording trauma in fragmentary remains. I then use these methods to collect data and compare trauma in the Krapina

Neandertal sample with trauma in a similarly fragmentary 14th Century C.E. sample from Portugal.

In the seventh chapter, I discuss the conclusions of this dissertation, and apply the results to the broader contexts of Neandertals studies and studies of trauma in general, and make recommendations for avenues of future research.

CHAPTER II

DEFINITION AND ASSESSMENT OF TRAUMA

A. Chapter II Introduction

The study of trauma is just one aspect of how paleopathology assesses the health of past populations. There is an underlying assumption in the comparative study of trauma that differences in the patterns of trauma between populations reflect differences in exposure to environmental hazards and/or differences in cultural responses to those hazards. However, there are many ways in which patterns of trauma may differ that are related to the composition of the samples being compared.

In this chapter, I describe how evidence of trauma is defined and communicated to other researchers. Many aspects of how much evidence of trauma is observed are linked to the nature of the sample being observed. The effects of some of these sampling biases such the differential ease of observation of types of trauma, variability in age at death and taphonomic modification, and differences in how evidence of trauma is counted by researchers are reviewed. I also summarize the various ways "patterns of trauma" are defined and compared. I conclude this section with a "wish list" of aspects that a sample should have in order for research into its trauma to have the highest resolution and be most representative of the trauma that occurs in the living population. I then compare this ideal sample with the realities of the extant Neandertal sample.

B. Definitions of Trauma

In this section, aspects of the definition of trauma will be discussed. These definitions derive from medical and paleopathology literature.

Conventionally, the term "trauma" refers to an injury. However more precisely, there are two aspects to how trauma is defined by most researchers. The first aspect is from the perspective of the person being acted upon or "the victim" who suffers the injury or wound which is termed "trauma". The second aspect is the external (to the victim) agent that causes this trauma to the victim. Unlike other pathologies that occur from disruptions within the victim's body, trauma is defined by its direct external source. This direct external source refers to something in the victim's environment, such as hazardous terrain, falling stalactites, exiting a mother's womb, abusive spouses, etc.

Trauma is defined by Roberts (1991) as "any bodily injury or wound, and may affect bone or soft tissue of the body." Similarly Kilgore *et al.* (1997: 103) functionally define trauma in the perspective of the victim "as evidenced by a fracture, dislocation or muscle pull". Ortner's (2003:119) definition adds a few more details: "1) partial to complete break in a bone, 2) an abnormal displacement or dislocation of joints, 3) a disruption in nerve and/or blood supply, and 4) an artificially induced abnormal shape or contour of the bone." Lovell (1997:139) expands this definition to include the concept of outside agency in the definition of trauma. She states that "Trauma may be defined in many ways but conventionally it is understood to refer to an injury to living tissue that is caused by a force or mechanism extrinsic to the body." Stedman's (1982) medical definition of trauma refers to this outside agency as "harsh contact with the environment."

In summary, trauma is defined by a physical impact on the victim from an outside force. The affect of this impact may be limited to the soft tissue or it may be observed in the underlying bone as a fracture, dislocation or muscle pull that has the potential to disrupt nerve and/or blood supply. It is this outside agency that differentiates trauma from other pathologies that affect the body from the inside and may also cause damage to bone.

C. Identifying Trauma in Bones

In this section, aspects of the way trauma is observed in bone will be discussed. The first of these aspects is the assessment of when trauma occurred in relation to the individual's time of death. The next aspect to be discussed is a summary of the types of trauma that have been recognized by different authors and how those traumas appear in the cranial and postcranial regions of the body. The influence of age at death and taphonomy biases in the observation of trauma will also be summarized.

C1. Time of trauma

In both archaeological and forensic settings, determining when trauma occurred in relation to the individual's time of death is a crucial aspect of trauma analysis. In this section, the stages of fracture healing as well as assessing when trauma occurred in relation to the death of the individual will be discussed. Differences in the appearance of trauma that occurred during the individual's lifetime versus at the time of death versus after death will also be summarized.

Many traumas that occur during the lifetime of an individual are not visible in the archeological record. Except in special cases of preservation such as mummification, freezing or being deposited in anaerobic environments such as bogs or lead coffins, soft

tissue is not preserved for very long after death and any evidence of trauma that is not present in bone is lost. Breitmeier *et al.* (2005) analyzed the pathological results of 87 individuals who were buried between 5 days and 16.8 years before exhumation and determined any soft tissue damage was difficult to observe after 8 years and for many parts of the body the duration was even shorter. Because of this lack of long-term soft tissue preservation, almost all trauma analysis of past populations is limited to the trauma that may be observed in bones. Therefore it is important to understand how bones react to forces of trauma both during the life of an individual when they are covered by soft tissue as well as after death when they are exposed to taphonomic forces without the protection of overlying tissue.

Knowledge of when a trauma occurred in relation to the death of an individual is important for understanding behavior in the past. Trauma that healed during the lifetime of the individual shows that the person was able to live despite injury and depending upon the location and severity may show some kind of assistance and care given by other members of the group. Trauma that occurs around the time of death is either trauma that contributed to the death of the individual before any healing could occur or might represent some type of funeral processing of the corpse when it was recently deceased. Trauma that happens a long time after death when the soft tissue has disappeared and the physical properties of the bone have changed can be caused by forces such as later funeral processing, scavenger activity, and soil perturbations. It is important to be able to recognize the interval in which trauma has occurred so that its behavioral relevance to the question being asked may be assessed.

Recognizing signs of healing in bone is the most important way to determine if trauma has occurred during the lifetime of an individual. The process of healing differs depending on the type of bone that is injured. Because of differences in their formation and composition, tubular bones (long bones such as humerus, phalanx, clavicle, tibia, etc.) have different stages of healing than flat or irregular bones which are largely comprised of cancellous bone (e.g. bones of the skull and pelvis).

C1a. Time of healing in tubular bones

Lovell (1997) recognizes five overlapping stages of healing in tubular bones (i.e. cortical bone found in the shafts of long bones) that she compiled from the medical literature (Patton 1984; Adams 1987; Apley and Solomon 1992):

1. The first stage of fracture healing in tubular bones is haematoma formation that happens within 24 hours of fracture. In this stage, a haematoma is formed by the seepage of blood from torn vessels and the fractured ends of the bone die because of lack of blood supply.

2. The next stage, cellular proliferation, occurs during the next three weeks. In this stage, osteoblasts of the periosteum and endosteum deposit osteoid around each end of the fracture and push the haematoma aside. It is towards the end of this stage when healing can be first observed on radiographs as osteoid is deposited and begins to form a callus around the broken ends.

3. The formation of this callus represents the next stage in healing of the tubular bone. During the next three to nine weeks, the osteoid becomes mineralized and forms a callus of woven bone that externally bridges the gap between the fractured ends and acts as a splint to stabilize them.

4. The next stage, which Lovell (1997: 145) refers to as "consolidation", is highly variable in duration. Depending on the diameter of the bone, location of the bone within the body, and nature of the fracture itself, it may take a few weeks to a few months for the callus of woven bone to consolidate into mature lamellar bone and a solidly united fracture area. Smaller diameter bones heal more quickly than larger diameter bones. Bones of the upper limbs heal more quickly than those of the lower limbs. Spiral and oblique fractures heal more quickly than transverse fractures.

5. The final stage to the healing process in tubular bone is the gradual remodeling of bone to its original form. This stage takes place slowly over the next six to nine years as the bone strengthens along lines of mechanical stress. This strengthening results in lines of increased density on radiographs, "Harris lines," that mark the site as a healed fracture on adult bones. In children, as discussed later in this section, the site of a healed fracture may be completely obliterated by the growth process and leave no sign of previous trauma.

C1b. Time of healing in cancellous bone

The stages of healing of cancellous bone are simpler and quicker than those of tubular bone because cancellous bone already has a mesh-like structure and no medullary canal. Because of this, a much larger area between fracture fragments come into contact and osteoblasts can penetrate the mesh more easily than they can the compact tubular bone. Rather than indirectly uniting the fragments by means of a callus that spans the periosteal and endosteal surfaces, union occurs directly between the fragments. According to Lovell (1997):

1. The first stage of cancellous bone healing is, as in tubular bones, haematoma formation happens within 24 hours of fracture. In this stage, a haematoma is formed by the seepage of blood from torn vessels and the fractured ends of the bone die because of lack of blood supply.

2. The second stage occurs when the initial haematoma is penetrated by proliferating bone cells growing directly from opposing fracture surfaces.

3. The third stage occurs when the developing tissues fuse when they meet and calcify to form woven cancellous bone.

C1c. Antemortem, perimortem and postmortem trauma

The ability to discern whether any stages in the healing process have taken place is vital to assessing whether the trauma occurred during the lifetime of the individual. If there is any sign of healing present at the fracture site, it is clear that this injury occurred while the individual was still alive. Antemortem trauma is defined by the observation of some stage of healing. Stages of healing are normally not observable until about three weeks after the trauma occurred, according to Lovell (1997: 322), however Sauer states that remodeling indicates that an injury occurred "at least a week before death." Antemortem trauma is clearly trauma that has occurred during the individual's lifetime, even though health status, the location of the injury on the victim, and genetics also contribute to the time it takes to show sign of healing (Sauer 1997). Since there is "unequivocal evidence" (Walker 2001:578) that antemortem trauma occurred while the person was still alive, many studies of trauma in archaeological populations are limited to antemortem trauma.

The lack of time for an observable bony reaction to trauma in the couple of weeks before death produces the same visual results as the lack of observable bony reaction to trauma in the few weeks after death. Because it is impossible to distinguish the trauma that occurs immediately pre-mortem from the immediately postmortem before the body starts to significantly decompose and its organic components deteriorate, this interval is known as "perimortem." This perimortem interval may be weeks or months in duration depending on the decomposition rate after death. As long as bone retains its viscoelastic nature, trauma cannot be distinguished as absolutely postmortem. Trauma that occurs during this interval may represent a lethal wound or may be caused by the handling of the body after death. Since it is difficult to distinguish which of these is the case, most paleopathologists are very conservative in recording trauma that occurs during this period unless there is very strong evidence, for example a projectile point lodged in a vertebra, that the trauma probably occurred before the victim died. Trauma that occurs during this interval is mostly underreported in archaeological skeletal populations whereas it makes up the bulk of autopsy findings in clinical populations where time of injury can be determined by soft tissue reaction.

Although antemortem trauma shows clear signs of the healing process which distinguishes it from perimortem trauma, there are many aspects that both intervals share in the appearance of trauma on bone due to the integrity of the organic components of the body that distinguish them from the postmortem interval. These aspects, according to Lovell (1997:145), include the "uniform presence of stains from water, soil, or vegetation on broken and adjacent bone surfaces; the presence of greenstick fractures, incomplete

fractures, spiral fractures, and depressed or compressed fractures; oblique angles at fracture edges; and/or a pattern of concentric circular, radiating, or stellate fracture lines."

Unlike perimortem trauma, postmortem trauma is trauma to the human remains that occurs at some interval long after death. During this interval, bone has lost its viscoelastic properties and is exposed to the elements by the decay of the soft tissue that had previously surrounded it. During this interval, bone is very brittle and friable. It is easily broken by carnivore or scavenger activity (analyzed in detail by Shipman 1981), the movement of soil, and other site formation processes. Villa and Mahieu (1991) outlined five testable attributes to distinguish "green" (i.e. perimortem) from post-depositional bone breakage in humans in the context of distinguishing "natural" fractures from those caused by humans to extract marrow. These attributes include the fracture angle formed by the fracture surface and the bone cortical surface, the shape of the bone fragments, the circumference of the diaphyseal shaft, the degree of shaft fragmentation and the breadth to length ratios of the shaft splinters. In postmortem interval trauma, bones tend to be broken at right angles, most fractures tend to be transverse in outline, shaft diameters tend to be complete, and shaft fragments tend to break into shorter splinters. Lovell (1997:145) offers another differentiation between perimortem and postmortem trauma attributes: "a non-uniform coloration of the fracture ends and the adjacent bone surface, especially light-colored edges."

Being able to assess at what stage trauma occurred makes it possible to determine what trauma happened during the lifetime of the person. Since most studies of trauma focus on the behavior of humans during their lifetimes that exposed them to this trauma, these studies mostly are limited to antemortem trauma and perimortem and postmortem

traumas are excluded. In these studies, the presence of antemortem trauma is defined by evidence of healing. Some studies are exclusively focused on the perimortem interval: these include studies that focus on how individuals have died, such as those concerning potential mass graves of victims of inter-personal conflicts such as the Ofnet massacre described by Frayer (1997), as well as how bodies were processed immediately after death, such as those concerning potential cannibalism described by Turner (1983). Finally it is important to distinguish postmortem trauma from perimortem trauma so that postmortem trauma is not falsely considered to represent funeral preparation of the victim contemporary with his death as was determined in the case of Engis by White and Toth (1989).

C1d. Section summary: time of trauma

In this section, ways of assessing when trauma took place relative to the lifetime of the victim were reviewed. These ways include the diagnosis of healing to trauma as it takes place in tubular and cancellous bone during the life of the victim. The period that surrounds the death and immediate funeral preparation of the individual is also distinguished from the period long after the death of the victim by differences in the physical properties of bone during these intervals.

C2. Types of Trauma

In this section, various ways of categorizing types of trauma will be discussed. These ways include defining various types of injury by their outside agency, their appearance on bone, degree of severity, and where they occur on the body. Examples of types of trauma that commonly occur on the cranium and postcranial bones will be discussed.

C2a. Categorizing types of trauma

Types of trauma have been categorized in many different ways by different scholars. Often these categories are delineated both by the intent of the external agent who inflicted the trauma and by its appearance on the victim. Such categories may include "weapon wounds" (Ortner and Putschar 1981; Knowles 1983; Merbs 1989), "trephination" (Ortner and Putschar 1981; Knowles 1983), "scalping" (Ortner and Putschar 1981; Merbs 1989), "surgery" (Merbs 1989), "decapitation" (Bennike 1985; Liston and Baker 1996), "hanging/strangling" (Bennike 1985), "amputation" (Webb 1995), "cannibalism" (Turner 1983; Vila and Mahieu 1991) and "pregnancy-related trauma" (Ortner and Putschar 1981). Although these categories are informative in well-preserved individual cases of injury, it is hard to use them to be able to compare trauma in large skeletal populations where intent is largely unknown. For this reason, Lovell (1997:140) states: "It may be more prudent, however, to first sort injuries according to their predominant characteristic: either *fracture* (any break in the continuity of bone) or *dislocation* (the displacement of one or more bones at a joint), rather than to classify injuries in a manner that implies causation or intent."

A traumatic injury to a joint may result in a dislocation. Most categorizations of trauma list dislocation as one type of trauma (Steinbock 1976; Ortner and Putschar 1981; Knowles 1983; Merbs 1989; Roberts and Manchester 1995; Lovell 1997). It is occasionally possible to observe direct evidence of dislocation in skeletal specimens (Wood Jones 1910; Ortner and Putschar 1981; Jurmain 1989; Roberts and Manchester 1995; Kilgore *et al.* 1997). However, in a review of the literature on dislocation, Jurmain states that "the prevalence of such injuries is quite low" and the "paleopathological data

relating to dislocation are simply a collection of case reports" (1999:211). Dislocation often results in damage to the joint capsule and surrounding ligaments and possible joint incongruence which may evidence itself in bone as osteoarthritis. For this reason, some investigators such as Berger and Trinkaus (1995) and Gardner and Smith (2006) include the presence osteoarthritis (OA) or "degenerative joint disease" (DJD) in their list of indications of trauma. Osteoarthritis, however, is complex in etiology. Although trauma to a joint that is severe enough to result in a dislocation often results in osteoarthritis in that joint, the observation of osteoarthritis in a joint can be the result of many different factors. According to Panush and Inzinna (1994:1):

> A traditional understanding of DJD was that this was a 'wear and tear' phenomenon that accompanied aging or unusual circumstances. As noted, it is now appreciated that a variety of physical, biomechanical, occupational, and sports related conditions, environmental conditions, genetic factors, trauma, inflammation, congenital abnormalities, and nutritional and metabolic conditions are relevant.

To consider evidence of osteoarthritis as sign of previous traumatic injury may not be a conservative or perhaps an accurate assessment. Other reviews of osteoarthritis from a clinical perspective have also cast a doubtful light on whether trauma to a joint even leads to osteoarthritis in most cases. Mankin *et al.* (1986:1139) state "Very little epidemiologic data exist to show that chronic occupational trauma or even acute injury lead to OA." and goes on to say "In fact, although anecdotal evidence for the association of OA with trauma is quite strong, there are few reliable and definitive epidemiologic correlative studies."

There are many different types of trauma recognized in the literature. Few, however, are particularly relevant to the analysis of long-dead archaeological samples since they rely on the assumption of a particular direct agent or intent, mostly occur as a

perimortem event, or rely on ambiguous evidence for a diagnosis. Even for dislocations, recognized by Lovell (1997) as a "more prudent" category along with fractures to define trauma by, direct evidence of dislocation seems to be rare even in fairly well preserved samples and the indirect evidence of dislocation determined by the presence of osteoarthritis may not be conclusive. It seems to make sense to limit the collection of trauma data to the presence of fractures which are relatively unambiguous and easy to macroscopically diagnose. By concentrating on the direct presence of fractures and not on their etiology or on indirect indications of trauma, trauma counts are made more comparable between collections and less subject to personal interpretation or speculation. The following section outlines the most prevalent types of fractures and how they are observed on cranial and postcranial human remains.

C2b. Types of fractures

According to Lovell (1997:141) in her review of fracture analysis, a fracture is "an incomplete or complete break in the continuity of a bone." Depending upon whether the mechanism of injury is direct trauma or indirect trauma, different types of fractures are produced. Direct trauma is when the break occurs at the point of impact and may produce the following general types of fractures: penetrating, comminuted, transverse, and crush.

Penetrating fractures occur when a large force is applied to a small area and the bone cortex is penetrated. Examples include an arrow piercing the cranial vault or an amputation piercing a limb.

Comminuted fractures occur when the bone is broken into three or more pieces, usually also as the result of a large force being applied to a small area. Examples include

high velocity bullets penetrating the cranial vault or blunt force trauma being applied to a limb.

Transverse fractures occur when a small force is delivered to a small area where force is applied perpendicular to the bone. An example of this might be a kick in the shin of a soccer player from another player.

Crush fractures occur when a force is applied directly to cancellous bone. This force produces a depression fracture if applied only to one side of the bone or a compression fracture if applied to both sides of the bone. Examples of this type of fracture include blunt force trauma to the cranial vault or the incomplete penetration of a low velocity missile such as a musket ball (Liston and Baker 1996).

An indirect fracture occurs when the fracture is not located at the point of impact. Types of indirect fracture include: oblique, spiral, greenstick, impacted, burst and avulsion fractures (Lovell 1997).

Oblique fractures occur when there is rotational or angular stress on the long axis of a bone. When healed, these fractures are hard to distinguish from spiral fractures which occur when there is rotational and longitudinal stress along the long axis of the bone which produces a spiral line that winds down the bone.

Greenstick fractures are incomplete fractures that occur when there is bending of bone but the bone does not break. These fractures are common in children due to the pliability of their bones.

Compression fractures occur when bone ends are driven towards each other by the force of the trauma. An example of this might be seen in the proximal humerus when a person catches him or herself on an outstretched hand.

An avulsion fracture occurs when a proximal or distal end of a bone is torn away from the rest of the bone by tension on a ligament or tendon attachment. These mostly occur during childhood before the epiphyses are fused to the shaft.

A burst fracture occurs only in the vertebral column as vertical compression ruptures a vertebral disk and disc tissue is forced into the vertebral body. Evidence of this is often seen in the form of a Schmorl's node which is a shallow depression with rounded edges located centrally or slightly posteriorly usually on the inferior vertebral end plate (Jurmain 1999).

Lovell's review of the different types of fractures, as summarized above, was compiled out of orthopedic literature including Adams (1987), Schultz (1990), Gustilo (1991), Harkess and Ramsey (1991), and Apley and Solomon (1992). These typologies of fractures come from studies of living people in a clinical setting where it is possible to observe the state of the fractured bone during all stages of healing. Studies such as Galloway (1997) offer even more detailed assessments of the forces that produce the different types of trauma recognized by Lovell (1997); however, in an archaeological setting, most of the fractured bone that is analyzed comes from antemortem healed fractures where it is often difficult to assess what kind of fracture took place. It is much easier to assess types of fractures on unhealed bone, such as is observed in perimortem or antemortem trauma, but this information is not necessarily relevant to the trauma experienced by the individual during his or her lifetime. For this reason, many studies of trauma in skeletal populations may list each incidence of trauma individually in their report and try to discern what type of fracture may have occurred, but for the purposes of comparing trauma between populations, simple counts of all fractures observed without

specifying type are compiled for each skeletal element or region of the body. The following is summary of the most prevalent types of fracture observed in the cranium, postcranial long bones and other postcranial bones. This summary will only include a few of the types of fractures specified above that seem to be most easily observed and recognized in paleopathological studies of trauma within specific populations.

C2bi. Most Prevalent Types of Cranial Fractures

As is the case for all types of trauma, there are many ways to organize and classify various types of cranial fractures. The interpretation of the mechanism of injury for cranial fractures is very complicated and is based on the patterning of fracture lines, the specific bones involved and the degree of deformation, etc. (Kaufman *et al.* 1997). In order to examine evidence of cranial fractures, it is first important to distinguish a cranial fracture from other lesions of infectious origin. Walker (1989) offers four distinguishing criteria of a cranial fracture caused by trauma from a bony reaction due to an infectious etiology: 1) In traumatic injuries there is an absence of reactive bone indicative of an infectious etiology. 2) Lesions elsewhere on the skeleton may suggest a systemic infection whereas traumatic injuries are usually single. 3) Many injuries caused by trauma to the cranium show as well-delineated circular or ellipsoid depressed pattern. 4) In traumatic injury, fracture lines at the periphery of the depressed areas may be preserved.

Most cranial fractures that affect the vault are caused by direct trauma. There are two types of fractures most commonly observed: depression and penetrating.

Depression factures are caused by a direct blunt force that crushes the outer table of the cancellous bone and produces a depression in the bone that is often round or

ellipsoid in shape which varies in size depending upon size of the agent of the injury. The point of impact is the depressed area from which linear fractures may radiate. Injuries of greater force will produce more inward displacement of the outer table of the bone and potentially result in a portion of the bone becoming detached. Depression fractures are most often observed in frontal and parietal bones and can be the result of injuries such as blows from clubs, stone axes or other blunt objects.

Figure 2.1. Minor cranial depression fracture on the left side of the frontal fragment of Krapina 4 near the coronal suture (Photo: D.W. Frayer)

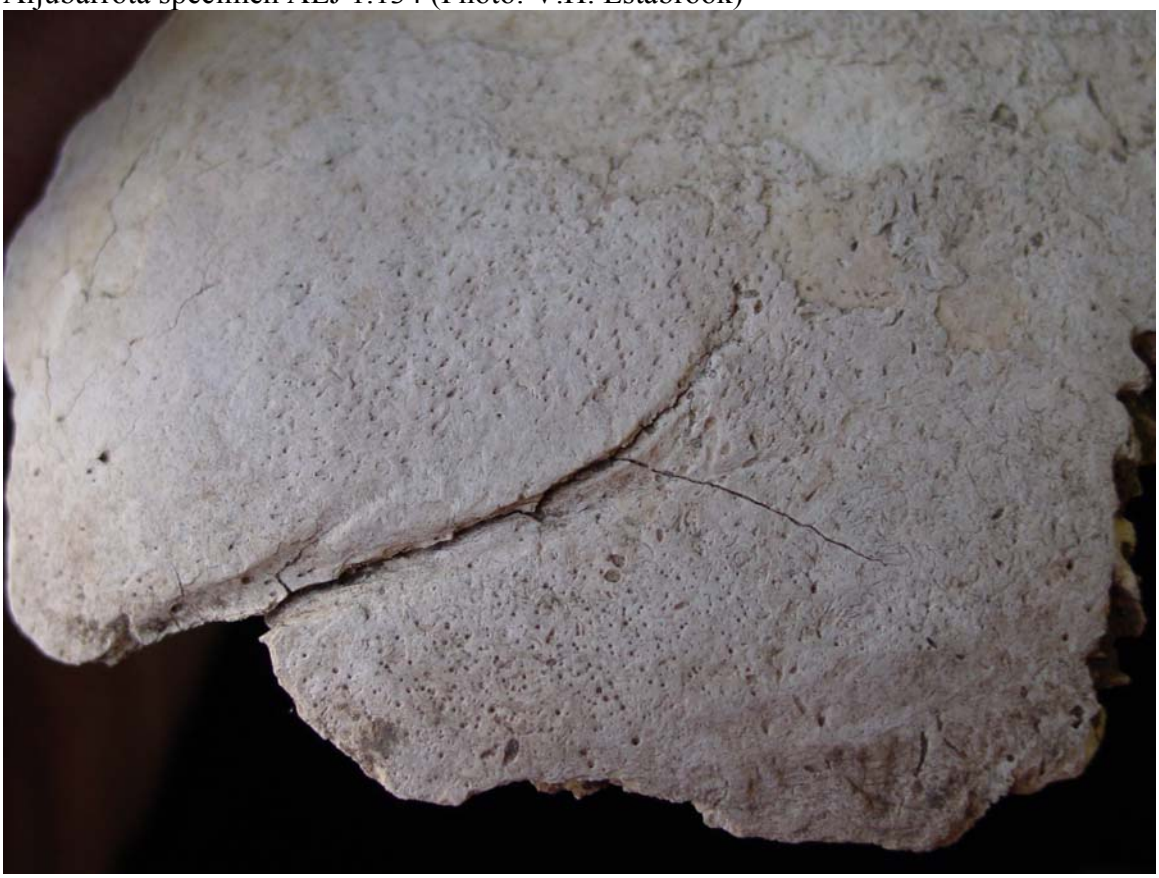
Depression fractures are often assessed as a sign of interpersonal violence (Walker 1989; Jurmain and Bellifemine 1997; Rocsandic *et al.* 2006), although in the case of Aboriginal Australians, Webb (1995) suggests that some of depression fractures may have been self-inflicted during the course of mourning rituals. In forensic literature there is also incidence of depression fractures being caused by falls onto furniture corners or concrete steps (Polson *et al.* 1985). Although modern medical literature does not seem

to have much to say on the subject of depression fractures that do not penetrate into the inner table (perhaps because X-rays or MRI can distinguish them from injuries that require medical attention), there are some examples of discussion of this type of fracture in 19th century medical textbooks such as Gross (1882: 68):

> Fracture of the external table alone of the skull is extremely uncommon, and can happen only in the adult, or in persons whose cranial bones have a distinct diplöe. Moreover, its occurrence implies unusual brittleness of the outer table, and inordinate firmness of the inner. The fracture is generally of small extent, and the depression inconsiderable. The most common cause is a blow from a narrow, blunt-pointed body. Besides being momentarily stunned, the patient suffers no particular inconvenience, save what results from the scalp lesion. The diagnosis of such a fracture must necessarily be obscure, and, unless great care be taken, it might easily be confounded with an ordinary punctured fracture. Mistake will be best avoided, in case of wound, by the careful use of a fine probe, carried around the edge of the depressed bone, by the pressure of the finger, and by filling the artificial hollow with water. If the probe enter any side crevices, the finger cause motion, or the water disappear, there will be reason to conclude that the fracture involves both tables of the bone, and that it is of a punctured nature. The injury requires no particular treatment, apart from which that which may be necessary on account of the lesion of the scalp and brain.

Penetrating fractures to the cranium occur when a small area of impact is assaulted by a large or sharp direct force. The severity of the impact that produced the penetrating fracture may be determined by the extent to which the fracture is comminuted, the degree of displacement of the bone fragments as well as the extent and degree of separation of the linear fractures (Lovell 1997:150). When the penetration is caused by a projectile, the size of the fracture depends on the size of the size and speed of the projectile. When the penetration is caused by contact with a sharp edge as wielded in a chopping motion, it may be accompanied by some degree of depression as well as splintering of the bone with outward displacement near the point of impact if the weapon is withdrawn with a twisting motion.

Figure 2.2 Perimortem penetrating fracture to right parietal near temporal line, Aljubarrota specimen ALJ 1.134 (Photo: V.H. Estabrook)



Cranial vault injuries are the type of injuries most frequently observed to the cranium in archaeological samples. This might be due to their relative frequency within the population or it might be affected by the relative degrees of preservation of the bones of the cranial vault versus bones of the face at many sites (Walker 1997). Nasal fractures are the fractures most commonly observed as a manifestation of a blow to the face (Walker 1997:154). Such a blow produces one or more linear fractures in one or both nasal bones depending on direction of the impact. If the impact comes from one side, often fragments of the impacted nasal bone are pushed laterally away from the impact and linear fractures may also be observed on the frontal process of the adjacent maxilla. If the impact comes from straight on, both nasal bones are more likely to show linear

fractures as the force radiates transversely across the bridge of the nose. Nasal injuries may be produced by punches or other intentional blows to the face or accidentally by falls or collisions such as those observed in soccer players (Walker 1997). Injuries to the zygomatic area evidenced by linear fractures or depressions are also occasionally observed.

Depression fractures to the bones of the cranial vault are clearly the most commonly observed evidence of cranial trauma. Their relative high frequency, however, may be the result of preservation biases. The first possible bias is the high degree of preservation of some of the bones of the cranial vault. The bones of the vault that tend to be most affected by depression fractures, frontal and parietals, are also bones often relatively well preserved in archaeological samples compared to other, more fragile, cranial bones such as maxillas, sphenoids and nasals. The second possible bias is that the degree of injury produced by a depression fracture is less likely to be fatal than other types of injuries to the cranial vault such as penetrating fractures. Because depression fractures are less likely to be fatal and more likely to show signs of healing, they are also more likely to count as an incidence of trauma in studies that are limited to antemortem trauma. Finally, the risk for types of blunt force injury that produce depression fractures might simply be higher in many populations than the risk for other types of cranial injury. This final factor seems to be the underlying assumption in many analyses and comparisons of trauma between populations.

C2bii. Most Prevalent Types of Postcranial Long Bone Fractures

All long bones are tubular bones that may exhibit the various types of fractures already summarized above. Long bones can exhibit direct and indirect fractures. Of the

types of direct fractures, long bones may exhibit penetrating, comminuted and transverse fractures. Of the types of indirect fractures, long bones may exhibit oblique, spiral, greenstick, impacted and avulsion fractures. In long bone healed antemortem trauma, however, it may be difficult to distinguish fracture types beyond the two very general categories of direct or indirect. For this reason, fractures in long bones are often not identified by the types of fractures stated above. Instead, types of fractures in long bones are identified and the forces that created them are understood by the location in the body in which the fracture occurred rather than by the specific properties of the fractures themselves. In this section, the most common types of long bone fractures will be reviewed for the upper and lower limbs.

Many of the fractures observed in the upper limbs are the result of the impact of falling onto an outstretched hand. Fracture damage from such a fall is most often observed in the radius, although the ulna and humerus may also be affected. The most common type of radial fracture resulting from such a fall occurs in the distal shaft of the radius usually about 2 cm above the distal articular surface and is called a Colles' fracture. Other types of fractures in the radius also associated with falls are the Galaezzi fracture-dislocation which, like the Colles' fracture, involves only the radius and the Monteggia fracture-dislocation which involves the ulna as well as the radius. The Galaezzi fracture-dislocation occurs higher in the radial shaft than the Colles' fracture, usually at the junction of middle and distal thirds of the radial shaft and is associated with the dislocation of the inferior radio-ulnar joint. The Monteggia fracture-dislocation involves a fracture to ulnar shaft, accompanied either by the displacement of the radial

head or the fracture of the radial diaphysis if the radial head is not displaced (Jurmain 1999: 219).

In the humerus, neck fractures may also result from falls onto an outstretched hand especially if the bone itself has already been weakened by factors such as osteoporosis (Lovell 1997:160). Direct trauma to the shoulder such as the impact of a fall may result in the fracture of the greater tubercle of the humerus but most direct trauma to the shoulder results in fractures of the scapula.

Another common type of fracture observed in the forearm is the so-called "parry" or "nightstick" fracture. This fracture occurs when a blunt trauma being aimed at the head is fended off by up-raised pronated forearm causing a fracture to the shaft of the ulna.

Figure 2.3. Healed fracture to left ulnar shaft, Krapina 188.8 (Photo: M.H. Wolpoff)

Since Elliot Smith and Wood Jones (1910) first interpreted this fracture to the ulnar shaft as a "parry fracture," its appearance in skeletal populations has been regarded as a sign of interpersonal violence (Jurmain 1999:215). The automatic interpretation of ulnar shaft fractures being the result of interpersonal violence has been called into question with studies of skeletal populations, such as Smith (1996) and Kilgore *et al*. (1997) where

“parry” fractures do not seem to be accompanied by other signs of interpersonal violence anywhere else in the skeleton. It is possible to misinterpret a Monteggia fracture as a “parry fracture,” where the ulnar shaft was fractured and the radial head was displaced but did not produce permanent bone remodeling indicative of such as displacement, or where the fractured ulna was preserved but the distal end of the radius or the entire radius was not preserved (Jurmain 1999:221).

Other fractures may occur to the upper limbs but their etiology is mostly less specific than the previously mentioned types of fractures, and these fractures do not have specific names. Likewise, incidence of trauma to the lower limbs is mostly referred to by its location on the bone and not by a specific name implying location and cause of a trauma. The most frequent traumas to the lower limbs (and second only in general frequency to fractures of the distal radius), according to Lovell (1997), are caused by indirect trauma to the ankle in the form of abduction or lateral rotation to the medial malleolus of the tibia and the lateral malleolus of the fibula. Trauma of this kind is usually the result of falling or stepping onto an uneven surface. Fractures to the neck of the femur may be frequent in elderly individuals and are often seen as a secondary consequence of osteoporosis. Fractures to the femoral and tibial shafts are due to severe direct or indirect trauma. Because they require long periods of immobilization (approximately two months for the tibia and four months for the femur) to heal properly, such fractures may result in deformity and added stress to knee or ankle joints causing osteoarthritis. However, the presence of osteoarthritis without other signs of healing is not indicative of a fracture.

The interpretation of the forces which produce a fracture, especially in long bones, but also for other parts of the body, is starting to be understood as more ambiguous than previously imagined. It is important to be able to examine the entire fracture pattern in an individual in order to assess the etiology of a specific incidence of trauma.

C2biii. Most Prevalent Types of Fractures in Other Postcranial Bones

Postcranial bones that are not long bones include mandibles, hyoids, scapulas, clavicles, sternums, vertebras, ribs, sacrums, innominates, and bones of the hands and feet. Some of these postcranial bones are tubular bones while others are cancellous which affects the way traumatic forces impact the bone and the types of trauma observed. Many studies of trauma within skeletal populations exclude may exclude postcranial elements other than long bones from their investigation because of the lack of preservation of these generally smaller and more fragile skeletal elements. This exclusion also creates an influence of precedent when non-long bone postcranial elements from well preserved samples are also excluded because of the lack of comparative populations in the literature (Brickley 2006: 61). In this section, the most common types of fractures of these bones will be reviewed.

Mandible

Fractures of the mandible do not appear to be common in archaeological populations (Lovell 1997: 158). One of the reasons that fractures to the body of the mandible may not be so frequent is its high degree of density. When mandibular fractures do occur, the force of fracture often radiates from the site of impact to the opposite side of the jaw which causes a fracture both at the site of impact and at its opposite side. The

most frequent area of injury to the mandible is to the condylar neck at 29.1% of fractures and these injuries heal fairly readily with little loss of function (as reported by Goldman 2008). According to Galloway (1999:77), fistfights are a frequent source of mandibular injury and tend to result in fractures at the mandibular angle. Other sources of mandibular fractures in modern populations mostly involve automobile related trauma (Galloway 1999).

Hyoid

Hyoids are rarely preserved or recovered from archaeological settings (Lovell 1997:158). Incidences of hyoid trauma, however, are of special interest to forensic anthropologists as evidence of manual strangulation (Ubelaker 1992). Hyoids are mostly prevented from accidental trauma by their position behind the mandible and signs of fracture often indicate some form of massive trauma either to the mandible or directly to the throat. It is important to recognize, however, that the greater horns of the hyoid fuse rarely in individuals under 20 years of age and that there is a great deal of variability in fusion even after that, therefore there is a possibility that non-fusion may be misinterpreted as fracture (Ubelaker 1992).

Scapula

Most scapular fractures, although rare, occur as the result of a direct trauma. According to Galloway (1999:117), the body of the scapula is the most frequently fractured part but direct trauma to the shoulder may also cause fractures to the acromion and, more rarely, to the coracoid process.

Clavicle

Fractures to the clavicle are relatively frequent. In many samples, clavicles are the most frequently fractured bone [such as at Libben (Lovejoy and Heiple (1981)] . Mostly these fractures are due to indirect trauma such as the result of a fall onto the shoulder or onto an outstretched hand and are observed on the middle and lateral two-thirds of the bone. Often these fractures, when healed, exhibit some deformity due to the lack of immobilization for an adequate duration of time. Other clavicular fractures occur at birth if the baby's shoulders are too large to be maneuvered through the birth canal (Galloway 1997:114).

Sternum

Due to the crushing nature of a blow severe enough to damage the sternum, antemortem sternum trauma is rare because sternal trauma is mostly fatal (Galloway 1997:110). Also the xiphoid process of the sternum may be ossified in such a way that it presents the appearance of perforation but this is not related to any traumatic event.

Rib

Although rib fractures "are consistently amongst the most frequently recorded fractures in archaeological skeletal material, from all time periods and a wide range of geographical locations" (Brickley 2006:62), they do not seem to be so consistently recorded and documented as fractures to other parts of the body such as the cranium and long bones. According to Brickley (2006: 62), a possible reason for this omission is due to the trivial way that rib fractures are perceived in the clinical setting as well as the "general perception" that ribs are not well preserved in archaeological settings (Brickley 2006: 68).

Ribs differ with respect to shape, size, position in the thorax, and muscle attachment, some ribs seem to be more vulnerable to traumatic fracture than others. The ribs most vulnerable to fracture are located in the mid-thorax from the fourth rib to the tenth rib (Brickley 2006:70). Because the function of the rib is to protect the viscera, rib morphology allows for some degree of "in-bending" prior to fracture and most fractures to ribs in children present as a greenstick fracture rather than a full break due to the further elastic nature of immature bone (Galloway 1999: 107). In adults, however, rib fractures are common and also potentially fatal because of their potential to pierce the lungs or viscera. Lovell(1997:157-158) lists such resulting complications as lacerations of the pleura, lungs or intercostals vessels, pneumothorax, hemothorax, "flail" damage where second ribs are broken in two places, producing movement of a section of the chest wall during breathing, and damage to internal organs caused by a free-floating rib fragment. Despite these potential complications, according to Brickley (2006), most rib fractures observed in the archaeological context do not seem to be fatal and show signs of healing.

Antemortem mid-thorax rib fractures can be classified into one of two different types: transverse or oblique (Galloway 1999:107). Transverse fractures, the more common of the two types, are produced by direct blows to the chest and mostly occur in the anterior portion of the rib (Galloway 1999). Oblique fractures occur near the lateral curvature of the rib and are produced by forces such as crushing or bending such as may be caused by a fall from a great height (Galloway 1999). Postmortem rib fractures commonly occur along the spine as scavengers force the ribs out of alignment to gain access to internal organs.

Figure 2.4 Healed rib fracture from Aljubarrota collection, no specimen number (Photo: V.H. Estabrook)

Vertebrae

Although some vertebral fractures may be caused by direct trauma, most vertebral fractures are due to indirect trauma and/or stress. Vertebral spondylolysis, the complete or incomplete separation of the neural arch from the body of the vertebra most commonly expressed in lower lumbar vertebrae, begins as a microfracture caused by acute overloading events but subsequent chronic stress promotes its malunion (Lovell 1997:158). This type of vertebral fracture is associated with lifeway stress such as observed in arctic adapted peoples, and some types of athletics including gymnastics, football and water sports involving rowing or paddling (Merbs 1996).

Another type of fracture due to indirect trauma to the vertebral column is a burst fracture. A burst fracture appears in the vertebral column as vertical compression ruptures

an intervertebral disk and disc tissue is forced into the vertebral body. Evidence of this is often seen in the form of a Schmorl's node which is a shallow depression with rounded edges located centrally or slightly posteriorly usually on the inferior vertebral end plate (Jurmain 1999).

Pelvis

In general, the pelvis is well defended from traumatic injury by the muscle and fat that surround it and by the strength of its ligaments. Fractures to the innominates and the sacrum are rare and usually are the result of the impact of a large kinetic force, such as being struck by an automobile or falling from a great height (Galloway 1999:161). Such forces can result in the fracture-dislocation of the hip as the femur is driven through the floor of the acetabulum (Lovell 1997). Sacral fractures are rare and are often the result of forces acting on the entire pelvic ring and are mostly linked to a perimortem event (Galloway 1999). Coccygeal fractures occur when an individual lands in a sitting position but are seldom observed in an archaeological setting, even though they are not fatal, but because the coccyx is seldom preserved (Galloway 1999).

Hands

Metacarpals and phalanges are the most commonly injured bones of the hand. Most metacarpal fractures are either observed in the shaft or in the neck. Metacarpal fractures to the shaft tend to be oblique fractures caused by direct blows whereas those to the neck result from impact stress such as often occurs when hands clenched into a fist meet a hard object (Galloway 1999:154). Fractures of phalanges tend to be crushing fractures caused by fingers getting caught between colliding objects (Galloway 1999:156).

Most carpal fractures involve only the scaphoid. These fractures are the result of a fall or blow directly to the palm of the hand where the scaphoid is compacted between the distal radius and the capitate (Galloway 1999:147). The hook of the hamate may be fractured by a fall on a dorsiflexed wrist or as the result of direct violence (Galloway 1999: 151). All other carpal fractures are uncommon.

Feet

The most common site of injury in the foot is the calcaneus. The majority of calcaneal fractures are caused from falling from a height onto the heels, the so-called "lover's heels" (from those injuries received from jumping off a balcony after being detected in a tryst) (Galloway 1999:211). This type of fracture is often observed as either a crush injury that may be associated with other crush fractures in the thoracic or lumbar vertebrae, or as a split or crack in the subtalar tuberosity (Lovell 1997:164).

As in the hand, metatarsals and phalange injuries in the foot are the next most common sites of injury. According to Galloway, the phalanges of the foot are "small bones ideally positioned to collide with a wide variety of objects" (1999:222). The proximal phalanges seem to be the most vulnerable to fracture. The base of the fifth metatarsal is a common site of avulsion fractures. The fracture is called a "tennis fracture" and is caused by a contraction of the *fibularis brevis* muscle or the pulling on the plantar aponeurosis as may occur when the foot is abducted while the ankle is plantar flexed in a situation such during a game of tennis (Galloway 1999).

C3. Age-at-Death biases in identifying trauma

In this section, biases in identifying antemortem trauma in skeletal remains of different ages at death will be reviewed. The ability of bones to respond to traumatic

forces changes throughout the lifetime of an individual. Because of these changes in the elasticity and density of bone, different types of fractures may occur depending on the age of the individual at the time when the trauma occurred. Also, the longer a person lives, the more time he or she has to accumulate injuries. Differences in the way trauma affect juvenile, adult and older adult bone during the lifetime of the individual will be discussed as well as differences in the evidence of antemortem trauma visible at death.

C3i. Changes in physical properties of bone during life

The physical properties of bone change throughout the lifetime of the individual. During fetal development most the skeleton is made of the same woven bone that appears during fracture repair (discussed previously) and has a relatively high number of osteocytes compared with mature lamellar bone. Lamellar bone replaces this woven bone over time and is laid down much more slowly. This process of ossification begins before birth and continues as lamellar bone is remodeled into haversian bone formed by secondary osteons replacing the existing lamellar bone throughout the life of the individual. These Haversian systems perforate the bone to contain blood, lymph and nerve vessels that replace the nourishment from surface blood vessels in the more porous woven bone. As the individual ages, the number of secondary osteons increases. Because bone strength is partially related to the proportions of primary and secondary osteons, a higher proportion of secondary osteons is accompanied by a decrease in bone density (Currey 1984). Immature bones have fewer but larger Haversian canals with higher water content and are less brittle. As an individual ages, the number of secondary osteons increases and bone becomes less dense and more brittle. This loss of elasticity contributes to the decrease in the maximum strain that can be withstood, the shear strength and the

average tensile strength of the bone over the lifetime of an individual at a rate of 4% to 7% per decade after the age of twenty (Galloway 1999).

Levels of mineral density in bone, i.e. the concentration of inorganic matter within a given volume of bone, also change during the lifetime of an individual and peak between 30 to 35 years of age (Galloway 1999). This peak is followed by a gradual loss with increasing age in men and a more precipitate loss in women for the first five to fifteen years after menopause followed by a more gradual loss. In both men and women, loss of bone density is correlated with increased risk of fracture, especially in the case of loss of extremely large amounts bone tissue clinically termed "osteoporosis" that is associated with some postmenopausal women (Mazess 1987).

C3ii. Trauma in juvenile bone- "not on your permanent record"

Observations of fractures that occur during childhood are not always comparable in the skeletal record to observations of fractures that occur during adulthood. There are several reasons for this. These reasons include differences in the reaction of immature bone to traumatic forces, differences in anatomical structures during childhood and their susceptibility to forces of traumatic stress, and differences in degrees of healing and the obliteration of superficial signs of fracture.

Immature bones are more elastic in their ability of absorb traumatic forces than their adult counterparts. This higher level of absorption is due to relatively higher content of woven bone and cartilage in immature bone. Because children's bones are more pliable and porous, they are more likely to respond to traumatic forces by bending rather than breaking. Although this bending may not cause a visible reaction from the bone, when it does, it is often observed in the "greenstick" type of fracture where the angulation

forces place one side of the bone under tension while the other side is under compression. This results in a an incomplete transverse fracture beginning on the tensile side which usually extends to the midline of the bone while the remaining unfractured remains bent or bowed (Galloway 1999). This type of fracture may heal more quickly than a complete break depending upon its location in the body.

The period when bones are growing includes the fetal stage (the period before birth), infancy (from birth to three years old), childhood (from three to twelve years old) and adolescence (twelve to twenty years old) (Buikstra and Ubelaker 1994). Growth and development occurs at different rates during each of these stages so that evidence of trauma that occurs earlier may be less likely to persist into adulthood than trauma that occurs late in adolescence. During this growth of bones, the epiphyses which are cartilaginous at birth are gradually replaced by bone until skeletal maturation. Although the epiphyses are protected against injury because of the resiliency of the cartilage during most of growth, as they become increasingly bony, the risk of fracture to the physes or growth plates increases as the protective cartilage thins (Jones 1994).

Juveniles also may be exposed to different sources of potential trauma depending upon their age because of differences in their participation in activities as well as differences in their size. Injuries due to falls are a good example of this. Although infants and young children are more likely than their adolescent counterparts to fall during the process of learning how to walk, falls are less likely to cause observable injury. This is because the kinetic force of a fall, the product of body mass and acceleration, is much smaller in a light and low-to-the-ground toddler than in an almost adult sized adolescent. Adolescence is a time when not fully skeletally mature individuals are initiated into their

adult tasks and may be not only at greater risk for exposure to trauma than more experienced adults but also less likely to have evidence of fracture completely remodeled during their remaining growth.

Immature bones heal more quickly than mature bones when fractured. This is due to their increased vascularization and greater osteogenic activity at the interface with the periosteum (Glencross and Stuart-Macadam 2000). The rate of healing is directly related to the age of the child at the time of the injury. A fracture to the shaft of a femur takes about three to four weeks to heal in newborns while the same fracture takes twelve to sixteen weeks to heal in adolescents (Jones 1994). There is also a faster rate of remodeling that accompanies bone growth in immature skeletons. This is especially the case when there is two or more years of growth left, the injuries are close to the metaphysis where turnover is the quickest, and when changes in the bone's alignment or angulation occur in the plane of motion (Glencross and Stuart-Macadam 2000). Evidence of healed injuries is more likely to be obliterated in such cases of immature skeletal trauma than in adult counterparts (Ortner and Putschar 1985). Most signs of childhood fracture persist into adulthood when the fracture occurs at midshaft and, because of shortening, angulation or rotation, the bone's alignment or angulation is at a right angle to the plane of motion (Glencross and Stuart-Macadam 2000). Displaced fractures that cross the growth plate are also more likely to leave persistent surface alterations visible to macroscopic examination as well as radiographs (Glencross and Stuart-Macadam 2000).

In the archaeological context, signs of trauma to skeletally immature individuals are mostly likely to be observed on remains that did not survive long into adulthood. Glencross and Stuart-Macadam (2000) argue that it is possible in adult remains to

differentiate healed injuries that occurred during childhood from those that occurred during adulthood by observing in modern clinical data what types of injuries seem to occur mostly during childhood and looking for those in the adult skeletal record.

C3iii. Trauma in Adult Bone- "what doesn't kill you makes you stronger"

Properties of skeletally mature bone span two age categories "young adult" (ages twenty to thirty five years old) and "middle adult" (ages thirty-five to fifty years old) (Buikstra and Ubelaker 1994). The properties of skeletally mature bone differ from properties of juvenile bone and from properties of senescent bone (which will be discussed in the next section). Trauma that occurs to skeletally mature bone is the trauma most likely to be observed as healed antemortem trauma in adult skeletons. This is both because mature bone is less likely to completely remodel after a trauma than immature bone and also because adults are more likely to expose themselves to higher levels of "occupational" risk for trauma. There may be, however, a great deal of variability in an individual's personal exposure to risk of trauma. This variability might be due to division of labor, interpersonal violence and/or bad luck as well as how long the individual was alive. In comparing rates of trauma in populations, it is assumed that individuals who come into contact with a higher number of direct external sources of potential trauma will experience more trauma than those who come into contact with fewer sources of potential trauma.

According to Judd (2002), implicit in this assumption that individuals who experienced more traumas also experienced a higher frequency of encounters with sources of trauma, is a sense that a person has a random risk of exposure to trauma, which she does not regard as accurate. Judd discusses the possibility that some people

may be more prone to trauma than others for reasons other than differences in exposure to hazards. She quotes the conclusion of Sims *et al.* (1989) that trauma ranks as a "chronic and recurrent disease." In her review of recent clinical literature (Reiner *et al.* 1990; Smith *et al.* 1992; Poole *et al.* 1993; Hedges *et al.* 1995; Williams *et al.* 1997 and Kaufmann *et al.* 1998), Judd shows that clinicians have begun to develop a profile of people who experience repeat experiences of trauma, "the injury recidivists." These are people who "accumulate an aggregate of traumatic lesions over their lifetime, which is precisely what bioarcheologists observe in archeological skeletal collections" (2002:89). These "injury recidivists" in Judd's Nubian sample were mostly males whose age at death was less than 35 years old which seems to follow the pattern of males whose first injury occurs at about 20 years of age and present another injury during the next five years seen in clinical literature.

This concept of some members of a population being more at risk for repeat trauma than others challenges one of the underlying assumptions in trauma analysis in a population. This assumption is that it is an individual's exposure to environmental hazards (rock falls, violent conflict with another human, close contact with large ungulates in death throes) that puts him or her at risk for trauma rather than some other, more intrinsic, factor such as a higher degree of aggression, poor peripheral vision, clumsiness etc. The implications of Judd's (2002) findings is that there may be other biases in observed frequencies of trauma that are not related to an individual's age at death or frequency of environmental exposure to trauma. Some people are simply more "accident prone" than others. Therefore, one of the importances of large samples with

many individuals is that the influences of such individuals are mitigated by the weight of the rest of the sample.

In any case, the older an individual is at the time of death, the more likely it is that he or she has survived an incidence of trauma and his or her skeleton will show some indication of antemortem trauma. As fractures heal in adults, it becomes increasingly more difficult to determine when in the past the trauma had occurred relative to the individual's age at death. Because of this inability to pinpoint when during life a trauma occurred, the age-at-death structure of the group will have an influence on any prevalence data from that group.

Lovejoy and Heiple (1981) address this problem by estimating the age at death into five-year age classes. For each age class, the number of individuals in that class was multiplied by midpoint age of the class or the "person years at risk" (i.e. for the age group 5-10 years at death the "person years at risk" should be 7.5 years, however there seems to be a misprint in their data table, Table 2 (Lovejoy and Heiple 1981:537) and their "person years at risk" column appears to be out of synch with their age class column) to create a number of "total person years at risk." For each age class, they also counted the total number of fractures. The number of fractures observed in each age at death class was then divided by the "total person years at risk" and multiplied by a factor of 10^5 which denotes "fractures per person years at risk." They then graphed their result with "age at death" on the x-axis and (a slightly obscure transformation of) "fractures per person years at risk" on the y-axis (Lovejoy and Heiple 1981: 538). Although they make much of the two small peaks in their graph at 15-20 years and 45-50 years, they do not test the significance of the differences in numbers of fractures during these two periods from the

neighboring age classes. Antemortem fracture rates steadily rises until the age of fifteen and then rise only slightly afterwards until about age forty when they taper slightly. One of the problems with the application of this approach is that determining age at death for adults over about 30 to within a five year period is difficult even with a complete and well-preserved skeleton for many reasons including increasing degrees of individual variability as one ages and the lack of known age-at-death reference samples from sources other than urban nineteenth and twentieth century populations.

Other ways of addressing the influence of the age at death structure of a group involve matching the age at death distributions of the different groups being compared. One of these approaches involves matching the age distribution of groups being compared by creating age-at-death cohorts and comparing the lesion prevalence data within those cohorts (Bridges 1991). However, with this approach, age cohorts are often broad and individuals at the older end of the cohort may skew the overall lesion prevalence data for the group, especially in the older cohorts. Another approach is to test whether there are statistically significant differences in the age-at-death distributions of two samples being compared using chi-square or some other statistical measure, and if no differences are found, then the lesion prevalence data for the samples may be compared (Bridges 1991).

Glencross and Sawchuk (2003) use Lovejoy and Heiple's (1981) concept of "total person years at risk" to significantly assess statistical differences in the number of traumatic lesions between populations by considering "person years" from two different samples to be Poisson counts and testing the null hypothesis that there is no difference in traumatic lesion prevalence between the two populations being tested. They compute a

two-sided Z-statistic where x_1 and x_2 are two lesion counts and n_1 and n_2 are the sample sizes in "person years:" $Z = [(x_1/ n_1) - (x_2/ n_2)] / [sqrt ((x_1 + x_2) / (n_1 * n_2))]$. Glencross and Sawchuck (2003:372-373) recognize some of the limitations and potential sources of error to their method as being: " (1) differential preservation, (2) variance associated with aging methods employed and, (3) a lack of precision in aging older adults."

Unlike childhood injuries, healed fractures that occur during adulthood are likely to be present in the archaeological record and count towards the trauma observed in the skeletal population. Because populational trauma data are mostly destined to be compared with trauma data from other skeletal populations, it is important to recognize that the age structure of the adult population may influence the amount of trauma observed and also that the risk of experiencing trauma might be higher for some individuals within the population for reasons independent of the environmental risks shared by the population in general.

C3iv. Trauma in senescent bone: "old wounds and new hazards"

The age category "old adult" refers to adults over the age of fifty (Buikstra and Ubelaker 1994). Evidence of trauma in this category reflects not only the accumulation of healed trauma during the lifetime of the individual but also the effects of demineralization and brittleness caused by the accumulation of secondary osteons. As bones become more friable, muscles and sensory systems may also become weaker. Falling not only becomes a more likely hazard but may also be more damaging than at other stages of life. This is especially the case in women who, after menopause, experience a period of rapid bone demineralization followed by more gradual rate of demineralization more similar to that experienced by men. Because of increasing fragility

with increasing age, it also becomes more likely during this period that trauma itself or its immediate after-effects will be lethal in which case that trauma may be perimortem and not necessarily be observed in the archaeological record.

The older the adult, the more likely he or she is to have accumulated trauma during his or her lifetime. In addition, if the individual lives into senescence, decreases in the density of bone increase the likelihood of accidental fractures. Comparisons of frequencies of trauma lesions between populations, as stated previously, need to take the age-at-death structures of their populations into account in order to make sure a preponderance of older adults is not skewing the sample in one way while a preponderance of young adults is not skewing it in another.

C3v. The importance of recognizing age at death biases in trauma analysis

The explicit goal of most trauma analysis is to decipher the possible environmental hazards that individuals in a population faced as they experienced their daily lives by comparing the amount of trauma observed in that population with some other population. However, all environmental hazards being equal, the stage of life at which a traumatic injury occurs and the age at which the individual dies is likely to influence the outcome of whether or not that instance of trauma will be recorded in the skeletal record for posterity to excavate. Also, all environmental hazards being equal, the age at death structure of a population will influence the observable number of traumatic instances in that population and may skew its comparison with other populations.

C4. Taphonomy biases in identifying trauma

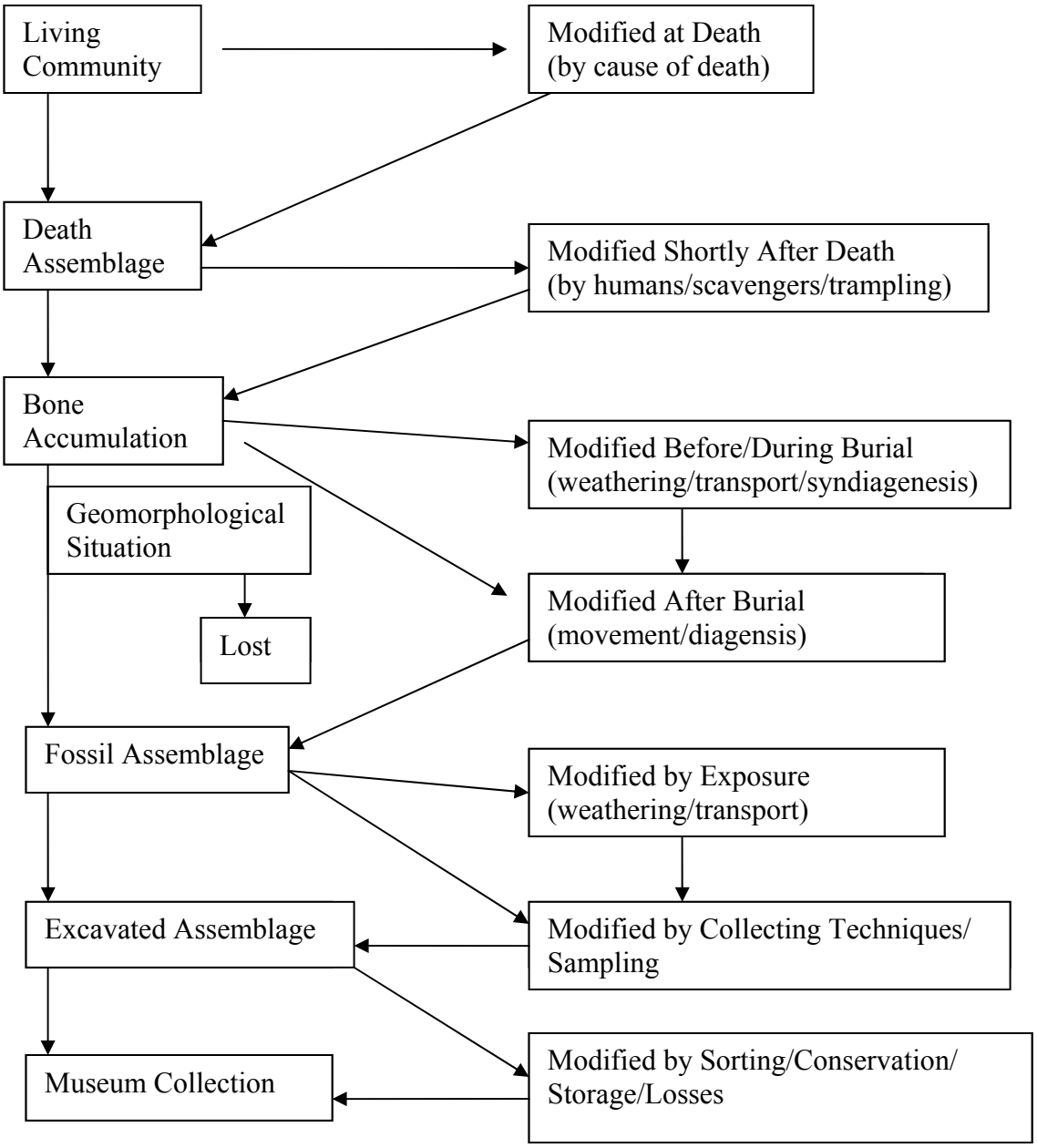
In this section, the influence of taphonomical biases in preservation on the observation of trauma will be reviewed. The influence of these biases include some types

of bones being more likely to be preserved and later recovered, some types of individuals being more likely to be preserved and later recovered, and the potential loss of data useful in the analysis of trauma in fragmentary and/or commingled remains. When trauma data from different sites are compared, differences in preservation at each site have the potential to skew interpretation of the relative amounts of trauma at each site in ways that need to be, at least, acknowledged and possibly avoided.

C4i. Definition of taphonomy

The term "taphonomy" was coined in 1940 by Efremov from the Greek words *taphos* (burial) and *nomos* (laws) to denote the study of the details of the transition of organics from the biosphere into the lithosphere i.e. the geological laws of burial and decomposition. During this process, the living community of organisms is transformed by a series of modifications into its final resting place in a collection of skeletal remains studied at a museum. This transformation occurs through the following processes, according to Andrew and Cook (1985): modification at death by the cause of death; modification shortly after death by humans, scavenger, trampling, etc.; modification during burial such as through weathering, transport, and syndiagenesis or "the early burial phase of bacterial activity in which organic matter provides the nutrient for bacterial metabolism" (Lyman 1994: 514); modification after burial by movement of the soil and diagenesis or the chemical and mechanical alterations to organic remains after burial (Lyman 1994: 506); modification by collecting and sampling techniques; and finally, the modification by sorting, conservation, storage, and losses. These modification processes and their relationships to observable assemblages are shown in Figure 2.6.

Figure 2.6. Taphonomic processes from Andrew and Cook's (1985) model of taphonomic history



During each of these stages of modification, evidence of traumatic fracture may be obliterated, lost and/or rendered less useful for comparative purposes. Within the "living community" there is the community of live animals in their natural proportions whereas the "death assemblage" represents a subset of this "living community" whose remains are available for collection by people, carnivores, or other agent of bone modification. Only some of these "death assemblage" remains will come to be deposited or buried at a site and of these, some will be lost through geomorphological processes such as attacks from flora such as plant roots and fauna such as snails and insects and chemical erosion by the soil. The "fossil assemblage" represents the remains that survive at a site until excavation or collection and these too may be modified or lost if exposed to the surface of the soil where they might be as easily destroyed by weathering or washed away as found by human excavators. The "excavated assemblage" represents the part of the "fossil assemblage" that is collected by human agents and often represents a sampled subset of the whole "fossil assemblage" in the ground and its future preservation is highly dependent on how it is collected, curated, and stored as it makes its way into a "museum collection."

C4ii. Taphonomic effects on the preservation of individual skeletal elements

Although the taphonomic affects on the preservation of individual skeletal elements have been part of the analysis of faunal assemblages by archaeologists and paleontologists such as Guthrie (1967), Brain (1976) and Binford (1981) for many decades, these affects on the preservation of individual human skeletal elements were not studied until the late 1980s (Waldron 1987).

According to Henderson (1987), factors intrinsic to the preservation of certain skeletal elements include the shape, size, density and age at death. The shape of the bone (flat, tubular, cubical or irregular) affects how susceptible it is to warping and crushing by soil pressure and to breakage. Cancellous bones, such as skulls and innominates, are particularly vulnerable to mechanical breakdown (Henderson 1987: 44). The size of the skeletal element not only plays a role in how quickly the bone decays—the rates of decay are inversely proportional to bone size—but also the increased likelihood that a larger bone will be excavated because smaller bones tend to be missed or left behind (Henderson 1987: 45). The density of bone is determined by the proportions of compact and cancellous bone and the higher the proportion of compact bone, the more likely the bone is to be recovered. Because bones of juveniles are smaller and have higher proportions of cancellous bone than their adult counterparts, they are more vulnerable to faunal disturbance, destruction and loss (Henderson 1987: 45).

Mays (1991) conducted a survey of bones recovered from 250 medieval burials of adult monks in Blackfrairs' Friary, Ipswich. He found that the most poorly preserved and least recovered bones (less than 50% recovery) include, from least to slightly more preserved: foot seasmoids, hyoid bones, ribs, cervical vertebrae, sternum, carpals, phalanges, and thoracic vertebrae. Slightly better preserved bones (50-80% recovery) include, from least to more preserved: metacarpals, lumbar vertebrae, clavicles, scapulas, sacrums, fibulas, tarsals, and pelves. The best preserved bones (80-100% recovery) include, from better to best preserved: patellas, ulnas, radiuses, metatarsals, humeri, femurs, calcanei, taluses, tibias, skulls and mandibles. May's finding were slightly different from those of Waldron (1987) who conducted a similar survey on a Romano-

British site in London dating from the second to fourth centuries C.E. with 88 adult burials. Waldron found that the least well preserved elements (less than 20% of the expected elements preserved) include the phalanges of the hands and feet, the carpals, the coccyx, the body of the scapula, the right proximal fibula, and complete skulls. The next least preserved elements (between 20% and 40% of expected elements preserved) include the left and right parietals, the coracoid process of the scapula, the sternum, fibulas (other than the very poorly preserved right proximal part), patellas, and pubic symphyses. Better preserved elements (between 40% and 60% of the expected elements preserved) include frontals, occipitals, mastoids, zygomatics, maxillas, clavicles, cervical, thoracic and lumbar vertebras, glenoid processes of the scapula, humeri, radiuses, ulnas, femurs, tibias, taluses, calcanei, metacarpals, metatarsals, acetabula, and ischial tuberosities. The best preserved elements (between 60% and 70% of expected elements preserved) include mandibles, petrous portions of temporals, the auricular surface of the ilium and the sciatic notch. Most of the differences between Mays's (1991) and Waldron's (1987) surveys stem from Waldron's inclusion of parts of bones versus Mays's inclusion only of whole bones.

In general, the best preserved skeletal elements tend to be mandibles and very dense portions of other bones such as the petrous portion of the temporal. Other elements, such as many parts of the skull and most of the long bones are also well preserved. The least well preserved elements tend to be either composed mostly of cancellous bone such as the ribs, are fragile as the body of the scapula, or small as phalanges. The lack of preservation of some elements directly influences the amount of trauma data that may be gleaned from a sample since one cannot get data from elements that do not exist. Skeletal

elements from some individuals, such as infants and children, also tend to be more poorly preserved than others because of intrinsic aspects of their bone structure. Their lack of preservation in some sites may skew the demographics of the observed population and its observed trauma.

C4iii. Taphonomic troubles: problems with fragmentary and commingled remains

During taphonomic processes, some skeletal elements may fragment and some individuals may become commingled with the bones of someone else. If this happens to a few elements or a couple of individuals in the population being sampled, these anomalies may be excluded from the data compiled from the population as a whole. However, if the entire population is commingled or most of the remains are fragmentary, the demographic and traumatic data that may be taken from the skeletal population will be more limited than that which can be taken from a group of well preserved individuals.

Although in a forensic or mass disaster context where the victims are known there is an effort to sort out commingled remains into individuals (for example, Stewart 1970), commingled remains often end up in collections sorted by skeletal element. Antemortem fracture data can still be taken from these remains but, for most bones, these data will be lacking in context as far as sex of the individual and age at death. If trauma occurs in bones such as the skull, mandible or pelvis that may be used to guess sex and age at death, antemortem fracture data coupled with demographic data may be preserved but it will not be in the context of all the traumas that occurred to that individual. It is possible to tell if an individual was immature or an adult from most other isolated elements, however determining more precise age is not possible. Sex may be guessed at by seriating the relative sizes of a group of elements but such guesses are likely to be

accurate only at the extremes of the spectrum. Since most clear indicators of ages and sexes of individuals may not be directly linked to the skeletal elements that show antemortem trauma, an assessment of group demography from diagnostic bones assumes that the demographically diagnostic bones come from exactly the same sample of individuals as the bones with trauma. Unless the sample is very well preserved and most skeletal elements seem to be well matched in content with the demographically diagnostic bones, the validity of this assumption may be questionable. In any case, the direct demographic link between the age and sex of the individual and his or her trauma is likely to be lost in the case of commingled remains.

Fragmentary remains are also problematic in the assessment of trauma. The ability to assess traumatic lesions is highly biased in favor of complete or virtually complete skeletal elements. Forces such as trampling, carnivore activity, weathering, and chemical decomposition fragment bone and may mask signs of antemortem trauma. Fragmentation may also lead to bone fragments such as shafts not being readily identifiable and less likely to be included in counts of skeletal elements at a site and perhaps less likely to be closely analyzed. Also, in many cases, incomplete bones are neither included in counts of skeletal elements from a site nor in the analysis of trauma at that site. If some elements are fragmentary but the remains are all associated with a single individual, then it is likely that this individual's demographic profile will be included in the sample but perhaps not all his or her traumas.

Skeletal remains that are both fragmentary and commingled are the most problematic group of bones on which to assess trauma. Not only are important demographic data lost due to commingling but trauma data are likely to be lost as well.

Perimortem fragmentation of bone is likely to be unnoticed and certain types of healed trauma that are more unambiguously observed on fragments such as cranial depression trauma may be one of the few traumas that are not masked by fragmentation. It becomes very difficult to determine the counts of skeletal elements present within the sample since it is unclear how many individuals constitute the sample and Minimum Number of Individuals (MNI) counts off of certain diagnostic bones form the best possible guess. The validity of the assumption that aging and sexing of such a sample from demographically diagnostic bones is representative of the population as a whole becomes even more questionable than when the complete skeletal elements commingled without fragmentation. Because it is so hard to assess the demographics of a fragmentary population, it is equally hard to know whether there is an age at death bias skewing trauma data within the sample. This, in turn, makes comparisons of trauma data with better preserved samples fraught with the possibility of misinterpretation.

C4iv. Biases inherent in the comparison of samples with different preservation

Even within the same site, it is possible for the forces of taphonomic modification to influence some skeletal remains more than others. It is almost always the case that a better preserved sample will produce more complete and reliable data than a less well preserved sample. It is often the case in the analysis of trauma that better preserved samples with their more complete and reliable data, for example Libben (Lovejoy and Heiple 1981), become standard reference collections against which other samples are compared. This may be problematic when the samples being compared have very unequal levels of preservation. In the less well preserved sample, some trauma data may be lost due to fragmentation and data from some skeletal elements such as ribs or

phalanges may not be comparable if most of those elements are not preserved. The differential preservation of some skeletal elements may create a skew in the "lesser" sample where most of the trauma appears to occur in only a few of the better preserved elements. When this pattern of trauma in the "lesser" sample is compared to the trauma observed in the "better" sample, the patterns of trauma might look different but this might be an artifact of taphonomic preservation as much as difference in environmental hazard or activity pattern.

The role that taphonomic forces play in the preservation of bone directly affects the ability of the researcher to analyze trauma within a sample of bone. The goal of the study of trauma in human skeletal remains is to get information about the hazards that the "living community" faced as they went through their daily lives. However, during the process by which that "living community" becomes a "museum collection," a series of taphonomic modifications may happen that can alter the material remains of that "living community." It is therefore important to try to decipher how much one's data are altered by processes of taphonomy and how it affects what one is able to observe in the museum context. This is not to say that comparisons between collections of skeletal remains should not be made, but it is naïve to assume that all data are collected of the same level of resolution and that all differences between collections stem from differences in the living populations.

C. Section Summary

In this section, aspects of the way trauma is discussed and potential sampling biases were reviewed. In trauma analysis, it is assumed that the frequency of injury directly reflects the frequency of an individual's exposure to extrinsic environmental

hazards and that comparisons of frequencies of trauma between populations reflect differences in relative exposures to environmental hazards. However, the impact of sampling biases may skew comparisons so that differences or similarities in patterns of trauma between groups are not reflected. These potential sampling biases are summarized in Table 2.1.

Table 2.1 Summary of potential sampling biases

Sampling Biases	Details
Some kinds of trauma are more readily observed	-injuries that influence bone -antemortem trauma (this interval differs depending on the kind of bone) -fractures (versus dislocations) -injuries to bones that are intrinsically more likely to be preserved -injuries to bones that are intrinsically more likely to analyzed
Age-at-death structure of population influences the frequency of observation of trauma	-juvenile bone growth obliterates most evidence of trauma -most evidence of trauma in adults accumulated during adulthood -senescence results in decreasing bone density and higher risk of fracture -old adults have longest time to accumulate evidence of trauma
Other factors also skew frequencies of trauma within a population	-differences in occupation related to gender -differences in occupation related to other factors such as age or status -"trauma recidivists" i.e. accident-prone individuals may skew trauma frequencies in small samples
Other factors also skew frequencies of trauma between populations	-different level of preservation of the sample -different levels of inclusion of fragments in data counts -differences in whether perimortem trauma is included -different levels of resolution in observation

D. Description and Recording of Trauma

In this section, standards for recording trauma during the past thirty years will be reviewed. Ways that instances of trauma are counted and ways in which trauma is described and depicted by different researchers will be discussed.

Instances of trauma are only relevant when they are described and published. Researchers have been grappling with how to record and disseminate pertinent information about they trauma they observe throughout the history of paleopathology. Until the past few decades, however, most of the data on trauma in skeletal populations was primarily descriptive and anecdotal. Although there are still many publications that describe in detail some massive trauma in one or a handful of individuals (Powers 2005; Homes Hogue 2006; Kanz and Grossschmidt 2006; Mitchell 2006; Jimenez-Brobeil, Al Oumaoui, and du Souich 2007), most current publications about trauma are studies of trauma within larger populations and the descriptions of trauma are mostly quantitative by skeletal element.

D1. Standards of describing trauma

Although there had been other attempts to quantifiably compare incidences of trauma within a population to a wider context of trauma observed in other groups (such as Wood-Jones 1910, Angel 1974 and Steinbock 1976), Lovejoy and Heiple (1981:529) set what was to become the modern standard for deriving "meaningful data on traumatic lesions from skeletal populations." In order to analyze trauma from Libben, a Late Woodland sample from northern Ohio they set down the following protocol: (a) each skeleton was observed on at least three separate occasions by at least two observers; (b) all bones were carefully observed for evidence of fracture and the completeness of each

bone and the nature of each fracture were noted; (c) only complete/intact bones, whether fractured or normal, were used in quantitative analysis in order to assure "that fractured specimens did not receive undue attention (which might lead to sampling bias)" (Lovejoy and Heiple 1981: 529); (d) each fracture was briefly described as to its location on the bone and "type" or appearance of the fracture; (e) antemortem and perimortem fractures were recorded as long as the bone was intact; (f) for each skeleton the sex and age at death were recorded and these data were used to calculate the mean age at death and sex ratio for each of the (intact) "major" long bones as well as the mean age at death for individuals with fractures; (g) since some individuals may only have one intact bone, fracture rates per individual were calculated by assuming that the "missing" bones had the same fracture rate as those actually observed.

Buikstra and Ubelaker's (1994) standards for data collection from human remains were organized to provide a framework for the compilation of large amounts of data from Native American remains stored in museums and other publicly funded institution before the remains were repatriated under the Native American Graves Repatriation Act. Their procedure for documenting fractures is the following (all coded aspects are in parentheses): (a) record the type of bone fractured; (b) record the side and section of the bone containing the fracture; (c) code the fracture as one of nine different basic types (complete, partial/greenstick, simple, spiral, compression, depressed fractures involving the outer table, depressed fractures involving both the inner and outer tables, and pathologic fractures that follow other bone weakening illness); (d) record information about the shape of the fracture and/or the weapon that produced the insult (blunt round, blunt oval, edged or bladed fractures, projectile entry, projectile exit, embedded

projectile, amputation); (e) record time of trauma if there is no sign of healing (perimortem, ambiguous); (f) record the stage of callus formation and/or other healing developments if there are signs of healing (woven bone, sclerotic bone formation, obliteration, nonunion, pseudoarthrosis, tissue necrosis, infection, arthritic change, joint fusion, myositis ossificans; (g) record presence and potential origin of dislocation (traumatic or congenital). In addition to the trauma data, data were also collected regarding the bones present in each individual, each bone's state of completeness, age estimate for the individual based on three different parameters, estimated sex based on five parameters observed in the pelvis and five from the skull, taphonomic modification to each individual such as stage of weathering, discoloration, polish, cutmarks, evidence of gnawing and other forms of cultural modification as well as data on other types of pathologies, trepanation and cranial deformation.

Grauer and Roberts' (1996) protocol describes adult long bone fractures in a way that provides information not only about the fractures themselves but also their levels of healing and possible treatment in past societies. Their procedure for documenting fractures is the following: (a) the remains of individual adults were assessed for sex and age at death using as many techniques as possible using independent assessments of dimorphic features of the pelvis and cranium for sex and dental eruption, formation and attrition rates as well as epiphyseal and sutural fusion, and pubic symphyseal morphology for age at death; (b) the long bones of all skeletons (humerus, radius, ulna, femur, tibia, and fibula) were evaluated macroscopically and fractures were recorded by their position along the shaft; (c) the presence and results of healing were recorded and the affected bone was compared with the unaffected bone on the contralateral side from the same

individual in order to recognize and quantify bone loss or shortening as well as any rotational or linear deformity; (d) good alignment and angulation, good apposition or partial apposition, degenerative joint disease and overlap or distraction of the healed fracture was recorded in order to assess signs of treatment such as splinting; (e) evidence of nonspecific infection in the form of localized periosteal reaction was recorded in order to determine whether the fracture had been compound and prone to infection; (f) each fracture was radiographed and from this a determination of fracture type, aspects of healing, presence and degree of displacement, apposition and angulation were assessed.

Lovell's (1997) method for the description of fractures collects information in order to serve as a basis for inference about the mechanism of injury. It is predicated on the identification of the skeletal elements involved, the type of injury and detailed descriptions of deformation and any associated non-traumatic lesions that may indicate causality or complications that occurred after the injury. Specific types of injury are linked to the forces that created them therefore determining the type of fracture is paramount. For cranial fractures, the bones involved, the patterning of fracture lines and the presence of deformation is recorded and the type of trauma is deduced from these features. Long bone fractures are first classified by their position relative to the joint as either intraarticular or extraarticular and then from are classified into types of fractures associated with this position. Other components of long bone fracture (length, apposition, rotation, and angulation) are also measured and recorded so that the mechanism of injury can be recorded and degree of deformity can be assessed. Lovell then provides a list of commonly seen fractures according to their anatomical location, possible complications of the injury and their affects on healing. By using the characteristics of the fracture

itself, the skeletal pattern of trauma in the individual and the population, and the cultural and environmental context of the remains, it is possible to identify the mechanism of the injury and point to the logical cause of the fracture.

Galloway's (1999) protocols for describing trauma come from a forensic context in order to determine the sequence of perimortem injury. As a way to clearly document all aspects of how the individual was injured and how these injuries might interrelate, a series of three stages are followed: preanalysis, analysis of the remains, and postanalytic production of the final report. In the preanalytic stage, the remains are recovered, autopsied, and initially documented. The protocols for initial documentation include: (a) a written record is made noting the location, dimensions, and condition of each defect; (b) diagrams of the injuries are drawn onto representations of a skeleton or skull; (c) a photo record is made of overall shots and close-ups detailing the defect and may also be supplemented by a digital recording of the skull and other skeletal elements; (d) the timing of defects is then assessed as to whether they are antemortem, perimortem or postmortem. During the analytic phase, defects relevant to the death of individual are analyzed in the following ways: (a) all elements are examined thoroughly both by gross examination and under a microscope; (b) all fractures are identified radiographically; (c) injured areas and the anatomical relationship between elements are reconstructed; (d) interpretation of the reconstruction may point in more specific detail to a possible etiology as well as the force required to produce such and injury; (e) experimental studies may be created to try and replicate the etiology and forces that are hypothesized to have created the injury with appropriate written and photographic documentation. Finally, in

the postanalytic stage, a written report is made of findings and preparations for court appearances are made.

Although the general aims of the analysis of trauma are similar for each of the protocols i.e. documenting how an individual was injured and assessing the etiology of that injury, each set of protocols offers a different slant on the relative importance of aspects of the information the researchers consider to be of most interest. Lovejoy and Heiple (1981) are most concerned with the demographic profiling of trauma within a population whereas the standards of Buikstra and Ubelaker (1994) are based on recording as much information about all aspects of individual skeletons before the material remains themselves disappear. Grauer and Heiple (1996) are interested in the degree to which fractures show healing in past populations while Lovell (1997) is mostly concerned with assessing the forces that produce specific types of fractures. Galloway (1999) is similarly concerned with assessing forces that produce fractures but within the context of advocating a specific hypothesis of how a person died. Each protocol offers different levels of resolution in looking at trauma. Because of differences in these levels of resolution, some protocols may be more or less relevant to the needs of a specific study.

Because my study of trauma in Neandertals is based almost entirely on fragmentary bones, many aspects of these protocols could not be applied. Lovejoy and Heiple's (1981) exclusion of fragmentary bones would have left me with very little to study of an already small sample. Also, assessing age-at-death and sex ratios for each long bone was often impossible. Grauer and Robert's (1996) protocols similarly expected mostly intact skeletons of discrete individuals and are inapplicable to fragmentary and comingled remains. Although Lovell's (1997) and Galloway's (1999) protocols mostly

deal with recording trauma from fairly recently deceased individuals, they both offer high resolution approaches to individual fractures which I try to incorporate in my own work. Because the standards of Buikstra and Ubelaker (1994) were created to record all skeletal elements, aspects of their standards were useful to the recording of data about fragmentary elements and trauma. However, these protocols all mostly expect whole bones and individual skeletons. In Chapter VI, I review the literature about assessing patterns of trauma from fragmentary samples and offer novel methods of my own for collecting data and trauma frequencies from fragmentary and comingled samples.

D2. Ways of Counting Trauma

Collections of trauma data within populations use many different protocols for how they count the instances of observed trauma. In these protocols, decisions are made as to how the raw instances of trauma should be tabulated. Two of these major decisions are whether to count both antemortem trauma and perimortem trauma and whether trauma observed on incomplete bones is to be included. When samples from two different populations are to be compared, it is important that any differences in trauma counting protocol are noticed so that trauma comparisons reflect populational differences in exposure to trauma during life rather than sampling biases.

D2a. Inclusion of antemortem and perimortem trauma

The decision as to whether to count both antemortem and perimortem trauma, or antemortem trauma only or perimortem trauma only, seems to be related not only to the objective of the research but also to degree of preservation of the skeletal remains. In general, if the objective of the research is to determine the pattern of trauma at a specific site with well preserved skeletal material, both antemortem and perimortem fractures will

be included in the trauma counts. If the skeletal material being studied is not well preserved then studies of trauma in the population are more likely to be limited to signs of healed trauma because it is more difficult to separate perimortem trauma from postmortem breakage.

There is considerable variability in which kinds of trauma are included as well as in the disclosure of which kinds of trauma are included. Studies such as Frayer's (1997) investigation of the remains from Ofnet, and Kanz and Grossschmidt (2005) analysis of gladiator head injuries, are both specifically concerned with perimortem injuries. Other studies such as Jurmain and Bellifemme (1997), Alvrus (1999), Brickley (2006), and Jiménez-Brobeil *et al.* (2007) specifically state that they are only concerned with antemortem injuries. Studies such as Billard (1991) and Tung (2007) specifically state that they have examined all injuries, both antemortem and perimortem. Other studies such as Lovejoy and Heiple (1981), Standen and Azzaruia (2000), and Jurmain (2001) do not specifically state whether injuries are both antemortem and perimortem but leave clues in the descriptions of fractures that show the inclusion of at least some perimortem trauma while other studies such as Kilgore *et al.* (1997), Judd (2004), Djurić *et al.* (2006), Domett and Tayles (2006), and Mitchell (2006) appear to be describing only antemortem fractures but never explicitly state that this what they are doing.

It is important to know which kinds of trauma are being included when comparing rates of trauma between different sites and data from different investigators. In general, trauma counts are likely to be higher if perimortem trauma is included. Since the likelihood of the inclusion of perimortem trauma seems to increase with better preservation of skeletal material, better preserved material is likely to have higher trauma

counts than less well preserved material for reasons that are not reflective of differences in trauma in the living populations.

Comparisons of trauma data from different sources may not be comparing equivalent data and the results may not be indicative of intrinsic differences between the samples but rather different sampling biases. This is especially true when modern clinical data are compared with archaeological data. Clinical data have inherent biases such as the underreporting of some kinds of trauma, especially trauma caused by non-fatal interpersonal violence such as spousal abuse, while other kinds of trauma where lawsuits or worker's compensation may be involved such as car accidents or injuries incurred on the job are more consistently reported (Hamberger *et al.* 2004). For the injuries that are reported, clinical data are more complete than any archaeological data since there are no biases in observing trauma because of the age of the victim or taphonomic preservation of specific elements bias. Although clinical data are wonderful source of information on trauma in living populations, they are probably not directly comparable to trauma data gleaned from archaeological populations.

In general, the ability to observe instances of trauma in skeletal remains is facilitated by the completeness of those remains. For clinical data, the living human skeleton is as complete as it might possibly be and all fractures can be identified. In cases where perimortem fractures may be observed in the archaeological context, bones also need to be well preserved because indications of perimortem fracture are more ambiguous than antemortem fracture. If there is variability in the preservation of remains at a site, the inclusion of perimortem fractures in the sample may create a situation where perimortem fractures in the less well preserved remains are underrepresented. This also

occurs when fracture rates are compared between sites with different levels of preservation or when incidents of antemortem and perimortem trauma are included for one site and not the other. Therefore it is very important to know whether a potential comparative sample is including perimortem fractures as well as antemortem fractures.

D2b. Inclusion of Fragmentary Remains

Some studies choose to include all observable instances of trauma regardless of the fragmentary nature of the individual bone while others choose only to include fractures observed on whole unfragmented bone and ignore data from fragmentary remains in their total trauma counts. As in the case of inclusion of perimortem trauma in the total trauma counts for a site, the decision to include or exclude trauma observed on fragmentary remains often depends on the level of preservation at a site perhaps more than a methodological bias. Reports of sites where bones are well preserved in general are the ones most likely to exclude trauma observed on fragmentary bones in their total trauma counts. Reports from sites where all or most of the bones are in a fragmentary state are more likely to include trauma data from fragmentary remains because excluding fragments would mean excluding most of the sample.

Because there is considerable variation around how well a sample is preserved, there is also considerable variation in how trauma observed in fragmentary elements is treated. In some cases, such as Lovejoy and Heiple (1981) and Dommett and Tayles (2006), trauma counts are only included for complete bones. In other cases, such as Jurmain (2001:14), “completeness” may be considered in a more relative fashion and defined as “being at least two-thirds present with all major articular areas preserved.”

Alvrus (1999) includes only long bones that are at least 70% complete and crania or mandibles that are at least 50% complete in the sample from which trauma is counted.

Judd's (2004) criteria differed depending upon whether the bone showed signs of trauma. She divided long bones into five segments and included them in her sample counts if they included four or more of the bone segments but if the bone included an incidence of trauma, bones with three or fewer intact segments were also included. Carpals, tarsals and phalanges without trauma were included if they were 75% or more complete but if they showed trauma, less than 75% complete bones were also counted.

Generally for less well preserved samples, the degree of completeness necessary to be counted within the trauma sample diminishes. Brickley's (2006) study of rib fractures counts all ribs that have heads even though fragmentary and Robb (1997) counts trauma in fragmentary skeletal elements by dividing bones into regions such as "proximal," "middle" and "distal" shafts for long bones and counting the number of those regions present that contain more than half of a region (this will be discussed in more detail in Chapter 4). Other studies exclude all skeletal elements except those that come from individuals who fit specific criteria: whose age at death and sex can be assessed (Judd 2002); who show signs of traumatic lesions caused by violence (Rocsandic 2006); who are not children, trophy heads or are poorly preserved (Tung 2007). However, it is as often the case as not, that all bones may be included, complete and fragmentary, in the sample but that it is not specifically stated.

Any decision around which skeletal elements to include or exclude creates a sampling bias. Excluding trauma data from incomplete skeletal elements from the sample in which trauma is analyzed may decrease the size of the sample, may exclude

individuals, such as juveniles, whose bones are more likely to be fragmentary, may overrepresent individuals whose remains are treated with more care, and may underrepresent instances of trauma in skeletal elements that erode more quickly. Including trauma data from incomplete skeletal elements in the sample from which trauma is analyzed may underestimate the rate of instances of trauma per skeletal element represented since fragmentary skeletal elements may be counted more than once and the postmortem fragmentation of a bone may obscure signs of trauma. Where these sampling biases become especially problematic is in cases where multiple sites are compared that are not consistent in their sampling biases. When samples from a more fragmentary collection are compared with a sample that excludes all bones that are incomplete differences in patterns of trauma may appear that reflect the differences in the composition of the samples rather than in any differences in activity in the living populations.

D. Summary: Ways of Counting Trauma

A common problem with comparing trauma data from one site and one set of researchers to data obtained at another site with another set of researchers is that the way trauma data are collected and reported generally seems not to be consistent from site to site and researcher to researcher. Because of these inconsistencies, trauma counts from may differ not because of differences in the environmental hazards experienced by living populations, but because of differences in how trauma is counted at the site by researchers. These differences in the inclusion of perimortem trauma may increase the counts of trauma occurrence. Differences in the inclusion of fragmentary remains may inflate the total number of bones present at a site and make the instances of observed

trauma look rarer in the collection where fragmentary remains are included. Although most paleopathological studies of trauma assess trauma frequencies in skeletal samples based on fairly complete individuals and issues of differences in the inclusion of fragmentary remains are of little consequence, the fragmentary nature of the Neandertal sample creates a situation where how trauma is counted is of paramount importance in determining creadible comparative results.

E. Patterns of Trauma

Depending upon the context, "pattern of trauma" may mean the way in which an individual person was injured, the frequency of injury of individual bones in a collected sample, the ratio of "body areas" showing trauma in a collected sample, the frequency of individuals injured in a collected sample differentiated by age or sex, the frequency of a specific type of trauma in a sample population, or the comparison of some or all of these aspects between populations. In this section, the various definitions of "patterns of trauma" will be discussed and compared.

E1. Patterning trauma at the individual level

A "pattern of trauma" in an individual skeleton is the relationship between one or more traumatic lesions and where the lesions appear on the body and the physical aspect of the lesion (size, severity, type of injury etc.). There is an assumption that many means of injuries produce distinctly different "patterns of trauma." In the close examination of where and how an individual was wounded, it is possible to address by what means this individual might have been wounded. In a forensic context, examination of "patterns of trauma" always occur at this level in order to determine how an individual may have died or experienced a distinctive trauma during his or her lifetime that might lead to a positive

identification of the remains (Ubelaker and Scammell 1992). Such patterns might relate to aspects of perimortem trauma such as the type of weapon used, the sequence of traumatic injuries, or the location where trauma occurred. Such patterns may also relate to antemortem trauma, such as evidence of previous injuries not related to the individual's death, but distinctive enough to be able to positively identify the person from x-rays.

Although the aims of the paleopathological context are somewhat different from that of the forensic study, the "pattern of trauma" of an individual is similarly studied to give clues about the life and death of the person. However, the difference is that, in most cases (except for some famous examples such as the massacred family of Tsar Nicholas II (Maples and Browning 1994)) there is no way of identifying the individual therefore the role of corroborating traumatic lesions is not necessary. Antemortem traumatic lesions are of interest, in this case, because their "patterns of trauma" may be consistent with the consequence of some hazard that was encountered as part of their lifestyle. It is also often more difficult to analyze "patterns of trauma" and their potential causes of trauma in the paleopathological context because individual skeletons are less likely to be well preserved than in a forensic setting and potential hazards are less likely to be clear because of an incomplete understanding of cultural practices and potential weapons.

E2. Patterning trauma at the group level

At the group level, "pattern of trauma" is a measure of frequency and distribution of traumatic lesions throughout the sample. It can denote any or all of five different ways of looking at trauma distribution and frequency: per skeletal element, per area of the body, per individual, by demographic element or by type of injury.

E2a. Frequency of incidents of trauma per skeletal element

One way of recording the "pattern of trauma" for a group is by counting the number of bones present of each skeletal element and the number of traumatic lesions in each of the bones. The most common way to describe the prevalence of trauma is as a percentage of bones with injuries out of the total number bones. These percentages may then be compared with the percentages of trauma for other bones in the sample or with other samples. Early studies using percentages of trauma by element in their analyses include Wood Jones's (1910) comparing a pooled sample from Pre-Dynastic through post-Roman Christian Period Nubian cemeteries to early 20th century clinical populations from London and New York, and Angel's (1974) meta-analysis of eleven samples from Greece spanning the Early Neolithic through the "Romantic" (19th century) periods and one combined sample from 20th century United States.

Assessing percentages of bones with traumatic injuries by element makes comparisons with other bones in the body as well as with other skeletal samples fairly straightforward. However, this approach can lead to recognizing differences that are not statistically significant because the number of bones observed is often not considered in the argument after the percentages have been calculated. The possibility of an insignificant difference is especially likely when the number of bones is small as it often is in the case with archaeological material. The same consideration applies when trauma in different collections is compared on a given element or based on all the bones observed.

E2b. Overall patterns of traumatic involvement by relative proportions

Another way to look at "patterns of trauma" is to look at the overall pattern of traumatic lesions in each region of the body as a proportion of the total trauma in a sample. In this method of analysis, the body is divided into regions (such as head/neck, upper limbs, hands, torso, lower limbs, and feet) and incidents of trauma are counted by region. The counts from each region are then divided by total number of instances of trauma in the sample. The proportions (out of the total number or incidents of trauma in the sample) of incidents of trauma in each body region may then be compared both among the regions in the same sample and between different samples. This way of looking at the "pattern of trauma" does not address how *frequently* trauma occurs in any region of the body; it only addresses relative *proportion* of the total trauma that occurred in any region. Jurmain (1999:222) credits the popularization of this approach to traumatic analysis to various clinicians such as Breiting *et al.* (1989), Danielsen *et al.* (1989), and Aalund *et al.* (1990) who studied patterns of deliberate violent injuries on living populations that involved both soft tissue injuries as well as fractures.

This way of looking at trauma by region rather than individual bone enables researchers to get a more integrated view of injury involvement and it allows for the relative proportions to be compared between groups even when sample size is very different; however there are some problems with this approach to analyzing trauma. The most significant problem is the question of whether the counts of traumatic incidents are comparable (Jumain 1999:226). Differences in preservation of skeletal elements (see above) in archaeological populations and differences in reporting (minor and/or not "settable" such as ribs) injuries in clinical populations may skew proportional injury

counts towards higher levels of trauma in better preserved bone and bones that are injured in ways that necessitate medical intervention. The other problem lies in the potential confusion between proportion and frequency in analysis. The proportions of injured regions in a population with infrequent injury may be very similar to those in a population with a high frequency of injury. This similarity in proportions, however, probably reflects little actually similarity in activities. A hypothetical example might be comparing a middle school class to a professional hockey team where the injuries of a few children (fall from the monkey bars, a car accident and a skiing mishap) occur to their regions of the body in the about same proportion as those of an NHL team where most of the members have sustained some form of traumatic injury during their careers. In such a situation, the comparison of proportions of traumatic injuries is meaningless. It is important, therefore, that comparisons of proportions of traumatic injury be fairly tightly controlled in their context for the results to have much potential relevance.

E2c. Prevalence of Trauma per Individual

Another measure of trauma within a population is number of traumas per individual. This rate estimates the prevalence of trauma within a population from the perspective of individual people rather than by skeletal element. There are two major ways that rate of trauma per individual is measured: some form of mean average where all the instances of trauma are added together and then divided by the number of identified individuals present in the sample (Standen and Arriaza 2000; Jurmain 2001; Kanz and Grossschmidt 2006) or by looking at percentages of the individuals within the population that show no incidences of trauma, one incidence of trauma, and more than one incidence of trauma (Judd 2002) or one, two and three lesions (Webb 1995) or

simply no incidences of trauma versus one or more incidences of trauma (Donnett and Tayles 2006).

In order to determine the rate of trauma per individual, the number of individuals in the population must be measured. For well-preserved discrete burials, this simply involves counting the number of people within the sample. The total number of people within such a sample may be further divided into age at death classes or sex or both. When burials are not well preserved, various ways of estimating the number of individuals present within the population are used so that a measure of trauma prevalence within a population may be calculated. Walker (1997) estimates the number of individuals examined for trauma in fragmentary populations by recording the percent completeness of the skeletal elements of interest (in this case nasal bones and the cranial vault) for each individual examined to create a measure of the "effective number of people" i.e. an estimate of number of complete individuals within his sample. It is this "effective number of people" that is divided by number of trauma in the two cranial areas of interest in order to look at the rate of trauma. Other researchers such as Alvrus (1999) analyze all skeletal elements in a similar fashion but most studies that discuss trauma prevalence per individual do not systematically record the number of individuals who possess all comparable elements and instead treat all individuals examined as though they are each totally complete (Walker 1997:149). This may become a problem in the case of thinner and more fragile bones such as nasals, maxillae, and ribs that are most likely to be broken or incomplete in some individuals and are therefore not comparable to other individuals who possess these bones intact. The result of such variability in preservation is the underestimation of the prevalence of trauma in individuals since the number of

individuals actually sampled for an injury to a particular element is actually less than the total number of individuals in the group.

Estimating the prevalence of trauma per number of individuals is necessary, however, as a prerequisite in determining the prevalence of fractures per age at death class and in determining the prevalence of fractures for males versus females within the sample. Since these are often important measures of comparison, simply dividing the number of fractures observed per skeletal element by the number of skeletal elements that appear within the sample is not enough.

E2d. Frequency of incidents of trauma by demographic component

There are many questions about how risk of trauma is distributed within a population. Often, the frequency of trauma is used as a proxy measure for risk of trauma. A way to look at how trauma is distributed is to divide the population into smaller segments such as age or sex. In samples where the sex and/or age of the individuals in that sample can be assessed, "patterns of trauma" can be examined by sex and/or age class. This way of looking at the frequencies of trauma brings a more nuanced perspective to injuries within a population as well as addresses the sampling biases caused by age and sex. Although discussions of differences in frequencies of specific kinds of trauma occurred in studies such as Buhr and Cooke (1959), Brothwell (1961) and Wells (1964), the work on the Libben collection by Lovejoy and Heiple (1981) set the standard for including information about age and sex and part of the analysis of trauma frequency within a population.

By age class

Examining the distribution of trauma within a sample by age class reveals possible age biases in the prevalence of trauma as well as looking at the times of life during which there is a higher risk of injury. In order to examine "patterns of trauma" according to age class, the individuals that make up the skeletal sample must be well preserved so that indicators of age can be assessed and the sample must be large enough for there to be a statistically significant group for each age class.

One of the early uses of examining age class patterns of trauma was a study by Buhr and Cooke (1959) that addressed whether fractures in the elderly were becoming more common. In order to address how trauma is distributed throughout the population in terms of risks incurred at various ages, Buhr and Cooke divided the group of individuals who reported trauma to the Radcliffe Infirmary into "age-groups". They had eight "age-group" categories that spanned the first eight decades of life and one category for individuals over the age of eighty. By looking at the age distribution of fractures, the authors could assess the upward spike in the number of reported injuries after the age of forty and examine possible factors to account for this.

The importance of understanding the influence of age at death biases on a sample was discussed earlier in this chapter. Examining how the trauma observed within a population occurs during the lifespan of an individual is not only important for assessing the comparability of samples but also for understanding how the influences of environment and activity pattern may change during the live of individuals within the population.

The observed trauma within a population needs to be divided into age at death classes that are small enough to be meaningful but large enough to be reasonably accurate. Many studies of trauma in archaeological population look at instances of trauma per age at death class, but these classes are divided in many ways. Lovejoy and Heiple (1981) divide age at death into classes of five year intervals. Such small divisions of age categories are probably not so useful because this degree of precision probably outstrips accuracy for adult age classes and findings of slight dips or peaks in trauma between age classes is probably reflective of minor sampling biases rather than any phenomenon in the living population. Buikstra and Ubelaker's (1994) age classes divide juveniles into infant (birth to three years old), child (three to twelve years old) and adolescent (twelve to twenty years old) and adults into young adult (twenty to thirty-five years old), middle adult (thirty-five to fifty years old) and old adult (over the age of fifty). This division of age class represents a less precise but probably more workable division of age at death for most samples. Although other authors such as Alvrus (1999) and Judd (2002) may modify these categories to include more categories between the ages of eighteen and forty, for the most part age classes of older adults tend to be broad in most cases, even for Lovejoy and Heiple (1981) whose five year intervals only go to age fifty. According to Glencross and Shawchuck (2003:370) the broadness of this final age category (potentially spanning as much as forty years) may cause a situation where "one of two samples being compared may actually be skewed towards the older end of the age grade possibly affecting the overall lesion prevalence for the group." Although this is potentially problematic, until age-at-death estimates become more accurate for the oldest group of adults, this broad category of "old" probably will continue to be used.

Even the broader age at death categories are probably too precise in cases of fragmentary remains. In fragments, it is possible to distinguish juvenile from adult bone but it is often not possible to assess the number of individuals within the sample or further divide adults into smaller age at death classes. If data are mixed where some individuals are better preserved than others, trauma data may be excluded for not fitting into the age at death framework (as in Judd 2002).

Buhr and Cooks' (1959) approach to examining the rate at which different age segments report trauma is relatively straight-forward in their clinical population. In a clinical population, the age at which trauma is experienced is known. This is not true in an archeological population. In an archeological population, if one is very lucky, some estimate of age-at-death may be assessed (with various degrees of accuracy—see above in section C3 for discussion). However, the age at which trauma is experienced is difficult to ascertain in most cases. Therefore many studies of archeological populations that report incidence of trauma by age class treat age at death as though it were age at injury e.g. Lambert (1997), Judd (1999) and Jurmain (2001). When two or more groups are being compared, prevalence of skeletal lesions is compared according to age-at-death cohort groupings (Bridges 1991; Waldron 1994; Keenleyside 1998; Brasili *et al.* 2004). A caveat to this approach is that some samples might be composed of individuals who skew towards the older side of their cohort grouping (Bridges 1991; Glencross and Sawchuck 2003). One way of addressing a possible disparity in age structure is to test the age-at-death distribution of the samples for statistically significant differences before comparing differences in the amount of trauma (Bridges 1991).

Treating age at death as age at injury creates a sampling bias because the higher the age at death, the higher the likelihood of an incidence of trauma. Therefore studies of trauma by age class in archeological populations do not yield results comparable to Buhr and Cooke or any other clinical population where age at reported injury is recorded rather than total injuries incurred during one's lifetime. Lovejoy and Heiple (1981) dealt with this issue by creating a measure of "years at risk" (see Section C3iii for full discussion of their methods) that attempted to equalize the different lengths of exposure to potential trauma by dividing the sum of "years at risk" in each age class by the number of traumas reported in that age class. However, according to Glencross and Sawchuck (2003:370), "relatively few studies in paleopathology have adopted this (Lovejoy and Heiple's) approach."

By sex

Looking at differences in prevalence of trauma by sex highlights potential differences in activity patterns between adult men and women in a group. Also dividing the trauma prevalence of a group according to sex reveals any bias due to preferential preservation of one sex over the other. In order to assess trauma patterns according to sex, the individuals in the sample need to be well enough preserved so that indicators of sex are observable.

Differences in frequency and location of trauma between the sexes have been observed in all the hominoids (Lovell 1990; Jurmain and Kilgore 1998) as well as in other mammals (Jarman 2000). Reasons for the differences in trauma patterns within a group include differences in foraging strategies (Hawkes 1990; Hill and Hurtado 1996; Sugiyama and Chacon 2000; Hawkes *et al.* 2001), differences in levels of participation in

inter-group violence (Chagnon 1968, 1988, 1992; Walker 1989; Hill and Hurtado 1996; Frayer 1997; Abbink 1999, 2000; Bouroncle 2000), and differences in spousal abuse and other intra-group violence (Chagnon 1988; Burbank 1992; Webb 1995; Wilkinson 1997; Tang 1999).

In many ways it is much easier and less methodologically ambiguous to split the adults in the sample into male and female groups. In most cases, sex is clearer and easier to assess than age at death and there is no accumulation of trauma issues that arise in examining older age classes. As with examining trauma instances by age at death cohorts, individuals need to be assessed for indicators of sex in order to be included in the sample. This excludes most juveniles because pre-puberty sex assessment is difficult. It also excludes most commingled and/or fragmentary remains since traumatic injury may occur on a bone that does not have any sex-distinguishable characteristics. For injuries that occur on the cranium, mandible, or pelvis, sex assessments may be made with reasonable accuracy but it is different in the case of long bones and other skeletal elements. It is possible to make a crude assessment of a set of the adult representatives of the same element in a collection by seriating the group and assuming some degree of gender dimorphism. Seriating may work with some success at the smallest and largest ends of the spectrum, but it is often difficult to assess a set point in the middle.

Although looking at trauma from the perspective of potential occupational differences based on gender is useful for getting a sense of the living population, getting this quality of data, as with age at death classes, is limited mostly to well preserved collections where sex may be accurately assessed. Some bones in less well preserved collections may also be able to show some sign of sex specific characteristics, but most of

the bones do not lend themselves to more than a "guesstimate" based on size and robusticity.

There are two different ways to examine patterns of trauma by sex. One way involves comparing the number of individual male and female skeletons with trauma out of the total number of individuals in the sample (mostly as percentages e.g. Martin 1997). Another way to compare patterns of trauma by sex is to count the number of bones with trauma by element and then compare the percentages with trauma between males and females (e.g. Angel 1974). A consequence of not being able to assess the sex of individuals in a sample is that it is impossible to ascertain whether or not biases in the sex ratio are influencing the observed frequency of trauma.

E2e. Frequency of incidents of trauma by type of injury

Another way to look at "patterns of trauma" is to count trauma in terms of aspects of the injury itself. This can be measured in a few different ways. One way is by the type of injury, such as examining the rate of depression fractures versus simple fractures to the bones of the cranium by Walker (1997). Another way is to make some measure of differentiation of severity of injury (e.g. "presence or absence of endocranial damage" in Wilkinson 1997: 33). Another way is to look at trauma in terms of the weapon used, such as e.g. gunshot vs. bayonet vs. fracture caused by a fall in Scott *et al.* (1998).

Not only is information about who is experiencing trauma and how much trauma they are experiencing of potential interest in assessing the activities of a population sample, determining the agency and intent of the that trauma is also of interest. As discussed in previous sections in this chapter, some kinds of trauma are associated with interpersonal violence, such as penetrating fractures, while others are associated with

accidental injury such as falling. Injury to some regions of the body, such as the face, is more often associated with interpersonal violence than the same kinds of injuries to other parts of the body (Walker 1997). Some kinds of injuries, such as "parry fractures" have been assumed as evidence of interpersonal violence for about a century since Wood-Jones (1910). The direct assumption that some kinds of fractures automatically should be classified as "violent" while others are classified as "accidental" (e.g. as in Judd 2002) has been challenged by Lovell (1997), Jurmain (1999) and Galloway (1999).

In order to get at distinctions in different kinds of trauma in a way that does not involve such assumptions, Lovell (1997) recommends that traumatic lesions be differentiated into types of fractures (e.g. transverse, oblique, spiral, depression, perforating, etc.) and mechanisms of injury (indirect, direct, blunt force, sharp force, etc.). When this information is paired with the location in the body in which the fracture occurred, frequencies of specific types of injuries can be tabulated and analyzed in a way that does not depend on similarities to previously identified agents of trauma. Rather than stating that a group of fractures in a population were identified as "violent," stating that there were a group of "blunt force depression fractures to frontals" does not make assumptions as to the intent of the etiology of the fracture. Although stating more details about a fracture gives a more accurate sense of exactly what is occurring, it becomes more difficult to reduce the data into categories for comparison. Authors such as Kanz and Grossschmidt (2005) and Djuric et al. (2006) succeed in the happy medium between Lovell's standards of the reporting of traumatic injury types, forces and bones affected and showing the data in ways that facilitate comparison

Looking at "patterns of trauma" in terms of aspects of injuries can be an informative approach to trauma because it differentiates levels of severity as well as intent: a traumatic lesion observed on the ulna can represent anything from a minor healed fracture due to a fall to an amputation but it would represent very different things for the person experiencing it. This measure of trauma is used the least frequently of any of the "patterns of trauma" probably because this measure is the most difficult to score and it is often very difficult to determine weapons.

E3. Section Summary

In this section, various ways of determining "patterns of trauma" were defined and compared. The different ways patterns of trauma may be measured and some of the limitations inherent in such measures are summarized in Table 2.2.

Table 2.2. Summary of ways of examining patterns of trauma

Pattern of Trauma	What is measured and limitations
Individual Level	-how a person was injured during life -how a person was injured during perimortem interval, especially in a forensic context
Frequency by skeletal element	-prevalence of injury to each element -takes sample size into account -comparative measure with other samples
Overall pattern of traumatic involvement by relative proportions	-proportion of total trauma contributed by each area of the body -does not take sample sizes into account
Prevalence of trauma per individual	-either a mean average or counted by category (one trauma, two traumas, etc.) -mostly useful for discrete individual burials -difficult to estimate for fragmentary remains

Prevalence of trauma by sex	-sum of traumas for males and females -distinguishes differences in activities related to gender differentiation -mostly useful for discrete individual burials where sex can be determined
Prevalence of trauma by age-at-death class	-addresses how frequently trauma occurs for each age cohort -distinguishes differences and biases due to different age cohorts -most useful for discrete individual burials were age-at-death can be determined
Prevalence of trauma by type of injury	-counts of different types of fractures on bone or by body region -addresses differences in potential sources of injury -often involves assumptions about the etiology of fractures

"Patterns of trauma" may be looked at in terms of bones injured, areas of the body where injuries occur, demographic components, and aspects of the injuries themselves such as severity or type of weapon used. Aspects of the sample determine what patterns it is possible to define. In order to look at demographic components of injury such as the age and/or sex of people who experienced trauma, the sample needs to be composed of isolated individuals (i.e. not comingled) who are well preserved enough to be able to determine age and/or sex. Other aspects such as types of injury require well preserved individual bones but not necessarily well preserved individuals.

In this dissertation, I will examine Neandertal trauma using many of these ways to address patterns of trauma. In Chapter III, I summarize the pattern of trauma at an individual level for each of the Neandertals that exhibit evidence of traumatic injury. In Chapter IV, I examine the significance of patterns of trauma as they relate to the sample of injured Neandertals from the perspective of demographic components such as age-at-death and sex, and type of injury. In Chapter V, I examine the relative frequencies of trauma for elements within a sample of European Neandertals and the prevalence of trauma by age-at-death and sex. In Chapter V, I also compare the frequencies of trauma by element in the European Neandertal sample to other comparative samples. In Chapter VI, I compare the frequency of trauma by element between a single Neandertal site and a comparative sample where all bones are fragmentary and collected under the same protocols.

F. Aspects of the "Ideal" Population for Assessing Trauma

This section will present a "wish list" of aspects that a sample should have in order for research into its trauma to have the highest resolution and be most representative of the trauma that occurs in the living population. These aspects include large sample size, a high degree of bone preservation, a defined period of burial usage for the site, that the interred population mirrors the living population in age, activities practiced, and social strata, and that there be radiographs of all of the specimens and that the investigators describe and analyze all bones in a consistent way. In the following section, aspects of this ideal are compared with the current realities of the extant Neandertal sample.

The object of most studies of instances of trauma in populations is to discover whether a population is engaging in activities that predispose them to injuries that are different from injuries observed in other populations. However, in order to be able to compare trauma in populations, there must be the assumption that the mortuary populations are accurately representing all the people living at that time. In order to see how activity patterns are reflected in incidences of trauma in individual people, there must be enough incidences of trauma to enable significance. Because trauma seems to be a rare event, there needs to be enough people in the population so that an insignificant but perceived pattern is not the result of a small population size. The "ideal" population also contains qualities which minimize (and/or make possible to analyze) any biases in preservation where the cemetery population and its trauma does not reflect the living population. These qualities combine to produce a sample with which hypotheses about trauma may be reasonably tested because what is being observed is likely to reflect the activities and demographics of the population rather than the serendipitous preservation of a "lucky" few individuals which may skew the analysis. Although a few populations may approach this ideal fairly closely, e.g. the crew of the "Mary Rose" (Stirland 2001), it is difficult to achieve many of these aspects in populations that date before the period of written history. It is useful, however, to understand in what ways a population does not meet these criteria so that testable hypotheses can be structured in a way that makes the most of the data, but does not overstep their limitations.

F1. Large sample size

Sample size matters. The larger the sample, the more likely it is to find incidences of trauma and for those instances to be significant when compared with other populations. Larger samples also limit the influence of many potential biases.

F2. High degree of preservation

A high degree of bone preservation ensures that most of the trauma that occurred to individuals in the sample will be observable. The more fragmentary the bones, the more likely trauma will be obscured by postmortem damage.

F3. Individuals buried within a defined period of time

It is assumed that the risk of experiencing trauma is based on the activities in which the population is engaged. If it is unclear whether a mortuary population was engaged in the same activities for the duration of its burial period, it becomes difficult to make claims regarding the "meaning" of the trauma. Changes such as the advent of agriculture, riding horses, industrial factories, and driving cars all bring differences in ways people may be injured. Therefore it is important to be able to define the period of time when the cemetery was being used in order to know that people being buried were living under the same constraints or, if they are not, to realize that and analyze the trauma accordingly.

F4. Cemetery population reflects mortality rates of the population

This demographic concern also affects trauma analysis. Most studies of trauma in cemetery samples assume that these samples mirror the age at death and sex ratio distribution of the population as a whole and the trauma observed in the sample reflects the trauma experienced by members of the larger population. However, this is not always

the case; there are many scenarios where some subset of the population is overrepresented in the cemetery sample. Examples of this include burials of soldiers (over-representation of prime age males), victims of raids during times of war (overrepresentation of women, children and old people), victims of infectious disease (overrepresentation of children and old people), sex-specific monastic orders and other scenarios where only some of the population are given preferential burial treatment in association with status. In a situation such as that observed by Kanz and Grossschmidt (2006) of a cemetery full of gladiators, one would not imagine that the trauma rates are reflective of the Roman population in general.

F5. Knowable differentiations in socio-economic status if present

Similar to understanding whether the cemetery population reflects the age at death and sex ratio distribution of the population, it is also important to know whether there are class distinctions within the cemetery sample that might lead to an overrepresentation of one social segment of the population which is engaged in different activities from other segments of the population. Again, Kanz and Grossschmidt's (2006) gladiators are a good example of this as is the phenomenon that elites in a social group may be buried in different places or ways that preferentially facilitate their preservation.

F6. All specimens radiographed

All specimens in a cemetery sample population should be observed equally rigorously and all cemetery sample populations should be observed consistently. One way of insuring that all specimens are observed in the same way is to radiograph the samples to look for breaks perhaps not obviously visible. It is especially problematic when one collection is compared with another collection that has not been observed with

the same rigor. This often creates a bias where more trauma is observed in the more rigorous observed sample not necessarily because there really is more trauma but because of differences in the intensity of observation. By standardizing the ability to observe trauma, the results of comparisons become more credible.

F7. Section summary: "ideal" population for assessing trauma

It is important to consider aspects of the "ideal" population for assessing trauma so that this ideal may be compared with the realities of aspects of the sample at hand and their potential limitations. In Table 2.3, the aspects of this ideal population are summarized.

Table 2.3. Aspects of the "ideal" population for assessing trauma

Aspects of "Ideal" Collection for Trauma Analysis	Benefit
Large sample size	-more likely to find evidence of trauma -more likely for instances of trauma to be significance -limits the influence of potential biases
High degree of preservation	-most/all trauma observable
Individuals buried within a defined period of time	-population likely to be engaged in similar activities -inconsistencies known and can be accounted for
Knowable differentiations in socio-economic status	-status may influence activities engaged in -if biases due to status, needs to be accounted for
All specimens radiographed	-all evidence of trauma most likely to be observed -all specimens given equal levels of evaluation

All of these aspects of the "ideal" trauma study population help minimize potential biases in the preservation of the human remains that might skew or potentially discredit the results. Because it is difficult to ascertain the biases in many prehistoric skeletal samples, it is difficult to determine how accurately the sample represents the

population and whether the trauma and demographic data collected are reasonable reflections. In the following section, the "ideal" population scenario will be compared with the realities and limitations encountered when assessing patterns of trauma within the Neandertal sample and comparing those patterns with other samples.

G. Limitations of Neandertal Data for Trauma Patterning

The Neandertal sample, when regarded as a single entity is referred to in this dissertation as the "Neandertal Metaset." It is very different from most other samples analyzed in the paleopathological literature. The first major difference is that the Neandertal Metaset represents dozens of sites from all over Europe and western Asia that span over a 100,000 year period. Second, there are limitations from the poor preservation quality of the Neandertal remains and how little is understood about possible sampling biases. The third major difference is the high level at which many Neandertal remains have been scrutinized, compared to more recent human samples. Finally, the Neandertal Metaset is different from samples analyzed in paleopathological literature because it does not currently exist; however, in the past, efforts have been made to catalogue information about fossil hominids into one place (Oakley *et al.* 1971), these efforts have not been updated to reflect new Neandertal discoveries. It is important to understand the differences and limitations of the Neandertal sample compared with most paleopathological samples so that appropriate analyses can be made and conclusions about trauma within the Neandertal sample do not extend beyond its limitations.

In this section, the limitations of the available material for examining trauma in Neandertals will be reviewed. These limitations include the disparate nature of the location and chronology of the samples, different levels of preservation depending on the

site, possible preservation biases of some elements, potential age and sex biases in the Neandertal sample, possible differences in the activities of males versus females, possible biases in the mortuary treatment of the sample, small sample size, non-standardized reporting of the Neandertal remains, and the lack of comparability of the Neandertal remains to other published samples. The degree to which some of these limitations influence the composition of the sample is unknown and not amenable to estimation.

G1. List of limitations: taphonomic differences

The first group of limitations is the lack of overall comparability of Neandertal sites. Because of the disparate nature of the "Neandertal Metaset," there are many taphonomic issues that prevent bones from individuals from being reasonably comparable even within the appropriate sample for the purposes of the study of trauma. These issues include differences in geographical location, time, and extent of preservation.

G1a. Disparate in time and location

The Neandertal Metaset is made up of individuals that cover a wide geographical and chronological range. Their geographical range extends over thousands of miles; north into Germany, south into Israel and east into Uzbekistan. The time range on this sample is over 100,000 years, ranging from 130,000 B.P. at Krapina (Rink *et al*. 1995) to 29,000 B.P. at Zafarraya (Hublin *et al*. 1998).

This lumping together of all Neandertals is the geographical and temporal equivalent of putting together a sample made up of the remains from Qafzeh in Israel (100,000 B.P.), Dolni Vestonice in the Czech Republic (27,000 B.P.), a Linear Pottery site in Austria (5500 BCE), Trojan War dead (1188 BCE), Roman centurions in Italy (0 BCE), Medieval plague victims from a village in Germany (1348), Crimean War soldiers

(1855), and a current cemetery population from France (2009). Such a sample would never be compiled in a paleopathological context because we imagine that the life of the people during these times differed radically. Although clearly during the past 5,000 years there has been a rapid acceleration of culture and technology, it seems presumptuous to assume that there were no differences in lifestyle due to differences in the environment and/or due to culture during the 100,000 that the "classic" Neandertals inhabited Europe and west Asia.

G1b. Different levels of preservation depending on site

The Neandertal Metaset is constituted of individuals from about a hundred different sites. Because of the extreme antiquity of the sites and differences in their taphonomic histories, preservation of the skeletal remains differs enormously. These differences in preservation make direct comparisons between individuals from different sites problematic unless some standard of preservation is met. In most paleopathological studies, that standard is to report trauma only from whole bones. In the context of Neandertals, however, the application of such a standard would leave very few bones with which to work; therefore, incomplete remains need to be combined and this leaves the problem of wide range of "incompleteness" present in the Neandertal Metaset and the bias against the observation of trauma that increased fragmentation brings.

G1c. Possible preservation biases by element

Some skeletal elements are more readily preserved and identified than others. Preservation bias by element has already been discussed in Chapter 2. The lack of preservation of some elements obliterates possible trauma that might have been observed were they in better condition. In addition, some bones, such as bones of the cranial vault,

are more likely to be identified as human in their fragmentary state than other bones such as long bones, ribs or bones of the hands and feet.

G2. List of limitations: unknown sampling biases

Because so little is understood about Neandertal culture and behavior, it is difficult to know the nature and extent of possible biases within the sample. Some of these biases are due to differences in activity patterns during the lifetime of the individual and some of these biases are due to potential differences in the way the remains of individuals are treated after death.

G2a. Activity engagement by age and sex is unknown

It is unclear how Neandertals structured many of the activities of their societies. Some models posit extreme differentiation of gender assigned roles (Binford 1992; Soffer 1994). However, because of the low magnitude of sexual dimorphism and the fact that hypertrophy is seen in both males and females (Cachel 1997; Soffer 1994), the validity of this model of separation between the sexes is unclear. If males and females did radically different activities, one might expect differences in patterns of injury. If they did more or less the same activities, these differences would not be very pronounced. Deciphering differences by sex is hindered by the absence of sufficient preservation of Neandertals remains. The sex of most individuals cannot be identified and this issue cannot be addressed, nor can preservation biases by determined. Also it is unclear if age-cohorts engaged in different activities. If young adults engaged in less potentially dangerous activities than prime age adults, then the frequency of trauma would be very dependent on the age-at-death structure of the population. Because the distribution of activities by age is unknown, it is difficult to assess whether activity patterns related to age influence

the trauma frequencies observed in the population or whether the patterns of trauma only reflect the accumulation of trauma throughout the life of the individual.

G2b. Bias in burial or mortuary treatment is unknown

Most Neandertal remains are fragmentary and it is very difficult to accurately determine their age-at-death and sex. Because the demographic details of many sites are unknown, it is unclear whether there are biases in what remains have survived to be excavated that do not reflect the true age distribution of the population from which they sample. Another problem is that biases in preservation may differ from site to site. It is possible that some groups of well preserved remains may not accurately represent the age-at-death structure of the population and, instead, reflect some mourning rituals of a specific group or some other bias. Two of the famous Neandertal sites, Shanidar and Krapina, seem to have very different age-demographic profiles: Shanidar has a predominance of older individuals preserved at this site (Trinkaus 1983) whereas, at Krapina, there are many immature specimens preserved compared to older adults (Wolpoff and Caspari 2006). Is this because of differences in survivorship at the two locations or is it because of some preferential mortuary treatment or some other taphonomic factor? Because very little is understood about Neandertal interment practices, and the possible variations of these practices, it is hard to determine both if demographic biases are present and why such biases might exist.

G3. List of limitations: the incomparable Neandertals

The third way Neandertal Metaset data are problematic in a paleopathological context is the difficulty of analyzing them in the context of other samples. Reasons for this difficulty include the smallness of the Neandertal Metaset sample, its high level of

fragmentation, the lack of any standard of reporting Neandertal remains in the literature, and the lack of comparability with other published samples.

G3a. Small sample size

Small sample size is one of the biggest limitations in looking at trauma within the Neandertal sample. Even in large and well-preserved skeletal collections, traumatic lesions are rare events; therefore in small and ill-preserved skeletal collections, traumatic lesions are less likely to be observed. The Neandertal sample, taken as a whole, is composed of about two dozen moderately to well-preserved individuals (including infants and juveniles). The rest of the Neandertal sample is made up of very fragmentary remains that are mostly not identifiable as individuals and often do not represent whole bones. In most studies of trauma in the paleopathology context, fragmentary bones are not counted as per the standard defined by Lovejoy and Heiple (1981). If this standard was applied to the analysis of trauma in Neandertals, very few of the bones of even the well and moderately preserved individuals could be included. Although there have been studies examining the demographics of the Neandertal sample as a whole, much of the Neandertal used in studies such as Trinkaus (1995) and Wolpoff and Caspari (2006) involve “dental” rather then “skeletal” individuals. Dental remains offer useful information regarding age-at-death, but they provide little context for trauma in the population.

G3b. High degree of fragmentation in the Neandertal sample

As previously mentioned, fragmentary remains make up a large portion of the Neandertal Metaset. It is more difficult to observe trauma in fragmentary remains because postmortem breakage often masks antemortem and perimortem injuries. Analysis

of fragmentary remains is problematic because counts of broken bones may overrepresent the number of elements present in a sample and there are very few comparative samples where fragmentary bones have been included. Many of the fragmentary Neandertal remains are also commingled remains which makes assessing the demographic structure of the population very difficult.

G3c. Non-standardized reporting and analysis of Neandertal remains

Not all reports of Neandertal remains are created equal. There are some exquisitely meticulous catalogues of some sites such as Krapina (Radovčić *et al*. 1988; Kricun *et al.* 1999) where not only have all the remains been viewed by many different researchers and updated accordingly, but also, all the remains have been radiographed so that trauma present may be observed that is invisible to the eye may be observed. There are other specimens such as Saint Césaire and the Le Moustier skull that have been scanned using computer tomography that also revealed information about trauma not visible to the naked eye. However, there are many specimens that are not so well reported, well-examined, or whose remains were lost or damaged during the Second World War. This lack of consistency in the examination of all the remains that make up the Neandertal Metaset biases the well-examined remains to show more trauma than remains that have not been scrutinized so carefully, by so many people, or with so much technology.

G3d. Publication biases

Some Neandertal specimens are more well-published and well-known than others. These are often the specimens that have the highest level of preservation; however, it is unclear whether they are the most representative sample of the Neandertal population

because many of the best preserved Neandertals are male and old. If only these specimens are used in a study of trauma, such as Underdown (2006) [reviewed in Chapter III], the pattern and frequency of trauma is probably quite different than it would be if the entire Metaset is used. However, it is to be remembered that the Neandertal Metaset does not currently exist because it would take a high degree of coordination to track down and catalogue every Neandertal bone ever excavated. Until such time as this is possible, any subset of the Neandertal Metaset will involve some degree of bias based on what has been published and accessibility of publications through search engines and journals.

G3e. Lack of comparability with data from other published populations

The Neandertal Metaset is different from other published paleopathological samples in many ways. The first difference is that the vast majority of archeological samples whose demographic and trauma data have been published contain only individuals with intact, or mostly intact, skeletons. This is not the case with the Neandertal Metaset. The second difference is that most collections come from one specific place and date from one specific time period that spans no more than a few hundred years. This is also not the case with the Neandertal Metaset. The third difference is that the data for most samples have been collected by an individual or a team working within the same set of standards for data collection. This is also not the case with the Neandertal Metaset. Because of all these differences, the comparisons of Neandertal skeletal data with those from more modern previously published sites seem to be based on unjustified assumptions of comparability.

G4. Section summary: Limitations of Neandertal Data

In this section, the aspects of the limitations of the available material for examining trauma in Neandertals were reviewed. These limitations and their consequences are listed in Table 2.4.

Table 2.4. Limitations of the Neandertal Metaset

Limitation	Consequence
Metaset does not currently exist	-any study of Neandertal trauma biased by sites chosen -likely emphasis on best preserved and well published specimens
Disparate in time and location	-does not account for differences in environment -does not account for any group specific behaviors
Different levels of preservation	-well preserved skeletons more likely to show trauma -fragmentary samples less likely to be counted
Possible biases by element	-some elements intrinsically more likely to be preserved -some elements more likely to be identified
Activity engagement by age and sex is unknown	-unclear if males and females should be treated separately -the impact of age-cohort patterning of activity is unknown
Bias in mortuary treatment is unknown	-difficult to determine whether age-at-death structure of sites reflect age-at-death structure of population -age-at-death structure might be due to preferential mortuary treatment for some individuals -age-at-death structure might be due to some other taphonomic factor
Small sample size	-any sampling bias has major impact -cannot exclude fragmentary bones -many bones do not come from identifiable individuals

High degree of fragmentation	-trauma more difficult to observe -number of bones per element overrepresented -demographic structure of the population difficult to assess
Non-standardized reporting of Neandertal remains	-different levels of observation (radiographs, CT scans) -well-examined remains more likely to have trauma observed
Publication biases	-best preserved specimens get most attention - some publications easier to search for and access
Lack of comparability with other published populations	-data do not come primarily from intact skeletons -not specific to one time and place -many different researchers and standards of data collection and reporting

H. Chapter II Conclusion

In this chapter, I described how evidence of trauma is defined and communicated to other researchers. The affects of some of sampling biases such the differential ease of observation of types of trauma, variability in age at death and taphonomic modification, differences in how evidence of trauma is counted by researchers and patterns of trauma are assessed was reviewed. The chapter also includes a "wish list" of aspects that a sample should have in order for research into its trauma to have the highest resolution and be most representative of the trauma that occurs in the living population. The chapter concluded by summarizing various ways the Neandertal Metaset differs from the ideal collection for assessing patterns of trauma.

Trauma is defined by a physical impact on the victim from an outside force. This affect of this impact may be limited to the soft tissue or it may be observed in the underlying bone as a fracture, dislocation or muscle pull that has the potential to disrupt nerve and/or blood supply. It is this outside agency that differentiates trauma from other pathologies that affect the body from the inside and may also cause damage to bone. Various ways of categorizing types of trauma were discussed in this chapter. These ways include defining various types of injury by their outside agency, their appearance on bone, degree of severity, and where they occur on the body. Examples of types of trauma that commonly occur on the cranium and postcranial bones were also discussed.

There are several ways of assessing when trauma took place relative to the lifetime of the victim. These ways include the diagnosis of healing to trauma as it takes place in tubular and cancellous bone during the life of the victim. The period that surrounds the death and immediate funeral preparation of the individual is also distinguished from the period long after the death of the victim by differences in the physical properties of bone during these intervals.

The ability of bones to respond to traumatic forces changes throughout the lifetime of an individual. Because of these changes in the elasticity and density of bone, different types of fractures may occur depending on the age of the individual at the time when the trauma occurred. Differences in the way trauma affect juvenile, adult and older adult bone during the lifetime of the individual will be discussed as well as differences in the evidence of antemortem trauma visible at death.

After an individual is buried, taphonomic forces may influence the ability of the observer to detect trauma. The result of these biases include some types of bones being

more likely to be preserved and later recovered, some types of individuals being more likely to be preserved and later recovered, and the loss of data useful in the analysis of trauma in fragmentary and/or commingled remains. When trauma data from different sites are compared, differences in preservation at each site have the potential to skew interpretation of the relative amounts of trauma at each site in ways that need to be, at least, acknowledged and possibly avoided.

Analyzing occurrences of trauma by comparing skeletal samples from different sites is not entirely straightforward because of the lack of consistency of trauma recording protocols. In these protocols, decisions are made as to how the raw instances of trauma should be tabulated. Two of these major decisions are whether to count both antemortem trauma and perimortem trauma and whether trauma observed on incomplete bones is to be included. When samples from two different populations are to be compared, it is important that any differences in trauma counting protocol are noticed so that trauma comparisons reflect populational differences in exposure to trauma during life rather than sampling biases.

"Patterns of trauma" may be looked at in terms of bones injured, areas of the body where injuries occur, demographic components, and aspects of the injuries themselves such as severity or type of weapon used. Aspects of the sample determine what patterns it is possible to define. In order to look at demographic components of injury such as the age and/or sex of people who experienced trauma, the sample needs to be composed of isolated individuals (i.e. not comingled) who are well preserved enough to be able to determine age and/or sex. Other aspects such as types of injury require well preserved individual bones but not necessarily well preserved individuals.

In order for sampling biases to be avoided or (at least) recognized, several criteria need to be met both for the sample being analyzed and for all the comparative samples. These criteria include a large sample size, a high degree of bone preservation, a defined period of burial usage for the site, that the cemetery population mirrors the living population in age, activities practiced, and social strata, and that there is a consistency in the analysis of the bones themselves which includes radiographs of all of the specimens.

In the following section, in contrast to the "ideal" population, aspects of the limitations of the available material for examining trauma in Neandertals were reviewed. These limitations included the disparate nature of the location and chronology of the samples, different levels of preservation depending on the site, possible preservation biases of some elements, potential age and sex biases in the Neandertal sample, unknown possible differences in the activities of males versus females, unknown biases in the mortuary treatment of the sample, small sample size, non-standardized reporting of the Neandertal remains, and the lack of comparability of the Neandertal remains to other published samples.

In conclusion, trauma is a rare event that may be difficult to observe on skeletal samples in a consistent way even when the individuals in the sample did experience bone damaging injury. Therefore it behooves researchers to consider the ways in which their samples may be skewed before making conclusions about the activities of a population based on the observed traumas that individuals experienced.

CHAPTER III

THE HISTORY OF TRAUMA ANALYSIS IN NEANDERTALS

A. Chapter III Introduction

In this chapter, I summarize the history of the discovery and interpretation of trauma in Neandertals. The first section of the chapter, I address the discoveries of individual Neandertal remains which showed signs of trauma, and the primary descriptions of those traumas. In this first section, I also discuss how interpretations of trauma in individual Neandertal skeletons were rooted in contemporary ideas of the place of Neandertals in relation to modern humans and the role of technology in the identifying and interpreting trauma in individual remains. In the second section, I summarize the history of interpretation and conclusions about trauma in Neandertals as a group.

B. Observations and Interpretation of Trauma in Individual Neandertals

In this section, the history of observations of trauma in individual Neandertals will be reviewed. These individuals exhibiting indications of trauma include remains from Feldhofer Cave, La Chapelle-aux-Saints, La Ferrassie, Krapina, La Quina, Tabūn, Šala, Shanidar, Kebara, Kiik-Koba, Le Moustier I and Saint Césaire. For each site, the location, date of discovery, and remains discovered will be summarized, the original

interpretation of the trauma observed will be stated, and the historical context of that interpretation will be addressed, when applicable. The sites I review are summarized in Table 3.1 (for full details about each individual and site, see Appendix A).

Table 3.1 Summary of Neandertals with trauma

Site	Country	Date excavated	Sex and age of individuals with injuries
Feldhofer 1	Germany	1856	Male, > 40 years
La Chapelle-aux-Saintes	France	1908	Male, ~30 years
Krapina	Croatia	1899-1905	Krapina 4: cranium, adult male Krapina 180: ulna, adult Krapina 149: clavicle, adult Krapina 188.8: ulna, adult Krapina 5: cranium, adult male Krapina 31: frontal, adult female Krapina 34.7: parietal, adult
La Quina H5	France	1908-1920	Female, adult
Tabūn C1	Israel	1930s	Female, ~30 years
Šala	Slovakia	1961	Female, young adult
La Ferrassie	France	1909-1921	La Ferrassie 1: male, 40-55 years La Ferrassie 2: female, 20-40 years
Shanidar	Iraq	1950-1960s	Shanidar 1: male, 35-50 years Shanidar 3: male, 35-50 years Shanidar 4: male, 35-50 years Shanidar 5: male, 35-50 years
Kebara KMH 2	Israel	1980s	Male, 25-35 years
Kiik Koba 1	Ukraine	1924-1926	Male, > 40 years
Le Moustier 1	France	1908-1914	Male, 12-13
St. Césaire	France	1979	Male (?), young adult

During the century and a half of scientific inquiry into the lives (and deaths) of Neandertals, the interpretations of their pathologies have played a key role in how Neandertals have been perceived both in academic and popular presses. During the first few decades of Neandertal study, there were attempts to explain their unusual morphology by the argument that they were modern humans with pathologies. This changed at the turn of the twentieth century when there was enough fossil evidence to

demonstrate their antiquity and characteristic morphology. However, the analysis of the severely pathological, but relatively complete, La Chapelle-aux-Saints individual became acknowledged as the "Neandertal standard." before the extent of his pathologies were recognized. Neandertals continued to be defined by their pathologies though the focus shifted from regarding "normal" Neandertals as pathological modern humans to regarding a pathological Neandertal as the "normal" Neandertal. Although La Chapelle itself has been reinterpreted over time, defining the lives of "normal" Neandertals by pathological specimens has been a re-occurring theme in paleoanthropology (e.g. Pettitt 2000). During the late twentieth and early twenty-first centuries, the study of Neandertal trauma as an insight into their lifeways has become increasingly important. Although evidence of trauma has been published for individual specimens for more than a century, more recent systematic analyses of trauma in Neandertals as a group (such as Berger and Trinkaus (1995), Jurmain (2001), Underdown (2006), and Gardner (2004 and 2007)) have opened new avenues of inquiry and interpretation.

B1. The Feldhofer Neandertal

In 1856, the skeleton of an individual who would become the Neandertal holotype was discovered in Feldhofer Cave near Hochdahl, between Elberfeld and Düsseldorf in Germany (Fuhlrott 1859). The originally discovered remains of an old adult male who died over the age of forty include a calotte, five fragmentary ribs, a fragmentary scapula, a clavicle, complete right humerus, radius, and ulna, incomplete left humerus and ulna, a fragmentary left ilium, and both fairly complete femora. This individual has been identified as an old adult male who died over the age of forty. Recently, Accelerator Mass Spectroscopy dating techniques have yielded an age of 40,000-45,000 years B.P for

the Feldhofer remains (Schmitz *et al.* 2002). Very fragmentary remains from at least two other individuals have also been reported since the discovery of Feldhofer 1 (Schmitz *et al.* 2002).

Incidents of trauma, as well as misinterpretations of pathology, have been noted since the discovery of this Neandertal holotype in Feldhofer Cave. The bones from the left upper limb clearly showed signs of healed trauma near the olecranon process as well as atrophy to the humerus and ulna on that side caused by the decrease in range of motion. The first full report of this pathology is from Schaaffhausen (1858: 457-458).

> Ein linkes Oberarmbein, an dem das obere Drittheil fehlt, und welches so viel dünner ist, dass es von einem andern Menschen herzurübren scheint; ein linkes Ellenbogenbein, das zwar völlständing aber Krankhaft verbildet ist, in dem der proc. Coronoideus durch Exostose so vergrössert ist, dass die Beugung gegen den Oberarmknocken, dessen zur Aufnahme jehes Forsatzes bestimmte foss. ant. Major auch durch Knochenwucherung verschwunden ist, nur bis zum rechten Winkel möglich war. Dabei ist der proc. Anconaeus stark nach unten gekrümmt. Da der Knochen keine spururen rhachitischer Erkrankung zeigt, so ist anzunehemen, dass eine Verletzung während des Lebens Ursache der Ankylose war. Diese linke Ulna mit dem rechten Radius verglichen lässt auf den ersten Blick vermuthen, dass die beide Knochen verschiedenen Individuen angehört haben, denn die Ulna ist für die Verbindung mit einem solchen Radius um mehr als einer halben Zoll zur kurz. Aber es ist klar, dass diese Verkürzung sowie die schwäche des linken Oberarmbeins Folgen der angeführten krankhaften Bildung sind.
>
> A left humerus, of which the upper third is missing, and which is so much thinner, that it seems to come from different person; a left ulna, that is, indeed, complete but is pathologically distorted, in which the coronoid process is so enlarged by exostoses that the bending against the humerus was only possible until the right angle. Moreover, the anconeus process is strongly distally curved. Here the bone shows no signs of rachitic illness, thus it is to be accepted that an injury during life was the cause of the ankylosis. This left ulna, when compared with the right radius, leaves us, at first glance, to presume that the two bones had belong to two separate individuals, rather than that the ulna, more than half an inch too short, is to be joined with such a radius. However, it is clear that this shortening and the atrophy of the humerus are the consequence of the pathological shape. (Translated by VHE)

Schaaffhausen argued that there were no other signs of pathology in the specimen besides the distortion observed in the left humerus and ulna, both traumatic in etiology. The other anatomical anomalies he observed in the individual, which became the type specimen "Neandertal," he attributed to the fossil's extreme antiquity as a pre-dilulvial human "diese menschlichen Gebeine stammten aus einer Zeit, in der die zuletzt verschwundenen Thiere des Diluvium auch noch lebten" [these human bones are descended from a time in which the last extinct animals of the Flood were also still alive] (Schaaffhausen 1858:454).

Other colleagues, however, did not agree with this assessment. Mayer (1864) asserted that the distinctive features of this individual were not due to antiquity but to a combination of pathology and lifestyle. He saw this individual as a pathological modern human, but believed that the pathologies were not traumatic in origin. Instead, he regarded the morphology of the left humerus and ulna as being the consequence of rickets. His conclusions were that the individual was of Asian origin, a "Mongolian Cossack," who suffered from childhood rickets but went on to ride into Europe during the Napoleonic Wars, under the command of General Tcheritcheff, where he died in the cave and was covered over by sediment. Because Mayer had previously accused Schaafhausen of 'weitgreifende Folgerung' (wide reaching/improbable conclusions) in his analysis of the Feldhofer 1 remains, Mayer's own view was satirized for the English speaking audience by Huxley (1864:581) as a model of "scientific sobriety":

> Thus the hypothesis which is held up to us by Professor Mayer as an example of scientific sobriety is this: that the Neandertal man was nothing but a rickety, bow-legged, frowning Cossack, who, having carefully divested himself of his arms, accoutrements and clothes (no traces of which were found), crept into the cave to die and has been covered up with loam two feet thick by the 'rebound' of the muddy cataracts which (hypothetically) have rushed over the mouth of his cave.

Mayer was not alone in trying to describe some of the earliest discoveries of Middle Paleolithic humans as modern pathological specimens, and thus deny their antiquity and ancestry. At the discovery of the juvenile Šipka mandible, Virchow (1882) concluded that it was a robust "adult with a pathological eruption pattern." During this time the presence of pathology was often hypothesized to account for any anomalous morphology rather than the hypothesis of humankind's antiquity. The presence of traumatic pathology in the Feldhofer individual confounded this issue even further because some of his "strange" morphology was caused by trauma, but some of it was not. Virchow (1872:158) was quick to recognize many pathologies in the Feldhofer skull; however, only one anomaly, an exocranial injury to the right side of the occipital, is probably traumatic in origin:

> Über der Linea nuchae (semicirc. occipit. superior), welche in der Mitte statt der Protuberantia occip. Externa eine flache Vertiefung besitzt, und parallel mit ihr legit eine seichte Grube von fast 2.5 Centim. Querdurchmesser und mit einem Winkel von etwa 135º eine viel grössere und breitere, übrigens auch nur seichte Grube, welche sich bis auf eine Fingerbreite (14 Millim.) der Lambda-Naht nähert; sie ist 25 Millim. Lang, hat fast 20 in der grössten Breite, einen unebenden, sehr compacten Grund und in der Mitte, wie eine niedrige Insel, einen flachen Knochenvorsprung von 10 Millim. Länge und 4-5 grössten Breite.
>
> Over the nuchal line, which in the middle in the place of the external occipital protuberance, there is a shallow cavity, and parallel to it lies a shallow pit of nearly 2.5 cm. The transverse diameter and with an angle from about 135º much bigger and broader, besides not only the shallow pit, which draws near to a finger's breadth (14mm) of the lambdoid suture; it is 25 mm long, and has nearly 20 mm at it widest breadth, an uneven, very compact pit and in the middle, like a grudging island, a flat bony protuberance 10 mm in length and 4-5 mm at the widest." (Translated by VHE)

In a later publication, Schwalbe (1901: 13), describes this lesion as "rauhe körnige Fläche" ("rough granular surface").

Because the Neandertal remains from Feldhofer clearly showed some evidence of pathology (due to traumatic injury), arguments explaining all of his "irregularities" in morphology compared to modern humans as caused by some pathology have persisted. These pathological arguments include rickets (Virchow 1872 and Ivanhoe 1970), syphilis (Wright 1971), and iodine deficiency (Dobson 1998). The persistence of the pathology argument in explaining Neandertal morphology has been a consistent factor in the study of Middle Paleolithic humans. Some of these interpretations, such as rickets, iodine deficiency and syphilis, are fairly easily dismissed except by creationists such as Lubenow (1992), but other arguments that use evidence of traumatic pathology to explain behavioral isolation of Neandertals from other groups of humans persist in academic discourse (such as Klein 1999 and Pettitt 2000). This difference in interpretation is reflected in the following generalization: during the nineteenth century, some scientists saw "normal" Neandertals as pathological modern humans, whereas during parts of the twentieth century pathological Neandertals were viewed as "normal."

B2. La Chapelle-aux-Saints and Other Misinterpretations of Pathology

It was not until the turn of the twentieth century that these few Neandertal fossils (Feldhofer, Šipka, etc.) ceased being recognized as pathological humans, and began to be viewed as fossil humans showing a peculiar morphology. This was due to the discovery of and publication of a preponderance of specimens all showing both a similar morphology and "prediluvian" antiquity. These sites include Spy (Fraipont & Lohest 1886; de Puydt & Lohest 1887), Krapina (Goranović-Kramberger 1899, 1906, 1908 etc.), La Chapelle-aux-Saints (Boule 1908, 1911-1913), Ehringsdorf (Pffeiffer 1909), Le Moustier (Hauser 1909) and La Quina (Martin 1911, 1913).

In this context it is an ironic twist that the most complete preserved individual to be discovered in the early twentieth century was La Chapelle-aux-Saints, an adult male with severe osteoarthritis and several other non-traumatic pathologies. Boule's substantial monograph (1911-1913) on this skeleton "…served to establish the La Chapelle specimen as the 'classic' Neandertal and Boule's conclusions as the standard interpretation of these Pleistocene hominids" (Trinkaus 1985:20). Boule's (1912:165-168) reconstruction of La Chapelle interpreted the vertebrae damaged by osteoarthritis as being chimpanzee-like and reconstructed his posture with neither much cervical or lumbar lordosis. Other more simian interpretations of La Chapelle's anatomy included bent knees, an opposable big toe, and an anterior jutting face. For his reconstruction Boule also used parts of La Ferrassie 1 and 2 to fill in for regions missing or taphonomically damaged in La Chapelle. One of these regions was the greater trochanter of the femur where Boule used La Ferraissie 1's right proximal femur as representative (1912:141). This was an unfortunate choice because La Ferrassie greater trochanter was abnormally enlarged due to a healed fracture (Dastugue and Lumley 1976:615) and, as Trinkaus notes (1985:34), there were other complete and non-pathological specimens of greater trochanters available at the time such as Feldhofer, Spy 2, and Krapina 213 and 214. This made for a stoop-shouldered, shuffling, barely bipedal view of Neandertals that endured for nearly half a century within the field of paleoanthropology and continues to linger in the popular conscious. It was not until publications by Arambourg (1955) and Straus and Cave (1957) that La Chapelle's particular pathologies were decoupled from the scientific conception of Neandertal "normality" and recognized for what they were.

The "Old Man" of La Chapelle was discovered in 1908 near Brive, Corrèze near the Dordogne River in France (Bouyssonie *et al.* 1908) at a Würm II site (Vandermeersch 1965) dated to about 60,000 years B.P. The remains of this adult male include complete, or nearly complete, cranium, mandible, clavicles, humeri, ulnas, and patellas, and fragmentary vertebras, ribs, radiuses, innominates, femurs, tibias, fibulas, and hand and foot bones. Although his osteoarthritis and the loss of all but one of his teeth gives him the appearance of being at the older end of the adult spectrum, other indications of age such as changes to the auricular surface and degree of premolar wear put his age at death around thirty years (Trinkaus 1995). This skeleton shows signs of many pathologies including: degenerative joint disease in cervical and thoracic vertebrae, the left hip, and the temporomandibular joints, as well as bilateral auditory exostoses and the antemortem loss of many teeth (Trinkaus 1985). However, one healed fracture to a distal mid-thoracic rib is the only one of these pathologies that seems to be traumatic in origin (Trinkaus 1985:30-31):

> The primary lesion of the La Chapelle-aux-Saints 1 ribs is a healed fracture of a right mid-thoracic rib that was broken just proximal of the costal cartilage attachment. The callus is 21.4mm long dorsally and 22.6 mm long ventrally, and it is 10.0mm larger superoinferiorly and 6.7 mm larger dorsoventrally than the adjacent rib shaft. Radiographically there is no trace of a fracture line, and the callus is relatively smooth, suggesting that it occurred long before death, and was completely healed. It is unlikely to have caused more than a temporary discomfort.

The observation of pathology in the remains from Feldhofer Cave obscured the interpretation of his antiquity and conclusions about his place in human evolution, in parallel ways the initial lack of observation of pathology in the La Chapelle remains obscured the understanding of Neandertal mobility (and possibly cognition) and their place in human evolution. Although Feldhofer 1 and La Chapelle-aux-Saintes exhibited

some instances of trauma that were recognized fairly quickly, it is the high degrees of preservation of both of the individuals and conceptions about their pathology which make them historically important specimens from which many ideas about Neandertals were conceived and continue to resonate.

B3. Individual Reports of Trauma: Krapina, La Quina, Tabūn, Šala, La Ferrassie

During most of the twentieth century, records of trauma in Neandertals were in the context of individual sites and there was little comparison with trauma observed in other Neandertals. Unlike the early discoveries of well-preserved individuals such as Feldhofer 1 and La Chapelle aux Saints 1 whose morphologies shaped much of the early understanding of Neandertals, some of the individuals that showed signs of trauma at these sites were fragmentary or were not as well disseminated at the time as the two early major skeletons. These individual sites that reported incidences of trauma include the Krapina remains, La Quina 5, the Tabūn I female, and, later, Vlček's (1969) report of a healed injury to the frontal of Šala 1. Also during this time there were, as previously noted, corrections of Boule's lack of recognition of pathologies in La Chapelle (Arambourg, 1955; Straus and Cave, 1957) and La Ferrassie 1 (Dastugue and Lumley, 1976).

B3a. Krapina

The Krapina rock shelter site is located 55 km north of Zagreb in Croatia. It was excavated between 1899 and 1905 and yielded a total of 874 human remains, the largest sample of Neandertals to be found at a single site (Gorjanović-Kramberger 1899 and 1906). The site has been dated by ESR and U-series to 130 kyr. Although there are multiple stratigraphic levels that yielded hominid remains at Krapina, these levels

represent a fairly rapid accumulation of sediment—probably spanning no more than 20 kyr (Rink *et al.* 1995). Because the remains from Krapina represent fragmentary disarticulated bones, there are many different estimates of Minimum Number of Individuals (MNI). The number of individuals represented at this site has been calculated at 75-83 people by the dental sample (Wolpoff 1976), however other methods have yielded MNI estimates between 12 (Smith 1976) and 38 (Ullrich 2006).

Pathology at Krapina was first reported by Gorjanović-Kramberger (1908). In his article "Anomalien und Pathologische Erscheinungen am Skelett des Urmenschen aus Krapina," Gorjanović-Kramberger identified pathologies in a frontal torus (Krapina 4), an ulna (Krapina 180), and a clavicle (Krapina 149).

Krapina 4

Krapina 4 is a combination of adult fragments that contains part of the right supraorbital, much of the frontal squama (formerly known as D_1 made up of frontal 4 and 37.13) and some of the left parietal (34.5). It has been tentatively identified by Berger and Trinkaus (1995:843) as male, with which this author (VHE) concurs after seriating the three partly complete skulls and some of the frontal/supraorbital tori.

There is some question as to the nature of the injury to this fragment, perhaps due to labeling issues (Krapina 4 was composed of the D_1 frontals and Krapina 5 was composed of the D_2 parietals). It is listed in Radovčić *et al.* (1988: 15) as having "a healed scalp wound" and is described by Gardner and Smith (2006:473) as a "healed depression fracture to frontal." However, both Berger and Trinkaus (1995:843) list this as an "exocranial injury to the parietal", and Kricun *et al.* (1999:17) as "a 1cm radiolucency with a sclerotic margin in the anterior aspect of the left parietal bone that represents a

healed depression fracture". I observed the injury to Krapina 4 to be located on the left side of the frontal squama near the coronal suture and did not observe any evidence of trauma to the parietal section of the fragment. This is likely the fracture described by Gorjanović-Kramberger (1908:110); however, it is not completely clear from either the illustration or the description that this is the fracture to which he is referring:

> Diesbezüglich kommt ein Stirnfragment mit dem rechten Überaugenwulst in Betracht. Ich würde dies Stück nicht erwähnen, wenn es nicht das einzige unter den relativ zahlreich vertretenen Überaugenwülsten wäre, an welchem nachfolgendes zu sehen ist. An der oberen Torusfläche, 14mm vom Rande und an der Temporallinie liegend, sehen wir eine ovale, etwa 7 mm lange, glatte Grube G und zwischen dieser und dem Torusrande an zehn eingetiefte Löcher P. Diese groben Poren sind nicht rund, sondern von mehr unregelmässiger Gestalt, weil sie in ziemlich tiefe Furchen auslaufen, welche zuweilen die Poren untereinander verbinden. Die Lage dieser Löchelchen bei jener Grube und der Umstand, dass ich diese Erscheinung bloss an diesem einen Torus fand, ist es, was mich auf den Gedanken führt, er läge hier ein Fall einer durch Slag oder Stoss verursachten Verletzung des Supraorbitalwulstes und ihrer Folgeerscheinungen vor.
>
> Regarding this [subject of traumatic pathology], it is worth considering a fragment of frontal with the right supraorbital torus. I would not mention this piece, if it was not the only among the relatively numerous supraorbital tori, on any other one there is to be seen. On the upper squama, lying 14 mm from the edge and on the temporal line, we see an oval about 7mm long, smooth pit "G" [in the illustration] and between this and the edge of the squama, ten deep holes "P" [in the illustration]. These rough pores are not round; however they are of a more irregular shape, because they extend into rather deep furrows, where sometimes the pores interconnect. The position of these little holes near that pit and its circumstance, the phenomenon of which I find only on one torus, is such that I am drawn to the idea that here lies a case of an injury, caused by a blow or a knock, to the supraorbital torus and consequent appearance." (Translated by VHE)

Krapina 180

For the ulna, a right adult ulna shaft, later catalogued as Krapina 180, Gorjanović-Kramberger (1908:110) describes the following:

> Ein Brucht der Elle (Ulna). Es liegt die obere Häfte einer rechten Elle vor, die am ihrem Bruchende eine leichte knotige Schwellung zeigt, welche durch eine flache, breite Rinne teilweise vom Körper der Ulna abgesondert erscheint. Herr Primarius Dr. v. Cacković in Agram fertigte das beistehende Röntgebild des Bruchendes an,

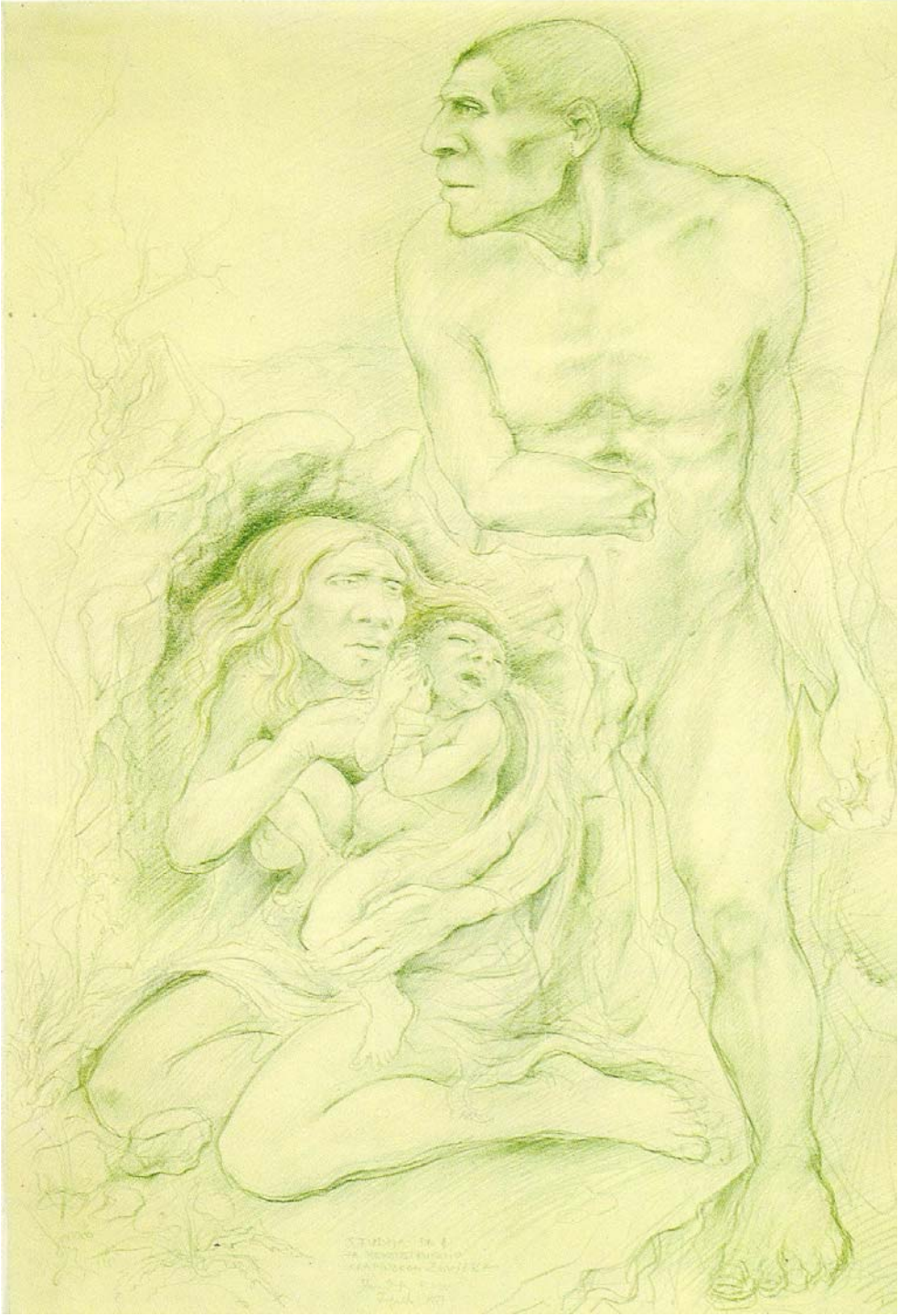
> und da sieht man eine scharfe Grenze zwischen dem Bruchrande, bis zu welchem deutlich die Trajectorien verlaufen, und der den Bruch überlagernden Neubildung.
>
> A break of the ulna: It lies on the upper half of the right ulna, where at its broken end a slightly lumpy swelling appears, which through a shallow, broad channel partly from the head of the ulna appeared isolated. Doctor Cacković made an X-ray of the broken end, and there one may see a sharp border between the broken edge, up to which clearly the trajectories go, and of that of the overlying new growth at the fracture. (Translated by VHE)

This ulna is described in Radovčić *et al.* (1988:90) as "right adult shaft from the coronoid process to the midshaft, with only the medial half of the coronoid process. Specimen is pathological; the distal end is the proximal half of the pseudoarthrosis." The fracture is described in Berger and Trinkaus (1995:843) as a "diaphyseal fracture and pseudoarthrosis." It is described in Gardner and Smith (2006: 481) as follows:

> The distal end of the shaft is a pseudo-arthrosis, which indicates a complete transverse fracture of the diaphysis that healed without attachment to the distal portion of the bone. It is also possible that the lower half of the arm was intentionally amputated. The pseudoarthrosis is well-healed and as with all the traumatic lesions in the sample, there is no sign of infection. The muscle marking on the bone, the well healed end and no radiographic evidence of disuse suggest that either: 1) the individual adapted his/her behavior and was able to continue using the disabled arm and to bear loads or 2) the individual lived long enough for the pseudoarthrosis to form but not long enough to experience atrophy and loss of bone density. Additionally, the well-healed state of a traumatic injury of this magnitude could also be interpreted as evidence of care-taking and knowledge of fracture management and possible amputation. Whichever the case, this bone clearly illustrates, along with the 34.7 cranial wound that Krapina Neandertals sustained and survived traumatic injuries during their lifetimes.

It is difficult to determine the sex of the individual from this shaft fragment. I seriated the Krapina ulna series and found that there were too few preserved proximal ends with shafts to be able to make good comparisons; however, this fragment was not the most robust present in the sample. In Popovića's depiction, Figure 2.1, of a pair of Neandertals at Krapina, the Krapina 180 individual is clearly shown as a male with an amputation (in Radovčić 1988:10).

Figure 3.1 Reconstruction of an imaginary Neandertal family by D. Popovića



Krapina 149

Gorjanović-Kramberger (1908:110-111) also described the healed clavicle fracture (later catalogued as Krapina 149) as follows:

> Ein Schlüsselbeinbruch. Ein rechtes Schlüsselbein ist vor seinem akromialseitigen Teile gebrochen. An der fraglichen Stelle ist nämlich der Knochen ziemlich verdickt. Das Röntgenbild desselben belehrt uns, dass die verdickte Partie des Schlüsselbeines aus einer lockeren Knochensubstanz besteht, welche sich auch demzufolge von dem intakt gebliebenen Teile des Knochens deutlich abgrenzt. Dass die starke Biegung der Clavicula eine Folge des Bruches ist, kann natürlich nicht behauptet werden, weil es auch normale derartig gebogene Schlüsselbeine gibt.
>
> A clavicle: a right clavicle is broken in front of the part on its acromial side. On the place in question, the bone is fairly thickened. The X-ray itself instructs us that the thickened part of the clavicle consists of a spongy bony material, which also divides itself off from the intact remaining portion of the bone. That the strong bend of the clavicle is a consequence of the break, naturally cannot be claimed, because there are also such clavicles that are normal [i.e. non-pathological].” (Translated by VHE)

This fracture is described in Gardner and Smith (2006:481) as follows:

> The more radical angle of the curvature of the distal portion of this element and the enthesopathies are better explained by trauma than by excessive repetitive strain by way of activity…Whether this individual experienced a severe muscle and/or ligament pull that fractured the bone or the bone was fractured and the enthesopathies are indicative of subsequent stress and compensation for the fracture is debatable but moot. The pathology of this bone is best represented by inclusion as a traumatic lesion.

I seriated the Krapina clavicle series and found that this fragment to be in the middle to slightly gracile range of the nine adult clavicles examined. It is listed as “F?”, a possible female, by Berger and Trinkaus (1995:843).

Other traumatic pathologies reported from Krapina were published after Gorjanović-Kramberger. These pathologies are listed in “The Krapina Hominids: An Illustrated Catalog of Skeletal Collection” (1988) and “The Krapina Hominids: A Radiographic Atlas of the Skeletal Collection.” They include another ulna (Krapina

188.8), and five cranial fragments (Krapina 5, 20, 31 and 34.7). Subsequent publications such as Berger and Trinkaus (1995), Gardner and Smith (2006), and Mann and Monge (2006) also describe some of the traumas at Krapina in greater detail.

Krapina 188.8

The ulna, Krapina 188.8, is part of an adult left proximal diaphysis. It extends from immediately distal of the coronoid process to approximately midshaft. I seriated the Krapina ulna series and found that there were too few preserved proximal ends with shafts to be able to make good comparisons, especially because of the healed fracture callous on Krapina 188.8. In Radovčić *et al.* (1988:91), its fracture is described as "The proximal end of the interosseous crest disappears into a distal healed fracture callous which continues to the midshaft break." It is described as a "proximal diaphyseal fracture" by Berger and Trinkaus (1995:843) and by Gardner and Smith (2006:481) as follows:

> Krapina 188.8, a left adult ulna, has a significant fracture callus at the proximal third of the diaphysis. Radiography showed cortical bone increase and central realignment of the trabeculae as part of healing process. In comparison to Krapina 179 significant remodeling occurred to this left ulna as a result of the fracture. This alteration due to injury would probably have affected the individual's ability to use the arm, especially in terms of bearing mechanical load.

Krapina 5

Krapina 5 is an adult partial cranium that includes portions of the left and right parietals, most of the right temporal and about half of the occipital. It has been identified as male by Radovčić *et al.* (1988) with which I concur. Its injury described as "At the end of the 46.4 mm of the left lambdoidal suture there is a healed scalp wound (ibid:16)." I observed that this area is marked by a slightly porotic crescent-shaped depression.

This injury is not referenced in Berger and Trinkaus (1995) or in Kricun *et al.* (1999). It is described in Gardner and Smith (2006:473) as "Possible small depression fracture on left parietal at the lateral end of the lambdoidal suture." This element was not included in previous analyses by Gardner (2004) or in her master's thesis (2001) "due to reservations in accepting these abnormalities as evidence of trauma" (2006:481).

Krapina 20

Krapina 20 is an adult left fronto-parietal fragment preserving the left side of a metopic suture. There is a small depression on the frontal squama about 15mm from the metopic suture, as indentified in Radovčić *et al.* (1988:22). This is also part of another small depression that is mostly obscured by the metopic suture that has been identified by the author and confirmed by Radovčić (personal communication, 7/2002) after a close examination of the area on the digital version of the Kricun *et al.* (1999) radiographs. After seriating the adult frontals, I put in into the putative female range of the spectrum. Only the original noted depression is mentioned in Gardner and Smith (2006). Neither of these depressions was included in Berger and Trinkaus (1995).

Krapina 31

Krapina 31 is a central fragment of an adult frontal squama. I seriated the frontal adult fragments and put Krapina 31 into the smaller, possibly female range of the sample. There is a small healed fracture 7mm medial to the temporal line on the left side (Radovčić *et al.* 1988: 31) which is slightly pitted in appearance. It is mentioned in Gardner and Smith as a "possible" healed fracture (2006:473) but it is not included in Gardner's 2001 and 2004 analyses of trauma from Krapina, Kricun *et al.* (1999), nor is it mentioned in Berger and Trinkaus (1995).

Krapina 34.7

Krapina 34.7 is a fragment of the asterionic region of a right parietal showing a "significant healed injury" (Radovčić *et al.* 1988). It is mentioned in Berger and Trinkaus (1995:843) as a "severe fracture," in Kricun *et al.* (1999) as perhaps "the residua of the body's attempt to heal a depressed fracture by the formation of periosteal bone" or "the residua of a leptomeningeal cyst," and in Gardner and Smith (2006:473) as a "significant healed head trauma along superior edge of specimen." However, it is also the subject of Mann and Monge's (2006:496) "A Neandertal Parietal Fragment from Krapina (Croatia) with a Serious Cranial Trauma" where they describe the lesion and address "To what pattern or patterns of trauma is this consistent?" They describe the lesion as follows (Mann and Monge 2006:497-498):

> On the superior and posterior part of the fragment, externally and internally, there is a clearly defined circular depression, the remains of a depressed cranial fracture beginning on the edge of the fragment, describing a quarter to half circle of open area that is directly upwards. How large the fracture was on the complete skull is unknown, but it certainly may have encompassed an additional part of the parietal and may also have continued onto the occipital bone. A rough measure of the area of traumatized bone, not including the thinned edges representing healing, is approximately 50mm in maximum extent, making it the largest cranial injury known for any Neandertal. The injury was sustained antemortem, as documented by the extent of healing at the edges of the depressed fracture site. Externally, the trauma can be seen as a circular depression beginning at the edge of the fragment. The depression and the pitted surface of secondary bone within the depressed area are clearly demarcated. Within the depression, the skull bone is considerably thinner, with a progressive thinning leading to the margin of the fragment, where there is an irregular, wavy edge of bone. At low magnification (4.2X), the edge of the bone appears smooth and even.
>
> Internally, this part of the bone corresponds to a depressed area of roughened bone. The margin of this internal area matches the area of thinning on the outer surface, but is somewhat larger, continuing posteriorly all the way to the lambdoid suture. Within the depressed area, secondary woven bone produced after the injury is present throughout this zone. A view along the edge if the depressed area shows a wavy, irregular line, but whether this is was the total extent of the secondary bone, or whether there was a thin layer of bone beyond this cannot be ascertained….The micrograph shows the external surface with the

> edge of the depression in the lower right hand corner. The woven bone can be clearly viewed covering much of the surface of the depressed area; in this image the edge possesses a clearly broken margin, which would appear to signify that prior to death, the bone had continued as a very thin layer, presumably covering over much if not all of the open area of fractured bone.
>
> The nature of the injury indicates that this individual was struck on the right back side of the skull, and that the resulting fracture created a depression on the external surface, and a wider injury on the internal surface, with the internal bony table shattering over a larger area, as is typical for cranial injuries of this sort. The illustrations document the process of bone healing, especially notable in the micrograph, which shows the pattern of woven bone deposition and the broken margin of the healing surface at the edge of the preserved fragment. The indications from the available evidence are of a considerable amount of healing.

Mann and Monge (2006: 498-499) also review possible proximate causes of the trauma to 34.7, including a leptomeningeal cyst ("unlikely"), trepanation ("cannot be completely ruled out"), a fall ("unlikely") and "an object at relatively high speed, making contact with the cranial bone with sufficient force to mimic the perforating effect on bone of a sharp force trauma without the secondary effect of a blunt force blow" (a "reasonable scenario"). Mann and Monge (2006:499) further examine whether this injury represents an accident or violence, however "given the relative rarity of signs of violence in the archeological record, the trauma displayed in Krapina 34.7 may be most appropriately interpreted as the result of accidental injury deriving from a life style inhabiting caves where cave roof falls are not uncommon." Mann and Monge (2006:501) conclude that "Lacking any definite evidence to account for this wound, the most parsimonious explanation of the cause of the trauma appears to [be] one of an accident associated with the lifestyle of living and sleeping in caves" and "Rather than saying life was hard and brutal among Neandertals as Pettitt (2000) argued by looking at older Neandertal skeletons, like La Ferrassie I and Shanidar I, it may be more appropriate to observe that

because of the complexity and adequacy of cultural mechanisms, life was sustainable even in the face of multiple insults."

Other trauma at Krapina?

Kricun *et al*. (1999: 15-16) list two other possible traumas that they identified through radiographic analysis of the Krapina collection:

Krapina 147: a clavicle with a "focal periosteal reaction on the anterior and posterior aspects." This is a similar description to the one that they made for the more universally recognized trauma to the Krapina 149 clavicle.

Krapina 117.3: a rib with a "possible traumatic reaction." This reaction is described as follows:

> There is focal endosteal sclerosis of both the anterior and posterior margins of the rib, associated with a faint partial radiolucent line in the anterior and posterior cortex. The focal anterior indentation of the cortex shows a sclerotic margin. These findings are most likely a healing response to a prior traumatic event.

Ullrich (2006:513) also remarks that some parietals (3, 33.3, 34.3. and 34.8) show "cranial traumas of similar shape and size as can be recognized on both above mentioned parietal bones (Krapina 5 and 34.7), but without any signs of healing, suggesting that these individuals died immediately after the injuries and had obviously been killed intentionally." However, no other source recognizes these fragments as showing any trauma.

Summary of trauma at Krapina

Because the sample of Neandertal remains from Krapina is so fragmentary, it is difficult to distinguish incidences of trauma from other perimortem damage. The following table is a summary of each of the putative traumas at Krapina with a list of sources that support this instance as traumatic in origin.

Table 3.2. Summary of trauma at Krapina (injuries used in later analyses in bold)

Specimen ID	Bone	Trauma Description	Source
Krapina 3	Cranium and partial face Adult Female	Unhealed depression to right parietal	Ullrich 2006
Krapina 4	**Right supraorbital, frontal squama and left parietal** **Adult** **Male**	**Healed depression to left frontal squama near coronal**	**Gorjanovic-Kramberger 1908** **Radovčić *et al.* 1988** **Gardner and Smith 2006** Berger and Trinkaus 1995 Kricun et al. 1999 List as trauma to left parietal
Krapina 5	**Left and right parietals, right temporal and occipital** **Adult** **Male**	**Part of a small depression to the posterior left parietal at the lambdoidal suture**	**Radovčić *et al.* 1988** **Gardner and Smith 2006**
Krapina 20	**Fronto-parietal fragment from left side of metopic suture** **Adult** **Female***	**1. Small depression at left of metopic suture on frontal** **2. Small depression at metopic suture on frontal***	**1. Radovčić *et al.* 1988** **1. Gardner and Smith 2006** **2. VHE***
Krapina 31	**Frontal squama** **Adult** **Female***	**Small healed fracture near left temporal line slightly pitted in appearance**	**Radovčić *et al.* 1988** **? Gardner and Smith 2006**
Krapina 33.3	Right parietal and temporal fragment Adult	Unhealed depression on right parietal	Ullrich 2006

Krapina 34.3	Left parietal fragment Adult	Unhealed depression on left parietal	Ullrich 2006
Krapina 34.7	**Right parietal fragment** **Adult**	**Severe healed depressed fracture to middle of right parietal**	**Radovčić *et al.* 1988** **Berger and Trinkaus 1995** **Kricun *et al.* 1999** **Gardner and Smith 2006** **Mann and Monge 2006**
Krapina 34.8	Left parietal fragment with small fragment of occipital Adult	Unhealed depression on left parietal	Ullrich 2006
Krapina 117.3	Right rib proximal fragment Adult	Focal endosteal sclerosis on anterior and posterior margins; healing response to trauma	Kricun *et al.* 1999
Krapina 147	Right clavicle: diaphysis and sternal end Immature	Focal periosteal reaction to anterior and posterior aspects	Kricun *et al.* 1999
Krapina 149	**Right clavicle** **Adult** **Female?**	**Healed fracture to distal portion**	**Gorjanovic-Kramberger 1908** **Radovčić *et al.* 1988** **Berger and Trinkaus 1995** **Kricun *et al.* 1999** **Gardner and Smith 2006**
Krapina 180	**Right ulna diaphysis** **Adult**	**Distal diaphyseal fracture and possible pseudoarthrosis or amputation**	**Gorjanovic-Kramberger 1908** **Radovčić *et al.* 1988** **Berger and Trinkaus 1995** **Kricun *et al.* 1999** **Gardner and Smith 2006**
Krapina 188.8	**Left ulna diaphysis** **Adult**	**Proximal diaphyseal fracture**	**Radovčić *et al.* 1988** **Berger and Trinkaus 1995** **Kricun *et al.* 1999** **Gardner and Smith 2006**

The presence of injury to Krapina specimens 4, 34.7, 149, 180 and 188.8 seem to be supported by most or all of the publications of trauma at Krapina. Other specimens with injuries noted by at least 2 different publications include Krapina 5, 20 and 31. Injuries to Krapina 3, 33.3, 34.3, 34.8 were only noted by one publication, Ullrich (2006), and not by me in my own observations of the Krapina specimens and will not be used in any subsequent analysis of trauma at Krapina. Injuries observed only by Kricun *et al.* (1999) to Krapina specimens 117.3 and 147 were seen by radiographic analysis and are not visible to "naked eye" analysis. Because the level of Kricun *et al.*'s (1999) radiographic analysis surpasses the level of analysis possible at the macroscopic level, I do not include their independent findings in subsequent analysis of Krapina trauma in Chapter VI.

B3b. La Quina

La Quina is a rock shelter site located in the Charente region of south-west France. It was originally excavated between 1908 and 1920 by H. Martin, then by his daughter G. Henri-Martin in 1965, and finally in a more recent series of excavations starting in 1986 by Debénath and Jelinek (Hardy *et al.* 1997). The original excavations yielded very fragmentary remains from over 25 individuals (ibid) that span from 65,000-35,000 years B.P. The most complete specimen in the collection, designated Quina H5, are the remains of an adult female that include fragments of a cranium, mandible, cervical vertebrae, scapulae, clavicles, humeri, an ulna, and both femora. Martin (1923) records one possible pathology which occurs on this most complete skeleton in the collection. The diameter of the humeral shaft from the left side of La Quina H5 is significantly

smaller than that of the right side. Martin (1923:220) identifies this difference as due to atrophy following a diaphyseal fracture as follows:

> En examinant comparativement les deux diaphyses, seulment sur la region moyenne à cause des fractures, à droite la circonférence donne 73 millimètres, et à gauche seulement 62 millimètres. L'écart est énorme.
>
> La diaphyse droite est fracture au point où finit la goutière bicipitale, la region qui s'étend au-dessous justqu'au tiers inférieur est aplatie, le diamètre transversal mesure 26 millimètres tandis que le diamètre antéro-postérier n'atteint que 19mm, 3.
>
> When the two diaphyses were compared, only measuring the middle region because of fragmentation, the circumference of the right side is 73 mm and the left is only 63mm. The difference is enormous.
>
> The right diaphysis is fractured at the place where distal attachment of the bicep ends, the area which extends underneath until the lower third is flat, the transverse diameter measures 26 mm while the anterior-posterior diameter only reaches 19.3mm." (Translated by VHE)

The other remains from La Quina are much more incomplete and often more fragmentary than H5. The site seems to contain a mix of the remains of children such as the H 18 skull and other fragments from adults, most of which are also cranial.

B3c. Mount Carmel Remains: Tabūn

The Mount Carmel remains come from caves in the Wadi el-Mughara region of what was then Palestine and now Israel. The entire Mount Carmel assemblage consists of seven fairly complete adults and three fairly complete juveniles from Skhul and one fairly complete adult female and some fragments from Mugharet al-Tabūn Cave. McCown and Keith (1939) note several possible traumatic injuries that they observed in the Mt. Carmel remains. These include a penetrating injury to the left innominate and a possible perimortem perforation to the left parieto-occipital region of Skhul IX, a healed fracture to the distal halves of the second and third metatarsals in the left foot of Skhul IV, and three perimortem injuries to the frontal, right temporo-mandibular region and lumbar

region of Skhul I. However, though these remains from Skhul are contemporary to Neandertals living in the region, they are traditionally identified as being "anatomically modern" rather than Neandertal and therefore are not counted in the sample of Neandertal specimens exhibiting trauma.

Only the Tabūn remains are considered to be Neandertal. The Tabūn Cave was excavated in the nineteen thirties by Garrod and her team (Garrod 1934, 1935, 1936 and Garrod and Bates 1937). The most complete of these remains is Tabūn C1, an adult female who died at about 30 years of age (McCown and Keith 1939). The specimen consists of a skull, mandible, most vertebrae and ribs, a fragmentary left scapula, fragmentary clavicles, fragmentary sternum, a complete left humerus and a partial right humerus, a complete left radius, a complete left ulna and pieces of the right, a fairly complete left hand, some parts of the left and right innominates, an almost complete right femur and fragmentary pieces from the left side, mostly complete right and left tibiae except for crushed left and right proximal ends, a mostly complete right fibula except for the proximal end and the left side is represented only by fragments from the middle third of the shaft, a proximal end bearing the crushed head and the distal extremity, and a complete left talus but mostly incomplete or fragmentary other bones of the feet (McCown and Keith 1939:9). She was recovered with the remains of a neonate who was not preserved (Shea 2003). The Tabūn site also contains the mandibular remains of a male in his thirties as well as other postcranial remains and some teeth from other individuals. The layer where these remains were discovered is currently dated to about 122,000 years B.P. (Grün and Stringer 2000).

McCown and Keith (1939) do not record any observed trauma or pathology for the Tabūn C1 female. The only reference for trauma to her skeleton is in Berger and Trinkaus' (1995:843) article on Neandertal trauma where she is listed as having a "distal diaphyseal lesion" on her fibula, although the side is not specified. Her right fibula is listed as "almost complete" except for the head which is missing, and the left fibula is listed as being composed of four fragments consisting of the middle third of the shaft, the proximal end of the shaft with crushed head, and the distal extremity (McCown and Keith 1939:51). Since both sides seem to have some portion of distal end present, it is not possible to determine which side has this lesion or why this lesion escaped notice during earlier analyses of the remains from Tabūn.

B3d. Šala

In 1961, a frontal was discovered in a sandbank in the river Waag near a sandpit, 300 m downstream from a road-bridge near Bratislava in Slovakia (Vlček 1964). The frontal was the only hominid specimen discovered at the site and was not associated with any cultural material, however it was associated with remains from other Upper Pleistocene fauna (Smith 1982). Its morphology places it probably in the middle of the Last Glaciation (50,000-30,000 years B.P.) (Klein 1999: 482). In his monograph on the Czechoslovakian Neandertals, Vlček (1969:155) reports a healed fracture on the Šala 1 frontal as follows:

> In der Gegend des Planum supraorbitale befindet sich rechts eine ovale ausgeheilte Schramme in der Grösse 10 x 7 mm, welche die ganze Dicke der Lamina externa durchzieht und in der Knochendiplöe noch einen leichten Defekt bildet. Die Wände dieses Defektes sind durch einen neugebildeten Knochen ausgeheilt. Die Umgebung der Schramme ist stark atrophisch, so dass der Torus supraorbitalis hier verdünnt ist. Dieser Befund bietet einen Beweis für eine ausgeheilte Verwundung warscheinlich durch einen Schlag mit einem scharfen Gegenstand, mit einem Stein oder Zahn."

> In the region of the supraorbital plane on the right side, there is an oval healed scar 10 by 7 mm in size, which passes through the entire thickness of the external lamina and even in the bony diplöe a slight defect is found. The walls of these defects are healed across newly created bone. The area of scarring is strongly atrophied, so much that the supraorbital torus is thinner here. This state presents evidence of a healed wound likely through a blow with a sharp object, with a stone or a tooth. (Translated by VHE)

Because this specimen is only represented by a frontal, determining age range and sex is difficult. However, given the complete preservation and complete lack of closure of the coronal suture it is probable that the frontal comes from a younger adult and the relative gracility of the supraorbital torus and size of frontal sinus compared to other Neandertals put it onto the female side of the range (Vlček 1969: 155-182).

B3e. La Ferrassie

Although the remains from La Ferrassie were discovered in 1909-1921, they were not published as a monograph until 1982 (Heim 1982). The remains of two adults, two children and three neonates or fetuses were found in a rock-shelter near the village of Les Eyzies in the Dordogne Valley of south-west France (Peyrony 1934). Dating of the rock shelter indicates that the remains date from the cold phase of the early last glacial, as far back as 70,000 years B.P. (Fennell and Trinkaus 1997). The two adults consist of a male, Ferrassie 1 and a female, Ferrassie 2. The remains of the Ferrassie 1 male, who died at about 40-55 years old, include cranium, mandible, 23 vertebras, a fragmentary sacrum, 20 ribs, both clavicles, scapulas, humeri, radiuses, ulnas, femurs, tibias, and fibulas, fragments of the pelvis and a few bones of the hands and feet (Fennell and Trinkaus 1997). The remains of the Ferrassie 2 female have been aged at between 20 and 40 years old at death (Trinkaus 1995). Her remains include a more incomplete and fragmentary

skull than her male counterpart, 11 vertebrae, 19 ribs, both scapulae, humeri, femora, patellae, tibiae, fibulae, a right radius and ulna, some pelvic fragments and a few hand and foot bones (Capitan and Peyrony 1910). Of the five subadults found with them, the eldest, Ferrassie 3, is a child about 10 years old at death who is represented by skull fragments, both radii and ulnae and a few hand and foot bones (Capitan and Peyrony 1912). The next eldest, Ferrassie 6, is a child about 3 years old at death who is represented by vertebrae, ribs, both humeri, radii, ulnae, femora, and tibiae as well as the right fibula, pelvic fragments and a couple of hand and foot bones (Capitan and Peyrony 1921). The other subadults, Ferrassie 4a, 4b and 5, are all either the remains of fetuses or neonates and are represented mostly by long bones and some cranial fragments (Capitan and Peyrony 1912 and 1921).

In his work on the La Chapelle-aux-Saints skeleton, Boule used the La Ferrassie remains to supplement missing or incomplete areas. Heim (1982: 137) describes a periosteal infection to the tibias, possibly traumatic in origin, of La Ferrassie 1 as follows:

> Au niveau du quart inférieur et de l'extrémité distal des faces interne et postérieure des tibias de La Ferrassie 1, on remarque un surface irrégulière de nature certainement inflammatoire que nous pouvons interpreter comme une *périostite.* Cette partie de la jambe est en effet particulièrement vulnerable aux chocs et aux traumatismes d'autant plus qu'elle est en contact direct avec la peau. Sur l'os doit, où la processus inflammatoire est la plus pronounce, un dépression ovale siégeant au milieu de la zone infectée évoque un abcès ou un début d'ostéolyse. La lesion se retrouve également sur les péronés ainsi que nous verrons par la suite.
>
> At the level of the lower quarter and of the distal extremity of the internal surface and at the posterior of the tibias of La Ferrassie 1, one notices an irregular surface of a certain inflammation that we may interpret as periosteal. This part of the leg is, in effect, particularly vulnerable to shocks and traumas even more because it has direct contact with the skin. On the right bone, where the inflammation process is the most pronounced, an oval depression besieging in the middle of the infected zone evocative of an abscess or the beginning of osteolysis. The lesion is

found equally on the tibias as well as we could see afterwards." (Translated by VHE)

Heim (1982:153) also describes a proximal diaphyseal fracture to the left fibula of La Ferrassie 2 as follows:

> Ainsi que nous l'avons signalé sur les tibias, la face externe de la malléole du péroné de *La Ferrassie 1* est hérissée d'ostéophytes en rapport avec la périostite affectant la portion distal des deux jambes.
>
> L'extrémité supérieure de la diaphyse droite de *La Ferrassie 2* porte un renflement fusiforme d'origine pathologique. Cet épaissement intérsesse surtout le bord et la face postérieure de l'os. Les diamètres de la diaphyse relevés à son niveau indiquent une augmentation notable du caliber de l'os en comparaison des mêmes diamètres measures à gauche:

Diamètres	Fibula droite (au niveau de l'aplatissment)	Fibula gauche (au meme niveau)
Antéro-postérieur	18.5mm	12 mm
Transverse	14mm	7.5mm

> Sur la face externe, un orifice allongé plus gros que le trou nourricier représente sout un trou vasculaire, soit plutôt un début de fisulation de la région atteinte. En effet, le renflement présente une surface chagrinée faisant penser à un début d'ostéomyelite rapidement, enrayée et ayant fait son apparition à une âge précoce, voire même, selon J. Dastugue (1960), durant l'enfance.
>
> As well as we had reported it on the tibias, the external surface of the malleolus of the tibia of La Ferrassie 1 is bristled with osteophytes in keeping with the periosteal infection affecting the distal part of the two legs.
>
> The upper extremity of the right diaphysis of La Ferrassie 2 carries a fusiform bulging of a pathological origin. This thickening interests above all the edge and the posterior surface of the bone. The diameters of the diaphyses noted down at this level indicate a notable augmentation in of the bone in comparison to the same diameters measured on the right side:
>
> On the external surface, an elongated opening bigger than a nutrient foramen represents a vascular foramen, it is rather the beginning of fisulation of the attacked area. In effect, the bulge presents an upsetting surface putting into mind the beginnings of a rapid osteomyletis, checked and having its appearance at a precocious age during childhood as also observed by Dastugue (1960). (Translated by VHE)

Both the adult male and female at La Ferrassie show evidence of healed fractures to their lower limbs. Although Heim (1982) reported some signs of perostitis in the distal

part of both tibiae, he did not recognize an anomaly in the greater trochanter of the right femur of Ferrassie 1. Trikaus (1985:34) describes this sign of healed trauma as "abnormally enlarged" and goes on to describe the injury:

> The abnormality was the product of either an injury to the region affecting the M. gluteus medius and/or M. obturator externus or a fracture of the greater trochanter in which the detached portion was displaced proximomedially prior to healing (it should be noted that the recent description of this specimen [Heim 1982:121-123] also did not recognize its pathological condition, even though information on complete and normal Neandertal greater trochanters was available…"

Trinkaus, however, does not recognize the perostitis as a sign of previous trauma.

B3. Summary: early and mid-twentieth century discoveries of Neandertal trauma

Many Neandertal sites were discovered during the early and mid twentieth century. Some of these sites, including Krapina, La Quina, Mount Carmel, Šala, and La Ferrassie, contain Neandertal remains that show signs of healed trauma. These indications of healed trauma are distributed in the remains identified as adult females to the front of the cranium (Šala), the humerus (La Quina H5), and the fibula (Tabūn C1 and Ferrassie 2). Indications of healed trauma were observed in the upper thigh for the only adult male in this group (Ferrassie 1). Because injuries observed at Krapina occur on fragmentary remains, it is difficult to identify the individuals beyond adult versus juvenile. There were eight antemortem traumas observed at Krapina, all of them on adults. Five were on the cranium, two were ulnar, and one was on the clavicle.

B4. Paleopathology meets Paleoanthropology in west Asia

During the mid-twentieth century, while the field of paleoanthropology became primarily focused on ancestral relationships in human evolution, the field of paleopathology was beginning to develop from "a focus on the identification and

description of the earliest and most unusual pathological specimens to the interpretation of the social, cultural, or environmental causes of traumatic injury; their relation to biological variables, such as sex and age, that may have social or cultural relevance; and their temporal and spatial variation" (Lovell 1997: 139). There was some cross-pollination between paleoanthropology and paleopathology. One such pollinator was T. Dale Stewart, who not only published extensively on topics such as cranial deformation (1941), osteoarthritis (1935, 1947 and 1958), skeletal aging using the pubic symphyseal surface (1957) and wrote one of the first forensic anthropology textbooks (1979), but also excavated and published the Shanidar remains (1958, 1963 and 1977). Although it is impossible to know whether the detailed observation of trauma in the Shanidar remains would have been produced by a different researcher, it is important to understand that one of the predominant figures in the study of Neandertal trauma, Trinkaus' early major exposure to the subject came from his collaboration with Stewart that produced the Shanidar monograph in 1983 (according to Trinkaus and Shipman 1993). In this section, the trauma observed in remains from Shanidar, Kebara and Kiik-Koba will be summarized.

B4a. Shanidar

Shanidar Cave is located in the Zagros Mountains of northeastern Iraq and was excavated in the 1950s and 1960s by Solecki (1963 and 1971) and Stewart (1958). The site is dated to at least 45,000 years B.P. (Trinkaus and Zimmermann 1982). There were originally nine individuals identified from the remains, seven adults and two infants; however a tenth individual, a child who died at about 2 years of age, has recently been discovered amongst the faunal remains (Cowgill *et al.* 2007).

Although each of the original nine individuals excavated at Shanidar was incomplete compared to La Chapelle aux Saints, to date, they represent the largest collection of relatively complete Neandertals found at one site. Four out of the six well preserved adults show some form of trauma and of those, two "appear to have been severely incapacitated by their injuries" (Trinkaus and Zimmerman 1982: 61) which makes them the largest collection of identifiable individuals showing trauma that has been discovered.

B4ai. Shanidar 1

Shanidar 1 was a male who died between the ages of 35 and 50 years of age whose skeleton, though fragmentary, included portions of all anatomical regions. Shanidar 1 was one of the two "highly incapacitated" specimens recovered from the site: "Shandiar 1 was one of the most severely traumatized Pleistocene hominids for whom we have evidence. He suffered multiple fractures, involving the cranium, right humerus, and right fifth metatarsal, and the right knee, ankle and fifth tarsometatarsal joint show degenerative joint disease (DJD) which was probably trauma related." (Trinkaus and Zimmerman 1982: 62) His right clavicle, scapula and humerus all show signs of atrophy, especially in the humerus (Trinkaus 1983: 404-405). This right humerus also has two healed fractures: One on the diaphysis two-thirds of the way distally down the shaft which produced an angular deformity turning the diaphysis approximately twenty degrees medially (Trinkaus 1983: 404). The other fracture on the right humerus was at its distal end across the olecranon fossa and shows extensive exposure of trabecular bone which is either the proximal end of a fracture that did not reunite or formed a pseudoarthrosis or it may be the end of an amputation to the arm just above the elbow (Trinkaus 1983: 404-

405). There was also an osteomyletic lesion on the superior diaphyseal surface of the clavicle (Trinkaus 1983: 404). The right fifth metatarsal shows a healed fracture near the middle of the diaphysis that does not appear to have produced a loss of function to the foot (Trinkaus 1983: 405). On the cranium, there are healed scalp wounds to the right frontal and a healed crushing fracture to the frontal and zygomatic bones of lateral side of the left orbit leaving permanent deformation to the left side of the upper face and probably blindness in the left eye (Trinkaus 1983: 409). Trinkaus posed three different interpretations of Shanidar 1's injury pattern:

Scenario 1 is that "Shanidar 1 sustained a massive crushing injury to the right side of his body primarily in the region of the arm and shoulder…such as a rock fall…the fracture of the right fifth metatarsal probably occurred at the same time…the cranial injuries would be seen as secondary…they may have occurred at the same time from the individual falling away from the blow to the right side and striking a hard object, or they might have happened later as a result of the individual's ability to get around easily (Trinkaus 1983: 409-410).

Scenario 2 is that "the cranial trauma…caused blindness in that eye, it may also have damaged the left cerebral motor cortex…which could have caused hemiplegia to the right side of the body…a hypoplasia/atrophy of the upper limb would develop directly from this type of nerve injury…the right frontal scalp wound, the osteomyelitis of the right clavicle, the fractures and pseudoarthrosis/amputation of the right humerus, and the fracture of the right fifth metatarsal would have been seen as secondary to the cranial injury…one weakened by partial paralysis, would have been more susceptible to injury and infection." (Trinkaus 1983: 410)

Scenario 3 is that: a major injury to the brachial plexus that resulted in paralysis of the right arm and subsequent hypoplasia/atrophy of the various bones…(either) a traction injury to the brachial plexus (or) a penetrating wound to the shoulder or axilla …the humerus fractured at the same time…injuries to the cranium and right foot…having developed independently." (Trinkaus 1983: 410-411)

B4aii. Shanidar 3

The second "highly incapacitated" individual found in the Shanidar sample is Shanidar 3. The skeleton of Shanidar 3 is that of an adult male who died between the ages of 35 and 50 and displays evidence of antemortem trauma on the left ninth rib (Trinkaus 1983: 414). On the superior margin of the left ninth rib there is a partially healed injury in the form of a parallel sided groove about 1.5 mm wide showing exostoses along the edges of the groove (Trinkaus 1983: 414). It may have been caused by "a penetrating wound between the eighth and ninth left ribs" as "…the instrument responsible cut across the top of the ninth rib, forming the groove, and probably remained in the cut until the individual died" which would have been "at least several weeks after the wound was inflicted." (Trinkaus 1983: 414) Because the remains of Shanidar 3 were found displaced by a rockfall, it is possible that his "injury may of incapacitated him so that he was unable to avoid a later rockfall while in Shanidar Cave." (Trinkaus 1983: 414) Trinkaus (1983:414-415) asserts that this also may be the earliest known case of homicide since "the angle and precision of the wound make it unlikely that the injury was self-inflicted…close to what one would expect of a right-handed individual were to have stabbed Shanidar 3 while they were standing face to face."

B4aiii. Shanidar 4

Shanidar 4, an adult male who died between the ages of 35 and 50, exhibits a partially healed fracture of the right seventh or eighth rib near the angle evidenced by a moderately large callus (Trinkaus 1983:418). This injury was probably caused shortly before death but was not debilitating.

B4aiv. Shanidar 5

The remains of Shanidar 5 are those of an adult male, between the ages of 35 and 50 years old. There is a surface scar on the left frontal squama which appears to have been caused by a scalp wound that disturbed the periosteum but appears to have healed thoroughly (Trinkaus 1983: 419-421).

B4a. Summary: trauma at Shanidar

Evidence of healed trauma was observed on four out of the six well preserved adults from the Shanidar sample. Each of the individuals who show evidence of antemortem trauma is male and died between the ages of 35 and 50 years old. The other individuals represented in the sample who do not show signs of trauma are Shanidar 2, an adult male who died between the ages of 20 and 35 years, and Shanidar 6, an adult female who died between the ages of 20 and 35 years. Signs of trauma in Shanidar 1 appear on the right frontal and left frontal and zygomatic bones, the right humerus, the right clavicle and the right fifth metatarsal. Signs of trauma on Shanidar 3 appear as a penetrating wound to the left ninth rib. Signs of trauma on Shanidar 4 and 5 appear as a fracture to the right seventh or eighth rib and a surface scar to the left frontal squama, respectively.

B4b. Kebara

Mugharet el-Kebara is located in Israel on the western escarpment of Mt. Carmel about 13km south of Wadi el-Mughara where the Skhul and Tabūn remains were discovered (Bar-Yosef *et al.* 1992). The very complete post-cranial remains of the mandible, hyoid, upper limbs, trunk and pelvis of an adult male who died between the ages of 25-35 years were discovered here along with the fragmentary remains, mostly dental, of at least 28 other sub-adult and adult individuals (Bar-Yosef *et al.* 1992). The remains of this adult male, known as KMH 2, were dated by electron spin resonance to 64,000-60,000 B.P. (Schwarcz *et al.* 1989).

There is some question as to whether KMH 2 shows evidence of trauma. Bar-Yosef *et al.* (1992:530) state: "There is no evidence of trauma. Pathological changes are marked by ossification of the vertebrae ribs and sternum and dental pathology is limited to traces of enamel hypoplasia and hypercementosis." However, in their report on the pathology of KMH 2, Duday and Arensburg (1991:192-193) conclude the following:

> Au titre de la pathologie traumatique, nous rentiendrons la fracture de la base de deuxième métacarpien gauche et les lésions qui lui sont associées sur le trapézoïde et le troisième métacarpien, ainsi que la fracture très probable du processus épineux de la cinquième vertèbre thoracique. Il s'agit de lésions anciennes, bien consolidées, qui semblent n'avoir pas eu de consequences fonctionnelles notables. Sans doute faut-il également classer ici le pont de synostose entre les faces postérieurs du manubrium sternal et de la deuxième sternébre, s'il est bien la séquelle d'un hématome périosté, et même peut-être l'ossification endocostale droite dont nous avons montré qu'elle suit le trajet d'un muscle subcostale. On retrouve chez le sujet la fréquence des traumatismes qu'a soulignée E. Trinkaus (1983: 401-423) pour l'ensemble des néandertaliens. Mais contrairement aux lésions que cet auteur a mises en evidence à Shanidar, il ne s'agit ici que de traumatismes mineurs.
>
> Under the heading of pathological trauma, we accept the fracture of the base of the second left metacarpal and the lesions which are associated with it on the trapezoid and the third metacarpal, as well as the very probable fracture of the spinous process of the fifth thoracic vertebra. As far as these lesions are

> concerned, they are well healed and do not seem to have had any discernable functional consequences. Unequivocally, the synostosis between the posterior face of the manubrium and the gladiolus equally needs to be classified as traumatic if it really is the consequence of a periosteal hematoma; also perhaps the endocostal ossification on the right which we have shown that accompanies the path of a sub-costal muscle. One is reminded of that which is underlined by E. Trinkaus (1983:401-423) for the entire assembly of Neandertals on this subject of frequency of traumatic lesions. However, contrary to the kinds of lesion which that author observed as evident at Shanidar, we are only concerned here with minor traumas. (Translated by VHE)

Duday and Arensburg (1991:182-183) describe the pathology they observed to the thoracic vertebrae as follows:

> Les processus épineux préservés présentent une légère déviation vers la droite sur toutes les vertèbres thoraciques, à exception de T5: l'arête dorsale de celle-ci est strictment sagittale dans sa partie antérieure sur une longuer de 17mm, puis elle s'infléchit assez brusquement vers la gauche; l'angulation est marquee sur l'arête dorsale par un petit renflement, au voisinage duquel les faces laterals et inférieure de l'épine sont bosselées d'appositions osseuses anarchiques et hypervascularisées.
>
> La radiographie montre une condensation de la corticale dans la partie moyenne du processus épineux, et il est très vraisemblable qu'il s'agit là des séquelles d'une fracture incomplete, relativement ancienne et bien consolidée. La lesion touche également, mais à bien moindre degree, le processus épineux de T6 qui est strictement saggital et sur la face latérale droite duquel on retrouve à mi-longueur une petite plage hyper-vascularisée.
>
> The preserved spinous processes show a mild deviation towards the right side on all the thoracic vertebrae, with the exception of T5: the dorsal ridge of T5 is strictly aligned within the saggital plane for the anterior portion along a length of 17mm, then it bends quite abruptly to the left; the angulation is marked on the dorsal ridge by a small bulge, near which the lateral and inferior surfaces of the spine are bumpy with anarchic bony appositions and hypervascularities.
>
> The radiograph shows a thickening of the cortical bone in the middle of spinous process, and it is very probable that it is there as the result of an incomplete fracture, relatively old and well consolidated. The lesion approaches equally, but to a lesser degree, the spinous process of T6 which is strictly saggital and on the right lateral surface of which one finds again at the mid-length a small hypervascular surface. (Translated by VHE)

The trauma to the second left metacarpal is described as follows (Duday and Arensburg1991: 189-190):

L'extrémité proximale du deuxième métacarpien gauche a subi des remaniements considérables, qui se réduissent en fait à deux processus complémentaires: des anomalies par défaut sur la moitié médiale de la base, et des anomalies par excès sur sa moitié palmaire, de sorte qu'elle est à la fois beaucoup plus étroite et beaucoup plus haute que la doite.

En vue dorsale, les bases des deuxièmes métacarpiens sont relativement symétriques; mais sur la face palmaire, un puissant tubercle se développe du côté gauche entre l'insertion du muscle fléchisseur radial du carpe, et la surface articulaire proximale. Celle-ci se prolonge sur la face proximale du tubercule: elle a de ce fait un aspect cunéiforme à sommet antérieur. Elle est en outre parcourue d'un lacis de sins sillons entrecroisés qui séparent des plans légère,en facettés. Dans son ensemble, elle n'est que trés faiblement concave dans le sens transversal, essentiellement en raison d'effondrement de son bord médial qui est fortement échancré à l'union de ses tiers moyen et dorsal.

La face latérale est symétrique de la droite dans sa moitié dorsale, avec notamment une surface pour le trapeze parfaitement normale; dans sa moitié palmaire, on retrouve le tubercle que nous avons précédemment signalé dont l'extrémité est renforcée par une petite éminence osseuse arrondie. En arrière de l'insertion du muscle radial du carpe, qui est ici un peu faible qu'à droite, on voit trois trous vasculaires, dont un très important (2,7 mm sur 1,7 mm).

La face médiale a subi des modifications beaucoup plus importantes: alors qu'à droite, la surface destine au troisième métacarpien présente le classique contour bilobé, il ne subsiste à gauche qu'une petite facette plane, sensiblement circulaire, d'environ 5 mm de diamètre, située dans l'angle proximo-dorsal. Une plage rugueuse longe ses bords dorsal et distal; du côte palmaire, elle surplombe une depression ponctuée des gros orificies vasculaires, qui encoche profondément le bord medial de la surface articulaire proximale. La face médiale du bec palmaire néoformé est plus dense, mais bosselée et il semble impossible d'y retrouver le champ articulaire originel.

Ces anolaies se retrouvent évidemment, mais à une moindre degré, sur les os adjacents. Ainsi, sur le trapézoïde gauche, le bord distal de la face palmaire est renforcé en une crête tranchante, ce qui a pour effet d'augmenter à la fois le diamètre proximo-distal de la surface articulaire distale destinée au deuxième métacarpien. Cette dernière est à peine convexe dans le sens transversal, et son bord medial est effondré le long d'une plage irrégulière et déprimée; si l'on rétablit la concordance articulaire entre trapézoïde et deuxième métacarpien gauches, les encoches qui affectent leur bord medial se correspondent très précisement.

Sur la face latérale, la bas du troisième métacarpien n'est que légerement modifiée; toutefois, la surface articulaire destinée aux deuxième est trés faiblement développée dans sa partie palmaire, dont le diamètre proximo-distale maximal est à peine de 3,1 mm (contre 5,6 mm à droite). Son bord distal, festonné, est bordé d'une plage aux reliefs tourmentés qui remplace la fosse d'insertion du ligament métacarpien interosseux.

Il est donc manifeste que les lésions les plus importantes touchent la bas du deuxième métacarpien gauche. Leur orgine traumatique ne paraît faire aucun

doute: il s'agit d'une fracture bien consolidée et donc nettement antérieure au décès. Les anomalies que nous avons décrites sur le trapézoïde et le troisième métacarpien ne sont probablement que la consequence des modifications articulaires induites par cette fracture, et il n'y a pas de veritable lésion dégénérative: l'atteinte pourrait être très ancienne et même dater de l'enfance.

The proximal extremity of the second left metacarpal underwent considerable modification, which amounted to, in fact, two complementary processes: the anomalies by default on the medial portion of the base, and the anomalies by excess on the palmar surface, of the kind which is both very much narrowed and very much heightened compared with the right.

In the dorsal view, the bases of the second metacarpals are relatively symmetrical; but on the palmar surface, a powerful tubercle developed at the left corner between the insertion of the radially flexing muscle of the carpal, and the proximal articular surface. This is continued on the proximal surface of the tubercle: it takes on a cuneiform appearance on the anterior summit. On the distal surface of the tubercle, it is scoured by a lacing of crisscrossed furrows which separate the slight planes into facets. In all of this, it is only very weakly concave in the transverse direction, essentially because of the collapse of its medial border which is strongly 'encankered' at the union of its middle and dorsal thirds.

The lateral surface is symmetric on the right side of the dorsal portion with notably perfectly normal a trapezeal surface; on the palmar portion, one finds again the tubercle which we have previously described of which the extremity is reinforced by a small rounded osseous eminence. Behind the insertion of the radial muscle of the carpus, which is here a little more weak than the right, one sees three vascular pits, of which there is one very important one (2.7mm by 1.7 mm).

The medial surface underwent the very most important modifications: whereas on the right side, the surface intended for the third metacarpal presented a classically bilobed contour, on the left side it lingers only as a small facet plane, perceptibly circular, of about 5mm in diameter, situated at a proximo-distal angle. A rough shelf stretches along its dorsal and distal edges; on the palmar surface, it overhangs a depression punctuated by large vascular orifices, which notch the medial edge deeply at the proximal articular surface. The medial surface of the newly-formed palmar lip is very dense, but also embossed and it seems impossible to find the original articular field.

The anomalies are also found in evidence, but to a lesser degree, in the adjacent bones. However, on the left trapezoid the distal edge of the palmar surface is reinforced by a sharp crest, which has for an effect to augment at the same time the proximo-distal diameter of the distal articular surface destined for the second metacarpal. This last is scarcely convex in the transverse sense, and its medial edge is collapsed the length of an irregular and depressed shelf; if one restores the articular concordance between the trapezoid and the second left metacarpal, the notches which affect their medial edge correspond very precisely.

On the lateral surface, the base of the third metacarpal is only slightly modified; nevertheless, the articular surface destined for the second metacarpal is

> weakly developed on the palmar part, of which the maximum proximo-distal diameter is only 3.1 mm (as opposed to 5.6 mm on the right side). Its distal edge is bordered by a shelf of rough relief which replaces the pit of the insertion of the interosseous metacarpal ligament.
>
> It is consequently shown that the most important lesions affect the base of the second left metacarpal. Their traumatic origin does not seem to be in any doubt: it is the result of a well consolidated fracture and consequently clearly before death. The anomalies which we have described on the trapezoid and the third metacarpal are probably only the consequence of articular modifications introduced by this fracture, and are not truly degenerative lesions: the wounds are probably very old and date from childhood." (Translated by VHE)

In summary, Duday and Arensburg (1991) identify the location of healed traumas to KMH 2 as the second left metacarpal and the spinous process of the fifth thoracic vertebra. Other areas that also might show some signs of collateral lesions include the left trapezoid and third metacarpal as well as the spinous process of the sixth thoracic vertebra. The authors seem to be much less definite on the extent to which these other slight anomalies represent lesions to the bones themselves or are simply the consequences of irregularities in articulation caused by trauma to the neighboring second metacarpal and fifth thoracic vertebra. Although they also observed some weak deformation in the sternum that could be caused by trauma, the authors conclude that there are other explanations for it that are not traumatic in nature.

Berger and Trinkaus (1994) distilled the conclusions of Duday and Arensburg (1991) to fractures to spinous processes of the fifth and sixth thoracic vertebrae and fractured proximal epiphysis of the second metacarpal.

B4c. Kiik-Koba 1

Trinkaus *et al.* (2008) report a possible trauma on the Kiik-Koba 1 Neandertal. The Kiik-Koba site is located in the Crimea in The Ukraine and the burial level of this skeleton has been dated to somewhere between the early last glacial and late last

interglacial (OIS 4 or late OIS 5) of the Middle Paleolithic (Bonch-Osmolovskii 1940; Klein 1965). There were two human skeletons discovered at this site, one adult and one infant (possibly an intrusion). The adult, Kiik-Koba 1, skeleton consists of a right canine and elements from the hand, leg and foot. The skeletal elements of the hand include the right trapezium, the first and third metacarpals, four proximal phalanges, six middle phalanges, two ulnar distal phalanges and both pollical distal phalanges. The elements of the lower lib include a right patella, tibia and fibula. The bones of the foot include all of the tarsals, metatarsals, proximal phalanges, six middle and nine distal phalanges. The individual's age at death is estimated based on the canine occlusal attrition to be about greater than forty years of age and its sex, based on tibial length, is identified as male (Trinkaus *et al.* 2008).

A possible traumatic pathology to its right fifth pedal phalanx is described as follows by Trinkaus *et al.* (2008:109):

> The fifth right proximal phalanx, however, is clearly abnormal. There is a dorsal convexity to the shaft, dorsoplantar, and mediolateral midshaft expansions (midshaft diameters of 9.1 and 9.3 mm respectively versus 6.1 and 6.0 mm on the left), a slight shortening of the bone (articular length of 19.5 mm versus 20.8 mm on the left), and S-shaped parallel-sided contour to the bone in dorsal and plantar views as opposed to the normal straight hour-glass shape of the left bone, and a general irregularity of the subperiosteal surface. The proximal articulation and capsular attachments are normal, as is the trochlear surface of the head; there is no change on the associated fifth metatarsal head. These alterations of the right fifth proximal phalanx are best seen as the result of a fracture of the diaphysis.

Rokhlin (1965) also noted an abnormality in this phalanx and suggested that it might be due to osteomyelitis caused by trauma or frostbite. His radiograph of this bone reveals no sign of the fracture line (ibid: 223). Trinkaus *et al.* (2008) attribute this absence of a fracture line to the complete healing of the bone and note that there appears to be no loss of function once the lesion healed.

B4. Summary: late 20th and early 21st century discoveries of Neandertal trauma from west Asia

During the late 20th and early 21st century, several partial postcranial Neandertal skeletons displaying signs of trauma were discovered in sites in the Levant and The Ukraine. Evidence of healed trauma was observed on four out of the six well preserved adults from the Shanidar sample. Each of the individuals who show evidence of antemortem trauma is male and died between the ages of 35 and 50 years old. Signs of trauma in Shanidar 1 appear on the right frontal and left frontal and zygomatic bones, the right humerus, the right clavicle and the right fifth metatarsal. Signs of trauma on Shanidar 3 appear as a penetrating wound to the left ninth rib. Signs of trauma on Shanidar 4 and 5 appear as a fracture to the right seventh or eighth rib and a surface scar to the left frontal squama, respectively. Traumas to the 25-35 year old male skeleton found at Kebara, KMH 2, have been identified on the second left metacarpal and the spinous process of the fifth thoracic vertebra. Other areas that also might show some signs of collateral lesions include the left trapezoid and third metacarpal as well as the spinous process of the sixth thoracic vertebra. The approximately 40 year old male from the Kiik-Koba site in The Ukraine shows some anomalies in his fifth pedal phalanx which may be attributed to a healed traumatic incident.

Each of the skeletons displaying trauma in this group has been identified as male. Of the six males displaying instances of trauma, five are over the age of 35 years at death and one is between 25-35 years old. There were a total of ten areas showing signs of trauma for this group (although some of these areas represent multiple traumas on a single individual and may represent a single traumatic incident). Incident of cranial trauma appear on two of the individuals: Shanidar 1 (right side of frontal and left side of

frontal and zygomatic) and Shanidar 5 (left frontal). Evidence of trauma to the upper limbs appears on two of the individuals: Shanidar 1 (right humerus and clavicle) and KMH 2 (second left metacarpal). Evidence of trauma to the ribs and vertebra appear on three of the individuals: Shanidar 3 (left ninth rib), Shanidar 4 (right seventh or eighth rib), and KMH 2 (5th thoracic vertebrae). Evidence of trauma to the lower limbs appears on two individuals: Shanidar 1 (right 5th metatarsal) and Kiik-Koba 1 (right fifth pedal phalanx).

B5. New Technologies and Discoveries of Neandertal Trauma

During the late twentieth and early twenty-first centuries, the increasing powers of imaging technology has made possible new avenues of fossil reconstruction. Virtual reconstructions can now be made from fragile fossil material by a combination of computer tomography, graphics and stereolithography to create three-dimensional models of fossils that can be analyzed in greater depth either on the computer screen or modeled into casts that can be safely handled and easily disseminated. This new technology has enabled the discovery of indication of trauma on two Neandertal individuals, Le Moustier I and Saint Césaire, where such indications had previously gone unnoticed.

B5a. Le Moustier I

The Le Moustier rock shelter site, located in the Dordogne region of France, was excavated between 1908 and 1914. Remains from two individuals were found that date to about 45,000 B.P. The Le Moustier 1 remains are from an adolescent male, who died between the ages of 15-18, according to Ponce de Leon and Zollikofer (1999), or at around 13 years, according to Wolpoff (personal communication). This specimen

includes a cranium, mandible, and a partial post-cranial skeleton. The Le Moustier 2 remains come from an infant.

Ponce de Leon and Zollikofer (1999:488) digitally reconstructed the Le Moustier 1 skull and mandible and observed signs of a healed left mandibular condyle:

> Despite the precarious state of preservation of the skull, however, our observations support the hypothesis of a traumatic event. First the comparison of the left and mirror-imaged right condylar regions hints at bone resorption as well as apposition in the left condylar neck. (If the present state had been brought about by diagenetic causes, erosion of bone would be expected, while apposition would be highly unlikely.) Second, after inward rotation, the deformed left condyle fits tightly into the well-preserved glenoid fossa, while its mirror-imaged counterpart does not. This pattern is indicative of fracture of the left condylar neck, a traumatic event that is relatively frequent in adolescent modern humans as a consequence of falling down or blunt trauma. The large transverse forces present during impact may cause fractures in the condylar base and/or at the site of impact.

This fracture seemed to have healed well and Ponce de Leon and Zollikofer do not think that it had significant impact on the jaw function of Le Moustier 1.

B5b. St. Césaire

The St. Césaire 1 Neandertal remains of a partial skeleton of a single individual were discovered in 1979 at the collapsed rock shelter site, La Roche à Pierrot in Charente Maritime, France (Lévêque and Vandermeersch 1980). The remains recovered from this individual include a partial cranium and mandible and some fragments of the axial skeleton and limb bones and came from a layer dated at about 36,000 years B.P. (Zollikofer *et al.* 2002). St. Césaire 1 has been identified as a young adult, possibly male.

Computer-tomographic imaging and computer-assisted reconstruction by Zollikofer *et al.* (2002:6445) of the skull showed evidence of a healed fracture in the cranial vault as follows:

> The medial border of the cranial vault fragment of the St. Césaire Neanderthal deviates in its external and internal structure from both postmortem fractures and interosseous sutures. The external lamina of the bone is rounded off toward the medial margin, and the diploic region is covered with cortical bone. This morphology is characteristic of *in vivo* apposition of bone matrix and excludes postmortem abrasion and erosion as potential mechanisms….The most probable cause of the observed morphology is therefore bone regeneration following a lesion, a scenario that is corroborated by the close match of the St. Césaire fragment with that of comparative specimens exhibiting healed trepanations and scars.

Zollikofer *et al.* (2002: 6445) also determined that the "nearly straight border of the scar" showed evidence that the "individual most probably suffered a lesion from a blade-shaped object." This injury, however, does show signs of healing and remodeling during the lifetime of the individual with no sign of post-traumatic infection so it is unlikely that there is a direct causal connection between this injury and the individual's death.

B5. Summary: discoveries of Neandertal trauma using new technologies

Computer-assisted technology has enabled evidence of trauma to be detected in ways that have never been possible before. There is, however, a caveat to this technology. Because there are relatively few Neandertals relative to other samples of modern human bones, it is likely that Neandertals may be closely scrutinized by means of this sophisticated technology in ways that are unlikely to happen with other samples of humans. When trauma counts are compared between Neandertals and modern humans, it may become increasingly important that they all be assessed using the same technologies.

Computer-assisted technology has revealed evidence of trauma to two of the later Neandertals. Both are adolescents and probably both are males. Le Moustier 1 shows signs of healed left mandibular condyle and St. Césaire shows signs of a healed fracture to the cranial vault of the skull near the midline perhaps involving the right and left parietals and the frontal squama.

B5. Section Summary: Neandertals with trauma

Views of Neandertal trauma not only reflect the trauma observed but also reflect the scholarly bias and technological capacity of the researchers. The Neandertal individuals that show evidence of trauma include: Feldhofer 1 (humerus and occipital), La Chapelle aux Saints (rib), Šala (frontal), Krapina 4 (frontal), Krapina 5 (parietal), Krapina 20 (frontal), Krapina 31 (frontal), Krapina 34.7 (parietal), Krapina 149 (clavicle), Krapina 180 (ulna), and Krapina 188.8 (ulna), La Quina H5 (humerus), Tabūn C1 (fibula) and Ferrassie 2 (fibula), Ferrassie 1 (femur), Shanidar 1 (frontal and zygomatic bones, humerus, clavicle and metatarsal), Shanidar 3 (rib), Shanidar 4 (rib), Shanidar 5 (frontal), Kebara 2 (fifth thoracic vertebra and second metacarpal), Kiik-Koba 1 (right fifth pedal phalanx), Le Moustier 1 (mandible), and St. Césaire (cranial vault).

C. History of "bigger picture" interpretations of Neandertal Trauma

In this section, interpretations of trauma in metaset of collected Neandertal remains will be reviewed. The examination of incidents of traumatic lesions in skeletal remains is seen as a way of accessing information about Neandertal culture and lifestyle for the population as a whole. In looking at trauma throughout the whole group of Neandertals, the individual instances of trauma reported for individual sites are contextualized. Leading much of the analysis of the trauma observed in Neandertal remains as a group are Trinkaus and his students. Other authors such as Jurmain (2001) and Underdown (2006) have looked the conclusions of Berger and Trinkaus (1995) using different comparative samples or subsets of the Neandertal metaset. Moreover, some of those conclusions have been expanded into more speculative pronouncements by authors such as Pettitt (2000), and the popular press.

C1. "Hard Times"

By 1978, when Trinkaus wrote the first in what would become a series of articles about Neandertal trauma and mortality patterns, three elements had fallen into place. First, most of the fairly complete Neandertal skeletal remains had been discovered and analyzed by several different researchers and consensus views about what was or was not pathology had been reached. Second, the focus of paleopathology was expanding to include not only the study of singular pathologies of individual specimens but also more general patterns of health, trauma and mortality within skeletal populations. Third, discoveries like the "flower burial" at Shanidar, corrections of Boule's interpretations of Neandertal posture and locomotor abilities, and the discoveries of many more ancient potential human ancestors in Africa, had shifted the popular and scientific view of Neandertals away from being the most primitive and simian sub-human relative towards a view that Neandertal abilities and sensibilities might not be so much different that those of "modern" humans. These three aspects combined in a way that made examining aspects of Neandertal lifestyle and culture in more human terms not only possible but compelling and the study of their paleopathology offered a direct window on stresses and hazards in their lives.

Trinkaus' (1978) first article about the paleopathology of Neandertals as a group, entitled "Hard Times among the Neanderthals," was meant for popular consumption in *Natural History* but it set the tone for many of his later influential scholarly articles. This article sets what Trinkaus (1978:59) considers an important task in the future study of Neandertals:

> We must determine, therefore, the behavioral significance of the anatomical differences between the Neanderthals and other human groups, since it is patterns

> of successful behavior that dictate the direction of natural selection for a species. In the past, behavioral reconstructions of the Neanderthals and other prehistoric humans have been based largely on archaeological data. Research has now reached the stage at which behavioral interpretations from the archaeological record can be supplemented by analyses of the fossils themselves. These analyses of promise to tell us a considerable amount about the ways of the Neanderthals and may eventually help us to determine their evolutionary fate.

In this article, Trinkaus links (1978:63) the Neandertal "characteristic features" of the "exaggerated massiveness of their trunk and limb bones" to "a lifestyle that so consistently involved injury [that it] would have required considerable strength and fortitude for survival." Again, as it was in the 19th century, albeit in a more sophisticated way, Neandertal morphology is seen as the result of Neandertal pathology. Trinkaus (1978:63) concludes this first article to compile Neandertal trauma data from many sites by saying: "Certainly the hardships the Neandertals endured were beyond those commonly experienced by modern peoples." In a following article on Neandertal trauma with co-author Berger (1995), they attempt to show that these "hardships" cause a pattern of trauma in Neandertals that is different from all but a very specialized group of modern humans, rodeo riders.

Another article in *Natural History*, similarly intended for popular consumption by Geist (1981:26), introduced the idea that Neandertal encounters with "large, dangerous, mammals" involved "close-quarter confrontation hunting." In his discussion, Geist (1981:31) argues that a Neandertal hunter grasped his prey by the hair while his friend did the stabbing: "First, he had to evade the attacks, then quickly move in, attach himself to the body of the prey, and have the strength to hold on while an enraged beast tried to fling, shake and buck him off." Geist also argues (1981:35-36) that Neandertals were very skilled hunters, "super-predators," with a meat-based lifestyle and, as a

consequence, could not adapt to the retreat of the Würm ice during the interstadial period when their prey lost their shaggy coats and forests replaced the grasslands. Although Geist (1981) does not mention trauma, some of his ideas seem to be reflected in Berger and Trinkaus' (1995) analysis of Neandertal trauma and analyses of subsequent authors.

C2. "Wild West"-ern Europe and Asia: "Patterns of Trauma"

The subsequent and influential paper by Berger and Trinkaus (1995) followed Trinkaus' (1978) argument that the Neandertals experienced "a life style that so consistently involved injury." In this article, Berger and Trinkaus (1995:841) assessed the anatomical distribution of traumatic lesions and post-traumatic degenerative changes in Neandertals to test the null hypothesis that "… the anatomical distribution of traumatic injuries to the Neandertals falls within the range of variation of such distributions for normal recent human populations, given expected variations between populations of contrasting social and economic conditions."

In their introduction, Berger and Trinkaus (1995:841) state "… it has become apparent that post-traumatic lesions are common on well-preserved Neandertal remains, with at least one (major or minor) defect being found on almost every reasonably complete partial skeleton of a Neandertal past the age of 25-30 years at death." However, this paper does not test how common this perceived phenomenon actually is in other populations. Instead it tests whether Neandertals who show evidence of trauma show that evidence in proportionately the same regions of the body as more modern populations.

For samples of Neandertals, the authors use La Chapelle 1, La Ferrassie 1 and 2, Kebara 2, Krapina 4, 34.7, 149, 180 and 188.8, Neandertal 1, La Quina 5, Šala 1, Shanidar 1, 3, 4 and 5, and Tabūn 1. For the modern samples, the authors used both

archaeological samples and clinical samples. The archaeological samples include Carlston Annis (Late Archaic Amerindian site in northern Kentucky), Libben (Woodland Amerindian site in northern Ohio) and Nubia. The clinical samples derive from fractures diagnosed or reported in a medical setting in London and New York at the turn of the twentieth century, from the New Mexico Workers Compensation disability list from the 1990s and from a list of injuries compiled by the Professional Rodeo Cowboys Association.

Incidences of trauma were divided into seven categories of body region for each of the populations: head/neck, trunk, shoulder/arm, hand, pelvis, leg, and foot. Incidences of trauma in the Neandertal sample were defined as clearly antemortem identified healed lesions and signs of Degenerative Joint Disease (DJD) which might indicate a previous trauma. For the North American archeological samples, Libben and Carlston Annis, incidences of trauma are the raw counts of observed fractures (probably mostly antemortem). For the Nubian sample, incidences of trauma included lesions that show signs of healing i.e. antemortem and injuries that may have caused death and show no signs of healing i.e. perimortem. The London, New York, and New Mexico samples come from fractures observed on living patients in a clinical setting. The Rodeo data come from a tabulation of traumatic injuries reported by Rodeo cowboys to the Professional Rodeo Cowboy Association (P. R. C. A.) and the Mobile Sports Medicine Systems, Inc. These rodeo injuries were divided into two categories by the P. R. C. A.: “minor” and “severe.” The only injuries that counted towards the comparative sample were the “severe” injuries that either caused a fracture or were severe enough that if

untreated would have probably caused some bony reaction to the joint such as articular DJD.

In their comparisons, Berger and Trinkaus note some differences between the samples in the representation of various skeletal elements. The clinical samples represent all skeletal elements uniformly whereas in the archaeological samples various elements might not be represented uniformly because of taphonomic factors which might break or destroy smaller or more fragile elements and reduce their frequencies in the sample. However, with the exception of the Krapina sample, most of the Neandertal individuals represented show fairly good preservation and the authors consider their preservation comparable to the preservation of much more recent North American and Nubian archaeological samples.

For each of the skeletal populations, each incidence of trauma as defined above was added together. For each of the seven body regions the percentages of that total trauma was then recorded and graphed on a chart for comparison with the other groups, with body region on the x-axis and percentage of total trauma on the y-axis. Chi-square and associated P values were calculated using Stat-Xact Turbo (Mehta and Patel 1992) for the pairwise comparisons between the percentage distributions of Neandertals with trauma and the comparative samples. The adjusted residuals of the chi-squares were used to determine which portions of the distributions were significantly contributing to the differences between samples (Berger and Trinkaus 1995:845).

In comparison to the other groups, Neandertals show a significantly higher percentage of head/neck injuries (although mostly head rather than neck) than any other group at least the $p<0.05$ level except in the case of the Rodeo cowboys where there is no

significant difference (Berger and Trinkaus 1995: 846). There is also some tendency for Neandertals to have slightly lower percentage of leg and hand injuries than some of the groups although some of this may be due to the preservation of various elements. In doing a global chi-squared test to compare the complete trauma patterns for each of the groups to the Neandertal sample, all the groups except for the New York clinical sample and the Rodeo cowboy sample are significantly different at $P < 0.01$ (Berger and Trinkaus 1995: 846) for at least one anatomical region. Although the difference is not so significant as with the other comparative samples, the New York sample is still significantly different from the Neandertal sample at $p<0.05$ for the head/neck and hand regions. As for the rodeo cowboys, Berger and Trinkaus (1995:846) state: "There are little more than trivial differences between the various Neandertal lesion tabulations and the Rodeo one. The Rodeo sample has a slightly higher head injury frequency and the Neandertals have moderately higher trunk, arm, and leg trauma rates….Most importantly, the best comparison between the Rodeo lesion sample and a Neandertal one, to the 'Neandertal total' tabulation, produces a global chi-square- $P=0.89$!"

Berger and Trinkaus (1995:848) deny that sample size (i.e. the smallness of the Neandertal sample) or any Neandertal taphonomic preservation bias in favor of cranial remains are likely to account for this observed pattern. The authors (1995:849) argue that their results might show that the dearth of (healed) leg injuries in Neandertals compared to some of the other groups may be "a product of a need for maintained mobility among these hominids. Those no longer capable of keeping up with the social group, whether as a result of age or serious lower limb trauma, may have been left behind, to die in localities where their remains were not preserved or recovered." As for the high relative

percentage of injuries in the head/neck region, Berger and Trinkaus (1995:849) argue that this is unlikely due to higher levels of aggression and interpersonal violence in Neandertals because there was such a low population density in the Middle Paleolithic, but rather to "close encounters of a nasty kind" with large or medium sized ungulates, parallel to those experienced by the Rodeo cowboys. To the authors, this seems likely because Neandertal weapons do not show much evidence of including many long range projectiles and that most hunting would have been at close range and potentially dangerous to the hunters as well as the hunted.

C3. More Neandertal Injury: Jurmain, Underdown and Gardner

Some other works have addressed Neandertal trauma, following the lead established by Berger and Trinkaus (1995). Jurmain (2001) uses Berger and Trinkaus' Neandertal trauma data and protocol in order to look at patterns of trauma through examining relative frequencies of trauma per body region, as part of his analysis of California archaeological populations. Underdown (2006) attempts to identify whether there is any relationship between Neandertal trauma, behavior patterns, and/or ecology, by assembling skeletal data from a subset of Neandertal long bones and comparing it to several hunter/gatherer groups from Australia and the Arctic. Gardner (2004 and 2007) compares trauma data from Krapina and a few other Neandertal sites to other comparative collections such as Midwestern agricultural workers to address the sources of Neandertal trauma.

C3a. Jurmain (2001)

Jurmain (2001) uses the data on Neandertals and rodeo riders compiled by Berger and Trinkaus (1995) as a comparative sample in his analysis of trauma observed in

archaeological populations from California. Jurmain (2001) modifies the body regions studied to include only three categories: head/neck, upper appendages and lower appendages. The original categories of hands, arms, feet and legs have been compressed into "upper appendages" and "lower appendages" and the data from trunk and pelvis have been excluded because of variable preservation of those elements. Chi-square and associated P values were calculated using for the pairwise comparisons between the percentage distributions of the California samples, the Rodeo sample and the sample of Neandertals with trauma.

In comparing proportions of head/neck fractures, Jurmain similarly finds that rodeo riders had the highest proportion of fractures to that body region (55% of all fractures) followed by Neandertals (41%) and one of the California sites, SCl-038 (23%). In overall distribution of fractures throughout the three body regions, Jurmain also shows that SCl-038 is not significantly different from Neandertals ($p = 0.32$) and the other California site, Ala-329 ($p = 0.81$); however SCl-038 is significantly different in overall distribution in fractures from rodeo riders ($p = 0.007$) and Ala-329 is significantly different from Neandertals ($p = 0.04$). He concludes that the most distinctive component across the population samples he examined is the proportion of head/neck injuries, however, in the populations with the highest proportions in this area "risk factors appear to derive from either dangerous contact with large animals *or* (Jurmain's italics) from interpersonal conflict" (2001: 21). Therefore, high proportions of head/neck injuries are not shown to be exclusively the result of non-human animal agency as was postulated by Berger and Trinkaus (1995). Jurmain's final conclusion is that more work needs to be done in discovering ways of distinguishing the different agencies.

C3b. Underdown (2006)

In this paper, Underdown (2006) attempts to identify whether there is any relationship between Neandertal trauma and their behavior patterns and/or ecology. To do this, he assembled skeletal data from a subset of Neandertal long bones. He tested the significance of various ecological and subsistence patterns using chi-square. Underdown (2006:490) also compared his Neandertal sample to several hunter/gatherer groups from Australia and the Arctic by pairwise comparisons of the total trauma frequencies for each collection, for males and females, and for individual bones using ANOVA where the "top two in each case were awarded one point"; these scores were then combined to determine which sample fit the Neandertal profile best. However, much of the analysis Underdown discusses was based on percentage differences rather than statistical tests.

Underdown (2006:486) developed "a workable group of Neandertals" by including individuals in the sample only if more than 15% of long bones are present and the individual is classified as being over 5 years of age at death. The sites he used are Feldhofer (1 individual), Le Moustier (1 individual), La Chapelle-aux-Saintes (1 individual), La Ferrassie (3 individuals), Amud (2 individuals), Shanidar (6 individuals), La Quina (1 individual), Spy (2 individuals), Regourdou (1 individual), Kiik-Koba (1 individual), Teshik-Tash (1 individual), Tabūn (1 individual) and Krapina (10 individuals).

There are, however, several inconsistencies in his data collection, and analysis of the Neandertal remains, which mostly stem from Underdown's reporting only of percentages and not of raw data counts. Underdown's (2006:486) inclusion of skeletal remains from Krapina does not follow his criterion of "15% of the long bones being

present" nor is it possible to clearly assess age or gender from an individual specimen of a long bone from Krapina. He states that his Neandertal group was composed of sixteen males, eight females and seven individuals of indeterminate sex. This adds up to 31 individuals, as does the original list of specimens. However, his age profile breakdown for the Neandertal group is defined only in percentages that seem to imply 35 individuals. For his reports of percentages of trauma seen in Neandertals, it seems that the denominator is 9 instances of trauma in the group, but this is never actually stated and in his second table enumerating the Neandertal trauma per long bone the number of instances of trauma sums to 10. Underdown (2006:487) states "55.6% percent of the Neandertals displaying long bone trauma are males and 44.4% of the Neandertals displaying long bone trauma are females" i.e. 5 out of 9 versus 4 out of 9, in what is presumably an instance where precision outstrips accuracy. If any of that long bone trauma is from Krapina, which I imagine is the case, the sexing of any particular long bone is problematic at best. Similar issues arise from his age profile breakdown of long bones displaying trauma. In addition, there are other problems i.e. 127 + 135 = 272 not 265 (Underdown 2006: Table 2 page 487) and the stated frequency of trauma observed in his Neandertal group of 3.8% (Underdown 2006: 487) is not the same as 32.3% (Underdown 2006:489) he later states is the Neandertal frequency of trauma.

In the "workable group of Neandertals," Underdown observed nine occurrences of trauma. Of these, probably five were observed in males and four were observed in females. Underdown found that most of the trauma (7 out of 9 occurrences) was found in adults aged between 20 to 40 years old. There was one occurrence in adults over 40 years of age and one occurrence in adolescents between 10 and 20 years of age. Although there

appears to be fairly even distribution of cave and rock shelter sites, approximately two thirds of the injured Neandertals in the sample come from cave sites and almost all (8 out of 9) of the traumas occur in areas where large fauna are dominant. Underdown (2006:489) concludes from this: "This would appear to suggest that the Neandertals were using their environment in a very predictable, traditional way. Namely, that young adult males were encountering large prey and sustaining injury. They were present mainly at rock shelter and from an open biotype. The environmental conditions were harsh; cold and prone to variation."

For a comparative sample, Underdown created a database that included eight population groups of hunter-gatherers culled from his own collection, published material and unpublished raw datasets. Only data from long bones were collected. Absence or presence of trauma, sex and age of the individuals were recorded for each group. The Neandertal sample trauma frequency was compared with the eight hunter-gatherer groups. The "Desert" and "East Coast" Australian groups were found to have trauma profiles that were most similar to that of the Neandertal sample. According to the Underdown (2006:490), this pattern reveals that "The Neandertal method of hunting cannot be sustained as the cause of high rates of skeletal trauma. Instead foraging strategies seem to have played a hitherto overlooked role in the occurrence of skeletal injury." Underdown (2006:492) concluded that Neandertals "reluctant gardeners who tumbled too often."

Besides the vagueness around sample counts, numbers not summed correctly, and percentages off by an order of magnitude, the biggest weakness of this study is in the assembly of the Neandertal sample used by Underdown. Certainly many of the best

preserved Neandertals do show signs of trauma; however, the decision to include some of the Krapina specimens ("10 individuals" which probably means individual bones), especially when they do not seem to otherwise fit his sampling criteria, provokes the question of whether these specimens were chosen because many of them show evidence of trauma. Many of Underdown's results many also be explained as the result of biases in the Neandertal sample chosen, rather than ecological and subsistence patterns.

C3c. Gardner (2004 and 2007)

In a poster presented at the meetings of the American Association of Physical Anthropology in 2004 and a paper presented at the meetings of Canadian Association of Physical Anthropology in 2006, Gardner compared Neandertal trauma data to other comparative samples. Her 2004 poster compared traumatic injuries in agricultural workers engaged in "day to day routines of farm operation and animal management" (2004: 98) to those found in Neandertals, and rejected the null hypothesis that these workers experienced similar patterns of trauma as Neandertals. At the 2006 meetings, Gardner (2007:16) presented her result that "a more discrete analysis of the types and locations of cranial trauma in Neandertals reveal patterns that are similar to those seen in populations that engaged in non-lethal interpersonal violence. In addition, accidental blows to the head (i.e. rockfalls) and falls are also considered possible causes for traumatic injuries in Neandertals." This is similar to her conclusions in Gardner and Smith (2006:482) that:

> The Krapina sample, with 4 examples of well-healed exocranial depression fractures to the frontal and parietal, resembles patterns and types of trauma that have been attributed to non-lethal interpersonal violence in other populations. In addition, depression fractures to the crania can also represent injuries sustained as the result of falls, or from the impact of falling objects, such as rocks. Locomotion on uneven terrain, such as that at Krapina, often results in falls. In these situations

> upper limb injuries are three times more common than lower limb injuries, and head injury is the most common complication [according to Agarwal (1980)].

C3. Summary: analyses of Neandertal trauma following Berger and Trinkaus (1995)

Subsequent work on Neandertal trauma following Berger and Trinkaus (1996) continues, with the theme of looking for causes of these injuries. Jurmain (2001) and Gardner (2007) view non-lethal interpersonal violence as the probable cause of most of the trauma. Underdown (2006) [and to some extent Gardner (2004 and 2007)] view accidental falls as the primary source of injury.

C4. Interpretations of Neandertal trauma and lifestyle: Pettitt (2000) and others

The conclusions of Berger and Trinkaus (1995) have become widely accepted and disseminated both in academic publication and in the popular press. Most of these articles takes some of these conclusions (i.e. Neandertals often became injured because large ungulate interactions while hunting during the course of their lives, and there are no serious healed leg injuries because if an individual were not mobile, he or she would have been left behind and would not have survived) as the basis for asserting the dominant role of physical trauma in the lifecycle of Neandertals.

Pettitt's (2000) article "Neandertal Lifecycles" takes conclusions about trauma as evidence for building an argument about the pathological nature of Neandertals as a species. In it, Pettitt lists each stage of Neandertal life (infancy, adolescence/young adult and old age), and what he perceives as the major stressors. Infants are at risk of nutritional stress and infanticide (Pettitt 2000: 356). Adolescents/young adults are at risk of mortality due to their "participation in dangerous encounter hunting of medium and large sized herbivores" (Pettitt 2000: 357). Old adults are not often recovered because

they are abandoned when they limp around and cannot keep up with the group (Pettitt 2000: 357). With trauma happening "ubiquitously" during Neandertal life, Pettitt (2000: 360) asserts that "it is doubtful that either material culture of language played a major role in structuring Neanderthal social systems, and therefore some degree of social significance within Neanderthal society was attached to physical trauma and physical abnormalities." Because trauma defined the lives of the Neandertals, Pettitt (2000:362) concludes: "In this sense I suggest that it was the mime of their bodies accompanied by a simple dialogue, in a theater low on props and devoid of scenery, which created and constrained their social systems."

Klein (1999: 475-476) uses Berger and Trinkaus' (1995) arguments to conclude that antemortem trauma occurred less frequently in modern humans compared to Neandertals and "The most fundamental implication is that Neanderthal technology (or culture in general) was relatively ineffective at reducing wear and tear on Neanderthal bodies." Adovasio, Soffer, and Page (2007:157) similarly state "Neanderthal remains tell a story of a highly stressful life: they tended to die well before the age of 45, usually with bones that had been repeatedly broken and badly stressed." In a non-academic article, Mendez (2008) similarly uses the conclusions of others regarding Neandertal trauma to create arguments about prehistoric life in "How EVIL was the world before Noah's flood?" Using Berger and Trinkaus' (1995) data, Mendez (2008) argues that prehistoric peoples were "brutal," in addition to being inept hunters, and were therefore smitten by God.

C. Section Summary: analyses of Neandertal trauma

In this section, interpretations of trauma in metaset of collected Neandertal remains were reviewed. Trinkaus leads much of the observation and analysis of the trauma observed in Neandertal remains as a group [e.g. Trinkaus 1978, 1983, 1985; Trinkaus and Zimmerman (1982); Berger and Trinkaus (1995); and Trinkaus *et al.* (2008).] Other authors such as Jurmain (2001) and Underdown (1999) have examined the conclusions of Berger and Trinkaus (1995), using different comparative samples and/or subsets of the Neandertal metaset. Also some of those conclusions have been expanded into more speculative pronouncements by authors such as Pettitt (2000) and the popular press.

D. Chapter III Conclusions

In this chapter, the history of the discovery and interpretation of trauma in Neandertals was summarized. The first section of the chapter addressed the discoveries of individual Neandertal remains which showed signs of trauma and the primary descriptions of those traumas. This first section also discussed how interpretations of trauma in individual Neandertal skeletons were rooted in contemporary ideas of the place of Neandertals in relation to modern humans and the role of technology in the identifying and interpreting trauma in individual remains. The second section summarized the history of interpretation and conclusions about trauma in Neandertals as a group.

Since the discovery of the first "Neandertaler" at Feldhofer cave, issues of pathology and "Neandertal-ness" have been linked. Early in the history of Neandertal discovery and interpretation, some morphological features of Neandertals were argued to be pathologic in origin [e.g. Virchow (1872)], while other actual pathologies, such as the

severe osteoarthritis of La Chapelle, were regarded as typical Neandertal morphological features. In similar ways, Neandertal traumatic pathology has come to be regarded as a typical aspect of Neandertal life. In the following chapters, I examine aspects of how trauma is distributed throughout the extant collection of Neandertal specimens and address whether the frequency of Neandertal trauma is in any way different from that observed in groups of modern hunter-gatherers and nomads.

CHAPTER IV

ASSESSING PATTERNS OF TRAUMA IN NEANDERTALS

A. Chapter IV Introduction

In this chapter, I discuss various aspects of Neandertal trauma with the intent of testing the significance of its variability and assessing potential biases. These aspects include the temporal and geographical distribution of Neandertals with trauma, areas of the body with trauma, age and sex distributions of individuals with trauma, levels of preservation of individuals with trauma and degree of severity of injury. The significance of potential variation within these aspects of Neandertal trauma will be determined using analysis of two-way contingency tables using simulations (ACTUS2).

These tests of significance in the distribution of trauma within the sample of injured Neandertals cannot address the significance of the frequency of trauma in Neandertals. Tests of significance within the sample of injured Neandertals address how the trauma is distributed by age-at-death class, sex, level of preservation of the specimens, and dates and locations of the sites. I introduce another way of measuring trauma, the "degree of injury," where injuries a put into one of five categories depending on the severity and level of functional impairment. These tests represent one way of revealing potential biases in the ways trauma is distributed in Neandertals; however, these do not take into account aspects of the entire sample of Neandertals which do not show signs of injury.

B. Materials

In this chapter, I evaluate Neandertals with trauma, as reviewed in Chapter III. These Neandertals include Feldhofer 1, La Chapelle-aux-Saints, Krapina 4, 5, 20, 31, 34.7, 149, 180, La Ferrassie 1 and 2, Šala 1, Shanidar 1, 3, 4 and 5, Kiik Koba, Le Moustier 1, Kebara KMH 2, Tabūn 1, La Quina H5, and St. Césaire 1. The data for each of these individuals includes an approximate date for the site, its location, the degree of preservation of the individuals, and the distribution of trauma on the body (specific bone and side) and a brief description of that trauma. For some of the individuals, it was possible to assign a sex and/or an age-group category. Because all of the individuals were older than thirteen years at death, the age-groups were divided into three categories in individuals whose age-at-death could be assessed: Adolescent (13-20 years), Prime Adult (20-35 years) and Old Adult (35+ years). I also assessed the severity of the trauma. All of these data in their raw form are presented in an Excel spreadsheet in Appendix A.

C. Methods: Introducing ACTUS

The program ACTUS (Analysis of Contingency Tables Using Simulation) (Estabrook and Estabrook 1989) was written to address the problem of statistical analyses of two-way tables from small samples, to determine whether to reject a null hypothesis of independence. Such analyses are especially important in fields such as history and other social sciences (the context for which this program was created) or anywhere else where counts of differing character states are being compared. It has also been applied in ornithology (Marques 2004 and 2003), entomology (Raguso and Willis 2002, and ichthyology (Galhadro *et al.* 2008; Amorim *et al.* 2004; Faria *et al.* 2001; Almada *et al*. 1997; Oliveira *et al.* 1996). Because the approximation to classical statistical distributions

(such as chi-square) is poor when only a few cases are involved, the minimum number of cases expected under the hypothesis of independence must exceed four in order for tabulated probabilities to be accurate (Estabrook and Estabrook 1989:5). Also, with a small sample, when the null hypothesis of independence is rejected, it is difficult to tell which cells to interpret as being the ones more and/or less frequent than predicted under the null hypothesis, because the co-occurrences that merit a more substantive interpretation are not necessarily the largest or smallest counts (Estabrook 2002: 23).

C1. How ACTUS works

The computer program, ACTUS, calculates estimates of realized significance from small data sets. It does this is by comparing two classifications under the null hypothesis that they are independent. Counts of both of the classifications are arrayed in a contingency table. The program then uses a random number generator to simulate thousands of comparable data sets whose distributions are known to be random, and then it counts the number of simulated tables with entries that are larger or smaller than the corresponding entries input by the user. The results of an ACTUS analysis show not only whether the entire contingency table rejects the null hypothesis, but also which cells are larger or smaller than predicted.

ACTUS uses direct comparison of the value of a statistic calculated from the observed table with a value calculated in the same way from the a simulated table to estimate its realized significance with the fraction of simulated tables not less or not greater. This method works for any statistic, not just those that approximate a known pre-calculated distribution. It provides an easy-to-understand, direct measure of the extent to which an observed table differs from what might be predicted by a hypothesis of

independence. For this, ACTUS uses SAD: the Sum of the Absolute values of the Differences between the expected values and the observed values. SAD is the sum of the absolute values of the numbers in the Deviation table. Simulated estimates of significance of statistics such as chi-square or SAD depend on the hypothesis used to simulate. Usually, estimates of the significance of SAD are close to those for chi-square (Estabrook and Estabrook 1989).

ACTUS2 (the more recent version, published in Estabrook 2002) offers a choice of two different hypotheses of independence that result in different procedures for choosing at random which may result in different cells for interpretation.

One hypothesis of independence that can be chosen using ACTUS2 is "Hypothesis F" (i.e. for "frequency") and the standard chi-square distribution is derived from this hypothesis. Under this hypothesis, the probability that a simulated case occurs in a given column is proportional to the frequency of observed cases in that column AND the probability that the same simulated case occurs in a given row is proportional to the frequency of observed cases in that row. By means of a random number generator, ACTUS2 uses these probabilities to independently select a row and column for as many simulated cases are there were observed cases. A table of co-occurrences is generated using these simulated cases, which can be compared with the observed table. This "F-type" hypothesis of independence is appropriate where there is reason to believe that the observed cases represent a small sample of all the cases that ever existed and that if an equally representative small sample were available for study, rows and column totals would not be exactly the same.

The other hypothesis of independence that can be chosen using ACTUS2 is "Hypothesis P" (i.e. for "permutation"). Under this hypothesis, row and column totals do not vary and the possible contingency tables are limited to those with row and column totals equal to the row and column totals in the observed table (a small subset of the tables possible under "Hypothesis F"). This technique of permutation ensures that these totals remain the same while randomly and fairly independently simulating a contingency table. Hypothesis P is simulated by choosing one possible permutation of the observed cases and then successively assigning as many cases to column 1 as there are observed cases in column 1 and so on through the remaining columns so that all cases to be simulated have by assigned a column. The rows remain the same in the simulated table as in the observed table since the columns have been reassigned independently of the observed row. The table of co-occurrences is made from these simulated columns and rows and then compared with the observed table to increment counts in the big and small tables.

Fewer extremes in difference occur in P-simulated tables than in F-simulated tables. Because of this, extreme differences observed under Hypothesis P are usually considered more significant than under Hypothesis F although both hypotheses often flag the same cells.

ACTUS was written as a DOS program (Estabrook and Estabrook 1989) and the updated and enhanced version, ACTUS2 (Estabrook 2002), runs under WINDOWS or DOS and is available to download with explanations and examples from http://www-Personal.umich.edu/~gfe/. The user opens the ACTUS2 program and can chose to enter in a new data set or read in a previously saved data set. The user can then input his or her

row and column frequency for up to ten columns and ten rows and then chose a hypothesis from hypothesis menu and then click on the simulate menu. The user will then be asked how many simulations (up to 10,000) to run. The SAD and chi-square value for the table is then calculated and displayed. The user may select the "View" menu and take a look at the expected values, deviations from those values, small significances, big significances, and whole table significances.

C2.Interpreting results from ACTUS: an example

The use of ACTUS2 can be illustrated using the Neandertal skeletal remains from Krapina with at least 25% of the whole bone present to test the hypothesis that instances of trauma are observed in each of seven body regions in proportion to the number of bones representing that region. To test this hypothesis using ACTUS2 bones are classified in two ways: 1) whether they show trauma and 2) what region of the body they represent. Counts are arranged in a contingency table, as shown in Table 4.1, where 58 bones from the head showed no trauma and 5 bones from the head showed trauma, etc.

Table 4.1. Counts of all bones at Krapina distinguished by presence or absence of trauma, and body part.

Region of the Body	*# Bones with No Trauma*	*# of Bones with Trauma*
Head	58	5
Trunk	42	0
Arm	22	3
Hands	66	0
Pelvis	1	0
Leg	39	0
Feet	56	0

Under the null hypothesis, the expected value of each count can be calculated as its row frequency times its column frequency divided by the total number of bones in the whole sample. Table 4.2 shows expected values for the counts in Table 4.1.

Table 4.2. Numbers of observations expected under the null hypothesis with row frequencies (RF) and column frequencies (CF)

Region of the Body	*Expected # of Bones with No Trauma*	*Expected # of Bones with Trauma*	*Row Frequencies (RF)*
Head	61.3	1.7	63
Trunk	40.8	1.2	42
Arm	24.3	0.7	25
Hands	64.2	1.8	66
Pelvis	1.0	0.0	1
Leg	37.9	1.1	39
Feet	54.5	1.5	56
Column Frequencies (CF)	284	8	292

The extent to which these expected values differ from the observed counts is measured as the difference: that is, the expected value minus the observed count, as shown for each cell in Table 4.3.

Table 4.3. Deviations of observed counts Table 4.1 from expected values shown in Table 4.2

Region of the Body	*# Bones with No Trauma*	*# of Bones with Trauma*
Head	-3.3	3.3
Trunk	1.2	-1.2
Arm	-2.3	2.3
Hands	1.8	-1.8
Pelvis	0.0	0.0
Leg	1.1	-1.1
Feet	1.5	-1.5

The sum of absolute value of these differences, termed SAD (Sum Absolute Differences) over all the cells in Table 4.3, is a measure of the extent to which the whole table differs from what would be expected under the null hypothesis. ACTUS2 determines whether this difference is large enough to reject the null hypothesis by simulating a large number of contingency tables with the same rows and columns and the same number of bones, typical of what might be observed if the null hypothesis were true. To simulate a table, for each of the 292 bones it assigns a row with probability

proportional to the frequency of bones actually observed in that row and, independently, a column with probability proportional to the frequency of the bones actually observed in that column. It then calculates a value of SAD for that simulated table. In the analyses to follow, 10000 such tables are simulated. The realized significance of the observed value for SAD is estimated as the proportion of simulated tables with a value of SAD greater or equal to the observed value. An observed value of SAD that is so large that only a small proportion of simulated tables have a value of SAD as least that large supports an argument to reject the null hypothesis.

Turning again to the specific example, SAD is the sum of the absolute values of the 14 numbers in Table 4, which equals 22.36. ACTUS2 simulated 10000 tables under the null hypothesis that instances of trauma were independent of regions of the body. Out of 10000 simulations, the SAD values calculated from simulated tables were equal to or exceeded 22.36 (the SAD value calculated from the observed table) only 17 times. This estimates a realized significance of p= 0.0017, which might be rounded to p=0.002. Thus, we reject the null hypothesis and conclude that some regions of the body have trauma significantly more often or less often than the relative frequency of the bones recovered from that region. The counts in Table 1 suggest that trauma to the head and arm regions occurs more often, and to all other regions of the body less often, because the only instances of trauma are to the head or arm, and other regions of the body show none.

However are these values large or small enough to be significant? To determine whether any counts are significantly large, ACTUS2 counts the number of simulated tables with a count for each cell that was not less than the observed count for that cell. For uniform format, these counts are scaled to 'out of 1000'; they are shown Table 4. To

estimate the realized significance that an observed count is too large to be consistent with the null hypothesis, the number in its corresponding cell is divided by 1000.

Table 4.4. In each cell is the number of simulated tables (scaled out of 1000) whose count for that cell was not less than the observed count for that cell.

Region of the Body	*# Bones with No Trauma*	*# of Bones with Trauma*
Head	724	29
Trunk	448	1000
Arm	715	30
Hands	417	1000
Pelvis	617	1000
Leg	437	1000
Feet	431	1000

These results show that the 5 instances of trauma in the head are significantly many with realized p = 0.029, and the 3 instances of trauma in the arms are also significantly many with p = 0.030. This confirms what the original table of counts suggests. However, are all zeros reported for the other regions of the body significantly few?

To determine whether any counts are significantly few, ACTUS2 counts the number of simulated tables with a count for each cell that was not more than the observed count for that cell. For uniform format, these counts are scaled to 'out of 1000'; they are shown in Table 5. To estimate the realized significance that an observed count is significantly small to be consistent with the null hypothesis, the number in its corresponding cell is divided by 1000.

Table 4.5. In each cell is the number of simulated tables (scaled out of 1000 whose count for that cell did not exceed the observed count for that cell.

Region of the Body	*# Bones with No Trauma*	*# of Bones with Trauma*
Head	325	992
Trunk	615	320
Arm	369	995
Hands	635	164
Pelvis	747	973
Leg	623	338
Feet	627	218

None of the zeros from the original trauma counts is shown to be very significantly smaller than expected under the null hypothesis, but there are weak trends toward too few instances of trauma in hands (p = 0.16) and feet (p = 0.22). These ACTUS2 results are somewhat less obvious from the table of counts alone. Any argument that the lack of observed trauma in trunk, pelvis or leg is inconsistent with the null hypothesis would have no basis in data, and the lack of observed trauma in hands and feet is only very weakly inconsistent with the null hypothesis.

In presenting results of ACTUS2 analyses for the remaining questions, only the table of observed counts will be shown. Counts followed by +++ designate significantly larger counts than expected under the null hypothesis ($p < 0.05$) and counts followed by --- designate significantly smaller counts than expected under the null hypothesis ($p < 0.05$).

D. By Chronology and Geographic Location

In this section, the temporal and geographical range of Neandertals with trauma will be discussed. Dates for sites where Neandertals were discovered range from 130k (Krapina) to 36k (St. Césaire). Earlier European sites that show trauma such as Atapuerca (Perez et al. 1997) have not been included because they are significantly earlier than the "classic" Neandertals. Other Middle Paleolithic sites such as Skhul and Qafzeh have also been excluded because they are not Neandertals.

Table 4.6 presents a summary of aspects of the locations at which the remains of Neandertals with trauma were found as well as the chronology of those remains. These aspects include the type of site (rock shelter versus cave), the number of individuals with trauma, the distributions of trauma on the body, and the sex of the individuals. The

presence of question marks after male or female denotes a degree of uncertainty about the designation and two question marks denotes a high degree of uncertainty about the designation.

From this summary table, it is possible to test a few hypotheses about possible differences in Neandertals with trauma according to the time and place where they came to rest. These hypotheses include the independence of time period to the distribution of trauma on the body, the independence of geographical location to the distribution of trauma on the body, the independence of geographical location to site type, and the independence of geographical location to the sexes of the individuals with trauma. All counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.6. Neandertal remains with trauma organized by chronology, geographical location and type of site, distribution of trauma on body and sex of individuals

Time	Location and Type of Site	# of Individuals w/ Trauma	Distribution of Trauma on Body	Sex
130kyr	Croatia-Krapina *Rock Shelter*	8 (fragments)	3 Frontals 2 Parietals 2 Ulnas Clavicle	1 Male 1 Male ? 1 Female ? 2 Female ??? 3 Unknown
122kyr	Israel- Tabūn *Cave*	1	Fibula	Female
90kyr (?)	Crimea-Kiik Koba *Cave*	1	Pedal Phalanx	Male
70kyr	France-La Ferrassie *Rock Shelter*	2	Femur Fibula	Male Female
62kyr	Israel-Kebara *Cave*	1	Thoracic Vert 1-2 Metacarpal 2	Male
60kyr	France-La Chapelle *Cave*	1	Rib	Male
50kyr	France-La Quina *Rock Shelter*	1	Fibula	Female
45kyr	France-Le Moustier: 1 *Rock Shelter* Iraq-Shanidar: 4 *Cave*	5	Mandible (Le M) Humerus Metatarsal 5 2 Frontals Zygomatic 2 Ribs	5 Males
40kyr	Germany-Feldhofer: 1 *Cave* Czech Republic- Šala: 1	2	Occipital Ulna Frontal (Š)	Male Female?
36kyr	France-St. Césaire *Rock Shelter*	1	Frontal Parietal	Male?

D1. Hypothesis 1: Given Neandertals with trauma, distribution of trauma on the body is independent of time period.

One way to test this hypothesis is to divide the Neandertals with trauma into two groups, according to whether the date of their site falls into the third interglacial or fourth glacial, a division which happens to fall approximately halfway along the timeline. The early group sites, whose dates span from 130,000 BP through 80,000 B.P, include Krapina, Tabūn and Kiik Koba. The later group sites, which date from 80,000 B.P. through 36,000 B.P., include La Ferrassie, Kebara, La Chapelle-aux-Saints, La Quina, Le Moustier, Shanidar, Feldhofer, Šala and St. Césaire. Because there are so few instances of trauma, comparing individual bones with trauma is highly unlikely to show any significant differences. The division of the body into four regions (head, upper limbs, trunk, and lower limbs) compresses the categories enough so that gross differences in the areas of injury on the bodies of Neandertals may be discernable.

Table 4.7. Regions of the body with trauma by time

Region of the Body	Sites dating from 130kyr-80kyr	Sites dating from 80kyr-36kyr
Head	5	8
Upper Limbs	3	3
Trunk	0	5
Lower Limbs	2	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 6.7, the SAD value calculated from the observed table, for 4561 out of 10000 simulated tables, p=0.46. The whole table is consistent with the null hypothesis that the general areas on their bodies that Neandertals injured remained consistent through time. No individual count is significant.

There are other ways of dividing up the Neandertals with trauma into groups by smaller periods of time and this division might better mirror differences in technology. But to push the resolution of the dates, the bulk of the sites in the sample are Mousterian sites and differences in tool forms seem to be more related to regional variation rather than technological differences: "To assume a simple, direct equation between the forms of different types and the specific economic or technological activities for which they were employed would run counter to all recent research in these fields" [i.e. aspects of research into the morphology and specific functional orientation of Middle Paleolithic stone tools such as use-wear studies] (Mellars 1996: 318).

D2. Hypothesis 2: Given Neandertals with trauma, distribution of trauma on the body is independent of the site's geographic location.

This hypothesis is tested by dividing the Neandertal sites by geographic location into European sites (Krapina, La Ferrassie, La Chapelle-aux-Saints, La Quina, Le Moustier, Feldhofer, Šala, and St. Césaire) and Asian sites (Tabūn, Kiik Koba, Kebara, and Shanidar) and the instances of trauma into regions of the body (as discussed under the previous hypothesis).

Table 4.8 Regions of the body with trauma by continent

Region of the Body	Europe	Asia
Head	10	3
Upper Limbs	4	2
Trunk	1	4
Lower Limbs	3	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 10.4, the SAD value calculated from the observed table, for 1454 out of 10000 simulated tables, p=0.15. The whole table is consistent with the

null hypothesis that there is no difference in distribution of trauma in individual Neandertals in Europe and Asia. No individual count is significant.

D3. Hypothesis 3: Given Neandertals with trauma, the types of sites with traumatic Neandertal remains are independent of geographic location.

This hypothesis is tested by dividing the Neandertal sites with trauma by geographic location into European sites (Krapina, La Ferrassie, La Chapelle-aux-Saints, La Quina, Le Moustier, Feldhofer, and St. Césaire) and Asian sites (Tabūn, Kiik Koba, Kebara, and Shanidar) and then by the type of site (rock shelter or cave). Šala was excluded because it unclear from where the frontal was originally deposited.

Table 4.9 Type of site containing Neandertals with trauma by continent

Type of Site	Europe	Asia
Rock Shelter	5	0
Cave	2	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 7.3, the SAD value calculated from the observed table, for 199 out of 10000 simulated tables, p=0.02. Therefore, the entire table is inconsistent with the hypothesis that Neandertals with trauma were found in the same types of sites in Europe and Asia and the null hypothesis is rejected. No individual count is significant.

Although there are geological differences in the formation (and dissolution) of caves versus rock shelters, it is unclear whether there was any real functional difference between rock shelter and cave sites for the Neandertals. Except for Underdown (2006:488), who refers to rock shelter sites as “abri” and declares that the distinction is “robust enough to allow for the use of two categories,” most Neandertal researchers lump cave/rock shelters together as a single category to be meaningfully compared to open-air sites (such as Mellars 1996). It is important to note that there are no Neandertals with

trauma found at open-air sites because there is an absence of ANY organic material to be found at open-air sites (Mellars 1996:253). The absence of Neandertal remains from open-air sites probably reflects preservation issues, not the lack of mobility of old, sick or injured individuals, as is suggested by Berger and Trinkaus (1995:848-849): "Since most of our Neandertal specimens derive from rockshelter deposits, it is possible this pattern, as well as the dearth of older Neandertals in the sample is the product of a need for maintained mobility among these hominids." Other issues regarding levels of preservation and the observation of trauma in Neandertals will be analyzed and discussed in later parts of this dissertation.

The significant predominance of Neandertals with trauma found at rock shelter sites in Europe and cave in Asia might be due to differences in the geology of Europe and Asia rather than with Neandertal behavior. Further analysis of the availability of caves and rock shelters would be necessary to determine if differences were due to the differences in the habitat of Neandertals in Europe and Asia or reflect cultural or behavioral preferences.

D4. Hypothesis 4: Given Neandertals with trauma, distribution by sex is independent of geographical location.

This hypothesis is tested by dividing the Neandertal sites with trauma by geographic location into European sites (La Ferrassie, La Chapelle-aux-Saints, La Quina, Le Moustier, Feldhofer, Šala, and St. Césaire) and Asian sites (Tabūn, Kiik Koba, Kebara, and Shanidar) and then by the number of males and females found at the sites. The data from Krapina are excluded from this table because the identification of gender is very tentative on the fragments discovered at this site.

Table 4.10. Sex of Neandertals with trauma by continent

Sex	Europe	Asia
Female	3	1
Male	5	6

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 3.5, the SAD value calculated from the observed table, for 3137 out of 10000 simulated tables, p=0.31. The whole table is consistent with the null hypothesis that there is no difference in the number of males and females with trauma found in Europe versus Asia. No individual count is significant.

D5. Discussion and Summary: by chronology and geographic location

Neandertals with trauma occupy almost a 100,000 year swathe of time and a wide geographic distribution. Four hypotheses were generated about possible differences in Neandertals' trauma based on differences in geography and time.

Under the first hypothesis, the independence of time period and the regions of the body on which Neandertals experienced trauma was tested. The sample of Neandertals with trauma was divided into two groups based on whether their site dated from the earlier period (130kyr-80kyr) or the later period (80kyr-36kyr) and their trauma was divided into four regions of the body (head, upper limbs, trunk, and lower limbs). The data were found to be consistent with the null hypothesis of independence.

Under the second hypothesis, the independence of the geographic location where Neandertals remains with trauma were discovered and the regions of the body which they injured was tested. The sample of Neandertals with trauma was divided into two groups based on whether their site was located in Europe or in Asia and their trauma was divided into four regions of the body (head, upper limbs, trunk, and lower limbs). The data were found to be consistent with the null hypothesis of independence.

Under third hypothesis, the independence of the types of sites Neandertal remains with trauma were found and their geographic location was tested. At one level, this hypothesis does not even merit testing since all the Neandertal sites where trauma is found are all rock shelter/cave sites rather than open-air sites. If we are to differentiate between rock shelter and cave sites, there appear to be significant differences in the distribution of the two types of sites in Europe versus Asia (p=0.02). Functionally at a behavioral level, there appears to be little difference in whether a site is a rock shelter or a cave, according to most authors. In the next section, we will examine whether there are differences in the degree of preservation relating to differences in site type.

Under the fourth hypothesis, the independence was tested of the sex of individual Neandertals with trauma and the geographic location where they were discovered. The data were found to be consistent with the null hypothesis of independence.

Table 4.11. Results of testing hypotheses about site chronology and location for Neandertals with trauma (rejected hypotheses in bold)

Hypothesis	Outcome
Distribution of trauma on the body is independent of time period	*Consistent*
Distribution of trauma on the body is independent of a site's geographic location	*Consistent*
Types of sites with traumatic Neandertal remains are independent of geographic location	**Rejected**
Distribution by sex is independent of geographical location	*Consistent*

In summary, the only null hypothesis that was rejected was the independence of geographic location and site type. The distribution of rock shelters and caves is statistically significantly different in Europe versus Asia. There are significantly fewer rock shelters and more caves in Asia than would be predicted under the null hypothesis and significantly more rock shelters and fewer caves in Europe than would be predicted under the null hypothesis.

E. By Degree of Preservation

Another aspect of the sample of Neandertals with trauma is the degree of preservation of the remains of each individual. As discussed in Chapter II, the identification of many aspects of demographic identity (i.e. age and sex) as well as incidences of trauma depends upon the degree of preservation of the individual. In Table 4.11, the degree of preservation of each individual Neandertal with trauma is recorded. A "well preserved" Neandertal is an individual who retains over 40% of his or her skeleton. A "partially preserved" Neandertal is an individual who retains less than 40% of his or her skeleton but can still be identified as an individual and retains bones or fragments of bones from more than one region of the body. A "fragmentary" Neandertal cannot be identified as an individual skeleton and is only represented by a bone (or bones in the cases of Krapina 4 and 5) from one region of the body. Other aspects of Table 4.11 include site type (cave, rock shelter, or unknown), the sex of the individual (see Chapter III for how this was determined), and age class. Since all the Neandertal remains with trauma are adult (or almost adult), the age-at-death classes are divided into three categories: adolescent (13-20 years old), prime (20-35 years old), and old (over 35 years

old). The numbers in parentheses in the third fourth and fifth columns correspond with the numbers each individual with trauma is listed as in the second column.

From this summary table, it is possible to test a few hypotheses about possible differences in Neandertals with trauma according to their degrees of preservation. These hypotheses include the independence of preservation level to site type, the independence of preservation level to sex, the independence of preservation level to age-at-death class, and the independence of preservation level to age-at-death class by sex. All counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.12. Neandertal remains with trauma organized by degree of preservation, site type, sex, and age class (specimens in parenthesis represent numbers assigned in second column on the left i.e. "# of Individuals")

Degree of Preservation	# of Individuals	Site Type	By Sex	By Age Class (females in bold)
Well Preserved	11 1. Feldhofer 2. Kebara KHM 2 3. La Chapelle 4. La Ferrassie 1 5. La Ferrassie 2 6. Le Moustier 7. Shanidar 1 8. Shanidar 3 9. Shanidar 4 10. Shanidar 5 11. Tabūn C1	8 Cave (1,2,3,7,8,9,10, 11) 3 Rock Shelter (4,5,6) 0 Unknown	2 Female (5,11) 9 Male (1,2,3,4,6,7,8, 9,10,11) 0 Undetermin	1 Adolescent (6) 4 Prime (2,3,**5**,**11**) 6 Old (1,4,7,8,9,10)
Partially Preserved	3 1. Kiik Koba 1 2. La Quina H5 3. St. Césaire 1	1 Cave (1) 2 Rock Shelter (2,3) 0 Unknown	1 Female (2) 2 Male (1,3) 0 Undetermin	1 Adolescent (3) 1 Prime (**2**) 1 Old (1)
Fragmentary	9 1. Krapina 4 2. Krapina 5 3. Krapina 20 4. Krapina 31 5. Krapina 34.7 6. Krapina 149 7. Krapina 180 8. Krapina 188.8 9. Šala 1	0 Cave 9 Rock Shelter (1-8) 1 Unknown (9)	4 Female (*3,4,6*,9) 2 Male (*1, 2*) 3 Undetermined	1 Adolescent (**9)** ? Prime ? Old 8 Undetermined Adult

E1. Hypothesis 5: Given Neandertals with trauma, preservation level is independent of site type.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three categories of preservation (well, partial, or fragmentary) and the site at which they were found into one of two categories (cave or rock shelter). The individual from Šala was excluded from this analysis because it is unclear where the frontal was originally deposited.

Table 4.13. Level of preservation of Neandertals with trauma by site type

Level of Preservation	Cave	Rock Shelter
Well Preserved	8+++	3
Partially Preserved	1	2
Fragmentary	0---	9

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 14.8, the SAD value calculated from the observed table, for 17 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis that there is no difference in the degree of preservation according to site type and the null hypothesis is rejected. Two of the individual counts were also significant. The count of 0 instances of trauma in fragmentary remains from a cave site was significantly small at p=0.02 and the count of 8 instances of trauma in well preserved remains from a cave site was significantly big at p=0.05.

E2. Hypothesis 6: Given Neandertals with trauma, preservation level is independent of the sex of an individual's remains.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three categories of preservation (well, partial, or fragmentary) and the individuals that can be identified as male or female. The data from Krapina that could be given an attribution of sex (see Chapter III) were included.

Table 4.14. Level of preservation of Neandertals with trauma by sex

Level of Preservation	Female	Male
Well Preserved	2	9
Partially Preserved	1	2
Fragmentary	4	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 7.6, the SAD value calculated from the observed table, for 1082 out of 10000 simulated tables, p=0.11. The whole table is consistent with the null hypothesis that level of preservation of individual Neandertals with trauma is independent of the sex of the individual Neandertals with trauma. No individual count is significant.

E3. Hypothesis 7: Given Neandertals with trauma, preservation level is independent of age class.

This hypothesis is tested by dividing the individual Neandertal with trauma into one of three age-at-death classes (adolescent, prime, and old) and into two categories of preservation (well or partial). Fragmentarily preserved individuals were not included.

Table 4.15 Level of preservation of Neandertals with trauma by age-at-death class

Level of Preservation	Adolescent	Prime	Old
Well Preserved	1	4	7
Partially Preserved	1	1	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 2.4, the SAD value calculated from the observed table, for 5999 out of 10000 simulated tables, p=0.60. The whole table is consistent with the null hypothesis that level of preservation of individual Neandertals with trauma is independent of age-at-death class. No individual count is significant.

E4. Hypothesis 8: Given Neandertals with trauma, preservation level is independent of age class for both sexes.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three age-at-death classes (adolescent, prime, and old) for females and males and into two categories of preservation (well or partial). Fragmentarily preserved individuals were not included.

Table 4.16 Level of preservation of Neandertals with trauma by sex and age-at-death

Sex and Age Class	Well Preserved	Partially Preserved
Female Adolescent	0	0
Female Prime	2	1
Female Old	0	0
Male Adolescent	1	1
Male Prime	2	0
Male Old	7	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 4.0, the SAD value calculated from the observed table, for 3470 out of 10000 simulated tables, p=0.35. The whole table is consistent with the null hypothesis that level of preservation of individual Neandertals with trauma is independent of age-at-death class. No individual count is significant.

E5. Discussion and Summary: by degree of preservation

In this section, aspects of Neandertals with trauma were analyzed from the perspective of their degree of preservation. Each individual was put in one of three categories according to the level of preservation of his or her skeleton. “Well preserved” Neandertals retained over 40% of their skeleton, “partially preserved” Neandertals retained less than 40% of their skeleton but could still be identified as an individual and retained elements or fragments from more than one region of the body, and “fragmentary” Neandertals were only represented by a single bone, a fragment, or more

than one bone but from the same region of the body (e.g. the cranial remains of Krapina 4 and 5).

Under the fifth hypothesis, the independence was tested of preservation levels of Neandertals with trauma and the type of site at which they were found. The sample of Neandertals with trauma was divided into three groups based on their level of preservation and into two groups (cave or rock shelter) based on where the individual was discovered. The data were found to be inconsistent with the null hypothesis of independence (p=0.00) and the hypothesis was rejected.

Under the sixth hypothesis, the independence was tested of the preservation level of Neandertals with trauma and the sex of an individual's remains. The sample of Neandertals with trauma were divided into three groups based on their level of preservation and into two groups (female or male) based on various attributions of sex. The data were found to be consistent with the null hypothesis that level of preservation of individual Neandertals with trauma is independent of the sex of the individual Neandertals with trauma.

Under the seventh hypothesis, the independence was tested of the preservation level and the age-at-death class for Neandertals with trauma. The sample of Neandertals with trauma was divided into three groups based on their level of preservation and into one of three age-at-death classes depending upon previous attributions of age. The data were found to be consistent with the null hypothesis at p=0.60 under SAD. The whole table is consistent with the null hypothesis that level of preservation of individual Neandertals with trauma is independent of their age-at-death class.

Under the eighth hypothesis, the independence was tested of the preservation level and the age-at-death class for both sexes of Neandertals with trauma. The sample of Neandertals with trauma was divided into three groups based on their level of preservation and into one of six classes of age-at-death for males and females depending upon previous attributions of sex and age. The data were found to be consistent with the null hypothesis at p=0.35 that level of preservation of individual Neandertals with trauma is independent of their age-at-death class.

Table 4.17 Results of testing hypotheses about preservation for Neandertals with trauma

Hypothesis	Outcome
Preservation level is independent of site type	**Rejected**
Preservation level is independent of the sex of an individual's remains	*Consistent*
Preservation level is independent of age class	*Consistent*
Preservation level is independent of age class for both sexes	*Consistent*

According to this analysis, Neandertals with trauma appear to be better preserved in caves than in rock shelters. From a taphonomic perspective, this makes a certain amount of sense because, generally, caves are more likely to be less vulnerable to erosion and other natural forces than rock shelters and the skeletal elements of an individual are more likely to remain intact. However, it is possible that other factors involving human (by which I mean both "modern" and Neandertal) agency might also be a factor in levels of preservation.

Grave issues: burial and preservation

One question that might follow from these results is whether the significant presence of well-preserved Neandertals with trauma in caves is due to the excellence of caves at preserving bone or because some Neandertals purposefully buried their dead in caves.

There has been a great deal of debate around how to define deliberate burial and whether Neandertals practiced it. Traditionally, some of the ways deliberate burial has been defined included completeness and degree of articulation of the skeleton (McCown and Keith 1939, Binford 1968, Trinkaus 1985), the presence of grave goods (Movius 1953, Bonifay 1962, Leroi-Gourhan 1975), and the position of the skeleton in a way construed as "symbolic" such as fetal position or facing the sunrise or sunset, etc. (Peyrony 1934, Smirnov 1989). More recently, there has been much questioning whether some of these definitions of deliberate burial were actually not representative of deliberate human agency. Chase and Dibble (1987) and Lindly and Clark (1990) questioned the presence of "grave goods" as instead being objects accidently incorporated at the time of interment into the grave infilling. Gargett (1989 and 1999) confronts the "pre-1960s discipline-wide naïveté" (1989:177) by discussing geological perturbations that explain away the "burials" as the result of natural phenomena at La Chapelle-aux-Saints, Le Moustier, La Ferrassie, Teshik-Tash, Regourdou, Shanidar, Qafzeh, Saint Césaire, Kebara, Amud and Dederiyeh. However, the comments attached to Gargett (1989) refute his arguments about the lack of deliberate burials at La Ferrassie (Bricker 1989), La Chapelle-aux-Saints (Frayer and Montet-White 1989), and Shanidar IV (Leroi-Gourhan 1989). Mellars (1996) is similarly unenthusiastic about Gargett's

(1989) arguments and Belfer-Cohen and Hovers (1992) discuss whether Upper Paleolithic burials in the Levant would be similarly dismissed by Gargett. In his later paper, Gargett (1999:46) defines several aspects of what he considers purposeful burial, the protection of the corpse (evidenced by artificial stratum containing the remains that was created at the time of interment, rather than simply the presence of a depression into which the corpse is placed), and the complete and articulated individual skeletons (also necessary but not definitive of purposeful burial), but remains vague about other aspects because "each case is unique."

In order to address the question of whether there is any correlation between well preserved Neandertals with trauma and burial and/or caves and burial, it is first necessary to address which individuals scholars have hypothesized to have been buried. Ideally, the qualifications of a site being defined as a burial should include other aspects besides a high level of preservation. However, this is sometimes not the case (as in Trinkaus 1985) but there is a potential for circular arguments if one is trying to look at the relationship between site preservation and burial. Gargett (1999) does not recognize any of the Middle Paleolithic interments as purposeful burials but he includes a list of 32 "claimed" MP burials (Qafzeh is included, Skhūl is not). Smirnov (1989) includes 46 "Mousterian" burials (he includes all the specimens from Skhūl). Trinkaus (1985:211) only includes adult individuals for his "Neanderthal burial sample" and also excludes Neandertal 1 (Feldhofer), Régourdou, and Saint Césaire because of "obvious biases in skeletal part recovery when discovered" and "insufficient data." Harrold (1980) includes 36 "Middle Paleolithic" burials in his study (juveniles and individuals from Skhūl and Qafzeh are included however, Saint Césaire and Kebara 2 are not, probably because these sites were

not well published or published at all; also only four individuals from Shanidar (4, 6-8) are included).

The Neandertals with trauma that appear on all or most of these "burial lists" include: La Chapelle-aux-Saints, La Ferrassie 1 and 2, Le Moustier 1, Kiik Koba 1, Tabūn C1, Shanidar 4, St. Césaire and Kebara KHM 2. These break down in terms of preservation levels as follows:

Table 4.18. Neandertals with trauma, level of preservation and burial status (the numbers in parentheses represent the inclusion of all the Shanidar remains into the "buried" category)

Level of Preservation	Buried	Not Buried
Well Preserved	7 (10)	4 (1)
Partially Preserved	2	1

The outcome is consistent with the hypothesis of independence of preservation level and burial status for Neandertals with trauma at p= 0.93 (Shanidar 1,3,5 not counted as burial) and p=0.29 (counted). No individual count is significant. It made little difference whether or not all the Shanidar remains were counted as burials.

Other tests (not shown) of independence of burial status and site type, sex, and age also failed to reject the null hypothesis or yield any trends. Therefore, it appears that burial status has little to do with preservation levels for Neandertals with trauma. However, when one examines this question with the fragmentarily Neandertal remains presenting trauma, the picture is less clear.

All of the fragmentary remains of Neandertals with trauma, except for the Šala 1 frontal, were discovered at Krapina. Therefore it is important to review what is understood about the site formation process at Krapina. The short summary of Krapina site formation below suggests that human agency has been a factor at this site.

The Krapina site was recognized by Gorjanović-Kramberger when he went to investigate the place from which he had been sent some fossil mammal fragments that were found in the sand that the local inhabitants used for building purposes (Radovčić 1988). Though it is unclear how much perturbation and fragmentation at Krapina is due to this exploitation of sand from the site, it does appear that some of the fragmentation was due to Neandertal agency. Over the past hundred-plus years, several hypotheses have been offered to explain the distribution of remains over the Krapina site. These include: Krapina as regularly occupied living site (Gorjanović-Kramberger 1899, 1906, 1913; Malez 1970, 1978); Krapina as the site of cannibalism and/or massacre (Gorjanović-Kramberger 1901, 1906, 1909; Škerlj 1939, 1958; Tomić-Karović 1970; Chiarelli 2004); Krapina as a death trap for a group of run-away juveniles (Bocquet-Appell and Arsuaga 1999); Krapina as a site of purposeful burial (Trinkaus 1985); and Krapina as a secondary burial site following mortuary rites (Russell 1987a and 1987b, Ullrich 2006), or some combination of the above. Ullrich (2006:506) summarizes Gorjanović-Kramberger's initial excavation notes: "He also pointed out that skull fragments have never been discovered in connection with postcranial remains of the same individual and postcranial remains were never found in anatomical connections or anatomical positions." The high level of fragmentation and lack of articulation precludes it by some definitions as a site of purposeful burial. Studies of the anatomical distributions of the fragments at Krapina, such as Trinkaus (1985) and Van Arsdale (2007), appear to reach radically different conclusions about the random nature of the preservation of various elements at Krapina.

Because of the size of the Krapina collection and the scrutiny it has received by scholars, it is unclear whether its formation process as a site full of fragmentary

Neandertals remains is unique in the Middle Paleolithic or whether other sites with fragmentary Neandertal remains, such as Hortus, are the results of similar mortuary practices but have yet to be reviewed. However, most discussions of the Krapina remains involve the idea that this assemblage represents some degree of deliberate contemporary Neandertal behavior [except for Bocquet-Appell and Arsuaga (1999) and Van Arsdale (2007)]. For the purposes of analysis, let us assume that the sample from Krapina represents the results of some deliberate action on the part of friends and relatives, a.k.a. "a burial." The resulting table testing the relationship between degree of preservation and burial would look like this:

Table 4.19. Neandertals with trauma, level of preservation and burial status (the numbers in parentheses represent the inclusion of all the Shanidar remains into the "buried" category)

Level of Preservation	Buried	Not Buried
Well Preserved	7 (10)	4 (1) +
Partially Preserved	2	1
Fragmentary	8	0

The outcome was consistent with the hypothesis of independence of preservation level and burial status for Neandertals with trauma at p= 0.09 (Shanidar 1,3,5 not counted as burial) and p=0.40 (counted). This time, it made slightly, but not significantly, more difference whether or not all the Shanidar remains were counted as burials.

However, if the individuals with trauma at Krapina are not viewed as intentionally buried, the relationship between burial and preservation status becomes quite statistically significantly clear.

Table 4.20. Neandertals with trauma, level of preservation and burial status

Level of Preservation	Buried	Not Buried
Well Preserved	7 ++ (10+++)	4 -- (1---)
Partially Preserved	2	1
Fragmentary	0 ---	8 +++

The outcome is completely inconsistent with the hypothesis of independence of preservation level and burial status for Neandertals with trauma at p= 0.01 (Shanidar 1, 3, 5 not counted as burial) and p=0.00 (Shanidar 1, 3, 5 counted). One of the lessons of this comparison is that when sample sizes are very small, one site may have considerable statistical weight. The second lesson is that outcome of circular reasoning is often statistically significant (i.e. had the burial status of the samples with trauma been decided by their degree of preservation and articulation) and one must be vigilant to not get trapped. The third lesson is that Krapina is a very important site who depositional processes are not well understood. And, finally, it might be valuable to examine the relationship between individuals with trauma, burial status and preservation level in other ways (see Chapter V).

In summary, in this section four hypotheses were tested to address possible differences in Neandertals with trauma based on their degree of preservation. The only null hypothesis that was rejected was the independence of preservation level and site type. There were significantly more well preserved Neandertal remains with trauma found in caves and fewer found in rock shelters than would be predicted under the null hypothesis, and significantly fewer fragmentary remains found in caves and more found in rock shelters than would be predicted under the null hypothesis. However, these results do not seem to be well explained by differences in deliberate burial versus lack of burial.

F. By Distribution of Injury throughout the Regions of the Body

Another aspect of the sample of Neandertals with trauma is the pattern of injury occurrence over the body. Because the sample of Neandertals with trauma is so small, it is necessary to compress the categories of individual bones of the body into six regions.

Although this represents a grosser measure of the anatomical distribution of trauma in Neandertals, the larger numbers make trends a bit easier to discern, as previously discussed in section D1.

These regions of the body are head, trunk, arms, hands, legs and feet. “Head” is defined as cranium and mandible. “Trunk” is defined as vertebrae, ribs, sternum and pelvis. These first two categories are somewhat different from Berger and Trinkaus’ (1995) body categories in that cervical vertebra are included in the “trunk” category and not the “head” category and the pelvis is included in the “trunk” category rather than being its own category. However, since trauma in Neandertals has not been found in the cervical vertebrae or pelvis, it is a somewhat moot point where these bones are included but injuries to the neck seem more similar in etiology to injuries to the trunk of the body than to the head. “Arms” are defined as clavicle, scapula, humerus, radius and ulna, “legs” are femur, patella, tibia and fibula, and “hands” and “feet” are, of course, the bones of the hands and feet.

The summary table, Table 4.21, lists the body regions, the individual bones with injuries, the number of injuries and the age and sex of the injured individuals along with their site identification numbers. From this summary table, it is possible to test a few hypotheses about possible differences in Neandertals with trauma according to their pattern of injury occurrence over the body. These hypotheses include the independence of injured body region to sex, the independence of injured body region to age-at-death class, the independence of injured body region to age-at-death class by sex, and the independence of injured body region to preservation level. All counts were entered into ACTUS2 tables and tested for independence using the program’s frequency simulation

("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.21 Neandertal Injuries by body region, bone, number of injuries, and age and sex

Body Region	Bone	Number of Injuries	Sex and Age of Injured Individual
	Frontal	7	1 Unknown Adult Male: Krapina 4 2 Unknown Adult Fem: Krapina 20, 31 1 Female (?)-Ad: Šala 1 Male-Adolesc: St. Césaire 2 Male-Old: Shanidar 1 and 5
	Parietal	3	1 Unknown Adult: Krapina 34.7 1 Unknown Male: Krapina 5 1 Male-Adolesc: St. Césaire
	Occipital	1	1 Male-Old: Feldhofer 1
	Zygomatic	1	1 Male-Old: Shanidar 1
	Mandible	1	1 Male-Adolesc: Le Moustier 1
Total for Head		***13***	
	Vertebrae	2-Thoracic	1 Male-Prime: Kebara KMH 2
	Ribs	3	1 Male-Prime: La Chapelle 2 Male-Old: Shanidar 3 and 4
Total for Trunk		***5***	
	Clavicle	1	Unknown Adult: Krapina 149
	Humerus	3	1 Female-Prime: La Quina H5 1 Male-Old: Shanidar 1
	Ulna	3	2 Unknown Adults: Krapina 180, 188.8 1 Male-Old: Feldhofer 1
Total for Arms		***7***	
Total for Hand	Metacarpal	***1***	1 Male-Prime: Kebara KMH 2
	Femur	1	1 Male-Old: La Ferrassie 1
	Fibula	2	1 Female-Prime: Tabūn C1 1 Female-Prime: La Ferrassie 2
Total for Legs		***3***	
	Metatarsal	1	1 Male-Old: Shanidar 1
	Phalanx	1	1 Male-Old: Kiik Koba 1
Total for Feet		***2***	

F1. Hypothesis 9: Given Neandertals with trauma, sex is independent of the injured body region.

This hypothesis is tested by dividing the individual Neandertals with trauma by sex into females, males and unidentified, and by the body region (head, trunk, arm, hand, leg, or foot) exhibiting injury. Although attributions of sex have been made for some of the Krapina specimens, in this case they have been put into the "unidentified adult" column because these attributions are not nearly so firm as for the other individuals in the sample of Neandertals with trauma.

Table 4.22 Body region injured in Neandertals with trauma by sex

Region	Unidentified Adult	Female	Male
Head	5	1	7
Trunk	0	0	5
Arms	3	1	3
Hand	0	0	1
Leg	0	2+++	1
Foot	0	0	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 15.3, the SAD value calculated from the observed table, for 728 out of 10000 simulated tables, p=0.07. The whole table is consistent with the null hypothesis that sex is independent of injured body region. The count of 2 instances of leg injuries in females was significantly larger than expected (p=0.05).

When some of the Krapina data that have been given a sex attribution (Krapina 4,5,20, 31 and 149) are added to the male and female columns and the "unidentified adult" column was eliminated, the null hypothesis of independence of the distribution of trauma throughout the body and sex was not rejected (p=0.35) and the 2 instances of leg trauma were no longer found to be significant.

F2. Hypothesis 10: Given Neandertals with trauma, age class is independent of the injured body region.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three age-at-death classes (adolescent, prime, and old) and by the body region (head, trunk, arm, hand, leg, or foot) exhibiting injury. The data from Krapina have not been included in this table because of the lack of an age attribution.

Table 4.23 Body region injured in Neandertals by age class

Region	Adolescent	Prime	Old
Head	4+++	0	4
Trunk	0	3	2
Arms	0	1	3
Hands	0	1	0
Legs	0	2	1
Foot	0	0	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 15.5, the SAD value calculated from the observed table, for 248 out of 10000 simulated tables, p=0.02. The whole table is inconsistent with the null hypothesis that age class is independent of injured body region and the null hypothesis is rejected. The count of 4 instances of adolescent head trauma was significantly bigger than expected (p=0.05).

F3. Hypothesis 11: Given Neandertals with trauma, age class and sex are independent of the injured body region.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three age-at-death classes (adolescent, prime, and old) for females, males and unidentified individuals, and by the body region (head, trunk, arm, hand, leg, or foot) exhibiting injury.

Table 4.24. Body region injured in Neandertals with trauma by age and sex

Region	UnID Adult	Female Adolesc	Female Prime	Female Old	Male Adolesc	Male Prime	Male Old
Head	5	1	0	0	3	0	4
Trunk	0	0	0	0	0	3+++	2
Arms	3	0	1	0	0	0	3
Hand	0	0	0	0	0	1	0
Leg	0	0	2+++	0	0	0	1
Foot	0	0	0	0	0	0	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 24.0, the SAD value calculated from the observed table, for 162 out of 10000 simulated tables, p=0.02. The whole table is inconsistent with the null hypothesis that age and sex are independent of injured body region, and the null hypothesis is rejected. The counts of 3 trunk injuries in prime age males (p=0.03) and 2 leg injuries in prime age females (p=0.04) were significantly bigger counts than expected.

When all of the individuals from Krapina were eliminated, the null hypothesis of independence was still rejected (p=0.02) and the trends were mostly in the same places as in the previous trial. The 2 instances of prime female leg trauma (p=0.05) and the 3 instances of prime male trunk trauma (p=0.05) were still significantly bigger counts than expected.

F4. Hypothesis 12: Given Neandertals with trauma, degree of preservation is independent of the injured body region.

This hypothesis is tested by dividing the individual Neandertals with trauma into one of three states of preservation level (well preserved, partially preserved, or fragmentary) and by the body region (head, trunk, arm, hand, leg, or foot) exhibiting injury.

Table 4.25 Body region injured in Neandertals by degree of preservation

Region	Well Preserved	Partially Preserved	Fragmentary
Head	5	2	6
Trunk	5	0	0
Arms	3	1	3
Hands	1	0	0
Legs	3	0	0
Foot	1	1	0

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 16.3, the SAD value calculated from the observed table, for 494 out of 10000 simulated tables, p=0.05. The whole table is inconsistent with the null hypothesis that body region with trauma is independent of the preservation status of individual Neandertals, and the null hypothesis is rejected. No individual count is significant.

F5. Discussion and Summary: by body region

In this section, aspects of Neandertals with trauma were analyzed from the perspective of the distribution of injury throughout the regions of their bodies. Each incidence of trauma was put into one of six categories according to where on the body the injury occurred. These categories were Head, Trunk, Arms, Hands, Legs, and Feet.

Under the ninth hypothesis, the independence was tested of the distribution of injury throughout the body and the sex of an individual's remains. The sample of Neandertals with trauma was divided into three groups (female, male or sex unknown) based on various attributions of sex, and each incidence of injury was divided into one of six groups based on where in the body it occurred. The data were found to be consistent with the null hypothesis at p=0.07. The whole table is consistent with the null hypothesis that distribution of injury throughout the body is independent of the sex for the individual

Neandertals with trauma. There was one statistically significantly large count in this table which was the 2 instances of leg injuries in females (p=0.05).

Under the tenth hypothesis, the independence was tested of the distribution of injury throughout the body and the individual's age-at-death class. The sample of Neandertals with trauma was divided into three groups (adolescent, prime and old) based on various attributions of age at death, and each incidence of injury was divided into one of six groups based on where in the body it occurred. The data were found to be inconsistent with the null hypothesis of independence (p=0.02 under SAD) and the hypothesis was rejected.

Under the eleventh hypothesis, the independence was tested of the distribution of injury throughout the body and the individual's age-at-death class for males and females. The sample of Neandertals with trauma were divided into one of three age-at-death classes (adolescent, prime, and old) for females, males and unidentified individuals, and their injuries were divided into six categories according to the body region (head, trunk, arm, hand, leg, or foot) exhibiting injury. The data were found to be inconsistent with the null hypothesis of independence (p=0.02) and the hypothesis was rejected. When the sample from Krapina was removed, the data were still inconsistent with the null hypothesis (p=0.02).

Under the twelfth hypothesis, the independence was tested of the distribution of injury throughout the body and the level of preservation of the individual Neandertals with trauma. The sample of Neandertals with trauma was divided into one of three states of preservation level (well preserved, partially preserved, or fragmentary) and by the

body region (head, trunk, arm, hand, leg, or foot) exhibiting injury. The data were found to be inconsistent with the null hypothesis of independence was rejected (p=0.05).

Table 4.26 Results of testing hypotheses about distribution of trauma throughout the body for Neandertals with trauma (rejected hypotheses in bold)

Hypothesis	Outcome
Sex is independent of the injured body region *A. With Krapina sample as "unidentified"* *B. With some of Krapina sample given attribution* *C. Krapina sample excluded*	*Consistent*
Distribution of trauma on the body is independent of age class	**Rejected**
Distribution of trauma on the body is independent of Age class for both sexes	**Rejected**
Distribution of trauma on the body is independent of level of preservation	**Rejected**

Three out of the four hypotheses that were tested about the distribution of injury throughout the bodies of Neandertals with trauma were rejected. Distribution of injuries is not independent of age class, of age class for each sex, of level of preservation.

Trunk

Recovery of bones of the trunk differs most greatly between sites because many of these bones are likely to be very fragmentary and/or hard to identify (see Chapter II for explanation). Every instance of trauma to the trunk was observed in well-preserved individuals. The count of 3 instances of prime males with trunk trauma was significant at (p=0.03). Since the null hypothesis of preservation being independent of age and sex of the individual was not rejected and there were no trends, a relationship between the preservation of prime males and their rib trauma cannot be statistically inferred. Although

it is probable that degree of preservation probably plays a larger role in the preservation and recovery of trunk trauma than can be explained by these results (4/5 trunk traumas came from 2 well preserved sites), the lack of evidence of trunk trauma for any females, fragmentary adults, and younger males may also warrant other explanations that involve differences in behavior. The etiology of these injuries does not seem to point to a common cause: one individual injured two vertebrae (see Chapter III for the discussion of the reporting of trauma in Kebara KMH 2); two individuals had minor rib fractures (one near the angle and one near the costal cartilage) and one had a groove perhaps produced by being stabbed (Shanidar 3).

Legs

Leg trauma was observed only in well preserved individuals and it was the only place where well preserved females (all 2 of them) showed sign of injury. Although not significant in any way, there was also one instance of leg injury (femur) to an older male. Although the fibular injury to La Ferrassie 2 was well documented in the literature, the fibular injury to Tabūn C1 is only reported in Berger and Trinkaus (1995) and not in any of the site summaries by Garrod or McCown and Keith. The fact that the only two well preserved females both showed trauma in the sample place was found to be significant or a trend in each of the analyses. The real significance of this is unclear, especially outside the context of fibular preservation in general for Neandertals of either gender. However, it does seem to directly contradict Berger and Trinkaus' (1995:849) claim that there is an "absence of incapacitating lower limb injuries" and that "these hominids did not sacrifice the survival of the social group as a whole when it was threatened by an immobile

individual." Fibular injury is most often associated with fall or stepping onto uneven surfaces (see Chapter II), so it is likely these women were moving

In summary, the hypotheses of independence of the distribution of trauma throughout the body and the individual's age-at-death class and age-at-death class along with sex, and level of preservation of the remains were rejected. The hypothesis of independence of the distribution of trauma throughout the body and the sex of the individual was not rejected. Counts of prime male trunk trauma and prime female leg trauma were significantly higher than expected. However, because these results are only in the context of the distribution of trauma over the bones exhibiting trauma, the prevalence of trauma does not address its frequency within the total population of Neandertals or its context over all the bones that are preserved. These results only address significance in the distribution of trauma over the bones that have trauma.

G. By Side of the Body Injured

Another aspect of the sample of Neandertals with trauma is the pattern of injury occurrence over the sides of the body. The sample of Neandertal with trauma is divided according to the side where the trauma occurs. Some individuals have been excluded because of lack of identification in the literature of the side were the injury occurred, such as St. Césaire and Tabūn 1, or because the injuries are on the midline, such as Feldhofer 1 and Kebara KMH2.

The summary table, Table 4.27, lists the number of injuries and the individuals by the side where the trauma occurred, as well as by body region as defined in the previous section. From this summary table, it is possible to test a few hypotheses about possible differences in Neandertals with trauma according to their pattern of injury occurrence

over the two sides of the body. These hypotheses include the independence of the side of injury to the body region injured, the independence of the side of injury to age-at-death class, and the independence of side of injury to sex. All counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.27. By side, number of individual Neandertals with trauma, number of injuries, and number of injuries by body region (numbers in parentheses denote order of specimens in second column to the left)

Side	# of Individuals	# of Injuries	# Injuries by Region
Right	11 *1. La Chapelle* *2. Krapina 180* *3. Krapina 149* *4. Krapina 34.7* *5. La Ferrassie 1* *6. La Ferrassie 2* *7. Šala 1* *8. Shanidar 1* *9. Shanidar 4* *10. Kiik Koba 1* *11. Le Moustier 1*	14 *Frontal (7,8)* *Parietal (4)* *Mandible (11)* *Humerus (8)* *Ulna (2)* *Clavicle (3, 10)* *Rib (1,9)* *Femur (5)* *Fibula (6)* *Metatarsal (8)* *Pedal Phalanx (10)*	4 Head 4 Arm 0 Hand 2 Trunk 2 Leg 2 Foot
Left	11 *1. Feldhofer 1* *2. Krapina 188.8* *3. Krapina 5* *4. Krapina 20* *5. Krapina 31* *6. La Quina H5* *7. Kebara KMH 2* *8. Shanidar 1* *9. Shanidar 3* *10. Shanidar 5* *11. Krapina 4*	12 *Frontal (4,5,8,10,11)* *Parietal (3)* *Zygomatic (8)* *Humerus (6)* *Ulna (1,2)* *Metacarpal (7)* *Rib (9)*	7 Head 3 Arm 1 Hand 1 Trunk 0 Leg 0 Foot

G1. Hypothesis 13: Given Neandertals with trauma, distribution of trauma throughout the body is independent of side.

This hypothesis is tested by dividing the incidents of Neandertal trauma into one of six regions of the body where the injury is located (head, trunk, arm, hand, leg, and foot) and by the side of the body (right or left) where the injury is located. Only injuries to which a side could be attributed were used for this data table. St. Césaire 1 and Tabūn 1 were excluded because of lack of side identification and the occipital injury of Feldhofer 1 and the thoracic vertebral injury of Kebara KMH 2 were excluded because the injuries are on the midline.

Table 4.28. Body regions with trauma in Neandertals by side

Body Region	Right	Left
Head	4	7
Arm	4	3
Hand	0	1
Trunk	2	1
Leg	2	0
Foot	2	0

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 9.85, the SAD value calculated from the observed table, for 2242 out of 10000 simulated tables, p=0.22. The whole table is consistent with the null hypothesis of independence of body region with trauma and side. No individual count is significant.

When the categories of hand and foot where subsumed under “upper limb” and “lower limb” respectively, the null hypothesis was still not rejected.

G2. Hypothesis 14: Given Neandertals with trauma, sex of individuals is independent to side where injury occurred.

This hypothesis is tested by dividing the incidents of Neandertal trauma into the side of the body (right or left) where the injury is located and the individuals to whom

trauma occurred by sex. This data table includes injuries to which a side could be attributed and individuals to whom a sex could be attributed. St. Césaire 1 and Tabūn 1 were excluded because of lack of side identification, the occipital injury of Feldhofer 1 and the thoracic vertebral injury of Kebara KMH 2 were excluded because the injuries are on the midline, and the injuries of Krapina 34.7, 149, 180 and 188 were excluded because a sex could not be attributed to these specimens.

Table 4.29 Sex of Neandertals with trauma by side of injury

Side of Injury	Female	Male
Right	3	6
Left	2	7

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 2.0, the SAD value calculated from the observed table, for 6198 out of 10000 simulated tables, p=0.62. The whole table is consistent with the null hypothesis of independence of the sex of Neandertals with trauma and the side of their injuries. No individual count is significant.

G3. Hypothesis 15: Given Neandertals with trauma, age-at-death class is independent to side of injury.

This hypothesis is tested by dividing the incidents of Neandertal trauma into the side of the body (right or left) where the injury is located and the individuals to whom trauma occurred by age-at-death class. This data table includes injuries to which a side could be attributed and individuals to whom a sex could be attributed. St. Césaire 1 and Tabūn 1 were excluded because of lack of side identification; the occipital injury of Feldhofer 1 and the thoracic vertebral injury of Kebara KMH 2 were excluded because the injuries are on the midline; and the injuries of Krapina specimens to whom an age-at-death class could not be attributed.

Table 4.30 Age-at-death class by side of injury

Age Class	Right	Left
Adolescent	2	0
Prime Adult	2	2
Old Adult	6	5

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 3.29, the SAD value calculated from the observed table, for 5545 out of 10000 simulated tables, p=0.55. The whole table is consistent with the null hypothesis of independence of the age-at-death class of Neandertals with trauma and the side of their injuries. No individual count is significant.

G4. Discussion and Summary: by side

In this section, aspects of Neandertals with trauma were analyzed from the perspective of the distribution of injury between the two sides of the body. Each incidence of trauma was put into one of two categories according to where on the body the injury occurred: left and right.

Under the thirteenth hypothesis, the independence was tested of the side of injury and the distribution of injury throughout the body. The injuries were divided up according to side and then by the six regions of the body on which they occurred (head, trunk, arms, legs, and feet). The data were found to be consistent with the null hypothesis at p=0.22.

Under the fourteenth hypothesis, the independence was tested of the side of injury and the distribution of injury by sex of the individual. The injuries were divided up according to side and then by sex to individuals to whom a gender could be attributed. The data were found to be consistent with the null hypothesis at p=0.62. The whole table

was found to be consistent with the null hypothesis of independence of the sex of Neandertals with trauma and the side of their injuries.

Under the fifteenth hypothesis, the independence was tested of the side of injury and the distribution of injury to individuals according to age. The injuries were divided up according to side and then by age-at-death class into one of three categories (adolescent, prime and old) for individuals to whom an approximate age could be attributed. The data were found to be consistent with the null hypothesis at p=0.55. The whole table was found to be consistent with the null hypothesis of independence of the sex of Neandertals with trauma and the side of their injuries.

Table 4.31. Results of testing hypotheses about distribution of trauma by side of the body for Neandertals with trauma

Hypothesis	Outcome
Distribution of trauma on the body is independent of side of injury	*Consistent*
Sex is independent to side of injury	*Consistent*
Age at death class is independent to side of injury	*Consistent*

In summary, under all the hypotheses, the independence of side of injury to the distribution of trauma on the body, and the age and sex of individuals with trauma was not rejected. There is no statistical support for arguments of preferential siding of injury.

H. By Severity of Injury

Another aspect of the sample of Neandertals with trauma is the distribution of the severity of their injuries. Looking at patterns of trauma in this way seldom occurs within the paleopathological literature when looking at groups rather than describing the injuries of a single individual. However, because there the sample of Neandertals with trauma is small but fairly well documented, it is possible to examine each incidence of injury in

some detail and put them into a context based on the functional severity of the area of the body injured and the gravity of the injury. I have created five rough categories ("degrees" such as burns where higher numbers mean increased severity) to describe severity of injury.

First degree injuries involve non-incapacitating trauma to postcranial skeleton. These are injuries that are least likely to affect the mobility of an individual or involve any injury to the brain. They include injuries to the upper limbs, as well as some of the ribs and vertebrae that have been deemed well healed and without functional consequences. The mandibular condyle injury is included in this category because this injury does not affect mobility, although for a time it would influence the individual's ability to chew.

Second degree injuries may not even be so problematic to their sufferers as first degree injuries, but these involve the cranium so there is always the possibility of some loss of consciousness or mental impairment resulting from any head injury. All of these cranial injuries are either small cranial depression fractures involving only the outer table or some other superficial periosteal reaction.

Third degree injuries are serious and/or incapacitating injuries to the postcranial skeleton where the individual survived long after. These include any fracture to the leg or foot (although the inclusion of the Kiik Koba 5th pedal phalanx in this category rather than in the first degree category is debatable given the lack of severity of such an injury). This also includes the Krapina 180 ulna which is either a pseudoarthrosis or represents an amputation because the consequences of this injury endured long after it healed and would have slightly incapacitated this individual throughout his/her lifetime.

Fourth degree and fifth degree injuries are the most severe. Fourth degree injuries represent serious cranial trauma such as penetrating scalp wounds or crushing fractures to the side of the head which probably involved the loss of consciousness. Fifth degree injuries are defined as trauma that contributed as a direct cause of death. It is possible that many of the fourth degree injuries also contributed to the weakening of the individuals and were indirect causes of death, however all fourth degree injuries show some sign of healing.

This framework is unique to this dissertation; therefore comparisons cannot be made between the distributions of the severity of trauma in Neandertals with distributions of severity of trauma in other groups because most published work only reports the distribution of trauma over bones of the body and/or gives specific details for only the most severe injuries. This makes it difficult to examine the context of this distribution of trauma in any broader way. Moreover it is not possible to address the significance of the distribution of these levels of trauma throughout the body because these levels are defined, in part, by the affected part of the body.

The summary table, Table 4.32, lists the number of injuries and the individuals by the degree of severity of their trauma, as by sex and age-at-death class. From this summary table, it is possible to test a couple hypotheses about possible differences in Neandertals with trauma according to the degree of severity of their trauma. These hypotheses include the independence of the degree of severity of trauma to the sex and to the age at death of the individual. All counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation")

methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.32. Neandertals with trauma by degree severity of injury (numbers in parentheses denote order of specimens in second column to the left)

Degree of Severity	# of Individuals	# of Trauma	By Age Class	By Sex
First Degree *Non-incapacitating trauma to postcranial skeleton*	9 *1. Feldhofer 1* *2. La Chapelle* *3. Krapina 149* *4. Krapina 188.8* *5. La Quina H5* *6. Shanidar 1* *7. Shanidar 4* *8. Kebara KHM 2* *9. Le Moustier 1*	12 *Mandible (9)* *Humerus (5,6)* *Ulna (1,4)* *Metacarpal (8)* *Clavicle (3,6)* *Rib (2,7)* *Vertebra (8)*	1 Adolescent (9) 2 Prime(2,5) 4 Old (1,6,7,8)	2 Female (3,5) 6 Male (1,2,6,7,8,9)
Second Degree *Minor cranial trauma*	8 *1. Feldhofer 1* *2. Krapina 4* *3. Krapina 5* *4. Krapina 20* *5. Krapina 31* *6. Šala 1* *7. Shanidar 1* *8. Shanidar 5*	8 *Frontal (2,4, 5,6,7,8)* *Parietal (3)* *Occipital (1)*	1 Adolescent (6) 0 Prime 3 Old (1,7,8)	3 Female (4,5,6) 5 Male (1,2,3,7,8)
Third Degree *Incapacitating trauma to the postcranial skeleton or putative amputation*	5 *1. Krapina 180* *2. Tabūn 1* *3. La Ferrassie 1* *4. La Ferrassie 2* *5. Kiik Koba* *6. Shanidar 1*	5 *Ulna (1)* *Femur (3)* *Fibula (2,4)* *5th Metatarsal (6)* *Pedal Phalanx (5)*	0 Adolescent 2 Prime (2,4) 2 Old (3, 5)	2 Female (2,4) 2 Male (3,5,6)
Fourth Degree *Major cranial trauma-probably involving a loss of consciousness*	3 *1. Krapina 34.7* *2. Shanidar 1* *3. St. Césaire*	5 *Frontal (2,3)* *Parietal (1,3)* *Zygomatic (2)*	1 Adolescent (3) 0 Prime 1 Old (2)	0 Female 2 Male (2,3)
Fifth Degree *Fatal trauma*	1 *1. Shanidar 3*	1 *Rib*	0 Adolescent 0 Prime 1 Old (1)	0 Female 1 Male (1)

H1. Hypothesis 16: Given Neandertals with trauma, severity of injury is independent of age-at-death class.

This hypothesis is tested by dividing incidents of trauma into one of five degrees of injury and individual Neandertals with trauma into one of three age-at-death classes. This data table includes only individuals to whom an age-at-death class can be attributed (i.e. the Krapina remains have been excluded).

Table 4.33 Degree of severity of trauma by age class

Degree of Trauma	Adolescent	Prime	Old
1st Degree	1	2	4
2nd Degree	1	0	3
3rd Degree	0	2	2
4th Degree	1	0	1
5th Degree	0	0	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 7.0, the SAD value calculated from the observed table, for 5842 out of 10000 simulated tables, p=0.60. The whole table is consistent with the null hypothesis of independence of degree of severity of trauma and age class.

H2. Hypothesis 17: Given Neandertals with trauma, severity of trauma is independent of sex.

This hypothesis is tested by dividing incidents of trauma into one of five degrees of injury and individual Neandertals by sex.

Table 4.34 Degree of severity of trauma by sex (numbers in parentheses denote counts when specimens from Krapina removed)

Degree of Trauma	Female	Male
1st Degree	2 (1)	6
2nd Degree	3 (1)	5 (3)
3rd Degree	2	2
4th Degree	0	2
5th Degree	0	1

When the individuals from Krapina for whom a gender attribution could be made were included, the sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 4.0, the SAD value calculated from the observed table, for 6954 out of 10000 simulated tables, p=0.70. The whole table is consistent with the null hypothesis of independence of degree of severity of trauma and sex. No individual count was significant.

When the individuals from Krapina were excluded, the whole table continued to be consistent with the null hypothesis of independence at p=0.58. No individual count was significant.

H3. Discussion and Summary: by severity of injury

In this section, aspects of Neandertals with trauma were analyzed from the perspective of the distribution of the degree of severity of their injuries. Each incidence of trauma was put into one of five categories according to where on the body the injury occurred and how the individual's degree of incapacitation.

Under the sixteenth hypothesis, the independence was tested of the degree of injury and the age-at-death of the sample of Neandertals with trauma. This hypothesis is tested by dividing incidents of trauma into one of five degrees of injury and individual Neandertals with trauma into one of three age-at-death classes. The data were found to be consistent with the null hypothesis of independence of degree of severity of trauma and age class at p=0.60.

Under the seventeenth hypothesis, the independence was tested of the degree of injury and sex for the sample of Neandertals with trauma. This hypothesis is tested by dividing incidents of trauma into one of five degrees of injury and individual Neandertals

with trauma by sex. The data were found to be consistent with the null hypothesis of independence of degree of severity of trauma and sex at p=0.70 when Krapina was included and at p=0.58 when Krapina was excluded.

Table 4.35. Results of testing hypotheses about distribution of trauma by severity of injury for Neandertals with trauma

Hypothesis	Outcome
Severity of injury is independent of age at death class	*Consistent*
Severity of injury is independent of sex	*Consistent*

Neither hypothesis was rejected; therefore, there is no statistical support for any arguments against the independence of severity of injury and age and sex for Neandertals with trauma. Until there are other comparative samples that address the degree of severity of every injury, it is not possible to address whether Neandertals experienced more severe injuries than other groups. However, I would argue that looking at patterns of trauma in this way presents a way of grouping incidents of injury in a way that reflects degree of functional impairment (rather than simply comparing parts of the body where degree of injury is not taken into consideration).

I. By Age-at-Death Class

Another aspect of the sample of Neandertals with trauma is the pattern of injury occurrence over the different ages-at-death. Because all of the individuals were older than fifteen years at death, each individual whose age-at-death could be assessed was put into one of three different age-at-death categories: Adolescent (15-20 years, revised to 13 years to include Wolpoff's (personal communication) age estimate of Le Moustier 1), Prime (20-35 years), and Old (35+ years).

The division of the sample into these categories may reflect differences in cultural function in individuals within each of the age classes, however it certainly reflects the imprecision of assigning an age Neandertals remains. These age-at-death classes are slightly different from Trinkaus (1995) who assigns "Adolescent" to 10 to less than 20 years, "Young Adult" to 20 years to less than 40 years and "Old Adult" to over 40 years. Under the age-at-death classes in the context of this dissertation, "Adolescent" is defined by a 15th year eruption time for third molars (Wolpoff 1979; Ramirez Rozzi and Bermúdez de Castro 2004) which probably also marked the beginning of fecundability. "Prime" adult is defined by moderate dental wear and signs of epiphyseal and sutural fusion. This category probably reflects the "prime" child-bearing years for female members within a Neandertal population that would bring their oldest children into reproductive age. The use of the word "prime" is not a value judgment, but rather was selected as being more different in English usage from "Adolescent" than "Young Adult." The earliest age-at-death for "Old Adult" could have been 40 rather than 35 years, however, since the age-at-death of a few specimens spanned between 35 and 45 or 50, this puts them unambiguously into the "Old" category.

In the summary table, Table 4.36, I list the number of injuries and the individuals by age-at-death class and by sex for each age class. From this summary table, it is possible to test one new hypothesis about the distribution of trauma over age-at-death classes according to sex, as well summarize other age-at-death related results from previously tested hypotheses. These hypotheses include the independence of preservation level, distribution of trauma throughout the regions of the body, side of injury, and severity of injury to the age at death of the individual. All counts were entered into

ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.36. By age-at-death class, number of Neandertal individuals with trauma, number of injuries, and sex (numbers in parentheses denote order of specimens in second column to the left)

Age-at-Death Class	# of Individuals	# of Injuries	Sex
Adult Adolescent 13-20 years	3 individuals *1. St. Césaire 1* *2. Le Moustier 1* *3. Šala 1*	4 total *1. Frontal Slash* *1. Parietal Slash* *2. Mandible condylar fracture* *3. Frontal depression fracture*	2 males (1, 2) 1 female? (3)
Prime Adult 20-35 years	5 individuals *1. La Quina H5* *2. La Chapelle* *3. Kebara KHM 2* *4. La Ferrassie 2* *5. Tabūn I*	7 total *1. Humerus diaphyseal fracture* *2. Rib fracture* *3. Thoracic Vert 1 fracture* *3. Thoracic Vert 2 fracture* *3. Metacarpal 2 fracture* *4. Fibula Diaphyseal fracture* *5. Fibula Diaphyseal fracture*	2 males (2, 3) 3 females (1, 4, 5)
Old Adult > 35 years	7 individuals *1. Feldhofer 1 (Neandertal)* *2. Shanidar 1* *3. Shanidar 3* *4. Shanidar 4* *5. Shanidar 5* *6. La Ferrassie 1* *7. Kiik-Koba 1*	13 total *1. Occipital exocranial injury* *1. Ulna proximal epiphyseal fracture* *2. Humerus diaphyseal fracture* *2. Humerus distal epiphyseal fracture* *2. Metatarsal 5 diaphyseal fracture* *2. Frontal exocranial injury* *2. Frontal crushing lateral fracture* *2. Zygomatic crushing lateral fracture* *3. Rib 9 penetrating wound* *4. Rib 7 or 8 fracture* *5. Frontal surface scar* *6. Femur fracture greater trochanter* *7. Pedal phalanx fracture?*	7 males (all)

I1. Hypothesis 18: Given Neandertals with trauma, age-at-death class of individuals is independent of sex.

This hypothesis is tested by dividing individual Neandertals with trauma into one of three age-at-death classes (adolescent, prime, and old) and sex. This data table includes only individuals to whom an age-at-death class and a sex can be attributed.

Table 4.37 Neandertals with trauma by age-at-death class and sex

Age Class	Female	Male
Adolescent	1	2
Prime	3	2
Old	0	7

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 7.47, the SAD value calculated from the observed table, for 436 out of 10000 simulated tables, p=0.04. The whole table is inconsistent with the null hypothesis that the age-at-death class of individuals with trauma is independent of sex of individual Neandertals, and the null hypothesis is rejected

I2. Discussion and Summary: by age-at-death class

In this section, aspects of Neandertals with trauma were analyzed from the perspective of the distribution of injury among the three age-at-death classes. Each individual whose age-at-death could be assessed was put into one of three different age-at-death categories: Adolescent (15-20 years), Prime (20-35 years) and Old (35+ years).

Under the eighteenth hypothesis, the independence of sex and age-at-death class was tested. The data were found to be inconsistent with the null hypothesis of independence was rejected under SAD (p=0.04)

Other hypotheses that tested other aspects of age-at-death class include the independence of preservation level, distribution of injury throughout the regions of the

body, side of injury, and severity of injury. The results of these analyses have been reported and discussed previously in this chapter and are summarized below in Table 4.38.

Table 4.38. Results of testing hypotheses about distribution of trauma by age-at-death class for Neandertals with trauma (Bold denotes rejected)

Hypothesis	Outcome
Age at death class is independent of sex	**Rejected**
Preservation level is independent of age class	*Consistent*
Distribution of trauma on the body is independent of age class	**Rejected**
Age at death class is independent to side of injury	*Consistent*
Severity of injury is independent of age at death class	*Consistent*

In summary, the independence was rejected of age-at-death class and sex of individual Neandertals with trauma as well as the distribution of trauma throughout the regions of the body.

Adolescents

In adolescent Neandertals, instances of head trauma occurred significantly more frequently than expected (p=0.05); furthermore, all adolescent trauma is head trauma.

There are several possible explanations for this. The most likely is that this is a sampling issue based on results from only 3 individuals displaying 4 bones with signs of injury. Generally, cranial bones are more likely to be collected and identified than some types of other postcranial elements (see Chapter II for this discussion) so that the identification and preservation on the Šala 1 frontal and the Le Moustier 1 cranium might not be so surprising. Also the two authors who discovered the trauma to two of the three adolescent specimens, Ponce de Leon and Zollikofer, preferentially focused on the crania

of Neandertal adolescents. Moreover most childhood fractures remodel by adolescence, therefore visual observations of injuries are likely to be only those that occurred after growth, and fairly recent relative to the time of death. The distribution on the crania and mandible of these injuries do not point to a common etiology or degree of severity that would preclude the explanation of sampling error over that of an activity-based propensity for cranial trauma.

Prime Adults

It is with the distribution of trauma over the regions of the body for age-at-death class for both sexes that these very slight trends become significant differences in the distribution of trauma in prime adult males versus prime adult females (see results of hypothesis 11). Much of this statistical significance is driven by the overrepresentation of leg injuries in prime age females with trauma. Even more surprising, although not statistically tested here, is that both of these statistically significant leg injuries also occur to the same bone (fibula). Because most fibular injuries are caused by torque on the lateral malleolus due to falling at an awkward angle (see Chapter II for further discussion on injuries to the fibula), it is clear that these two individuals were engaged in some kinds of activities where such accidents could occur. It is hard to say much else about these injuries without not only a larger populational context and without comparative samples. Statistically, the smallness of the female sample of Neandertals with trauma makes the significance of two fibular injuries a significant trend occurring in excess of what might be expected at random. However, it is the smallness of the total female sample of Neandertals with trauma that also renders the results very sensitive to sampling errors.

The other part of this statistical significance is driven by trauma in prime males. Prime males with trauma have significantly more trauma to the trunk than is expected at random. However, it is important to understand the role that small sample size plays in significance. The prime male sample is only composed of 2 individuals (versus 7 old males), so any trauma in a category that is not well represented by old males (or by any other category) is likely to add to its significance. Two out of the three trunk traumas come from Kebara KMH 2 and because he is only one of two males (and one of five total primes) his impact is much more significant in his categories than the even more highly injured Shanidar 1.

Old Adults

There are more old adults than adolescents or prime adults (7 versus 3 versus 5), however all old adults are male. When the old adults are removed from the sex versus age-at-death class table, the null hypothesis of independence is not rejected (p=0.58 for SAD and p=0.63 for chi-square). It is the addition of the old men which drives the significance of the whole table to reject the null hypothesis of the independence of age and sex. Because they almost equal the number of individuals in the other two categories (7 versus 8) and surpass them in total number of incidents of injury (13 versus 11) it is not surprising to see trauma occurring to most parts of the body not being very significant. Also it is not surprising from a paleopathological perspective that old adults should show more injury because they have had more time to accumulate it and survive it.

What is surprising, however, is the lack of old females. Given the more equal sex ratio distribution in the other two categories, their absence begs the question of whether

their absence reflects a sampling bias in individuals with trauma or whether it is indicative of a more widespread absence of old females throughout the Neandertal sample.

In summary, the hypotheses of independence of age-at-death class and sex of the individual and the distribution of trauma throughout the regions of the body were rejected. The hypotheses of independence of age-at-death class and preservation level of individuals' remains, side of injury and severity of injury were consistent. In adolescents, there was a significant trend in the overrepresentation of head trauma. In prime adults, there was a significant trend in the overrepresentation of leg trauma (prime females), and in the overrepresentation of trunk trauma (prime males). Although sampling biases probably account for all the observed trends, the most questionable seem to be the higher than expected incidence of leg injury in prime females.

J. By Sex

Another aspect of the sample of Neandertals with trauma is the distribution of injuries between males and females. The sample of Neandertal with trauma is divided according to sex. Cranially, attributions of sex are based on vault length and height. Postcranially, attributions of sex to Neandertal remains are mostly based relative size dimorphism of various skeletal elements and, to a lesser extent, robusticity (Wolpoff 1999:683). However, for some of the specimens, including La Quina H5, there has been some debate around the attribution of sex (Genovés 1963): Martin (1913), Keith (1925), Morant (1927), Howell (1951), and Boule and Valois (1957) all attribute this skeleton as a female, whereas Hrdlička (1930) and McCown and Keith (1939) attribute it as a male. Because most Neandertal remains tend to be incomplete, it is difficult to form definite

attributions of sex, however there do seem to be some standard attributions to specific individuals that appear throughout recent (post 1970) literature which, for relatively well preserved specimens, seem reasonable. Although some of the individuals from Krapina, as well as Šala and Kiik Koba, have had sex attributed to them, in this case they are excluded because the lack of preservation of the remains make attributions of sex more problematic than in other more complete remains.

The summary table, Table 4.39, lists the number of injuries and the individuals by age-at-death class and by sex both sexes. From this summary table, it is possible to test one new hypothesis about the distribution of trauma over age-at-death classes according to sex (using the tighter identification criteria) as well summarize other results from previously tested hypotheses. These hypotheses include the independence of preservation level, distribution of trauma throughout the regions of the body, side of injury, and severity of injury to the age at death of the individual. All counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 4.39. Neandertals with trauma by Sex of the Individual, not including Krapina, Šala, or Kiik Koba (numbers in parentheses denote order of specimens in second column to the left)

Sex	# of Individuals	# of Injuries	By Age Class
Female	3 *1. La Ferrassie 2* *2. Tabūn 1* *3. La Quina H5*	3 *Humerus (3)* *Fibula (1,2)*	0 Adolescent 3 Prime (1-3) 0 Old
Male	10 *1. St. Césaire* *2. Le Moustier 1* *3. Kebara KHM 2* *4. La Chapelle* *5. Shanidar 1* *6. Shanidar 3* *7. Shanidar 4* *8. Shanidar 5* *9. Feldhofer 1* *10. La Ferrassie 1*	19 *Frontal (1,5,5,8)* *Parietal (1)* *Occipital (9)* *Zygomatic (5)* *Mandible (2)* *Vertebra (3,3)* *Ribs (4, 6,7)* *Humerus (5, 5)* *Ulna (9)* *Metacarpal (3)* *Femur (10)* *Metatarsal (5)*	2 Adolescents (1, 2) 2 Prime (3,4) 6 Old (5,6,7,8,9,10)

J1. Hypothesis 18a: Given Neandertals with trauma, age-at-death class of individuals is independent of sex.

This hypothesis is tested by dividing individual Neandertals with trauma into one of three age-at-death classes (adolescent, prime, and old) and sex. This data table includes only individuals to whom an age-at-death class and a sex can be attributed.

Table 4.40 Neandertals with trauma by age-at-death class and sex

Age Class	Female	Male
Adolescent	0	2
Prime	3	2
Old	0	6

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 7.39, the SAD value calculated from the observed table, for 197 out of 10000 simulated tables, p=0.02. The whole table is inconsistent with the null

hypothesis that the age-at-death class of individuals with trauma is independent of sex of individual Neandertals. The results were generally the same as the test of Hypothesis 18 in the previous section.

J2. Discussion and Summary: by sex

In this section, aspects of Neandertals with trauma were analyzed from the perspective of the distribution of injury between males and females. Although Neandertals exhibit some degree of sexual dimorphism that can be useful for attributing a sex to remains that do not include a pelvis, the fewer remains that are associated with an individual, the more potentially uncertain an attribution becomes. Table 4.39 is constituted of the individuals who have the most secure attributions of sex. When only these individuals were used to test the independence of sex and age-at-death in the sample of Neandertals with trauma, the hypothesis was also rejected, as it had been previously.

Other hypotheses that tested other aspects of the distribution of trauma between the sexes included the independence of the site's geographic location, preservation level, distribution of injury throughout the regions of the body, side of injury, and severity of injury. The results of these analyses have been reported and discussed previously in this chapter and are summarized below in Table 4.41.

Table 4.41. Results of testing hypotheses about distribution of trauma by sex for Neandertals with trauma (bold denotes a rejected hypothesis)

Hypothesis	Outcome
Age at death class is independent of sex	**Rejected**
Distribution of Neandertals with trauma by sex is independent of a site's geographical location	*Consistent*
Preservation level is independent of the sex of an individual's remains	*Consistent*
Sex is independent of the injured body region *A. With Krapina sample as "unidentified"* *B. With some of Krapina sample given attribution* *C. Krapina sample excluded*	*Consistent*
Distribution of trauma on the body is independent of age class for both sexes	**Rejected**
Sex is independent to side of injury	*Consistent*
Severity of injury is independent of sex	*Consistent*

Most of the hypotheses were found to be consistent that tested the independence of sex of the individuals with trauma to other aspects of their injuries and preservation. The only hypotheses that were rejected were those that also dealt with age-at-death classes: the independence of sex to age-at-death class was rejected, as was the independence of the distribution of trauma throughout the regions of the body when age-at-death class was coupled with sex of the individuals.

Females

For females with trauma, most of the significant trends involve the higher than expected at random level of leg trauma. This is seen in both in the distribution of trauma

throughout the body by sex and in the distribution of severity of injury by sex with an overrepresentation of third degree trauma (incapacitating injury i.e. trauma to the lower limbs or amputation).

Males

For males, aspects of trauma were not significant. This is probably the result of the predominance of males in general in the sample.

In summary, aspects of the distribution of trauma according to sex of the individual are generally less significant than those observed for age-at-death classes. Even under more rigorously observed attributions of sex, the hypothesis of the independence of sex and age-at-death is still rejected. Sex of the individual also seems to be a factor in the distribution of leg injury and preservation levels with females having higher levels of leg injury and lower levels of preservation of their remains than their male counterparts with trauma.

K. Chapter Conclusion

In this chapter, eighteen hypotheses about aspects of the sample of Neandertals with trauma were tested. These aspects included the temporal and geographical distribution of Neandertals with trauma, areas of the body with trauma, age and sex distributions of individuals with trauma, levels of preservation of individuals with trauma and degree of severity of injury. The significance of potential differences within these aspects of Neandertal trauma was determined using analysis of two-way contingency tables using simulations (ACTUS2). The results of these analyses are summarized in the following Table 4.42.

Table 4.42. Outcome of tests of hypotheses of Neandertals with trauma (Bold denotes rejected hypothesis)

Hypothesis	Outcome
1. Distribution of trauma on the body is independent of time period	*Consistent*
2. Distribution of trauma on the body is independent of a site's geographic location	*Consistent*
3. Types of sites with traumatic Neandertal remains are independent of geographic location	**Rejected**
4. Distribution of Neandertals with trauma by sex is independent of a site's geographical location	*Consistent*
5. Preservation level is independent of site type	**Rejected**
6. Preservation level is independent of the sex of an individual's remains	*Consistent*
7. Preservation level is independent of age class	*Consistent*
8. Level of preservation is independent of age class for both sexes	*Consistent*
9. Sex is independent of the injured body region	*Consistent*
10. Distribution of trauma on the body is independent of age class	**Rejected**
11. Distribution of trauma on the body is independent of age class for both sexes	**Rejected**
12. Distribution of trauma on the body is independent of level of preservation	**Rejected**
13. Distribution of trauma on the body is independent of side of injury	*Consistent*
14. Sex is independent to side of injury	*Consistent*
15. Age-at-death class is independent to side of injury	*Consistent*
16. Severity of injury is independent of age-at-death class	*Consistent*
17. Severity of injury is independent of sex	*Consistent*
18. Age-at-death class is independent of sex	**Rejected**

Hypotheses 1-4 were generated about possible differences in Neandertals' trauma based on differences in geography and time. The only null hypothesis that was rejected was the independence of geographic location and site type. The distribution of rock shelters and caves is statistically significantly different in Europe versus Asia. There are significantly fewer rock shelters and more caves in Asia than would be predicted under the null hypothesis and significantly more rock shelters and fewer caves in Europe than would be predicted under the null hypothesis.

Hypotheses 5-8 addressed possible differences in Neandertals with trauma based on their degree of preservation. The only null hypothesis that was rejected was the independence of preservation level and site type. There were significantly more well preserved Neandertal remains with trauma found in caves and fewer found in rock shelters than would be predicted under the null hypothesis, and significantly fewer fragmentary remains found in caves and more found in rock shelters than would be predicted under the null hypothesis. However, these trends do not seem to be well explained by differences in deliberate burial versus lack of burial.

Hypotheses 9-12 addressed possible differences in Neandertals with trauma based on the distribution of trauma throughout the regions of the body. The independence of the distribution of trauma throughout the body and the individual's age-at-death class and age-at-death class along with sex, and level of preservation of the remains were rejected. The hypothesis of independence of the distribution of trauma throughout the body and the sex of the individual was not rejected. Trends that seemed to be consistent throughout all the tests include the higher than random prevalence of leg injuries in prime age females

with trauma (significant as “female”, and significant as “prime female”), and, to a lesser extent, trunk injuries in prime males with trauma (significant as “prime male”). However, because these results are only in the context of the distribution of trauma over the bones exhibiting trauma, the prevalence of trauma does not address its frequency within the total population of Neandertals or its context over all the bones that are preserved.

Hypotheses 13-15 addressed possible differences in Neandertals with trauma based on the distribution of trauma by side of injury. Under all the hypotheses, the independence of side of injury to the distribution of trauma on the body, and the age and sex of individuals with trauma was not rejected. There is little statistical support for arguments of preferential siding of injury except for a weak trend in the predominance of lower limb injuries to the right side of the body.

Hypotheses 16 and 17 addressed possible differences in Neandertals with trauma based on the degree of severity of their injuries. Neither hypothesis was rejected; therefore, there is no statistical support for any arguments against the independence of severity of injury and age and sex for Neandertals with trauma. There were, however, weak trends for prime adults and females (the same 2 injuries) experiencing more 3rd degree injuries than might be predicted at random.

Hypothesis 18 addressed the independence of age-at-death class and sex for Neandertals with trauma. This hypothesis was rejected.

Out of these eighteen hypotheses, six were rejected. These were the independence of site types to geographical location and level of preservation, the independence of the distribution of trauma throughout the body to age class, age class by sex and level of preservation, and the independence of age-at-death class and sex. However, these

hypotheses only addressed these aspects for Neandertals with trauma, and not the entire Neandertal population. Without the context of aspects of this larger group, many of the results can be interpreted as issues of sampling biases rather than significant aspects of differentiation that reflect Neandertal behavior and culture.

In the following chapter, a large sample of European Neandertal will be analyzed under similar parameters to determine whether some of the biases observed in the sample of Neandertals with trauma also may be observed in a group of Neandertals as a whole. The frequency of trauma within this European sample will be compared to other groups of modern humans.

CHAPTER V

COMPARATIVE ANALYSIS OF TRAUMA FREQUENCY IN EUROPEAN NEANDERTALS

A. Chapter V Introduction

As discussed in the previous chapter, it is difficult to assess the significance of trauma distribution without assessing its frequency within the population. For Neandertals, assessing the frequency of trauma within the population as a whole is very difficult relative to other paleopathological study samples (as outlined in Chapter II). In this chapter, I examine ways of addressing the significance of trauma in the Neandertal sample as a whole and the problems inherent in this endeavor.

In the first half of this chapter, I generate a subset sample of European Neandertals and analyze aspects of its trauma in the context of the Neandertal sample as a whole. These aspects include the relationship between preservation and the observation of trauma, age-at-death class and preservation status, age-at-death class and the presence of trauma, and the preservation of individual skeletal elements and the presence of trauma. In the second half of this chapter, I compare trauma frequency by skeletal elements in the European Neandertal sample to samples from other hunter-gatherer, semi-sedentary forager, and nomadic populations.

B. Trauma in Context: the European Neandertal Sample

In this section, aspects of Neandertal trauma will be analyzed in the context of the Neandertal sample as a whole. These aspects include the relationship between preservation and the observation of trauma, age-at-death class and preservation status, age-at-death class and the presence of trauma, and the preservation of individual skeletal elements and the presence of trauma. Also in this section, the skeletal elements that make up the Neandertal sample will be compared to samples from other hunter-gather, forager, and nomadic populations.

Various authors have asserted that Neandertals had a high frequency of trauma during their lives [e.g. "…given that it was rare for Neandertals to reach adulthood without having broken at least one limb…" (Pettitt 2000: 361)], and, more specifically, that most well-preserved Neandertal males who died after the age of 35 exhibit some sign of trauma (Trinkaus 1978; Berger and Trinkaus 1995; Pettitt 2000; Underdown 2006). However, it is difficult to decouple observations of Neandertal lifestyle from sampling biases. It is also very difficult to address the sample of Neandertal remains in the same ways that other, more modern samples, are addressed in a paleopathological context by looking at the frequency of trauma for each skeletal element.

By examining the wider sample of Neandertals with and without trauma, some hypotheses about the relationships between incidents of trauma, preservation of remains, and age-at-death classes can be examined in a context more similar to paleopathological studies of more recent populations. As discussed in Chapter II, the presence or absence of trauma can be addressed in two different contexts: organized by the individual and by skeletal element. The first four hypotheses in this chapter test the independence of the

presence or absence of trauma at the individual level to preservation status, sex, age-at-death class and age-at-death class for each sex. The hypotheses six and seven in this chapter test the independence of the presence or absence of trauma for specific skeletal elements in the sample of European Neandertals and with some more recent samples from North America and Australia.

B2. Materials and Methods

For many reasons, it is difficult even to bring together, let alone analyze, the entire sample of every excavated Neandertal remain. However, it is possible to make a smaller subsample of this whole in a way that limits biases towards better published samples (as discussed in Chapter II).

The following table is a list of Neandertals, their publication sources and their level of preservation. They represent all individual Neandertals listed in the *Catalogue of Fossil Hominids: Europe* (Oakley *et al*. 1971). No Neandertal individuals published after 1971 were included because they do not appear in this compendium and there might be a bias produced by including some of the better published sites such as St. Césaire but not other more fragmentary specimens. Asian specimens were also not included because the attribution of many individuals to Neandertal versus "Anatomically Modern Human" is still an object of debate. Only indentified individuals from Krapina are listed in the following table (i.e. the skulls); however all fragments from Krapina are used in some of the analyses.

Individual Neandertal skeletons were given a preservation rating of Excellent, Partial or Fragmentary. The "Excellent" preservation rating denotes that most of the skeletal elements of the individual have been preserved and that the majority of the

individual bones are not in a very fragmented state. The “Partial” preservation rating denotes that more than a few of the skeletal elements of an individual have been preserved and these elements come from more than two regions of the body. The “Fragmentary” preservation rating denotes all other remains which may include single bones from the post-cranial skeleton, crania in a complete or incomplete state, and individuals for whom only a few postcranial elements preserved from the same region of the body.

Counts were taken for various aspects of the remains represented in this sample. These counts include number of individuals per age-at-death class, instances of trauma, and counts of individual bones. These counts were analyzed using the program ACTUS2 (as introduced in Chapter IV) where all counts are entered into ACTUS2 tables and tested for independence using the program’s frequency simulation (“F-simulation”) methodology for calculating SAD values and chi-square values and then using the entered tables to create 10,000 simulated versions of that table from which to test significance.

Table 5.1 List of European Neandertals, sources and level of preservation

Site Identification	Sources	Preservation
La Chapelle-aux-Saintes	Bouysonne et al. 1908; Boule 1908; Trinkaus 1985	Excellent
La Ferrassie 1	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Excellent
Le Moustier 1	Hauser 1909; Peyrony 1930	Excellent
Neandertal	Fuhlrott 1859; Schaaffhausen 1888; Schwalbe 1901	Excellent
Regourdou	Piveteau 1956; Bonifay and Vandermeersch 1962	Excellent
Roc de Marsal	Bordes and Lafille 1962; Legoux 1965	Excellent
Spy 1	Fraipont & Lohest 1886; de Puydt & Lohest 1887	Partial
Spy 2	Fraipont & Lohest 1886; de Puydt & Lohest 1887	Partial
Caminero 1	Duport 1966	Partial
Combe-Grenal 2	Bordes 1955	Partial
La Ferrassie 2	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
La Ferrassie 4b	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
La Ferrassie 6	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
Kiik-Koba	Bonch-Osmolovskij 1940, 1941, 1954; Klein 1965	Partial
La Ferrassie 3	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
La Ferrassie 4a	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
La Ferrassie 5	Peyrony 1934; Capitan et Peyrony 1909, 1910, 1912, 1921a, 1921 b; Heim 1968;	Partial
La Masque 1	de Lumley 1965	Partial
La Quina H5	Martin 1911, 1913, 1920, 1926	Partial

Sarosel'e 1	Formozov 1958; Klein 1965; Ullrich 1955; Vallois 1955; Klein 1969	Partial
Subalyuk 1	Szabo 1935; Bartucz and Szabo 1938	Partial
Teshik-Tash	Gremyastskij and Nesturkh; Movius 1953; Weidenreich 1945	Partial
Weimar-Ehringsdorf 7 & 8	Pfeiffer 1909; Weidenreich 1928	Fragmentary
Caminero 1	Duport 1966	Partial
Arcy 10	Leroi-Gourhan 1958	Fragmentary
Arcy 11	Leroi-Gourhan 1958	Fragmentary
Arcy 12	Leroi-Gourhan 1958	Fragmentary
Arcy 2	Leroi-Gourhan 1958;	Fragmentary
Arcy 3	Leroi-Gourhan 1958; Hamy 1904	Fragmentary
Arcy 6	Leroi-Gourhan 1950; Leroi-Gourhan 1958	Fragmentary
Arcy 8		Fragmentary
Arcy 9	Leroi-Gourhan 1958	Fragmentary
Beegden 1	Erdbrink and Tacoma 1966	Fragmentary
Biscegelie	Cardini 1955	Fragmentary
Cariguela	Sanchez 1960; de Lumley 1969	Fragmentary
Cariguela	Sanchez 1960; de Lumley 1969	Fragmentary
Cariguela	Sanchez 1960; de Lumley 1969	Fragmentary
Ca'Verde	Corrain 1963	Fragmentary
Chateauneuf-sur-Charente 1	Chauvet 1912; Cauvin 1969	Fragmentary
Chateauneuf-sur-Charente 2	Chauvet 1912; Cauvin 1969	Fragmentary
Circeo 1	Blanc 1939, 1951, 1954; Sergi 1939, 1954; Sergi and Ascenzi 1955	Fragmentary
Circeo 2	Blanc 1939, 1951, 1954; Sergi 1939, 1954; Sergi and Ascenzi 1955	Fragmentary
Circeo 3	Blanc 1939, 1951, 1954; Sergi 1939, 1954; Sergi and Ascenzi 1955	Fragmentary
Circeo 4	Blanc 1939, 1951, 1954; Sergi 1939, 1954; Sergi and Ascenzi 1955	Fragmentary
Combe-Grenal 1	Bordes 1955	Fragmentary

Cova Negra	Cerda 1946; Fuste 1953	Fragmentary
Devil's Tower	Garrod et al. 1928	Fragmentary
Engis 2	Schmerling 1833; Fraipont 1936; Tweisselmann 1958	Fragmentary
Fond-de-Foret	Tihon 1898; Twiesselmann 1958;	Fragmentary
Forbes' Quarry	Busk 1865; Broca 1869; Sollas 1907	Fragmentary
Ganovče	Petrbok 1937; Vlcek 1955	Fragmentary
Genay	Joly 1955	Fragmentary
Grotte Putride	Moulin 1907; de Lumley 1965	Fragmentary
Hortus 1	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 13 to 17	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 18	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 19	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 2	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 20	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 21	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 5	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 22-32	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 33-35	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 36-38	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Hortus 4	de Lumley 1965; Piveteau and de Lumley 1963	Fragmentary
Kiik-Koba	Bonch-Osmolovskij 1940, 1941, 1954; Klein 1965	Fragmentary
Krapina 1	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999;	Fragmentary
Krapina 2	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999; Gardner and Smith 2006;	Fragmentary

Krapina 3	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999;	Fragmentary
Krapina 4	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999;	Fragmentary
Krapina 5	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999;	Fragmentary
Krapina 6	Gorjanovic-Kramberger 1899, 1906; Radovcic et al. 1988; Kricun et al. 1999;	Fragmentary
Kůlna	Jelinek 1967	Fragmentary
La Cotte de St Brelade	Marlett 1916; Angel & Coon 1954	Fragmentary
La Crouzade	de Lumley 1965	Fragmentary
La Quina H1	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H10	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H11	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H12	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H13	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H14	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H15	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H16	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H18	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H2	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H23	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H27	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H3	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H6	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H7	Martin 1911, 1913, 1920, 1926	Fragmentary

La Quina H8	Martin 1911, 1913, 1920, 1926	Fragmentary
La Quina H9	Martin 1911, 1913, 1920, 1926	Fragmentary
Le Moustier 2	Hauser 1909; Peyrony 1930	Fragmentary
Le Petit-Puymoyen 1	Favraud 1908	Fragmentary
Le Petit-Puymoyen 2	Favraud 1908	Fragmentary
Le Petit-Puymoyen 3	Favraud 1908	Fragmentary
Le Petit-Puymoyen 5	Favraud 1908	Fragmentary
Le Petit-Puymoyen 6	Favraud 1908	Fragmentary
Lezetxiki	Basabe 1966	Fragmentary
Malarnaud 1	Regnault 1889; Pales 1958	Fragmentary
Malarnaud 2	Regnault 1889; Pales 1958	Fragmentary
Marillac 1	David 1934; Vandermeersch	Fragmentary
Marillac 2	David 1934; Vandermeersch	Fragmentary
Mauer	Schoetensack 1908; Wust 1951	Fragmentary
Monsempron 1	Vallois 1952; Coulonges et al. 1952	Fragmentary
Monsempron 3	Vallois 1952; Coulonges et al. 1952	Fragmentary
Monsempron 5	Vallois 1952; Coulonges et al. 1952	Fragmentary
Monsempron 6	Vallois 1952; Coulonges et al. 1952	Fragmentary
Monsempron 7	Vallois 1952; Coulonges et al. 1952	Fragmentary
La Naulette 1	Dupont 1866; Virchow 1882; Twiesselmann 1958	Fragmentary
Ochoz 1	Rzehak 1905; Vlcek 1958	fragmentary
Ochoz 2	Rzehak 1905; Vlcek 1958	fragmentary
Ohaba-Ponor	Gaal 1928; Gaal 1931	fragmentary
Pech de l'Aze	Capitan and Peyrony 1909; Patte 1957	fragmentary
Petralona	Kanellis 1964; Bostanci 1964	fragmentary
Pofi	Fedele et al. 1961; Passarello and Palmieri 1968	fragmentary
Romankovo	Nakel'skij and Karlov 1965	fragmentary
Sala	Vlcek 1964	fragmentary
Sedia del Diavolo	Blanc 1956; Rossi 1961	fragmentary

Šipka 1	Maska 1885; Schaaffhausen 1880; Vlcek 1958	fragmentary
Spy 3	Fraipont & Lohest 1886; de Puydt & Lohest 1887	fragmentary
Subalyuk 2	Szabo 1935; Bartucz and Szabo 1938	fragmentary
Weimar-Ehringsdorf 1	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 2	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 3	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 4	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 5	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 6	Pfeiffer 1909; Weidenreich 1928	fragmentary
Weimar-Ehringsdorf 9	Pfeiffer 1909; Weidenreich 1928	fragmentary

C. Results

Hypothesis 1: In the sample of European Neandertals, the presence of trauma is independent of the preservation status of an individual.

This hypothesis is tested by dividing the individual Neandertals in the sample into one of three categories of preservation (well, partial, or fragmentary) and counting the instances of trauma in each category. As in chapter IV, a "well preserved" Neandertal is an individual who retains over 40% of his or her skeleton. A "partially preserved" Neandertal is an individual who retains less than 40% of his or her skeleton but can still be identified as an individual and retains bones or fragments of bones from more than one region of the body. A "fragmentary" Neandertal cannot be identified as an individual skeleton and is only represented by a bone (or bones in the cases of Krapina 4 and 5) from one region of the body. The inclusion of fragmentary trauma, however, is problematic because often "individuals" in this category represent instances of a single

bone which may or may not represent the unique instance of the person (such as at Krapina). Therefore for the purpose of testing this hypothesis, the fragmentary data will be excluded and only the well and partially preserved data included.

Table 5.2. Individual Neandertals with and without trauma by level of preservation

Preservation status	Number of Individuals WITHOUT trauma	Number of Individuals WITH trauma
Well Preserved	2	4
Partially Preserved	13	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 8.36, the SAD value calculated from the observed table, for 323 out of 10000 simulated tables, p=0.03. The whole table is inconsistent with the null hypothesis of independence of the presence of trauma and the level of preservation of individual Neandertals. There are no significant counts.

However, when the fragments are added (and treated as individuals), the results are as follows:

Table 5.3. Individual Neandertals with and without trauma by level of preservation

Preservation status	Number of Individuals WITHOUT trauma	Number of Individuals WITH trauma
Well Preserved	2	4+++
Partially Preserved	13	3+++
Fragmentary	787	9---

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 26.3, the SAD value calculated from the observed table, for 0 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis of independence of the presence of trauma and the level of preservation of individual Neandertals. The count of 9 instances of fragmentary trauma was significantly smaller than expected at p=0.05. The counts of 4 instances of well preserved trauma and

the 2 instances of partially preserved trauma were significantly larger than expected at p=0.00.

In conclusion, the null hypothesis that preservation status of an individual is independent of the presence of trauma in the sample of European Neandertals was rejected. This provokes the question as to whether preservation status is independent of age-at-death class for well and partially preserved individuals in this sample. This can be tested by dividing the well and partially preserved individuals for whom age-at-death can be assessed into two categories: immature (individuals whose age-at-death is less than 13 years) and adult (individuals whose age at death is greater than 13 years).

Table 5.4 Individual adult Neandertals with and without trauma by level of preservation

Age-at-Death Class	Well Preserved	Partially Preserved
Immature	1	8
Adult	5	7

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 6.29, the SAD value calculated from the observed table, for 1278 out of 10000 simulated tables, p=0.12. None of the counts was significant. Therefore it does not appear that preservation status is influenced by age-at-death class in any significant way for partial and well preserved individuals.

Hypothesis 2: In the sample of European Neandertals, the presence of trauma is independent of the sex of an individual.

This hypothesis was tested by dividing the adults in the sample of European Neandertals for whom sex could be assessed into categories of male and female, and by presence or absence of trauma. The summary table, Table 5.5 lists the individuals used to test this hypothesis and the observed trends.

Table 5.5 Sample of European Neandertals by sex and trauma status

Sex of Individual	Number of Adults WITHOUT Trauma	Number of Adults WITH Trauma
Female	7 *Beegen 1* *Forbes' Quarry* *Krapina 3* *Krapina 6* *La Naulette* *Lezetxiki* *Subalyuk 1*	3 *La Ferrassie 2* *La Quina H5* *Šala*
Male	5 *Circeo 1* *Circeo 3* *Cova Negra* *Spy 1* *Spy 2*	7 *Feldhofer 1* *Kiik Koba 1* *Krapina 4* *Krapina 5* *La Chapelle-aux-Saints* *La Ferrassie 1* *Le Moustier 1*

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 6.18, the SAD value calculated from the observed table, for 1723 out of 10000 simulated tables, p=0.17. The results were consistent with the null hypothesis of the independence of sex of an individual and the presence of trauma. No count was significant.

Hypothesis 3: In the sample of European Neandertals, the presence of trauma is independent of the age-at-death class of an individual.

This hypothesis was tested by dividing individuals for whom age at death could be assessed into the following age-at-death categories: infant (birth-3 years), juvenile (3-13 years old), adolescent (13-20 years old), prime adult (20-35 years old) and old adult

(>35 years old). The summary table, Table 5.6, lists the individuals used to test this hypothesis and the observed trends.

Table 5.6 Sample of European Neandertals by trauma status and age-at-death class (where known sex appears in brackets: (M) for males and (F) for females)

Age-at-Death Class	Number of Individuals WITHOUT Trauma	Number of Individuals WITH Trauma
Infant	7 Grotte Putride La Ferrassie 4a La Ferrassie 4b La Ferrassie 5 Le Moustier 2 Kiik Koba 2	0
Juvenile	26 *Arcy 10* *Carigüela* *Chateauneuf-sur-Charente 1,2* *Circeo 4* *Combe-Grenal 1* *Devil's Tower* *Egnis 2* *Hortus 1, 2, 19, 22-32* *Krapina 1, 2* *La Cotte de St. Brelade* *La Ferrassie 3, 6* *La Masque 1* *La Quina H18* *Pech de l'Azé* *Roc de Marsal* *Šipka 1* *Spy 3* *Subalyuk 2* *Teshik-Tash* *Weimar-Ehringsdorf 7-8*	0
Adolescent	7 *Circeo 3* *Hortus 4, 5, 13-17* *Le Petit-Puymoyen 1,3* *Malarnaud 1*	2 *Le Moustier 1 (M)* *Šala (F)*

Prime Adult	7 *Combe-Grenal* *La Naulette 1 (F)* *Monsempron 3* *Spy 1,2 (both M)* *Regourdou 1* *Weimar-Ehringsdorf 9 (F)*	3 *La Chapelle-aux-Saints 1 (M)* *La Ferrassie 2 (F)* *La Quina H5 (F)*
Old Adult	3 *Forbes' Quarry (F)* *Sarosel'e 2 (F)* *Subalyuk 1 (F)*	3 *Feldhofer 1 (M)* *La Ferrassie 1 (M)* *Kiik Koba 1 (M)*

When each of the age-at-death classes was included, the results were as follows:

Table 5.7 Trauma status in European Neandertals by age-at-death class

Age-at-Death Class	Number of Individuals WITHOUT Trauma	Number of Individuals WITH Trauma
Infant	6	0
Juvenile	26	0---
Adolescent	7	2
Prime Adult	7	3
Old Adult	3	3+++

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 16.6, the SAD value calculated from the observed table, for 26 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis that age-at-death class is independent of trauma status and the null hypothesis is rejected. The count of 3 instances of Old Adult trauma was significantly higher than expected at p=0.05. The count of 0 instances of Juvenile trauma was significantly lower than expected at p=0.02.

However, when the juveniles are removed from the table the results are as follows:

Table 5.8 Trauma status in European Neandertals by age-at-death class without juveniles

Age-at-Death Class	Number of individual adults WITHOUT trauma	Number of individual adults WITH trauma
Adolescent	7	2
Prime Adult	7	3
Old Adult	3	3+

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 4.3, the SAD value calculated from the observed table, for 5816 out of 10000 simulated tables, p=0.58. The whole table is consistent with the null hypothesis of independence of the age-at-death class and trauma status. There were no significant counts.

Hypothesis 4: In the sample of European Neandertals, the presence of trauma is independent of the age-at-death class and sex of an individual.

This hypothesis was tested by dividing adult individuals for whom age at death and sex can be assessed into trauma status and the following age-at-death categories: adolescent (15-20 years old), prime adult (20-35 years old) and old adult (>35 years old).

Table 5.9 Trauma status in European Neandertals by age-at-death class for each sex

Age-at-Death class by sex	Number of individual adults WITHOUT trauma	Number of individual adults WITH trauma
Adolescent Unidentified	6	0-
Adolescent Female	0	1
Adolescent Male	1	1
Prime Unidentified	3	0
Prime Female	2	2
Prime Male	2	1
Old Unidentified	0	0
Old Female	3	0
Old Male	0	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 15.4, the SAD value calculated from the observed table, for 151 out of 10000 simulated tables, p=0.02. The whole table is inconsistent with the null

hypothesis of independence of the age-at-death class for each sex and trauma status. No count is significant.

When the unidentified by sex individuals are removed, the results are as follows:

Table 5.10 Trauma status in European Neandertals by age-at-death class for each sex

Age-at-Death Class	Number of adult individuals WITHOUT trauma	Number of adult individuals WITH trauma
Adolescent Female	0	1
Adolescent Male	1	1
Prime Female	2	2
Prime Male	2	1
Old Female	3	0
Old Male	0	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 8.0, the SAD value calculated from the observed table, for 2948 out of 10000 simulated tables, p=0.29. The whole table is consistent with the null hypothesis of independence of the age-at-death class for each sex and trauma status. No count is significant.

Hypothesis 5: In the sample of European Neandertals, the presence of trauma is independent of postcranial skeletal element.

This hypothesis was tested by counting each instance of an individual skeletal element for the European Neandertal sample. Only postcranial elements were included because descriptions of the crania were widely variable in the detail with which they were described. The totals reflect counts from all described elements without discrimination by preservation level.

Table 5.11 Trauma status in European Neandertal postcranial sample by skeletal element (in parentheses: =Total NOT from Krapina + total from Krapina)

Postcranial Element	Number of bones WITHOUT trauma		Number of bones WITH trauma	
Mandibles	79	(=37+42)	1	(=1+0)
Vertebrae	177	(=121+56)	0 -	
Ribs	172	(=102+70)	1	(=1+0)
Clavicles	35	(=19+16)	1 +	(=0+1)
Scapulae	26	(=7+19)	0	
Sternum	3	(=2+1)	0	
Humeri	57	(=36+21)	1	(=1+0)
Radii	29	(=17+12)	0	
Ulnae	39	(=23+16)	3 +++	(=1+2)
Bones of the Hand	127	(=57+70)	0	
Os Coxae	26	(=10 + 16)	0	
Femora	65	(=33 + 32)	1	(=1+0)
Tibiae	40	(=21+19)	0	
Fibulae	32	(=13 +19)	1 +	(=1+0)
Bones of the Foot	169	(=91 + 78)	1	(=1+0)

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 20.4, the SAD value calculated from the observed table, for 2084 out of 10000 simulated tables, p=0.21. The whole table is consistent with the null hypothesis of independence for the presence of trauma and the specific postcranial skeletal element. There was one significantly larger count than expected at random which was the 3 instances of ulnar trauma at p=0.01.

Hypothesis 6: For each postcranial skeletal element, incidence of trauma is independent of the population observed.

This hypothesis is tested by dividing the European Neandertal sample by element and comparing it to samples from other populations. These comparative samples come from the following sites: Libben, SCl-038, Ala-329, Pozzilli, Central Murray, Rufus River, South Coast (of Australia), Desert, and East Coast (of Australia). These populations were chosen because they represent hunter-gatherer, semi-sedentary forager or nomadic populations that are more likely to reflect similar environmental and lifestyle

stresses more similar to Neandertals than samples from Medieval London or 19th Century New York. Not all samples represent all elements.

Three of these comparative samples are from North America and represent hunter-gatherer or foraging populations. The sample from Libben represents a Late Woodland Native American semi-sedentary foraging population from Northern Ohio for whom only complete long bones were tabulated (published by Lovejoy and Heiple (1981)). The sample from SC1-038 represents a Native American hunter-gatherer population from the Santa Clara Valley in Central California, dating from between 240 BC to AD 1770, from whom only complete (defined in this case as at least 2/3 complete with "all major articular areas preserved") long bones were tabulated (published by Jurmain (2001)). The sample from Ala-329 represents a Native American population from the southeastern shore of the San Francisco Bay in California, dating from between 500 BC through the 1700s (published by Jurmain (1991) and Jurmain and Bellifemme (1997)).

One of these comparative samples comes from the mountainous zone of south-central Italy. The Pozzilli site dates from 600 BC-300 BC and is associated with the "shepherd-warriors" of the Samnite culture. This site was published by Brasili *et al.* (2004) and the authors included only bones greater than 75% present in their analyses.

The other five sites come from Australia and were published by Webb (1989) and (1995). He includes only complete long bones; however "exceptions to this were made with fossil material and individuals from under-represented areas" (Webb 1995:11). The 'central Murray' sample came from the George Murray Black collection which represents cemetery samples collected in the 1930s-40s from the banks and floodplains of the

Murray river over a general area rather than a specific site. This collection is not dated but might include, most recently, victims of diseases of European contact (circa 1790 and 1828-31) as well as a few burials dating from before European contact (Webb 1995: 13-16). The boundaries for this area enclose about 26,000 sq. km and include 700km of riverbank between Victoria and New South Wales. The Rufus River collection samples skeletal material from the area around Lake Victoria, Lindsay Creek, Chowilla, and the Rufus River (Webb 1995:17). Other skeletal samples were based on ecological zones which include Desert (arid central and western Australia), South Coast (representing coastal Victoria), and East Coast (representing coastal New South Wales and Queensland).

Table 5.12 Clavicle: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	35	1
Libben (U.S.A)	245	15 +++
SCl-038 (U.S.A.)	159	0 ---
Ala-329 (U.S.A.)	289	2 ---
Pozzilli (Italy)	56	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 41.13, the SAD value calculated from the observed table, for 0 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis of independence of incidence of trauma and population observed for clavicles and the null hypothesis is rejected. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.13 Humerus: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	57	1
Libben (U.S.A.)	447	3
SCl-038 (U.S.A.)	139	3
Ala-329 (U.S.A.)	299	1
Pozzilli (Italy)	70	0
Central Murray (Australia)	318	2
Rufus River (Australia)	111	2
South Coast (Australia)	121	1
Desert (Australia)	51	2
East Coast (Australia)	171	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 18.99 the SAD value calculated from the observed table, for 3788 out of 10000 simulated tables, p=0.38. The whole table is consistent with the null hypothesis of independence of incidence of trauma and population observed for humeri. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.14 Radius: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	29	0
Libben (U.S.A.)	349	20 +++
SCl-038 (U.S.A.)	155	6
Ala-329 (U.S.A.)	288	13
Pozzilli (Italy)	62	3
Central Murray (Australia)	180	1 ---
Rufus River (Australia)	186	2
South Coast (Australia)	91	2
Desert (Australia)	48	1
East Coast (Australia)	163	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 51.74, the SAD value calculated from the observed table, for

164 out of 10000 simulated tables, p=0.02. The whole table is inconsistent with the null hypothesis of independence of independence of incidence of trauma and population observed for radii. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.15 Ulna: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	39	3
Libben (U.S.A.)	340	11 ---
SCl-038 (U.S.A.)	134	10
Ala-329 (U.S.A.)	275	15
Pozzilli (Italy)	61	1
Central Murray (Australia)	170	11
Rufus River (Australia)	128	6
South Coast (Australia)	79	10 +++
Desert (Australia)	47	3
East Coast (Australia)	150	14

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 54.62, the SAD value calculated from the observed table, for 940 out of 10000 simulated tables, p=0.09. The whole table is consistent with the null hypothesis of independence of independence of incidence of trauma and population observed for ulnae. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.16 Femur: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	65	1
Libben (U.S.A.)	338	9 +++
SCl-038 (U.S.A.)	117	2
Ala-329 (U.S.A.)	313	0
Pozzilli (Italy)	80	0
Central Murray (Australia)	336	0
Rufus River (Australia)	167	0
South Coast (Australia)	133	1
Desert (Australia)	45	1
East Coast (Australia)	172	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 32.53, the SAD value calculated from the observed table, for 40 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis of independence of independence of incidence of trauma and population observed for femora and the null hypothesis is rejected. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.17 Tibia: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	40	0
Libben (U.S.A.)	344	5
SCl-038 (U.S.A.)	163	1
Ala-329 (U.S.A.)	310	5
Pozzilli (Italy)	75	3
Central Murray (Australia)	254	0
Rufus River (Australia)	154	1
South Coast (Australia)	201	0
Desert (Australia)	62	1
East Coast (Australia)	164	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 28.44, the SAD value calculated from the observed table, for

744 out of 10000 simulated tables, p=0.07. The whole table is consistent with the null hypothesis of independence of independence of incidence of trauma and population observed for tibia. The Neandertal counts did not represent deviations from what might be expected at random.

Table 5.18 Fibula: counts of incidences of trauma versus no trauma for each skeletal population

Skeletal Population	Number of Elements WITHOUT trauma	Number of Elements WITH trauma
European Neandertal Sample	32	1
Libben (U.S.A.)	348	9
SCl-038 (U.S.A.)	128	1
Ala-329 (U.S.A.)	237	0 ---
Pozzilli (Italy)	59	1
Central Murray (Australia)	177	0
Rufus River (Australia)	146	2
South Coast (Australia)	77	0
Desert (Australia)	38	3 +++
East Coast (Australia)	126	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 34.44, the SAD value calculated from the observed table, for 123 out of 10000 simulated tables, p=0.01. The whole table is inconsistent with the null hypothesis of independence of incidence of trauma and population observed for fibulas and the null hypothesis is rejected. The Neandertal counts did not represent deviations from what might be expected at random.

D. Discussion

The first four hypotheses tested aspects of the distribution of trauma throughout the European Neandertal. These aspects included degree of preservation, sex, age-at-death class and age-at-death class divided by sex. The results are presented in the summary table 5.19:

Table 5.19 Outcome of tests of hypotheses within the sample of European Neandertals (rejected hypotheses in bold)

Hypothesis	Outcome
Preservation status of an individual is independent of presence of trauma	**Rejected**
Sex of an individual is independent of presence of trauma	*Consistent*
Age-at-death class of an individual is independent of presence of trauma (juveniles included)	**Rejected**
Age-at-death class of an individual is independent of presence of trauma (when juveniles excluded)	*Consistent*
Age-at-death class and sex of an individual is independent of the presence of trauma (unidentified by sex individuals included)	**Rejected**
Age-at-death class and sex of an individual is independent of the presence of trauma (unidentified by sex individuals excluded)	*Consistent*

For adults in this sample, trauma cannot be shown to be distributed at random over well and partially preserved individuals or fragments. However, it was not disproven that trauma is distributed randomly over females versus males, over adolescents versus prime adults versus old adults, or over age-at-death class considered by sex. Although percentage comparisons yield what many seem significant results (such as 100% of old males show evidence of trauma whereas 100% of old females do not), rigorous tests of significance such as ACTUS2 filter reveal that these results do not represent bigger or smaller counts than could be predicted at random.

The last two hypotheses addressed the distribution of trauma for postcranial skeletal elements. The fifth hypothesis tested the independence of the distribution of trauma and the distribution of preserved skeletal elements. Under this hypothesis, all things being equal, the skeletal elements with higher counts of preserved elements should have higher counts of trauma, if it were equally distributed throughout the body. Although the results were consistent with the null hypothesis, the ulnae showed significantly more trauma than would be predicted at random at p=0.01. However, to test

how surprising or unusual this is in the context of how humans injure themselves, comparative samples needed to be brought considered as well. Counts of trauma versus no trauma for long bones from nine comparative samples were analyzed, to give context to the Neandertal injury counts. Although for some elements (clavicle, radius, femur and fibula) the null hypothesis of independence of incidence of trauma and the population observed were rejected for the table as a whole, the European Neandertal sample did not deviate from the predicted for randomness for any element. Postcranially, in this context, Neandertal trauma appears to be absolutely "in the middle of the range" for hunter-gatherer/forager/nomads.

However, the composition of the European Neandertal sample is, strictly speaking, not comparable to the comparative samples. First, the European Neandertal sample might not actually be very representative of all currently exhumed Neandertals (the "Neandertal Metaset"). Second, the way that the counts of individual skeletal elements were collected differs from the comparative samples. For the European Neandertal sample all instances of bones, whether whole or fragmentary, were included in the count of bones for each element, whereas, in the comparative samples most element counts only included whole bones. Because it is unclear to what extent these inconsistencies influence the results, the validity of results presented here is uncertain.

Two things, however, are fairly clear: first, the Neandertal sample is probably too small and trauma is too rare an event to expect much significance in its distribution. Second, for significantly high or low counts of trauma to have any meaning, counts of bones with trauma AND bones without trauma need to be compared with samples from other collections.

D. Chapter V Conclusion

In this chapter, issues were examined surrounding trauma analysis for the entire Neandertal sample. Mostly this chapter was an exercise in why, on one hand, the Neandertal sample does not lend itself to analysis under paleopathological standards but why, on the other hand, most of such standards are necessary to generate meaningful and significant results that may be understood over the noise of sampling biases.

In the first half of the chapter, aspects of Neandertal trauma were analyzed in the context of the Neandertal sample as a whole within a smaller subsection referred to as the "European Neandertal sample". Although this sample did not include all European Neandertals currently excavated, the restriction of the sample to only specimens that were listed in the *Catalogue of Fossil Hominid: Europe* (Oakley *et al.* 1971) limits a bias against subsequently published, but lesser known, specimens. Aspects relating to the independence of the presence of trauma and various personal indicators were examined. The aspects included the relationship between preservation and the observation of trauma in partially and well preserved specimens, age-at-death class and preservation status, age-at-death class and the presence of trauma, and the preservation of individual postcranial skeletal elements and the presence of trauma.

The skeletal elements that make up the Neandertal sample were also compared to samples from hunter-gather, forager, and nomadic populations. Only postcranial remains (the long bones plus the clavicle) were analyzed because of inconsistencies in reporting cranial remains for Neandertals and for some of the other samples. For adult Neandertals in the European Neandertal sample, the presence of trauma was found to be independent of level of preservation, age-at-death class, sex, and age-at-death class divided by gender.

There was a significantly high instance of ulnar trauma when postcranial skeletal element frequencies were compared in the European Neandertal sample; however the rate of ulnar trauma (as well as all other long bone trauma) was consistent with the distribution of trauma in all of the comparative samples.

In the following chapter, some of these limitations will be addressed with the imposition of a customized data collection protocol and the choice of collections that minimize some of the potential biases.

CHAPTER VI

TRAUMA IN NEANDERTAL REMAINS: NEW APPROACHES

A. Chapter VI Introduction

In this chapter, suggestions of alternate ways of addressing trauma in Neandertals will be discussed. These ways include the benefits of the analysis of a sample from a single site. New methodology for addressing the distribution of trauma in fragmentary remains will be summarized and then implemented in the comparisons of trauma between the Krapina Neandertal sample and a comparative modern sample from Portugal. Because the sample from Aljubarrota composed almost exclusively of adults, immature remains are not counted in the totals either at Aljubarrota or at Krapina.

B. Materials: Assessing Neandertal Trauma in a Focused Context

In this section, ways of addressing the limitations of the Neandertal sample for trauma will be discussed. One of these ways is to focus the analysis on a sample of Neandertals that come from a single site. The suitability of the Krapina sample to this role will be reviewed. Another problem discussed in the previous chapter was the lack of comparative samples, especially in the context of fragmentary remains. The Aljubarrota sample from São Jorge, Portugal will be proposed as an appropriate comparative sample because of the context of its preservation and its high level of historical documentation.

B1. Suggestions for addressing the limitations of Neandertal data

In the previous chapter, the limitations of the Neandertal sample for the analysis of trauma were reviewed. These issues included the disparate nature of the location and chronology of the samples, different levels of preservation depending on the site, possible preservation biases of some elements, potential age and sex biases in the Neandertal sample, unknown possible differences in the activities of males versus females, unknown biases in the mortuary treatment of the sample, small sample size, non-standardized reporting of the Neandertal remains, and the lack of comparability of the Neandertal remains to other published samples.

Until many more Neandertal remains are discovered to better contextualize the sample as a whole, limitations such as the lack of knowledge of possible differences in the activities of males versus females are likely to persist. Other issues such as small sample size and preservation biases of some elements are also likely to continue to be a problem. Questions as to whether there are age and sex biases in the preservation in the Neandertal sample are likely to remain unanswered and the source of argument for years to come.

However, some issues, such as the disparate nature of the location and chronology of the samples, different levels of preservation depending on the site, and differences in excavation, curation, analysis and reporting can be dealt with by limiting the sample analyzed to a single site, with a large enough sample size to facilitate hypothesis testing as well as represent a relatively unbiased sample from the population.

There are two sites, Shanidar and Krapina, which might fit the above criteria. These sites represent two large *sensu stricto* Neandertal sites in terms of number of

individuals represented. Because of the high level of preservation of each of the individuals in its sample, Shanidar would be a likelier candidate as a single Neandertal site with which to test hypotheses about patterns of Neandertal trauma. However, there are serious questions as to its suitability as representative sample for the Neandertal population because of its age-at-death class and sex distributions.

In the following table, age-at death class data from the European Neandertal sample and the sample from Shanidar are compared under the null hypothesis that age-at-death class is independent of the sample identity. This test of the null hypothesis addresses whether Shanidar is a suitable sample.

Table 6.1 Distribution by age-at-death classes for European Neandertal sample versus Shanidar

Number of Individuals per Age-at-Death Class	Number of Individuals in European Neandertal Sample	Number of Individuals at Shanidar
Infant	7	2
Juvenile	27	0---
Adolescent	9	0
Prime Adult	10	3
Old Adult	6	4+++

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 19.05, the SAD value calculated from the observed table, for 39 out of 10000 simulated tables, p=0.00. The whole table is clearly inconsistent with the null hypothesis that age-at-death class is independent of sample identity. The two biggest inconsistencies were the significantly bigger number of old adults in Shanidar sample (p=0.04) and its significant lack of juveniles (p=0.03).

The distribution of age-at-death class by sex in the adults of the European Neandertal sample can also be compared with that from Shanidar under the null

hypothesis that distribution by sex is independent of the sample identity. This test of the null hypothesis also addresses Shanidar's suitability.

Table 6.2 Distribution by sex for the European Neandertal sample versus Shanidar

Number of Individuals By Sex	Number of Individuals in European Neandertal Sample	Number of Individuals at Shanidar
Female	12	1
Male	12	5

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 6.4, the SAD value calculated from the observed table, for 1406 out of 10000 simulated tables, p=0.14. The whole table is consistent with the null hypothesis of independence of the distribution of sex and the sample identity.

Although it is quite possible that the European Neandertal sample is also not representative of a living Neandertal population, it is also clear that the preponderance of old adults and lack of juveniles in the Shanidar sample is unlike the conceptions of Neandertal demography shown in other research such as Trinkaus (1995) and Wolpoff and Caspari (2006). In the following part of this section, the suitability of Krapina to serve as a single representative sample for Neandertal trauma will be reviewed.

B2. The suitability of the Krapina sample for trauma analysis

Because the Neandertal remains from Krapina sample individuals from one geographical location and a time span of no more than 20kyr (Rink *et al.* 1995), they are likely to be the result of more uniform environmental conditions than the Neandertal Metaset. The sample from Krapina is also large enough to attempt hypothesis testing. Its Minimum Number of Individuals (MNI) estimates range from 14 (Malez 1971) to 75-82 (Wolpoff 1979). The Krapina sample includes elements from almost every bone in the body. Most importantly, it is excellently curated and catalogued (Radovčić *et al.* 1988;

Kricun *et al.* 1999) so that the total number of skeletal elements represented has been published and assessments of trauma are accessible and repeatable. Recent work has demonstrated that the demographic sample found at Krapina is consistent with other Paleolithic populations (Wolpoff and Caspari 2006). Aspects of the Krapina sample will be reviewed in the following subsection.

B2a. All elements are specific to time and place

The site has been dated by ESR and U-series to 130 kyr and, although there are multiple stratigraphic levels that yielded hominid remains at Krapina, these levels represent a fairly rapid accumulation of sediment—probably spanning no more than 20 kyr (Rink *et al.* 1995).

B2b. All elements have been excavated under the same treatment

Not only have all elements from the Krapina fossil sample been excavated under the same treatment, that treatment was far ahead of its time in terms of excavation and recording methodology. The Krapina rock shelter site was excavated between 1899 and 1905 and yielded a total of 874 human remains, the largest sample of Neandertals to be found at a single site (Gorjanović-Kramberger 1899 and 1906). As noted by Frayer (2006:3) and documented by Radovčić (1988) and Radovčić *et al.* (1988), Gorjanović-Kramberger was the first to "save virtually every Neandertal fossil he encountered" in addition to saving most of the faunal remains and stone tools. He was also the first to "preserve and map a detailed stratigraphic profile of a Neandertals site" as well as to create a numbering system for the fossils and record the levels from which they had been excavated (Frayer 2006:3).

B2c. All elements have been recorded

All elements from Krapina have been recorded and these records have been updated many times during the past century of research to reflect current understanding of how some of the elements might fit together as well as changes in designations of human material versus faunal material. In 1906, Gorjanović-Kramberger published letter designations for the most complete cranial and mandibular elements as well inventorying many of the fragmentary remains (Radovčić *et al* 1988:8). Sometime later (ca. 1924), he made a list of counts by element of all the specimens that he had identified as human which was later expanded upon and a new numbering system imposed by his successor Poljak in the 1930s (Radovčić *et al* 1988:8-9). Later inventories of all or parts of the collection include Malez (1971), Trinkaus (1975), Smith (1976), and Wolpoff (1979) which helped to form the illustrated descriptive catalogue published in 1988 by Radovčić, Smith, Trinkaus, and Wolpoff. This catalogue has been constantly updated and the more recent (2008) version exists in electronic form (Wolpoff, personal communication). I also visited the collection and recorded information about trauma and the composition of the sample.

B2d. All specimens have been radiographed

The treatment of the specimens from Krapina represents the gold standard in the documentation of prehistoric specimens also in the field of radiography. In 1902, Gorjanović-Kramberger published x-rays of some of the specimens from Krapina, making them among the first fossil humans to be radiographed just seven years after the details of Röntgen's discovery of X-radiation were published (Kricun *et al.* 1999). Although there were subsequently several other radiographs taken of a few specimens, it

was the work of Kricun *et al.* (1999) that created and published a radiographic atlas of the entire skeletal collection of fossil hominids from Krapina.

B2e. The collection is a representative sample of the population

Whether the mortuary profile of the collection of fossil hominids from Krapina is a representative sample of the living population is one of the more contentious issues surrounding this sample. This issue is closely linked to debates about whether this site contains deliberate burials of individuals after initial mortuary activities, a catastrophe or something else entirely. As in Chapter IV, there are many perspectives on this issue.

Over the past hundred-plus years, several hypotheses have been offered to explain the distribution of remains over the Krapina site. These include: Krapina as regularly occupied living site (Gorjanović-Kramberger 1899, 1906, 1913; Malez 1970, 1978); Krapina as the site of cannibalism and/or massacre (Gorjanović-Kramberger 1901, 1906, 1909; Škerlj 1939, 1958; Tomić-Karović 1970; Chiarelli 2004); Krapina as a death trap for a group of run-away juveniles (Bocquet-Appell and Arsuaga 1999); Krapina as a site of purposeful burial (Trinkaus 1985); and Krapina as a secondary burial site following mortuary rites (Russell 1987a and 1987b; Ullrich 2006). Ullrich summarizes Gorjanović-Kramberger's initial excavation notes: "He also pointed out that skull fragments have never been discovered in connection with postcranial remains of the same individual and postcranial remains were never found in anatomical connections or anatomical positions." (2006:506). A high level of fragmentation and lack of articulation precludes it by some definitions as a site of purposeful burial. Also as reviewed in Chapter IV, studies of the anatomical distributions of the fragments at Krapina, such as

Trinkaus (1985) and Van Arsdale (2007), appear to reach radically different conclusions about the random nature of the preservation of various elements at Krapina.

One of the most difficult aspects of this issue is that the fragmentary preservation of the skeletal remains at Krapina precludes a good understanding of the demographic profile of the site. The Minimum Number of Individuals (MNI) estimates for this site vary dramatically depending upon the element used to make the estimate as well as whether immature specimens are also considered. However, it methodologically makes the most sense to take the maximum MNI as the probable minimum for the site. This maximum MNI would be the 75 to 82 individuals estimated by Wolpoff (1979) using the dental remains.

What is clear about the Krapina sample is that there are many elements missing per individual. Although it is likely that this is in some part due to the Krapina site's role as a local sand pit before the fossils were identified (Radovčić 1988), it is also probable that some of this disarticulation and fragmentation occurred before the bones were put into the ground (Ullrich 2006). The combination of these two factors probably means the current sample of remains from Krapina represents a few pieces from many individuals rather than many pieces from a few individuals as is common in most well-known Neandertals sites. If this is the case, estimations of MNI would likely be disparate as well as, to some extent, meaningless because they do not come remotely close to actual number of individuals represented at the site.

Because it is difficult to get a sense of how many individuals are preserved at Krapina and consequently what the age-at-death and sex profiles look like for the site, it is impossible to directly assess whether or not Krapina is a representative sample of the

population of Neandertals living at this site. Wolpoff and Caspari (2006) use Libben demography to estimate a 69% survivorship for the "missing" (i.e. not well represented in the Krapina skeletal sample) infants and children under the age of five years under the assumption that both populations were stationary with a stable age distribution. They then added these 37 estimated kids to the survivorship distributions in order to make it comparable to the samples from Libben, Atapuerca, *Australopithecus* specimens and the Ache. They found that the sample from Krapina, Atapuerca and the australopithecines had very similar survivorship distributions that differed from Libben and the Ache. They concluded that the age-at-death distributions at Krapina and Atapuerca were consistent with the findings of Caspari and Lee (2004 and 2006) that the number of old (age-at-death) individuals in the population comes late in modern humans and that these distributions do not reflect any special or catastrophic profiles.

B2f. Limitations of the Krapina sample

From the perspective of its suitability for trauma analysis, the sample of specimens from Krapina has two major weaknesses that seriously limit its utility. The first major weakness is the fragmentary nature of the sample. The second major weakness is the lack of association of the postcranial fragments and most of the cranial fragments with a specific individual with an age-at-death and/or sex.

As reviewed in Chapter II, most paleopathological standards for collecting information about injury in a sample population require complete individual bones and almost all studies of modern human collections are based on complete individual bones. The fragmentary nature of the Krapina sample makes not only data collection under standard protocols impossible, but it also makes comparisons of trauma from the Krapina

sample with trauma from other populations incomparable under standard protocols. In order to assess the significance of the patterns of trauma at Krapina, protocols for collecting trauma from fragmentary remains must be chosen and established. These protocols also need to be used to collect data from the comparative sample.

Because the Krapina remains do not represent discrete individuals, it is impossible to address questions about the demographic patterning of trauma at this site. Through seriation, estimates of the sexual dimorphism of a group of isolated individual postcranial elements may be made, but in fragmentary remains this is likely to be difficult and fraught with potential inaccuracies. Although age-at-death profiles have been examined for the Krapina collection as a whole, these profiles come from dental remains and are not directly associated with the bones that potentially show trauma. The patterns of trauma relating to the distribution by sex, age-at-death or by individual cannot be assessed using the Krapina sample. However, it is possible to test hypotheses about the Krapina sample through element by element comparative analysis.

B3. The suitability of the Aljubarrota collection as a comparative sample for assessing Neandertal trauma

The importance of a fragmentary comparative sample is that postmortem fragmentation potentially erases some evidences of trauma. Although most of this potentially missing trauma is perimortem trauma, it is not exclusively so. The comparisons of frequencies of trauma from a collection where most of the elements are completely preserved to one where the elements are fragmentarily preserved, all things being equal, biases the observation of trauma towards the more completely preserved collection. Choosing a fragmentary comparative sample with which to analyze a fragmentary collection potentially eliminates some of this bias.

The Aljubarrota collection was chosen as a comparative sample for the Krapina remains because of its fragmentary nature, secondary burial status, and its well-known context. Superficially, comparing Croatian Neandertals with Spanish Medieval soldiers who were killed during an afternoon-long battle in Portugal would seem to be a far stretch and in many respects it is. However, very few collections of fragmentary remains come with such a detailed context and are accessible for study. In addition, although the individuals represented in the Aljubarrota collection died in battle, they were not mercenaries or profession soldiers (except for the knights whose bodies were ransomed back to their families shortly after death) and most observable trauma is likely to be injuries acquired during their lives from in a non-military context.

B3a. All elements are specific to time and place

In this subsection, a brief history of the Battle of Aljubarrota and the events that precipitated it will be reviewed. This history comes from the following texts: Carmo Reis (1987); Gama Barros (1885); Herculano (n.d.); Lopes (written 1430-50 but 1977 edition); Monteiro (2001); Oliveira Marques (1964); Serrão (1990); Tavares (1985).

In 1385, Portugal was a country divided in its loyalties. The death at age 38 of King Fernando I in October of 1383 left the country without a male heir. Three years previously he had been forced into making a treaty with the Juan I, King of Castile at the Peace of Salvaterra where Fernando gave Juan I the hand of his eight year old daughter, Beatriz, in marriage in return for the Castilians ending their siege of Lisbon. A couple months after Fernando's death, the marriage between Beatriz and Juan of Castile was celebrated. Although Beatriz's mother, Leonor, was the nominal regent for her daughter

until such time as Beatriz came of age and bore a child of her own to inherit the Portuguese throne, Juan of Castile was the de-facto King of Portugal.

This taking of the Portuguese throne by the King of Castile was odious to many of the Portuguese middle and lower classes. Castile and Portugal had been intermittently at war with one another for years, when they were not busy dealing with threats from the Moors, and Castile was clearly still considered the enemy by most of the Portuguese. Also, the Queen mother-regent Leonor was not a well-beloved monarch. The nobility was divided in their loyalties. The upper nobility were loyal to Beatriz, Leonor and Juan because they were invested in the upper hierarchy and many of them were intermarried with prominent Castilians themselves. The lower nobility and burghers had little to gain from Castilian rule but much to gain by supporting an alternate contender to the throne. Fernando's much younger bastard half-brother John of Avis was the master of the wealthy military-religious Order of Christ. He was a close surviving male relative to Fernando I and the burghers and lesser nobility chose him as their king in December 1383.

The Castilian force included about 17,000 individuals and was composed of 5000 heavy cavalry armed with lances, 2000 light cavalry, 5000 *besteiros* (mounted on horses but not armored), and about 6000 *peões* (foot soldiers) as well as 16 light cannons. The Portuguese forces had 2000 total cavalry, 1000 *besteiros*, 700 English archers, and about 4000 *peões* for a total of about 7,000 individuals.

On August 14, 1385, the two sides were in place and awaited further orders while taunting each other. Juan I, the King of Castile, decided not to attack that day and expected the Portuguese to become disheartened by the size of his army. However, his

command was not well transmitted and at about 3pm some restless soldiers in the vanguard (which was possibly infiltrated by pro-Avis supporters) began the attack and their lead was followed by the rest of the vanguard of the Castilian army.

The Castilians were hampered by terrain and the preparations made by the Portuguese. Only about a quarter of the cavalry making up the vanguard could ascend the slope to attack the Portuguese in position at the top of a rise on the narrow plain. Pits dug into the clay soil and covered with brush hampered the movement of the horses and the cavalry was decimated by the English archers. Although the Castilians eventually broke through the tiny Portuguese vanguard, they were forced to engage in hand-to-hand combat on foot with the majority of the Portuguese army. Attacks from the flanks by another group of Castilians were repulsed by the Portuguese who were protected behind the earthworks and tree trunks that they had previously set up. Eventually, the Portuguese rearguard was able to close around the Castilian vanguard and slaughter the ones that did not flee. While most of the remaining Castilian forces were fleeing, one cavalry group persisted in attacking the Portuguese from the rear until nightfall when they too retreated. The entire battle lasted less than 5 hours. No accounts record exactly how many people died that day, but historians estimate somewhere between three and four thousand individuals died on the field, mostly from the Castilian side (estimates of Portuguese losses range from about 600 to 900 individuals) (Monteiro 2001:258-259).

The Portuguese forces imagined that the Castilian forces would return in the morning to decimate them. That night they repaired their physical defenses, removed the corpses out of their occupied zone, and sent their wounded south on carts. However, the next day no one came to challenge them. The Castilians had fled, probably believing that

the Portuguese forces were stronger and more numerous than imagined. Although Juan I managed to return to Castile, some of his forces were not so lucky because the retreat had been so disorganized that soldiers were picked off by locals as they tried to make their way back. Rich prisoners of war were ransomed and others were sent back by ship under the orders of John of Avis.

Some of the bodies of the high ranking Portuguese dead were taken to a local monastery for burial while most of the others were probably collected by members of their families or friends. The night after the battle, the Portuguese *peões* walked through the field of battle with torches to identify the Portuguese dead and send them away for burial. Any wounded Castilians who were left were killed. The Castilian dead were examined for identity, stripped of all armaments and clothes, and left naked on the field. According to the chronicler, Lopes, who was writing half a century after the battle, that the following day after the battle "era muito que as aves nem os lobos, nem os case, não se chegavam a eles para os haver de comer" (*there were so many (corpses) that neither birds, nor wolves, nor dogs came because they had already eaten their fill*). By August 18th, he notes, the reek of the corpses was so foul that everyone quitted the area. The corpses were left to rot on the field of battle for years until work was begun on a small commemorative chapel (completed 1393) commissioned by the general who led the army to victory, Nuno Alvares, and the remaining skeletons were put into a mass grave. Paço (1990: 111) suggests that the remains of the corpses were collected from underneath the brush that covers the area. Mostly only the biggest and most easily spotted bones were deposited into the burial pit and the smaller more delicate fragments had already

succumbed to the effects of weather and/or were not collected because of lack of visibility.

The sample interred in this grave represents the Castilian dead who were not rich or important enough to have their bodies ransomed back to their homes. The Castilian *peões* were individuals who came from the social class just below *"cavaleiros"* (knights i.e. rich enough to own two or three horses to do battle on and mostly of the noble class). According to Serrão (1990: 51), the *peões* class represented adult males from the "middle class" who worked for or with money that included rural land owners of modest means, business owners and industrialists (rather than labored for keep or kind). They were obliged to provide military service (or buy their way out of it) as part of their rights and responsibilities as a free owner-class citizen. These foot-soldiers armed themselves according to their incomes. According to a document dated 4 March 1317, the types of armaments that the *peões* of the city of Lisbon were allowed to wield varied with their personal wealth: those whose net worth exceeded 100 Libras ("100 Pounds") were required to wield "espaldeira," "gorjeira," "escudo" and "lança"; those whose net worth was less than 100 Libras armed themselves with "lança," "dardos" and "besta." The role of the *peões* in battle was mostly hand-to-hand combat with other *peões* trying to kill or incapacitate each other, mostly by means of blunt force trauma or by stabbing. Because they needed to be mobile, the *peões* were lightly armored mostly with helmets and perhaps some chain mail covering the neck. The other role of *peões* in battle was killing un-horsed knights whose heavy armor hampered their movement and made them vulnerable to attack by blunt force.

In summary, the individuals from this battle of Aljubarrota sample represented adult, male, moderately wealthy, small landholders who were not professional soldiers. Any antemortem trauma they would have sustained likely came from their peace-time occupations, mostly, although not exclusively, from a rural context as relatively small scale farmers. Their bodies clearly sustained perimortem trauma, although its affect on the bones may not always be observable, and their bones clearly sustained postmortem damage from scavenger activity and weathering before they were buried.

Calibrated radiocarbon analysis of the bones recovered near the chapel of São Jorge showed a date of 600 ± 50 years BP, with a range of AD 1290- 1425 (for 95% probability) and AD 1300-1410 (for 68% probability). This puts the sample at approximately the right time to be from the battle (Cunha *et al.* 2001:134).

B3b. All elements have been excavated under the same treatment

The exact site of the battle of Aljubarrota and the mass grave was unknown until they were discovered by a youth group working on a gardening project along the grounds of the São Jorge chapel. All elements in this collection were excavated between 1958 and 1960, led by Lieutenant-Coronel Paço with the collaboration of the Military History Commission (Paço 1960). The excavated skeletal sample from the mass grave found a few meters south of the chapel contained 2,874 bones and was analyzed for the preliminary report by Xavier da Cunha of the Department of Anthropology, University of Coimbra (Paço 1962) using "os métodos e recursos então disponíveis" (*the methods and resources currently available)* (Monteiro 2001:9). The sample was found by him to be consistent with secondary burial of robust males. Most of the skeletal material was deposited at the University of Coimbra and is organized by element.

B4c. All elements have been recorded

Although it has not been catalogued, aspects of sample from the battle of Aljubarrota have been published in Paço (1962), Cunha and Silva (1997) and Cunha, Marques and Matos (2001). I also examined the sample and took my own data about trauma and the composition of the sample. Some of the bones have been radiographed in the context of examining age-at-death (Cunha and Silva 1997) and examining some of the individuals who showed signs of healed fractures (Cunha *et al.* 2001).

B4d. Limitations of the Aljubarrota sample

There are at least five major limitations of the Aljubarrota sample. The first is that it is fragmentary. The second is the lack of association of the fragments with a specific individual age-at-death and sex. The third is that it is clearly not a representative sample from the Iberian medieval population at large. The fourth is that there is some potential difficulty in distinguishing some kinds of perimortem trauma, such as depression fractures, from antemortem trauma. The fifth is that the elements preserved at Aljubarrota represent a very different distribution of the fragments over the bones of the body than those at Krapina.

The first two limitations, the fragmentary nature of the sample and the lack of association of the fragments with a specific individual demographic identity are the same as those of the Krapina sample.

Clearly, Aljubarrota has many limitations as a comparative sample in terms of its demographic profile. Using counts of femoral fragments, the maximum MNI is 414 for the site (Cunha *et al.* 2001: 134-135). Analyses of the few preserved fragments from os coxae as well as analyses of secondary sexual characteristics of cranial fragments and

long bone metrics indicate that most, if not all, the sample is likely masculine (Cunha *et al.* 2001: 144-145) . Age-at-death estimations for Aljubarrota are based on results from examinations of pubic symphyses and auricular surfaces as well as radiographic examinations of the epiphyses and humeri to look at the duration of closure of the epiphysis to the diaphysis, other suture closures, use-wear on teeth, and arthritic degeneration of various joints (Cunha *et al.* 2001:145). Although the ages for most the individual bones analyzed were about 18-25 years, there were a some middle aged adults and perhaps even a few as old as 65 (Cunha *et al.* 2001:145). There were also three immature elements (a right humerus, a left femur and a fragment of a mandible) that were each aged to about 4-4.5 years (+/- 12 months) and may represent as many as three children (Cunha and Silva 1997:597). The inclusion of these immature remains was probably accidental and may have happened when the remains from the battle were being transferred to the mass grave. The sample from Aljubarrota only reflects the activities of less than half (in terms of age-at-death and sex) and probably less then a quarter (in terms of activities based on occupation and social class) of the Medieval Iberian population.

The fourth limitation is the high level of perimortem trauma at Aljubarrota. As reviewed in Chapter II, some types of trauma such as simple fractures are fairly easily distinguished as antemortem versus perimortem. Other types of fractures, such as cranial depression fractures (especially when they are small or slight) are more difficult to distinguish. However, the fragmentary nature of the Aljubarrota sample is likely to obscure much of the perimortem trauma.

The fifth potential limitation of the comparison between Aljubarrota and Krapina is that the distribution of the individual bone of Aljubarrota sample among the skeletal

elements of the body is significantly different from that observed at Krapina. The following table 6.3 list the total number of elements preserved from each site.

Table 6.3 Distributions of the Krapina and Aljubarrota sites by element

Element	Krapina	Aljubarrota
Crania	176 +++	478 ---
Maxilla and Mandible	54 +++	70 ---
Vertebrae	56 +++	37 ---
Ribs	70 +++	27 ---
Scapulae	19 +++	5 ---
Clavicle	17 +++	3 ---
Sternum	1	2
Humerus	21 ---	544 +++
Radius	12	54
Ulna	18	69
Hands	70 +++	6 ---
Os Coxae	16 ++	37
Femur	32 ---	1023 +++
Tibia	19 ---	422 +++
Fibula	19 ++	36
Feet	78 +++	48 ---

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 1294, the SAD value calculated from the observed table, for 0 out of 10000 simulated tables, p=0.00. The whole table is inconsistent with the null hypothesis that distribution of the bones by element is independent of the identity of the sample and the null hypothesis is rejected.

Since it is possible that some of these differences might be driven by the very large counts of femurs, tibias and humeri (relative to other elements) from Aljubarrota, the distributions of elements were also compared with these bones removed. Counts of the distributions of all elements Krapina come from Gardner and Smith (2006: 472) and counts from Aljubarrota come from Cunha *et al.* (2001: 137).

Table 6.4 Distributions of the Krapina and Aljubarrota sites by element with humeri, femora and tibias removed (previous results in parentheses)

Element	Krapina		Aljubarrota	
Crania	176 ---	(+++)	478 +++	(---)
Maxilla and Mandible	54	(+++)	70	(---)
Vertebrae	56 +++	(+++)	37 ---	(---)
Ribs	70	(+++)	27 ---	(---)
Scapulae	19 +++	(+++)	5	(---)
Clavicle	17 +++	(+++)	3 ---	(---)
Sternum	1		2	
Radius	12 ---		54 +++	
Ulna	18 ---		69 +++	
Hands	70 +++	(+++)	6 ---	(---)
Os Coxae	16 --	(++)	37 ++	
Fibula	19 -	(++)	36 +	
Feet	78 +++	(+++)	48 ---	(---)

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 538, the SAD value calculated from the observed table, for 0 out of 10000 simulated tables, p=0.00. The whole table is still inconsistent with the null hypothesis that distribution of the bones by element is independent of the identity of the sample and the null hypothesis is rejected. The majority of the counts (16/26) were significantly different.

General trends in the differences in the distributions of bones by element in the two collections include an overrepresentation of the larger long bones (humerus, femur and tibia) and cranial bones in the Aljubarrota sample, and very little representation of the other bones compared to Krapina. Although the differences in the distributions of elements in the two samples are significant, element by element comparisons of trauma frequencies are not affected by overall distributions of the bones.

There are limitations to the Aljubarrota sample as a comparative sample, but most of these limitations derive from parameters that are known about the sample. Most other

archaeological samples (especially for fragmentary samples) are not so well historically documented and their limitations are unknown. Certainly, the demography of the sample and the distribution of skeletal elements are very different from that observed at Krapina and results must be analyzed with this in mind.

B4. Section Summary

In this section, ways of addressing the limitations of the Neandertal sample for trauma were discussed. One of these ways is to focus the analysis on a sample of Neandertals that come from a single site. The suitability of the Krapina sample to this role was reviewed. Another problem discussed in the previous chapter was the lack of comparative samples, especially those consisting of fragmentary remains. The Aljubarrota sample from São Jorge, Portugal was proposed as a suitable comparative sample due to the context of its preservation and its high level of historical documentation.

C. A New Method of Collecting Trauma Data for Fragmentary Remains

In this section, I discuss methods of collecting trauma data for fragmentary remains. As reviewed in Chapter II, fragmentary remains have been mostly ignored in the analysis of trauma in a paleopathological context for the past thirty years. However, several authors (Robb 1997; Walker 1997; and Judd 2007) have created standards of recording and analyzing fragmentary remains in order to take better advantage of their samples. A persistent limitation of these methods is their approach of integrating data from fragmentary remains into a context that facilitates ready comparison to non-fragmentary samples from the literature. This has inspired some fairly complicated

analytical techniques. A different approach to collecting and analyzing data about traumatic frequencies will be introduced and discussed.

C1. Review of previous approaches to data collection and analysis for fragments

As discussed in Chapter II, the methods of counting elements introduced by Lovejoy and Heiple (1981) have become the standards for data collection for many paleopathological studies relating to trauma analysis. Their method of only including complete bones in element and fracture counts not only makes methodological sense with respect to not overestimating the number of elements actually present in collection, but also makes practical sense in that the completeness of an entire element is unambiguous, and counting complete elements is quick and repeatable. Lovejoy and Heiple's methods are appropriate if most of the bones represented in the sample are complete. However, there also exist samples, such as Krapina and Aljubarrota, where none or almost none of the bones represented in the sample are complete. It may be imagined that very few studies of fractured skeletal material exist unless there is some very compelling reason due to its rarity to bother with its analysis, such as great antiquity (e.g. fossil hominids), a long term survey of health (such as Angel 1974; Webb 1995; and Robb 1997), or some other specialized reason where a specific site must be analyzed (such as military history/national pride for the Aljubarrota remains). Given a choice, any researcher interested in a topic such as medieval European paleopathology would prefer a well preserved skeletal sample that is relatively easy to observe and unambiguous to analyze. Therefore only a few researchers have tackled approaches to the data collection and analysis of fragmentary specimens.

There are two very simple approaches to dealing with fragmentary remains in a paleopathological analysis. The first method is to note that the sample is fragmentary but then to treat the fragments as whole bones [such as in Angel (1974) and Webb (1989)] and almost all paleopathological comparisons of fossil bones from different sites (such as Berger and Trinkaus 1995; Underdown 2006 etc.). The other method, in cases where instances of trauma are rare, is to describe each instance of trauma individually without considering a larger context [such as in Webb's (1995) treatment of the Australian Pleistocene remains].

Solving the problem of how to count and analyze fragmentary remains involve two separate problems. The first is how to collect data in a repeatable manner that describes the material being examined. The second is, once data have been collected, how to analyze it in ways that account for its fragmentary state.

Robb (1997) addresses the problem of using fragmentary and commingled skeletal remains in his comparative analysis of trauma for populations with varying degrees of preservation. In order to compile samples from the different periods of Italian prehistory from which rates of trauma could be compared, Robb pooled together specimens from over forty different Central and Southern Italian sites and "standardized" them. He divided the adult cranial and postcranial elements into regions. The cranium was divided into the following regions: maxilla, zygomatic, frontal orbit, frontal squama, parietal, occipital squama, occipital base, temporal squama, temporal mastoid, temporal petrous, and sphenoid. Only the mandible, scapula, pelvis and long bones of the postcranial skeleton were analyzed. Hand and foot bones, vertebrae, sternum and ribs were not analyzed. The mandible and sacrum were not further divided into smaller

regions. The scapula was divided into the glenoid process, base of spine, coracoid process, spine/acromion, and the body. The innominate was divided into ilium, ischium, and pubis. All of the long bones (clavicle, humerus, radius, ulna, femur, tibia and fibula) were divided into proximal epiphysis, proximal shaft, middle shaft and distal epiphysis. Counts of each region were taken only if half or more of that region was present in the specimen, because including specimens of less than half of the region present underestimates the trauma rates in periods of worse bone preservation (ibid:131). Right and left sides were combined in the region counts. This enabled Robb to record data from many of the more fragmentary specimens that would not have been included in other protocols such as Heiple and Lovejoy (1981). The counts of these regions were compiled and traumas were recorded for each of the four time periods, the Neolithic, the Eneolithic, the Bronze Age and the Iron Age.

Because the number of bone fragments observed representing regions ranged from 127 regions in the Neolithic to 509 regions in the Iron Age and differed vastly in the degree of preservation of individuals, Robb created an "estimated trauma incidence" probability per individual in order to compare trauma frequency in each time period. He did this by dividing the regions he tabulated into two categories: the cranium (containing left and right sides of the frontal orbit, frontal squama, parietal and occipital squama regions) and the postcranial skeleton (containing left and right proximal, middle and distal shaft regions for the clavicles, humeri, radii, ulnae, femora, tibiae and fibulae). For each time period, the percentage of regions with cranial trauma was calculated by dividing the total number of traumas observed in the cranium by the total number of bones counted in each of the regions that make up the cranium. In a similar manner, the

percentage of regions with postcranial trauma was calculated by dividing the total number of traumas observed in the long bones by the total number of bones counted in each of the regions of his postcranial category.

These percentages of regions with cranial and postcranial trauma were used to estimate the probability of traumas in a complete specimen i.e. the probability that an individual living during that time period would show cranial or postcranial trauma on any of the regions that Robb had designated. Robb calls this estimated probability of trauma "estimated trauma incidence."

In order to calculate this "estimated trauma incidence" Robb assumes that any one regions of the groups of his designated regions that make up the cranium or postcranial skeleton manifests trauma independently of any of the other regions in the cranium or postcranial skeleton. The probability x that there will be an incidence of trauma in any one of the regions that make up the cranium or postcranial skeleton is calculated by dividing the total number of traumas observed in the cranium or postcranial skeletons by the total number of bones counted in each of the regions in the cranium and postcranial categories i.e. the percentage of regions with cranial or postcranial trauma. The probability that a given region does NOT show trauma is therefore $(1-x)$. With 8 regions of the cranium and 42 regions of the postcranial skeleton, the probability that NONE of the regions shows trauma for an individual with all the regions represented is $(1-x)^8$ for the cranium and $(1-x)^{42}$ for the postcranial skeleton. Therefore the probability that an individual will show trauma in one region is $1-(1-x)^8$ for the cranium and $1-(1-x)^{42}$ for the postcranial skeleton. This is the probability that Robb designates as the "estimated trauma incidence" which he expresses as a percent of individuals showing any trauma in

the designated group of regions, and uses for the pertinent comparison of trauma frequency among the collections from each of the time periods.

This "estimated trauma incidence" converts the data from the unit of "region," which is not necessarily comparable to the work of other authors, to an estimate of the non-arbitrary unit of "individual." This is important because it uses fragmentary and commingled remains, which cannot be designated as coming from specific individuals, to estimate what fraction of people in the population suffered trauma. This estimate allows the fragmentary and commingled data to be compared with complete burials of single individuals in other paleopathological literature. Robb's approach is novel in that many of the fragments that he is able to use would not have been counted under other protocols that exclude bones that are not complete, or when a certain percentage of the entire bone complete. Also, especially for the cranium, the "estimated trauma incidence" allows the data to be compared for trauma observed in crania of complete individuals, which is often the unit of cranial trauma comparisons in other literature.

This estimate does, however, make some assumptions about the independence of trauma. These assumptions are that the probability of trauma is equally spread among the individuals in a populations and that trauma occurs in one region independently of its occurrence in other regions. The first of these assumptions is that the risk of trauma is spread equally through the population instead of just a few individuals being particularly prone to single or multiple traumas because of their occupation, sex, genetic predisposition etc. The other assumption is that a single incidence of trauma only occurs in one region, which, given the small size of the delineated regions, probably overestimates the incidence of trauma. Robb also assumes that the "estimated trauma

incidence" represents a meaningful comparison of risk of trauma in the different populations.

Walker (1997) also encountered the presence of fragmentary remains in his analysis of nasal fractures versus fractures. To deal with this problem he recorded the fragments as "fractional individuals" depending on the amount of bone present, creating counts of "effective number of people" that differed from the reported counts of total number of individuals examined. Rates of trauma per area were determined using this "effective number of people" in the denominator rather than the actual count of individuals. Alvus (1999) also follows Walker's methodology in creating counts of "effective number of people" to look at potential bias in the preservation of skeletal elements; however his trauma frequencies were calculated using whole bones.

Judd (2002) used "five different methods" of recording long bone trauma to determine whether meaningful differences in fracture frequencies existed depending upon what standards were used to collect data. However, in actuality, she used two different methods of collecting data and four different ways of counting trauma frequency.

She collected data using the "5-segment method" where each long bone was divided into 5 segments: proximal epiphysis, proximal shaft, middle shaft, distal shaft and distal epiphysis. She scored a segment as "complete" if more than 75% of the segment was present. She recorded traumatic lesion by bone and by section. In order to determine how much of the bone should count as "epiphysis," she applied Müller *et al.*'s (1990) "system of squares" where the widest part of the epiphysis determines the height and width of the area considered "epiphysis." Trauma data were recorded if the area showed a visible callus formation, an angular deformity of the bone or a non-union of

healed bone and the data included sex of the individual, bone element, side and segment location. She tallied the counts of each segment type for every element and the counts of trauma to make a "segment count frequency" (segments with fractures ÷ segments observed).

To analyze the frequency of fractures, Judd employed 4 sets of 2 protocols which added all fragmentary counts that contained trauma to decreasing levels of total bone preservation. For 1a, she counted only bones that were represented by 5 complete and undamaged segments. For 1b, she counted added all "damaged" bones (i.e. traumatized bone) with fractures, to her 1a count. For 2a, she counted all bones represented by 5 segments that were 75% or more complete. For 2b, she added traumatized bones with less than 5 segments that were 75% complete to her 2a count. For 3a, she counted all bones represented by 4 or more complete segments that were 75% or more complete. For 3b, she added traumatized bones with less than 4 segments that were 75% complete to the 3a count. For 4a, she counted bones represented by 3 or more segments that were 75% or more complete. For 4b, she added traumatized bones with less than 3 segments to the 4a count. For 5, she analyzed all segments that were 75% or more complete.

Frequencies of trauma per bone, of course, decreased as more bones were added to the "a" pile, however the differences did not seem to be significant differences between the results of "a" method counts or between "a" and "b" counts. She also measured the mean number of fractures per individual, the mean multiple injury score and the "individual counts of fractured people" (the number of individuals with one or more injury divided by the total number of individuals in the sample) for each "a" and "b" protocol. For the entire sample, by side, and for males and females, she also

calculated percentage of preserved bone by dividing "segments recovered" by "segments expected."

Judd found that although taking data for, and counting, all segments was the most time consuming for data collection, entry and analysis, that it also represented the most adaptable and complete way of recording a collection. Although when all fractures were added to the total counts (i.e. "b") methodology, there was no loss of injury counts, if these fractures were excluded because they were not from whole bone "21% of the total number of injuries would be excluded (Ibid: 1264) from the counts (i.e. 6 injuries out of 28 total injuries).

Robb (1997), Walker (1997) and Judd (2002) each address how to count and analyze fragmentary remains that incorporate them into a sample with whole bones. Robb and Judd both discuss collecting data about bones by dividing them into "regions" and taking counts of trauma in each of those regions. Walker (1997) proposes estimation of a percentage of bone preservation and adding these fractions to form an "effective number of people." To analyze the trauma counts based on fragmentary data, Robb proposes an "estimated trauma incidence" which represents a theoretical probability of trauma per individual based on the percentage of regions with trauma. Judd examines fracture frequencies under various counting protocols.

C2. A new approach to data collection and analysis for fragments

Although Robb (1997), Walker (1997) and Judd (2002) all deal with fragmentary remains as part of their samples, their samples are made up of discrete (although incomplete) individuals. All of their methodologies try to incorporate "missing" bones into counts of individuals, which makes sense when it is clear how many elements

"should" be available. However, in other situations where fragmentary remains must be dealt with, there is not a good sense of how many individuals are actually preserved in the sample. MNI counts vary from 3-414 for Aljubarrota (Cunha *et al.* 2001:135) and from 12-82 at Krapina (Ullrich 2006:505) depending upon what elements are chosen. In both of these cases trying to transform fragments into counts of individuals seems to be unnecessary.

Here I propose a method of recording each fragment by drawing its borders on an outline of a whole bone. The location of trauma is also recorded on this drawing along with information about the bone such as a description of pathology, taphonomic alterations, and photograph identity numbers. This allows for flexibility in data collection and later data counting. Because fragments are being compared with fragments in this study, I propose that each bone be divided into regions and that counts of trauma be taken solely in the context of presence in that region.

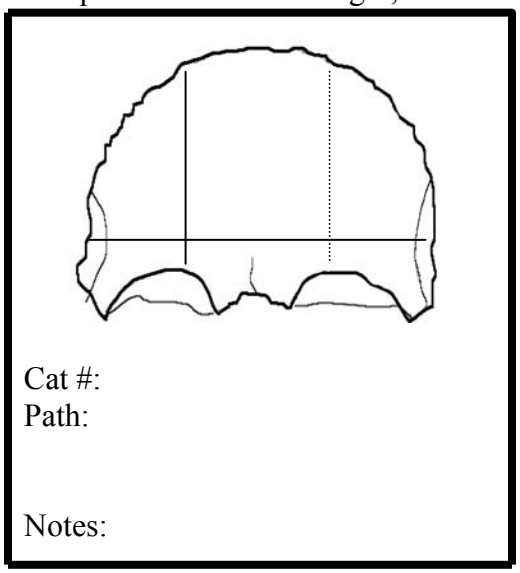
C2a. Data collection methodology

Because the collections at Krapina and Aljubarrota were composed almost exclusively of fragmentary remains, it was necessary to have a recording system that allowed the exact recording of the parameters of each fragment and the location of trauma. Given high resolution scanning and relatively ease of file conversions into PDF format, it is possible to store these notes both on paper as well as in electronic format to retrieve as needed. This recording method also allows for counts to be tallied of fragments in many different ways after the data collection has been finished, without any *a priori* limitations.

Collection of data was based on visual records for each of the bones. A sketch of the borders of the fragment was drawn onto an outline of the complete bone. In addition to the outline of the fragment, information about catalogue/specimen number, pathology, photograph number, and other notes were also recorded. On the drawings themselves, the outline of the fragment was made in blue ink, pathology was recorded in red ink and taphonomic irregularities were recorded with green ink (see Appendix for examples). The use of different colors facilitated quick visual summaries of the contents of the notes.

For cranial bones and mandibles, individual records were made of each of the bones. Figure 6.1 represents a sample of the blank filled in for an individual frontal and each page included 6 of these blanks.

Figure 6.1 Individual blank from a frontal record sheet (lines within the frontal did not appear on original data form and represent the division of the frontal into right, center and left squama sections and right, center and left supraorbital sections)



Data collection worksheets for each element are included in the Appendix.

Once these data have been recorded, protocols for counting instances of bone present were created. Under the assumption that each instance of a skeletal element was equally likely to be fragmentary as unbroken, counts were taken of the presence of

sections of the whole bone rather than as percentages of an unbroken bone. Cranial bones were divided in various ways depending upon landmarks and postcranial bones were each divided into three sections. Sections were counted as present if 50% of more of the bone was present in cases where this was feasible. However, exceptions to this are as noted below. Bones were only counted if they could be sided. Because most of the bones were fragmentary, the division of bones into sections had to represent distinguishable areas. This was occasionally problematic, as in the case of parietals. Also the division of bones into sections should represent "meaningful" area distinctions in terms of trauma data collection, rather than MNI counts. An example of this is the exclusion of counts of petrous portions of the temporal as irrelevant to the data gathering of incidences of trauma. Although petrous portions tend to preserve well because of their density, they are unlikely to show direct signs of trauma because they are mostly protected behind the temporal bones. Methods for dividing individual skeletal elements into sections are reviewed as follows.

Frontal

The most divisions of any single bone were for the frontal. To make counts of frontals preserved in each sample, the bone was divided into six sections and counts were taken for each section. These sections were right, center and left supraorbital regions and right, center, left squama. Because of frontal breakage patterns, especially for Neandertals, the squama was often separated from the supraorbitals. Simply dividing the frontal into right, center, and left portions would have excluded many of the supraorbital fragments.

Parietal

Parietals were divided into anterior and posterior halves. Presence in a section was recorded for fragments that could be sided and represented at least 50% of the section. Most parietals that could be sided also represented 50% or more of the total bone so scoring by section did not add many more fragments not already represented.

Temporals

Temporal squamae were divided by right and left sides. Mastoids were included in counts of the temporal squamae when they were attached. Although, analogous to the supraorbital region in the frontals, mastoids could have been counted as a separate area, the preserved mastoids were mostly attached to fairly large pieces of temporal. Petrous portions were not counted because they do not evidence signs of trauma.

Occipitals

Occipital squamae were divided into right, left and central sections. Basal section (i.e. basilar part and occipital condyles) were counted separately.

Zygomatic bones and nasals

Zygomatic bones and nasals were divided only by right and left sides if more than 50% was present and/or could be sided.

Maxillas and Mandibles

Maxillas and mandibles were divided into right, center and left sections. For mandibles, the ascending ramus and condyle were counted as separate sections. An analogous division was made for the facial portions of maxillas into right and left sides, however these were so poorly preserved (with the exception of Krapina 3) that counts were not taken.

Vertebras

Each of the three types of vertebras was divided into three sections. The sections were vertebral body, left side of the neural arch and right side of the neural arch. Spinous processes were recorded as part of either the right or left side depending on which side was preserved.

Pelves

Counts were made of each of the individual bones (pubis, ischium, ilium and sacrum) that make up the pelvis if a side could be attributed.

Ribs

Ribs were divided into right and left sides. Any rib fragment that could be sided was included.

Scapulae

All scapulae preserved in the two collections were very fragmentary (especially at Aljubarrota). Counts were taken of scapula that could be sided and had at least 50% of the glenoid fossa preserved or represented complete acromial or coracoid processes.

Clavicles

Clavicles were divided into a proximal (sternal) half and a distal (acromial) half. All clavicles that could be sided were included.

Bones of Hands and Feet

Counts were taken of each of the individual carpal and tarsal bones that could be sided. All metacarpals and metatarsals from digits 2-4 were counted into “metacarpal” or “metatarsal” categories. Phalanges from the first digits were counted separately as

proximal and distal. Phalanges from digits 2-5 were counted as proximal, medial and distal.

Long bones: humerus, radius, ulna, femur, tibia, fibula

Each of the long bones was divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. As noted by Judd (2002), it is difficult to put an endpoint on where the epiphyseal portion of the bone should be delimited from the diaphyseal portion. I generally drew the line between epiphyses and shafts at the place were the shaft begins to noticeably widen as it approaches the epiphysis; however it roughly corresponds with Müller *et al.* (1990) "system of squares," but is easier to spot on a fragment.

The worksheets for data collection for long bones were slightly different from those used for cranial and mandibular elements. Because there were so many long bone fragments, a more efficient system was devised to quickly record number of fragments represented per section. A summary sheet included a large outline of a complete bone from one side of the body. For each element, the proximal and distal limits of all fragments from that side were mapped on the outline and a running tally was taken for each of the sections. Worksheets similar to the ones used for the cranial remains were used only for bones that showed potential evidence of trauma. Examples of all these worksheets are in the Appendix.

C2b. Data analysis methodology

Although, data was collected for all elements, for the following, data counts were only analyzed for segments of elements that contained trauma in one or both collections

(first set) or trauma in both collections (second set). Because the sample from Aljubarrota composed almost exclusively of adults, immature remains are not counted in the totals.

The first set of comparisons between the distributions of trauma at Aljubarrota versus Krapina involves the distribution of trauma throughout the skeletal elements of the body. For each element, the null hypothesis is tested of independence between the distribution of trauma and the identity of the sample. For cranial fragments, totals from each of the delineated sections are combined to be the "total section count." For long bones, totals from right and left sides of the equivalent section are combined to be the "total section count". This total section count is much higher than just counting individual bones because a complete bone would count as "3" in the "total section count" rather than "1." However, because all elements are counted a consistent manner for both collections, this is not a problem. However, my counts are not comparable to other paleopathological studies.

The second set of comparisons involves the distribution of trauma throughout sections of the skeletal elements by side or "section" in the case of occipital and frontal squama. For each element, the null hypothesis is tested of independence between the distribution of trauma and the sides/sections of the element for each collection. For these comparisons, the distributions of trauma counts from sides are compared by element for cranial and long bone elements that contain trauma in both collections.

For both sets of comparisons, all counts were entered into ACTUS2 tables and tested for independence using the program's frequency simulation ("F-simulation") methodology for calculating SAD values and chi-square values and then using the

entered tables to create 10,000 simulated versions of that table from which to test significance.

C3. Section Summary

In this section, various methodologies for collecting data from fragmentary remains were reviewed. The need for methodologies that do not convert fragmentary remains into instances of complete remains was discussed. Instead, the methods proposed here convert all bones into delineated pieces referred to as "sections." Total counts of bones present in these sections as well as counts of trauma may then be taken. In this way, the actual number of bones with an area present may be directly compared. To analyze these data, it is proposed that counts of bones are to be compared by element and by side for sections with trauma.

D. Results: Patterns of Trauma at Krapina and Aljubarrota

In this section, independence of the distribution of trauma over elements preserved at Krapina and Aljubarrota will be tested in two ways. The first uses combined counts of sections of each element to test the null hypothesis of independence between the distribution of trauma and the identity of the sample for each element. This null hypothesis will only be tested for elements where one or both of the collections contained instances of trauma. The second uses counts of sides/sections of each element to test the null hypothesis of independence between the distribution of trauma and the sides/sections of the element for each collection. Differences in the distributions of trauma by side between the collections will be assessed for elements where trauma was observed in both the Krapina and Aljubarrota collections.

D1. By Element

For each element, the null hypothesis is tested of independence between the distribution of trauma and the identity of the sample. This null hypothesis is only tested for elements where one or both of the collections contained instances of trauma. Because neither collection contains trauma to temporals, maxillas, zygomatic bones, nasal bones, mandibles, vertebras, radiuses, bones of the hand, pelves, fibulas or the bones of the feet, comparisons are not included for these elements.

D1a. Frontal

Frontals were divided into two large sections, supraorbital region and squama, that will be discussed separately because trauma was present in both areas.

Results for frontal supraorbital

Frontal supraorbitals were divided into left, right and center sections. The presence of bone was scored in a section if 50% or more was present. "Total section count" represents the combined sum of counts of presence of bone from all three sections.

Table 6.5 Frontal supraorbitals: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	22	0
Aljubarrota	47	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 2.48, the SAD value calculated from the observed table, for 3335 out of 10000 simulated tables, p=0.33. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for frontal supraorbitals. There were no trends.

Results for frontal squama

Table 6.6 Frontal squama: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	20	3
Aljubarrota	93	7

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 4.52, the SAD value calculated from the observed table, for 3399 out of 10000 simulated tables, p=0.34. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for frontal squamas.

D1b. Parietal

Parietals were divided into anterior and posterior sections for right and left sides. Because trauma appeared only in the posterior sections, "total section count" represents the combined total of the left and right posterior sections.

Table 6.7 Parietals: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	14	2
Aljubarrota	24	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 0.73, the SAD value calculated from the observed table, for 8460 out of 10000 simulated tables, p=0.85. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for parietals.

D1c. Occipital

The occipital was divided into two large sections, the squama and the basal area, which were treated separately. There was no trauma observed in the basal area in either sample so only the distribution of trauma will be analyzed only for the squama. The occipital squama was divided into left, right and center sections. The presence of bone was scored in a section if 50% or more was present. "Total section count" represents the combined sum of counts of presence of bone from all three sections.

Table 6.8 Occipital: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	29	0
Aljubarrota	91	4

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 3.74, the SAD value calculated from the observed table, for 2502 out of 10000 simulated tables, p=0.25. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for occipital squamas. There were no trends.

Summary: Crania

I analyzed comparisons between Krapina and Aljubarrota for the following cranial sections where trauma was present in one or both collections: frontal supraorbitals, frontal squamas, posterior parietals, and occipital squamas. The null hypothesis of independence of the distribution of trauma and the sample identity was not rejected for any section of the crania.

D1d. Rib

Ribs were divided by right and left sides only for elements that whose side could be assessed.

Table 6.9 Rib: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	65	0
Aljubarrota	10	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 3.42, the SAD value calculated from the observed table, for 365 out of 10000 simulated tables, p=0.04. The whole table is inconsistent with the null hypothesis of independence of distribution of trauma and sample identity and the null hypothesis is rejected.

D1e. Clavicle

Clavicles were divided into a proximal (sternal) half and a distal (acromial) half for right and left sides. Because all 3 instances of preserved clavicle at Aljubarrota only included shafts, they will all be counted as "distal." Because trauma appeared only in the distal section, "total section count" represents the combined total of the left and right distal sections.

Table 6.10 Clavicle: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	6	1
Aljubarrota	3	0

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 1.2, the SAD value calculated from the observed table, for 4493 out of 10000 simulated tables, p=0.45. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for clavicles.

D1f. Humerus

Humeri were divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. Because trauma was present only in the shaft section, only shaft section counts for combined right and left sides will be compared.

Table 6.11 Humerus: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	4	0
Aljubarrota	140	2

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 0.22, the SAD value calculated from the observed table, for 4357 out of 10000 simulated tables, p=0.44. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for humeri.

D1g. Ulna

Ulnas were divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. Because trauma was present only in the shaft section, only shaft section counts for combined right and left sides will be compared.

Table 6.12 Ulna: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	5	2

Aljubarrota	29	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 5.73, the SAD value calculated from the observed table, for 405 out of 10000 simulated tables, p=0.04. The whole table is inconsistent with the null hypothesis of independence of distribution of trauma and sample identity for ulnas and the null hypothesis is rejected.

D1h. Femur

Femurs were divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. Because trauma was present only in the shaft section, only shaft section counts for combined right and left sides will be compared.

Table 6.13 Femur: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	15	0
Aljubarrota	947	13

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 0.8, the SAD value calculated from the observed table, for 5392 out of 10000 simulated tables, p=0.54. The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for femurs.

D1i. Tibia

Tibias were divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. Because trauma was

present only in the shaft section, only shaft section counts for combined right and left sides will be compared.

Table 6.14 Tibia: Comparison of instances of trauma per total section count

Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina	13	0
Aljubarrota	352	15

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 2.05, the SAD value calculated from the observed table, for 4612 out of 10000 simulated tables, p=0.46.The whole table is consistent with the null hypothesis of independence of distribution of trauma and sample identity for tibias.

Summary: Post-crania

I analyzed comparisons between Krapina and Aljubarrota for the following post-cranial bones where trauma was present in one or both collections: ribs, clavicles, humerus, ulna, femur, and tibia. The null hypothesis of independence of distribution of trauma and sample identity was not rejected for clavicles, humeri, femurs and tibias. The null hypothesis of independence was rejected for ribs (p=0.04) and ulnas (p=0.04).

D2. By Side

For each element, the null hypothesis is tested of independence of the distribution of trauma and the sides/sections of the element for each collection. Differences in the distributions of trauma by side between the collections are assessed only for elements where there was trauma in both the Krapina and Aljubarrota collections. Because both collections do not contain trauma to frontal supraorbitals, occipitals, temporals, maxillas, zygomatic bones, nasal bones, mandibles, vertebras, clavicles, humeri, radiuses, bones of

the hand, pelves, femurs, tibias, fibulas or the bones of the foot, comparisons are not included of the two collections for these elements.

D2a. Frontal Squama

Frontal squamas were divided into left, right and center sections. The presence of bone was scored in a section if 50% or more was present.

Table 6.15 Frontal squama: comparison of distribution of trauma by section

Section by Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina Right	9	0
Krapina Center	6	1
Krapina Left	5	2
Aljubarrota Right	21	1
Aljubarrota Center	38	3
Aljubarrota Left	26	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 9.04, the SAD value calculated from the observed table, for 5477 out of 10000 simulated tables, p=0.54. The whole table is consistent with the null hypothesis of independence of distribution of trauma and section for frontal squamas.

D2b. Parietal

Parietals were divided into anterior and posterior sections for right and left sides. Because trauma appeared only in the posterior sections, counts of distribution of trauma are analyzed only for the left and right posterior sections.

Table 6.16 Distal Parietals: comparison of distribution of trauma by side

Section by Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina Right	5	1
Krapina Left	8	1
Aljubarrota Right	14	2
Aljubarrota Left	10	3

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 3.90, the SAD value calculated from the observed table, for 8003 out of 10000 simulated tables, p=0.80. The whole table is consistent with the null hypothesis of independence of distribution of trauma and side for parietals.

D2c. Ulna

Ulnas were divided roughly into thirds representing proximal (epiphysis plus a bit of shaft), shaft (diaphysis), and distal (epiphysis plus a bit of shaft) for right and left sides. Fragments were recorded if 50% of a segment was present. Because trauma was present only in the shaft section, only shaft section counts for right and left sides will be compared.

Table 6.17 Ulnar shafts: comparison of distribution of trauma by side

Section by Collection	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Krapina Right	4	1
Krapina Left	1	1
Aljubarrota Right	20	1
Aljubarrota Left	19	0

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 6.21, the SAD value calculated from the observed table, for 1449 out of 10000 simulated tables, p=0.15.

Because of the significant differences observed in the distribution of ulnar trauma in the previous section, decoupling the samples from Krapina and Aljubarrota to test the hypothesis of the independence of the distribution of trauma by side clears some of the "noise" created by the significant difference in the sample sizes.

Table 6.18 Krapina: Distribution of ulnar trauma by side

At Krapina	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Right	4	1
Left	1	1

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 1.71, the SAD value calculated from the observed table, for 4725 out of 10000 simulated tables, p=0.47. The whole table is consistent with the null hypothesis of independence of distribution of trauma and side.

Table 6.19 Aljubarrota: Distribution of ulnar trauma by side

At Aljubarrota	Total Section Count WITHOUT Trauma	Total Section Count WITH Trauma
Right	20	1
Left	19	0

The sum of absolute difference values (SAD values) calculated from F-simulated tables were equal to or exceeded 1.90, the SAD value calculated from the observed table, for 3621 out of 10000 simulated tables, p=0.36. The whole table is consistent with the null hypothesis of independence of distribution of trauma and side

D3. Section Summary

In this section, independence of the distribution of trauma over elements preserved at Krapina and Aljubarrota were tested in two ways. The first way used combined counts of sections of each element to test the null hypothesis of independence between the distribution of trauma and the identity of the sample for each element. This null hypothesis is only tested for elements where one or both of the collections contained instances of trauma. The null hypothesis of independence was rejected only for ulnae and ribs. The second way used counts of sides/sections of each element to test the null hypothesis of independence between the distribution of trauma and the sides/sections of

the element for each collection. Differences in the distributions of trauma by side between the collections were assessed only for elements where there was trauma in both the Krapina and Aljubarrota collections: frontal squama, posterior parietal, and ulnar shaft. The null hypotheses of independence between the distribution of trauma and the side of the body were not rejected for any of the comparisons between Krapina and Aljubarrota.

E. Discussion of Results: Comparisons between Krapina and Aljubarrota

In this section, the results of the comparisons between the distributions at Krapina and Aljubarrota will be discussed. Also the limitations of fragmentary data will be reviewed in the context of these comparisons.

E1. By element

To test the significance of differences in the distributions of trauma by element combined counts of sections of each element were used to test the null hypothesis of independence between the distribution of trauma and the identity of the sample for each element. This null hypothesis is only tested for elements where one or both of the collections contained instances of trauma. In cases where neither collection contains trauma, comparisons are not included of the two collections for these elements: temporals, maxillas, zygomatic malars, nasals, mandibles, vertebras, radiuses, bones of the hand, pelves, fibulas or the bones of the foot. The null hypothesis was not rejected for frontal squama and supraorbitals, parietals, occipitals, clavicles, humeri, femora, and tibiae. The results of these tests of the null hypothesis are summarized in table 6.20.

Table 6.20 Results of comparing distributions of trauma at Aljubarrota and Krapina by element

Element	Result
Frontal Squama	*Consistent with null hypothesis of independence*
Frontal Supraorbital	*Consistent with null hypothesis of independence*
Parietal	*Consistent with null hypothesis of independence*
Occipital	*Consistent with null hypothesis of independence*
Ribs	**Null hypothesis rejected**
Clavicle	*Consistent with null hypothesis of independence*
Humerus	*Consistent with null hypothesis of independence*
Ulna	**Null hypothesis rejected**
Femur	*Consistent with null hypothesis of independence*
Tibia	*Consistent with null hypothesis of independence*

The null hypothesis of independence was rejected for ulnae and ribs, both at p=0.04. The distribution of trauma in ulnae is higher at Krapina than at Aljubarrota. The distribution of trauma in ribs is lower at Krapina than at Aljubarrota. The high relative frequency of ulnar trauma at Krapina may be explained by the lack of ulnar shafts preserved which gives the counts of 2 instances of trauma (versus 5 without) a lot of statistical weight. Similarly the high relative frequency of rib trauma at Aljubarrota might similarly be based on the lack of ribs preserved at that site (1 with trauma and 10 without versus 0 with trauma and 65 without). Given the paucity of these samples, it is difficult to strenuously argue that these "significant" results are not due to sample size.

Generally, counts of trauma were so rare in both collections that there were not significant differences in the distributions of trauma. There were two cases in which the differences in the distributions were significant, the ulnae and ribs. These cases were similar in three ways. First, in both of these cases, the collection in which this trauma was overrepresented also underrepresented instances of these bones without trauma relative to the other collection. Second, the other collection included a much higher total number of

bones. Third, differences in number of bones with trauma between the collections were 1 more instance in both cases.

Although differences were significant in the case of ulna and rib trauma, a case may be made that the significance was mainly driven by sampling bias in each element rather than real differences in trauma. Both of these samples were very small and the presence of a single trauma in the smaller sample, as in the case of the ribs, is enough to make the distributions of trauma very significant.

E2. By side

Looking at distributions of trauma by side used counts of sides/sections of each element to test the null hypothesis of independence between the distribution of trauma and the sides/sections of the element for each collection. Differences in the distributions of trauma by side between the collections were assessed only for elements where there was trauma in both the Krapina and Aljubarrota collections. Because neither collection contains trauma to temporals, maxillas, zygomatic malars, nasals, mandibles, vertebras, radiuses, bones of the hand, pelves, fibulas or the bones of the foot, comparisons are not included of the two collections for these elements. The null hypothesis was tested for frontal squamae, parietals and ulnae. Results are summarized in table 6.20.

Table 6.21 Results of comparing distributions of trauma at Aljubarrota and Krapina by side of element

Element	Result
Frontal squama	*Consistent with null hypothesis of independence*
Parietal	*Consistent with null hypothesis of independence*
Ulna	*Consistent with null hypothesis of independence*

In the all cases, the distribution of trauma over the sides/sections was consistent with the null hypothesis that the distribution of trauma was independent of side for both collections.

Evidence of trauma in human remains is rare and evidence of trauma in fragmentary remains is even rarer because many of the taphonomic processes that cause fragmentation are the same processes that obscure macroscopically observable aspects of trauma. Radiography of all specimens might be a solution; however it is not practical or even feasible for most samples. Moreover, radiography cannot address the parts of fragments that are not preserved. The methods of taking data and analyzing fragmentary remains summarized here have the advantage of addressing only the fragments that are present rather than trying to estimate full bones from such fragments.

F. Chapter VI Conclusions

In this chapter, suggestions of alternate ways of addressing trauma in Neandertals were discussed. These include the benefits of the analysis of a sample from a single site. A new methodology for addressing the distribution of trauma in fragmentary remains was summarized and then implemented in the comparisons of trauma between the Krapina Neandertal sample and a comparative modern sample from Portugal.

In the first section, ways of addressing the limitations of the Neandertal sample for trauma were discussed. One of these ways is to focus the analysis on a sample of Neandertals that come from a single site. The suitability of the Krapina sample to this role was reviewed. Another problem discussed in the previous chapter was the lack of comparative samples, especially in the context of fragmentary remains. The Aljubarrota

sample from São Jorge, Portugal was proposed as a comparative sample due to the context of its preservation and its high level of historical documentation.

In the second section, various methodologies that have been employed for collecting data from fragmentary remains were reviewed. The need for methodologies that do not convert fragmentary remains into instances of complete remains was discussed. Instead, the methods proposed here convert all bones into delineated fragments referred to as "sections." Total counts of bones present in these sections as well as counts of trauma may then be taken. In this way, the actual number of bones with an area present may be directly compared. To analyze these data, it is proposed that counts of bones are to be compared by element and by side for sections with trauma.

In the fourth section, independence of the distribution of trauma over elements preserved at Krapina and Aljubarrota was tested in two ways. The first way used combined counts of sections of each element to test the null hypothesis of independence between the distribution of trauma and the identity of the sample for each element. This null hypothesis is only tested for elements where one or both of the collections contained instances of trauma. The null hypothesis of independence was rejected for ulnae and ribs. The second way used counts of sides/sections of each element to test the null hypothesis of independence between the distribution of trauma and the sides/sections of the element for each collection. Differences in the distributions of trauma by side between the collections were assessed only for elements where there was trauma in both the Krapina and Aljubarrota collections: frontal squamas, posterior parietals, and ulnas. The null hypothesis not rejected for any of the elements.

In the fifth section, these results were reviewed and discussed with the conclusion that for most elements, the distribution of trauma at Krapina and Aljubarrota were not significantly different. Significant differences in the distribution of trauma in the ulnae and ribs are both based on differences of a single instance of trauma, very small samples, and large sample size differences. Because of all these factors, it is difficult to draw the conclusion that much difference in the distribution of trauma between the samples from Aljubarrota and Krapina may be assessed. The influences of sampling bias on very small samples with very few occurrences of trauma and taphonomic biases relating to the different exposures of the bones in the two collections seems to be as valid an explanation of significant results as differences in the activities of Neandertals and medieval Iberians.

CHAPTER VII

DISCUSSION

A. Chapter VII Introduction

In this chapter, I summarize and comment on aspects of Neandertal trauma. In the first section, I will address the problems and limitations in the analysis of Neandertals trauma presented in my thesis. In the second section, I will review my conclusions concerning trauma and what can be inferred about its role in Neandertal life. In the third section, I will discuss the role that trauma analysis should play in evolutionary studies and the dangers of over-reaching conclusions not supported by data. In the fourth section, I will conclude with some ideas for future work and possible directions for the study of trauma in Paleolithic populations.

In the author's note of Fraser's (2001) biography of Marie Antoinette, the author discusses the notorious "incident" that when learning that the poor had no bread to eat, Marie Antoinette is alleged to have said "Let them eat cake." Fraser points out that this statement was first attributed to a Spanish princess during the reign of Louis XIV and repeated about a series of princesses throughout the eighteenth century. Fraser (2001: xviii) asserts: "As a handy journalistic cliché, it may never die." I feel, similarly, that the image of the excessively injured Neandertal is pervasive and perhaps as ill-founded. Since the discovery of the first "Neanderthal" in Feldhofer Cave, many of the better known and complete Neandertal skeletons have showed some sign of trauma. In this

context, it is easy to imagine that Neandertal trauma is pervasive; however it is another thing to objectively compare trauma frequencies in Neandertals with those in other populations. Authors such as Trinkaus (1978), Berger and Trinkaus (1995), Pettitt (2000), and Underdown (2006) have assumed that trauma is very frequent consequence of Neandertal lifeways. Among these authors, only Underdown has attempted to document its frequency based on a very selective sample constituted almost exclusively of Neandertals with trauma.

For more than a decade since the publication of Berger and Trinkaus (1995) paper, misinterpretations of their conclusions have been taken as "fact" in the popular press on the subject of Neandertal behavior. The actual conclusion of Berger and Trinkaus (1995) was that Neandertal trauma was distributed throughout the regions of the body in ways more similar to rodeo riders than to the other comparative samples. They did not conclude that Neandertals were injured with the same frequency as rodeo riders nor did they show that Neandertals had higher rates of injury than other populations.

Perhaps this is a semantic misunderstanding of "pattern of trauma distribution." Depending upon the type of analysis, "pattern of trauma distribution" may refer to two very different concepts:

Trauma per region of the body ÷ total number of traumas observed in the group

And

Total number of traumas observed in the group ÷ total bones observed in the group

These represent two different concepts: one relating only to proportion of trauma distribution among individuals with traumatic injuries; the other relating to how much trauma there is in a group. Yet, in the popular (as well as the scientific) press, these

concepts tend to be confused. In this dissertation, I have questioned the validity of this perception of the excessively injured Neandertal in as many ways as feasible. Given the limitations of the available data, I found little evidence that Neandertals were more frequently injured or injured in different ways than the modern comparative samples.

B. Limitations in the Analysis of Neandertal Trauma

Although there are many problems with and limitations to the analysis of Neandertal trauma, the most serious and seemingly insurmountable is the quality of preservation of the sample. Even under the best of circumstances, there are many possible sampling biases that influence the results of analyses of trauma. In the case of Neandertal trauma, the effect of some of these biases is quite strong because of the small size of the sample. In this section, I will summarize the results of sampling biases in the analysis of trauma in general and within the context of the Neandertal Metaset, as well as present some of the problems in data collection and comparative analysis.

B1. The influences of sampling biases on the analysis of trauma

In the study of trauma, it is assumed that higher frequencies of observed trauma represent higher "occupational" risks of experiencing injuries for a population sample. However, there are many ways that the affects of sampling biases can negate such assumptions. Effects of sampling biases in comparative analyses of trauma were summarized in Chapter 2. These biases include the timing of trauma relative to mortality, preferential observation of some types of trauma, differences in the preservation of trauma related to age-at-death, differences in preservation of various skeletal elements, differences in preservation of samples, differences in recording protocols, differences in sample size, and other populational differences.

Trauma that occurs in the antemortem interval (at least 3-9 weeks before death for long bones) and (at least 1-3 weeks before death for cancellous bones) is more likely to be observable than trauma that occurs during the perimortem interval. Healing/healed incidences of trauma are much more likely to be unambiguously recorded as trauma. In cases where postmortem fragmentation is high, most perimortem trauma is lost. This was clearly seen in the case of Aljubarrota where all individuals died because of trauma, yet evidence of trauma was relatively rare.

Evidence of trauma is more easily observable for some types of fractures than for others. Evidence of antemortem dislocation is difficult to observe in archaeological populations. Crush fractures such as cranial depression fractures, are readily observed and therefore more likely to be counted than some other types of fractures, also cranial depression fractures occur on the cranial vault which is more likely to be preserved, and recognized as human, than other bones of the body. Ribs are often not observed in the context of traumatic study because of fairly high levels of postmortem fragmentation and their trauma tends to be under-reported. Similarly, injuries to phalanges of the hands and feet are also under-reported.

The age-at-death of an individual directly affects how much of the trauma that they experienced during life will be preserved. Evidence of traumatic injury that occurs when the individual is a juvenile is likely to be fairly quickly reabsorbed during growth and not be observable for very long after it happened. Once growth slows and stops, evidence of traumatic injury becomes more permanently observable. Thus, the relative lack of trauma observed in young versus old adults may not only reflect differences in relative trauma accumulation but also the fact that most juvenile trauma is unobservable.

In elderly individuals, often the highest number of injuries is observed. This is because the interval for the accumulation of observable injuries is of longest duration and also because bones become more brittle and more likely to fracture, and elderly people become more prone to tripping and falling. Understanding the demographic profiles of samples is important so that results are reflective of differences in activities of the populations, not skews in age-at-death structures.

The likelihood of a bone to be preserved is determined somewhat by variable taphonomic influences such as weathering, scavengers, collection techniques, etc. but it is determined also by intrinsic aspects of the bone, such as the shape of the bone, which influences its susceptibility to warping, crushing and postmortem breakage. Generally, denser and/or larger bones tend to be the best preserved elements. The lack of preservation of some elements directly influences the amount of trauma that may be observed in a sample because it is impossible to take data from bones that do not exist.

Preservation of a sample also directly affects the amount of trauma that may be observed. Well preserved skeletons where most elements are intact and in anatomical position are likely to preserve the most information about incidences of trauma. During the processes of fragmentation and disarticulation, evidence of trauma may be lost. Differences in frequency of trauma between two samples with different levels of preservation may be an artifact of the level of preservation rather than actual differences in frequency of trauma.

Along with the preservation level of a sample, decisions are made as to which bones to include in the sample. Some protocols exclude all incomplete bones from

analysis, while others do not. Differences in these protocols directly influence the documentation of frequencies of trauma and, in turn, the results of comparisons.

The size of a sample population also affects the significance of frequency of trauma as well as the observation of trauma. A single instance of trauma observed in a small sample is much more likely to be significant than a single instance of trauma observed in a large sample because instances of trauma are also more likely to be observed in larger samples.

Other biases also limit the ability of a sample to represent its source population. These biases include differences in burial based on social class, occupation, sex, etc. Biases, in clinical populations, are based on consistent reporting of some kinds of injures and underreporting of other kinds of injures (especially those not requiring medical attention or those caused by some types of interpersonal violence).

Tests of differences in the distribution of patterns of trauma between two or more groups should try to reflect differences in environmental or occupational hazards of the samples being compared. However, it is important to consider the role that sampling biases may play in the observation of differences in the distribution of patterns of trauma. The worse the preservation and the smaller the sample, the greater is the amount of sampling biases that have shaped the content of the sample. Therefore, in the context of the Neandertal sample, the effects of various biases need to be recognized and, as much as possible, accounted for. Comparisons of well-preserved large samples are much less likely to be affected by these issues and, may better reflect actual differences in lifestyle and risk between the samples.

B2. Sampling biases in the Neandertal Metaset

Most sampling biases in the Neandertal Metaset come from two factors: the small sample size and the generally poor level of preservation of the remains. As reviewed in Chapter V, the sampling biases that result from these two factors include preferential preservation of certain elements, the lack of preservation of indictors of sex and age-at-death, non-standardized reporting and analyses of Neandertal remains, and the frequent combination of all Neandertal remains together to constitute a "population" regardless of differences in time or location.

The parameters of demographic biases in Neandertals are poorly understood, both because of the poor preservation of the bones themselves, and because so little is understood about Neandertal culture. Even in the context of many single samples, it is unclear whether age-at-death groups and/or sexes are treated identically during mortuary rituals and whether the cemetery populations mirror the age-at-death structure of the living populations. The division of labor by sex within the Neandertal populations is also poorly understood.

However, the Neandertal sample that exists is the sample we must address. Although the most conservative approach to Neandertal trauma would be to agree that it is too fragmentary and problematic and stop using it to make arguments about Neandertal culture, this is not necessary. Alternate approaches may be taken to put Neandertal trauma into perspective through proper comparative contexts.

B3. Problems in data collection and comparative analysis

The biggest problem with comparative analyses of Neandertal trauma using modern samples is that the samples are not equivalent in their compositions. Modern samples come from a specific single site, from very bounded time periods (less than a few hundred years), and mostly include only complete bones in the frequency counts and analyses. This is not the case with Neandertals.

Lumping together all extant Neandertals into one big sample (i.e. the Neandertal Metaset) to realistically compare it to other samples is nearly impossible because of different levels of observation and standards of recording. Less well published individual bones are likely to be underrepresented. If there were a catalogue of every Neandertal remain that is currently curated AND each remain was well-described, then it would be possible to create a complete Neandertal Metaset. However, such things do not currently exist. Some of the larger collections such as Shanidar and Krapina are very well reported and documented, but other incomplete single bones may not even appear in any searchable literature. The closest thing to such a catalogue is Oakley *et al.*'s (1971) *Catalogue of Fossil Hominids* which is 38 years old and is often not very specific about individual bones (such as side and what parts are preserved). Let us imagine, however, that compiling an ideal catalogue of all Neandertal remains in a very descriptive format is possible and at some point in the future, it exists. If the Neandertal Metaset were a well-preserved large sample, the comparison of its contents to other more modern samples, without taking its other limitations (such as lack of knowledge about the mortuary treatment, the age and sex distribution of the sample, and non-standardized recovery and

reporting) into account, would still seem somewhat problematic. However, the Neandertal Metaset is neither a well-preserved or large sample; therefore such results lack credibility.

Although as part of my results in Chapter V, I compared distributions of trauma in a sample of European Neandertals to some modern samples, I have reservations about the results. The European Neandertal sample was not accumulated with the same sampling rigor as the other collections. I included all bones, including fragments, in the European Neandertal sample because the sample is composed almost exclusively of incomplete bones. The other comparative samples are based almost exclusively on whole bones with incomplete elements excluded. It is unclear how much this affects the compositions of the samples and, in turn, the frequencies of trauma. Maybe only a little or perhaps substantially, but I am forced to consider these results questionable and possibly unreliable.

I see two ways around these sampling incompatibilities. One way is to only compare Neandertal remains only to other Neandertal remains, such as comparing Neandertals with trauma to Neandertals without trauma. This gives us information about the distribution of trauma in Neandertals but it does not address whether this trauma is unusually distributed in the context of other human groups. The other way is to make the comparative sample more like the fossil samples by counting sections of bones instead of complete bones. I practiced with this method on the Aljubarrota and Krapina remains, and although hampered by the small sample sizes of both collections, data collection in this manner did not seem unduly difficult.

In summary, the role of trauma analysis is to offer a window into the environmental and occupational hazards members of a specific group faces in the course of his/her daily life. Ideally, the distribution of trauma throughout a sample reflects only engagement with daily hazards. There are many ways a sample may be biased so that the distribution of trauma within the sample reflects other things. It should be the goal of the researcher to at least make the reader aware of the possible biases of a sample. So that more proactive steps might be taken in addressing these biases. The Neandertal Metaset is crippled by so many inherent biases that it is not credible to make many arguments about the distribution of its trauma. If it were a modern sample, it is unlikely any researcher would preferentially decide to work on it. But because of the interest in Neandertals and their place in prehistory, the role trauma played in their lives and how it relates to our other knowledge of them will continue to be studied. It is important that such studies do not overreach the limitations of the sample and declare as fact aspects that were not or could not tested.

C. Trauma and Knowledge of Neandertal Lifeways

In this section, the results of all the various tests of hypotheses in this dissertation will be reviewed. In the context of these results, the importance of trauma in the life of a Neandertal will be discussed.

C1. Review of hypotheses about the distribution of Neandertal trauma

I analyzed aspects of the distribution of trauma in Neandertals from four different perspectives to address the question of in what ways the distribution of trauma in Neandertals is significant. In Chapter IV, I tested hypotheses about the distribution of trauma within the sample of individual Neandertals who showed signs of trauma. In

Chapter V, I tested hypotheses about the distribution of trauma in a sample of European Neandertals (with and without trauma) as well as compared the distribution of trauma in European Neandertals to that of other hunter-gatherer, semi-sedentary forager and nomadic populations. In chapter VI, I tested hypotheses about the distribution of trauma by comparing a sample from a single Neandertals site, Krapina, to a single modern site, Aljubarrota, using alternate methods for taking data from fragmentary remains that are first detailed in this dissertation.

I first tested hypotheses about significance in the distribution of trauma in Neandertals with trauma in the context of the following parameters: chronology, geographical location, site type, degree of preservation, regions of the body, side of the body injured, severity of injury, age-at-death class, and sex. Eighteen null hypotheses of no difference in trauma were tested for Neandertals with trauma. Six were rejected. The results of these tests of the null hypothesis are summarized in Table 7.1.

Table 7.1 Outcome of tests of hypotheses of the sample of injured Neandertals (Bold denotes rejected hypothesis)

Hypothesis	Outcome
1. Distribution of trauma on the body is independent of time period	*Consistent*
2. Distribution of trauma on the body is independent of a site's geographic location	*Consistent*
3. Types of sites with injured Neandertal remains are independent of geographic location	**Rejected**
4. Distribution of Neandertals with trauma by sex is independent of a site's geographical location	*Consistent*
5. Preservation level is independent of site type	**Rejected**
6. Preservation level is independent of the sex of an individual's remains	*Consistent*
7. Preservation level is independent of age class	*Consistent*
8. Level of preservation is independent of age class for both sexes	*Consistent*
9. Sex is independent of the injured body region	*Consistent*
10. Distribution of trauma on the body is independent of age class	**Rejected**
11. Distribution of trauma on the body is independent of age class for both sexes	**Rejected**
12. Distribution of trauma on the body is independent of level of preservation	**Rejected**
13. Distribution of trauma on the body is independent of side of injury	*Consistent*
14. Sex is independent to side of injury	*Consistent*
15. Age-at-death class is independent to side of injury	*Consistent*
16. Severity of injury is independent of age-at-death class	*Consistent*
17. Severity of injury is independent of sex	*Consistent*
18. Age-at-death class is independent of sex	**Rejected**

Statistical tests rejected two of the null hypotheses of independence of aspects of the locations and preservation conditions of the injured Neandertals sample. The data suggest that injured Neandertals who come from cave sites are significantly more likely to be well preserved and that injured Neandertals from Asia are overrepresented in caves. If Krapina is not counted as a burial site, then injured Neandertals who were (intentionally) buried are significantly more likely to be well preserved than those who were not.

Statistical tests rejected 3 of the hypotheses that all regions of the body are equally likely to have trauma. The significant distinctions in the distribution of trauma throughout the body were by age class, for age class by sex, and by level of preservation. Although the null hypothesis that sex is independent of the distribution of trauma throughout the body was not rejected overall, statistical tests suggest that among the injured Neandertal sample, females have a significantly high incidence of leg trauma. Statistical tests also suggest that injured Neandertal adolescents have a significantly high number of cranial injuries. When age class and sex were combined, prime males with trauma had a significantly high incidence of trauma to the trunk region and prime females with trauma had a significantly high incidence of leg trauma.

Of the null hypotheses tested for the sample of injured Neandertals regarding the distribution of injury by demographic aspects, the independence of age-at-death class and sex was rejected. All old individuals with trauma were male.

I next tested hypotheses about the distribution of trauma throughout a sample of European Neandertals where counts of instances with and without trauma were compared for the following parameters: preservation level of individuals, sex of individuals, age-at-

death class of individuals, age-at-death class by sex, and by skeletal element. The results are summarized on Table 7.2, as follows:

Table 7.2. Outcome of tests of hypotheses using the sample of European Neandertals (rejected hypotheses in bold)

Hypothesis	Outcome
Preservation status of an individual is independent of presence of trauma	**Rejected**
Sex of an individual is independent of presence of trauma	*Consistent*
Age-at-death class of an individual is independent of presence of trauma (juveniles included)	**Rejected**
Age-at-death class of an individual is independent of presence of trauma (when juveniles excluded)	*Consistent*
Age-at-death class and sex of an individual is independent of the presence of trauma (unidentified by sex individuals included)	**Rejected**
Age-at-death class and sex of an individual is independent of the presence of trauma (unidentified by sex individuals excluded)	*Consistent*
Presence of trauma is independent of skeletal element	*Consistent*

For all of the hypotheses involving parameters of individual identity (such as age and sex), only the individuals for whom such an attribution could be given were included. These individuals were exclusively in the "well preserved" and "partially preserved" categories. When juveniles were included, statistical tests showed an overrepresentation of old adults with trauma and juveniles without trauma. Although statistical tests did not reject the independence of skeletal element and presence of trauma overall, there was a significant overrepresentation of ulnar trauma.

In order to test whether the element by element distribution of trauma was significant in the context of other samples, I compared the incidence counts of trauma versus no trauma among the postcranial elements of European Neandertal sample, 3 Native North American samples, 4 Native Australian samples, and one European sample. Although there were significant differences in the distribution of trauma by element for

some of the collections, the European Neandertal sample was consistently in the middle of all distributions. The evidence did support the conclusion that European Neandertal trauma is more frequent or differently distributed than any of the comparative modern hunter-gatherer samples.

Finally, a single Neandertal site was compared with a comparative sample using consistent data collection methods that I created to address some of the limitations of highly fragmentary samples. Each element was analyzed separately. For the majority of the elements, there were no significant differences between the distribution of trauma at Krapina and Aljubarrota as summarized in Table 7.3. Although ribs showed more traumas in the Aljubarrota sample and ulnas showed more traumas in the Krapina sample, it is probable that this is due to very small sample size rather than substantive differences in the distribution of trauma.

Table 7.3 Results of comparing distributions of trauma at Aljubarrota and Krapina by element

Element	Result
Frontal Squama	*Consistent with null hypothesis of independence*
Frontal Supraorbital	*Consistent with null hypothesis of independence*
Parietal	*Consistent with null hypothesis of independence*
Occipital	*Consistent with null hypothesis of independence*
Ribs	**Null hypothesis rejected**
Clavicle	*Consistent with null hypothesis of independence*
Humerus	*Consistent with null hypothesis of independence*
Ulna	**Null hypothesis rejected**
Femur	*Consistent with null hypothesis of independence*
Tibia	*Consistent with null hypothesis of independence*

When the elements in which both samples showed signs of trauma were compared according to side of the body injured, there was no significant evidence of a “sided” distribution of trauma as summarized in Table 7.4.

Table 7.4. Results of comparing distributions of trauma at Aljubarrota and Krapina by side of element

Element	Result
Frontal squama	*Consistent with null hypothesis of independence*
Parietal	*Consistent with null hypothesis of independence*
Ulna	*Consistent with null hypothesis of independence*

These four different perspectives address differences in the distribution of trauma in Neandertals. The first perspective addressed significances in the distribution of trauma within the sample of injured Neandertals. This perspective highlighted some of the biases within the group of injured Neandertals. The second perspective addressed sampling biases in the group of Neandertals with trauma in the context of a large sample of Neandertals from Europe and showed that the presence of trauma is not independent of preservation status. The final two perspectives addressed Neandertal injury frequency from a comparative perspective. Although there are many limitations to the Neandertal sample in the context of paleopathological analysis, in each of the comparative contexts examined, Neandertal trauma was not shown to be outside the range of frequency or distribution throughout the body of the populations of hunter-gatherers, semi-sedentary foragers, nomads, and medieval small scale land owners being sampled.

C2. The importance of trauma in the life of a Neandertal

Unlike the conclusions of most authors who discuss Neandertal trauma (as reviewed in Chapter III), the data do not provide evidence that Neandertal trauma is outside of the range of trauma observed in modern human populations engaged in hunting and foraging food procurement strategies. The evidence does not support arguments of dissimilarity between Neandertal injury hazards and any hunter/forager/nomadic group. These injury hazards included interpersonal violence,

occupational hazards and accidental falls. None of the Neandertal injuries evaluated in Chapter IV revealed clear signs of having been gored by irate prey.

Certainly, trauma played a major role in the lives of a few Neandertals such as Shanidar 1 and Krapina 180, who had to live with permanent significantly crippling injuries for part of their lives. Trauma also played a role in the death of Shanidar 3, and probably St. Césaire and Krapina 34.7 as well. However, most traumas experienced by Neandertals were fairly minor, and when they are examined element by element, trauma rates per bone where shown to be unexceptional for modern populations.

C3. Life from a bone: Neandertal patterns of leg trauma and trauma in female

I would like to discuss two aspects that strike me as running counter to most of the common assumptions about trauma in Neandertals: the leg trauma and the trauma in females.

Some mileage has been made over "the fact" that Neandertals show little leg trauma and, therefore, incapacitated members of the band were left to die if they could not keep up with the group (Berger and Trinkaus 1995; Pettitt 2000). However, in the sample of Neandertals with trauma, there exist five examples of individuals with healed leg or foot injuries which would have severely limited their mobility for at least several weeks to several months. Because these injuries are well healed, they seem to have been dismissed as insignificant by Berger and Trinkaus (1995:848): "Moreover, none of their lower limb injuries would have impeded locomotion (however painful the might have been), and a couple (especially the fibular injuries of La Ferrassie 2 and Tabun 1) are trivial." This is not a reasonable conclusion, in my view, given that the length of time for healing minor fibular breaks, in the modern medical context, ranges from two to three

months with immobilization of the fractured leg and another six weeks with an air cast (Chrissos, personal communication).

I would also like to examine in more detail how trauma is distributed among Neandertal females. In all the discussions of hunting and comparisons with rodeo-riders, there has been little discussion of sex biases in Neandertal trauma. Authors seem to treat as male all Neandertal remains with trauma. However, a closer examination of Neandertals with trauma reveals that at least some of the Neandertals with trauma are female. Females with trauma tend to be slightly less well preserved than their male counterparts and females in general seem to have slightly less trauma than the males. In most of the tests that addressed the distribution of trauma by element, females showed significantly more leg (fibula) trauma than expected at random. Females also showed rates of head and arm injury equivalent to their male counterparts. Perhaps this means that female Neandertals were hunting too, or perhaps this means that the general frequency of trauma was not terribly high and not particularly based on occupational hazards. In summary, the distribution of trauma between Neandertal males and females does not seem to show a significant division of labor reflected in trauma.

D. Evolutionary Implications of the Study of "Paleo-trauma"

It is one of those "handy journalistic clichés" asserts that Neandertals are dumb (in all senses of the word) compared to modern humans, and that is why they went extinct. Publications in archaeological or biological science can be marshaled to corroborate this. The idea that Neandertals are more frequently traumatized than modern populations is based on little evidence, but it has been well received is because it dovetails nicely with this paradigm.

The most significant problem with trying to use techniques from paleopathology to look at the fossil record is that the fossil record is so poorly preserved that such techniques are often not feasible. “Corners get cut” as methods are bent to fit the sample available. All studies of “paleo-trauma” are guilty of this, including my own. It is important not to extend conclusions beyond what can be supported by data.

As nice as it might be to ignore the details of biases, they strongly influence the results when dealing with poorly preserved, small samples. If one ignores these details for the five second sound-bite, science often makes way for storytelling. Stories created about the life and death of individual Neandertals based on their trauma are compelling, in the same way that fiction written about the work of forensic scientists is compelling. Good stories do not necessarily make good science, but they do create handy journalistic clichés. My results suggest that “the highly traumatized Neandertal” is a cliché unsupported by evidence based on comparative studies of trauma frequency by element.

E. Future Work

In this section, avenues of future study arising from this dissertation will be addressed. These include methods of collecting and disseminating data on trauma, decisions about how Neandertals should be addressed for future study and ways of getting a firmer contextual grasp on Paleolithic trauma frequencies.

E1. Methods of collecting and disseminating data on trauma

Each sample is different, but all samples from cemetery populations probably contain at least a few broken bones. In Chapter VI, I outlined some methods for collecting data from fragmentary remains and ways to compare fragments without needing to “transform” them into whole bones. In order to get the most information out of

fragmentary remains, some consistent method needs to be used to study populations and to compare populations. It remains unknown how much data were not represented in each comparative sample used in Chapter V, but certainly some bones were excluded because of lack of preservation. Counting bones by sections of an element, rather than by complete element only, allows for almost all of a sample to be represented in frequency counts.

It is relatively straightforward to make visual records of bones onto templates, such as the ones included in Appendix B, and then scan them, store them and disseminate them as PDFs. Benefits of a hand-drawn visual record: it forces observers to examine the bone for longer than they might otherwise have done; exact locations of traumas are more readily visible in drawings than in photographs; and counts of bones may be taken in many different ways long after the records were created. With samples of indigenous populations rapidly being reburied, this versatility becomes increasingly important.

In order to achieve a clearer understanding of whether Paleolithic trauma is different from modern trauma, as much as possible, we need to use comparative samples that have been collected with the same methods as the fossil data. When data from the comparative collection have been gathered under a more exclusionary protocol, it is similar to comparing wild apples fallen off a tree to peeled, cored, pre-sliced apples from a grocery store: same fruit but all the junk has been removed. Unless the comparative samples are reported in ways similar to the fossil samples, the comparisons are at least slightly flawed and possibly seriously misleading.

E2. Choices about how Neandertals should be addressed

In Chapter II, I introduced the concept of the "Neandertal Metaset." Generally, studies of Neandertal trauma address Neandertals as a single population. From the perspective of trauma analysis, there are serious problems with this. The gravest of these is differences in the environments that Neandertals inhabited during their 100,000 years. Also, without serious cooperation and funding, putting together a realistic "Neandertal Metaset" will not happen. If better preserved and/or famous sites are preferentially lumped together, the diversity of Neandertal remains is diminished. Although it was not shown as significant in this dissertation, there seems to be an overrepresentation of well-preserved old men in the Neandertal sample (especially at Shanidar which is shown in this dissertation). Such a bias certainly skews trauma analysis.

Another way to address Neandertals is by looking at them as individual populational groups from specific times and places. These groups might include Krapina, sites from France from 50-70 k yr, and Shanidar. Questions about differences in the distribution of trauma in these samples might then be examined in contexts that reflect these specific places and times. Although small sample sizes will be clearly a hazard in such analyses, this is in many ways preferable to making assumptions about the uniformity of the lives of Neandertals.

In general, to better understand the diversity present in Neandertals culture, it is necessary to actually look for it. This is not accomplished by lumping all Neandertals together as a single sample. Many archaeologists seem to be much more willing to address this than biological anthropologists. The role of trauma analysis for populations is to see how behavior changes through time and get some context for the unknown

activities of some populations by the known activities of others. The comparison of different groups is extremely important to put frequencies of trauma into context. Such comparisons may be made among the groups of Neandertals, "pre-Neandertals" such as the group from Atapuerca, Upper Paleolithic groups, and various non-urban, non-agrarian populations where frequency count data may be assembled in identical ways and fragments are included.

F. Chapter VII Conclusion

In this chapter, I summarized and commented on aspects of Neandertal trauma. In the first section, I addressed the problems and limitations in the analysis of Neandertals trauma. These include problems with the Neandertal Metaset such as preferential preservation of certain elements, the lack of preservation of indictors of sex and age-at-death, non-standardized reporting and analyses of Neandertal remains, and the frequent combination of all Neandertal remains together to constitute a "population" regardless of differences in time or location. All of these limitations decrease the confidence with which comparisons of the Neandertal Metaset may be made to modern samples; however, the extant sample of the Neandertals is what we have.

In the second section, I reviewed my conclusions on trauma and what can be inferred about its role in Neandertal life. I found no evidence that Neandertals experienced trauma more frequently or with a different distribution throughout the body beyond what is commonly experienced by modern humans in the context of hunter-gatherers, nomads, semi-sedentary foragers and medieval small landowners. Therefore, the assertion that trauma played a more influential role in the lifeways of Neandertals than any of these other groups is not supported by the data.

In the third section, I discussed the role trauma analysis should play in evolutionary studies and the dangers of over-reaching conclusions. Although much has been made of high level of trauma in Neandertals within the paradigm of general Neandertal ineptitude, my data do not support the image of the highly traumatized Neandertal.

In the fourth section, I concluded with some ideas of future work and possible directions for the study of trauma in Paleolithic populations. Avenues of future work include more evaluations of comparative samples in ways that facilitate their comparison to fragmentary fossil humans and more evaluations of the range of trauma in the Middle and Upper Paleolithic perhaps based on smaller samples more reflective of a specific location of time. Such comparative samples might include "pre-Neandertals" such as the group from Atapuerca, Upper Paleolithic groups, and various non-urban, non-agrarian populations where frequency count data may be assembled in identical ways and fragments are included.

CHAPTER VIII

CONCLUSION

As detailed in Chapter VII, popular and professional conceptions of Neandertals includes the idea that they led much more traumatic lifestyles than most other groups of modern humans, as evidenced by their skeletal remains. These conceptions have not been rigorously tested with available data and appropriate statistics in a manner similar to most trauma comparative analyses in modern humans. This thesis reviews all relevant literature, assembles available data, and tests these conceptions with appropriate statistics. I found no evidence that the frequency or distribution of Neandertal trauma was outside the normal range of modern humans.

I draw from the sub-fields of paleoanthropology and paleopathology to examine ways of addressing a comparative context for the analysis of Neandertal trauma. Because the Neandertal sample is unlike most samples analyzed within the field of paleopathology, it is necessary to understand its differences and the ways these differences may distort the result of comparative analyses of trauma with modern human groups.

In the second chapter, I described how evidence of trauma is defined and communicated to other researchers. I examine the effects of some of sampling biases, such as differences in the ease trauma can be observed, variability in age at death and taphonomic modification, and differences in how evidence of trauma is counted by

researchers. I conclude the chapter with a "wish list" of aspects that a sample should have in order for research into its trauma to have the highest resolution and be most representative of the trauma that occurs in the living population, and I compare these ideals with the realities of aspects of the Neandertal Metaset.

I examined trauma frequencies by element both in the context of the large European Neandertal subset and within the largest Neandertal sample from a single time and place along with comparative samples that reflect the activities of non-urban pre-industrial groups and found no compelling statistical differences between the Neandertal groups and the comparative samples. These results are presented in the fourth, fifth, and sixth chapters and are discussed in seventh chapter.

In the fourth chapter, I tested eighteen hypotheses about aspects of the sample of Neandertals with trauma. These aspects included the temporal and geographical distribution of Neandertals with trauma, areas of the body with trauma, age and sex distributions of individuals with trauma, levels of preservation of individuals with trauma and degree of severity of injury. The significance of potential differences within these aspects of Neandertal trauma was determined using analysis of two-way contingency tables using simulations (ACTUS2). ACTUS is a powerful computational approach to statistical argument when data present in the form of sparse contingency tables. This thesis makes an example of its use for the edification of other scientists with similar data.

In the fifth chapter I analyzed aspects of Neandertal trauma in the context of the Neandertal sample as a whole but creating a smaller subsection referred to as the "European Neandertal sample". Aspects relating to the independence of the presence of trauma and various personal indicators were examined. The skeletal elements that make

up the European Neandertal sample were also compared to samples from other hunter-gather, forager, and nomadic populations. For adult Neandertals in the European Neandertal sample, the presence of trauma was found to be independent of age-at-death class, sex, and age-at-death class divided by gender. However, the presence of trauma was significantly more frequent in well-preserved individuals. There was a significantly high instance of ulnar trauma when postcranial skeletal element frequencies were compared in the European Neandertal sample; however the rate of ulnar trauma (as well as any other long bone trauma) was consistent with the distribution of trauma in all of the comparative samples.

In the sixth chapter, I discussed alternate ways of addressing trauma in Neandertals. These ways included the benefits of the analysis of a sample from a single site and the need of comparative samples that include fragmentary remains in their analyses. I introduced new methodology for addressing the distribution of trauma in fragmentary remains. I implemented this methodology in the comparisons of trauma between the Krapina Neandertal sample and a comparative modern sample from Portugal. Although there were significant differences in the distributions of trauma between the samples from Krapina versus Aljubarrota in the overrepresentation of ulnar trauma at Krapina and the overrepresentation of rib trauma at Aljubarrota, these differences are likely due to differences in the preservation of the samples. The novel methods described in this chapter for recording and analyzing trauma in fragmentary remains may be useful for future analysis of fragmentary material in other collections.

In the seventh chapter, I summarized and commented on aspects of Neandertal trauma. In the first section, I addressed the problems and limitations in the analysis of

Neandertals trauma. These include problems with the Neandertal Metaset such as preferential preservation of certain elements, the lack of preservation of indictors of sex and age-at-death, non-standardized reporting and analyses of Neandertal remains, and the frequent combination of all Neandertal remains together to constitute a "population" regardless of differences in time or location. In the second section, I reviewed my conclusions on trauma and what can be inferred about its role in Neandertal life. I concluded with some ideas of future work and possible directions for the study of trauma in Paleolithic populations. Avenues of future work include more evaluations of comparative samples in ways that facilitate their comparison to fragmentary fossil humans and more evaluations of the range of trauma in the Middle and Upper Paleolithic perhaps based on smaller samples more reflective of a specific location of time.

In this dissertation, I found no evidence that Neandertals experienced trauma more frequently or with a different distribution throughout the body beyond what is commonly experienced by modern humans in the context of hunter-gatherers, nomads, semi-sedentary foragers and medieval small landowners. Therefore, the assertion that trauma played a more influential role in the lifeways of Neandertals than any of these other groups is not supported by the data. These results imply Neandertals possessed a higher degree of cultural and/or physical adaptation to mitigate their environmental stresses than previously suggested by some of the research into their trauma.

APPENDICES

APPENDIX A Summary Tables of Neandertals with Trauma First Page

Site	Country	Site Age	Preservation	Source
Kebara KMH 2	Israel	62k	well	Bar-Yosef 1992; Berger and Trinkaus 1995; Duday and Arensburg 1991
Kebara KMH 2	Israel	62k	well	Bar-Yosef 1992; Berger and Trinkaus 1995; Duday and Arensburg 1991
Kebara KMH 2	Israel	62k	well	Bar-Yosef 1992; Berger and Trinkaus 1995; Duday and Arensburg 1991
Kiik Koba 1	Crimea	90k	partial	Trinkaus 2008; Rokhlin 1965
Krapina 149	Croatia	130k	fragmentary	Gojanovic-Kramberger 1908; Gardner and Smith 2006; Radovcic et al. 1988
Krapina 180	Croatia	130k	fragmentary	Gojanovic-Kramberger 1908; Gardner and Smith 2006; Radovcic et al. 1988
Krapina 188.8	Croatia	130k	fragmentary	Gardner and Smith 2006; Radovcic et al. 1988
Krapina 20	Croatia	130k	fragmentary	Gardner and Smith 2006; Radovcic et al. 1988
Krapina 31	Croatia	130k	fragmentary	Gardner and Smith 2006; Radovcic et al. 1988
Krapina 34.7	Croatia	130k	fragmentary	Mann and Monge 2006; Gardner and Smith 2006; Radovcic et al. 1988
Krapina 4	Croatia	130k	fragmentary	Gojanovic-Kramberger 1908; Gardner and Smith 2006; Berger and Trinkaus 1995; Radovcic et al. 1988
Krapina 5	Croatia	130k	fragmentary	Gardner and Smith 2006; Radovcic et al. 1988
La Chapelle-aux-Saints	France	60k	well	Boule 1911-1913, Berger and Trinkaus 1995; Trinkaus 1985
La Ferrassie 1	France	70k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
La Ferrassie 2	France	70k	well	Heim 1982; Trinkaus 1985; Trinkaus 1995
La Quina H5	France	50k	partial	Hardy 1997; Martin 1923;
Le Moustier 1	France	45k	well	Ponce de Leon and Zollikofer 1999, Hauser 1909
Neandertal (Feldhofer)	Germany	40k	well	Schmitz 2002; Schaaffhausen 1858; Huxley 1864; Mayer 1864; Virchow 1872, Schwalbe 1901
Neandertal (Feldhofer)	Germany	40k	well	Schmitz 2002; Schaaffhausen 1858; Huxley 1864; Mayer 1864; Virchow 1872, Schwalbe 1901
Sala 1	Czech Republic	40k	fragmentary	Sladek 2002; Vlcek 1969; Smith 1982
Shanidar 1	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 1	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 1	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 1	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 1	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 3	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 4	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
Shanidar 5	Israel	45k	well	Trinkaus 1983; Trinkaus and Zimmerman 1982
St. Cesaire	France	36k	partial	Zollikofer et al. 2002
St. Cesaire	France	36k	partial	Zollikofer et al. 2002
Tabun 1	Israel	122k	well	Garrod 1934-37; McCown and Keith 1939; Grun and Stringer 2000; Berger and Trinkaus 1995

APPENDIX A Summary Tables of Neandertals with Trauma Second Page

Site	Sex	Age	Bone w/Trauma	Description of Trauma	Side	Body Region
Kebara KMH 2	M	prime	T1	Fractured Spinous Process	C	Trunk
Kebara KMH 2	M	prime	T2	Fractured Spinous Process	C	Trunk
Kebara KMH 2	M	prime	Metacarpal 2	Fractured Proximal Epiphysis	L	Hand
Kiik Koba 1	M?	old	5th Prox Phalanx	Well healed diaphyseal fracture or frostbite	R	Foot
Krapina 149	F?	adult	Clavicle	Well healed fracture	R	Arm/Shoulder
Krapina 180	?	adult	Ulna	Well healed fracture with pseudoarthrois	R	Arm
Krapina 188.8	?	adult	Ulna	Well healed diaphyseal fracture	L	Arm
Krapina 20	F? VHE	adult	Frontal	Depression fracture	L	Head
Krapina 31	F? VHE	adult	Frontal	Healed fracture near temporal line	L	Head
Krapina 34.7	?	adult	Parietal	Large healing fracture	R	Head
Krapina 4	M?	adult	Frontal	Healed depression fracture	R	Head
Krapina 5	M	adult	Parietal	Possible depression on at lateral end of lambdoid suture	L	Head
La Chapelle-aux-Saints	M	prime	Rib	Anterior fracture	R	Trunk
La Ferrassie 1	M	old	Femur	Fractured greater trochanter	R	Leg
La Ferrassie 2	F	prime	Fibula	Proximal diaphyseal fracture	R	Leg
La Quina H5	F	prime		Probable injury to left arm	L	Arm
Le Moustier 1	M	adolescent	Mandible	Condylar fracture	L	Head
Neandertal (Feldhofer)	M	old	Occipital	Exocranial injury	C	Head
Neandertal (Feldhofer)	M	old	Ulna	Proximal epiphyseal fracture	L	Arm
Sala 1	F?	adult	Frontal	Healed lesion Right supraorbital torus	R	Head
Shanidar 1	M	old	Humerus	Mid-distal diaphyseal fracture	R	Arm
Shanidar 1	M	old	Humerus	Distal epiphyseal fracture	R	Arm
Shanidar 1	M	old	Metatarsal 5	Healed diaphyseal fracture	R	Foot
Shanidar 1	M	old	Frontal	Exocranial squamosal injury	L	Head
Shanidar 1	M	old	Zygomatic	Crushing lateral fracture	L	Head
Shanidar 3	M	old	Rib 9	Partially healed Penetrating wound	L	Trunk
Shanidar 4	M	old	Rib 7 or 8	Partially healed fracture	R	Trunk
Shanidar 5	M	old	Frontal	Surface scar on squama	L	Head
St. Cesaire	M?	adolescent	Frontal	partially healed lesion from slash	R	Head
St. Cesaire	M?	adolescent	Parietal	partially healed lesion from slash	R	Head
Tabun I	F	prime	Fibula	Distal diaphyseal lesion	?	Leg

APPENDIX B Fragmentary Element Blank Data Form: Frontals

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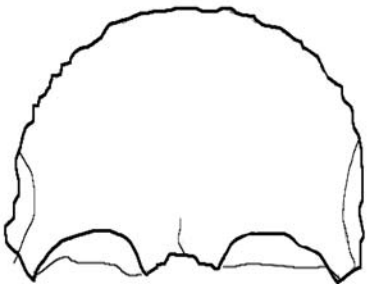

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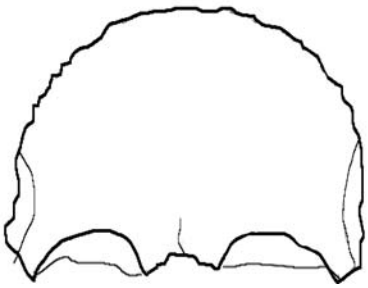

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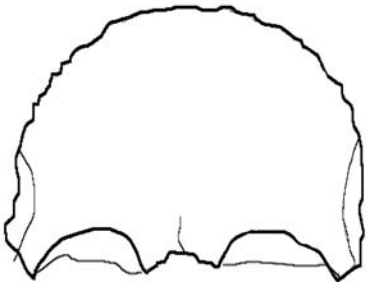

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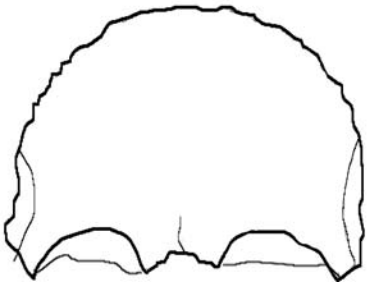

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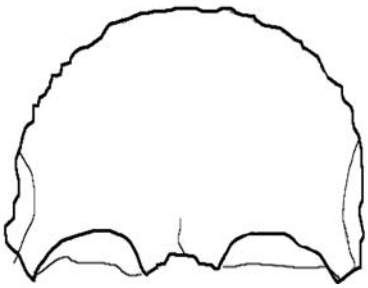

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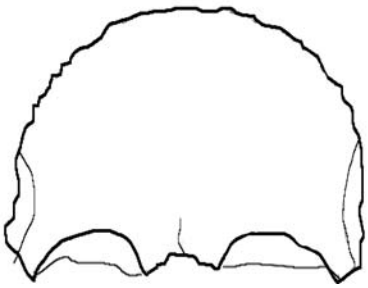

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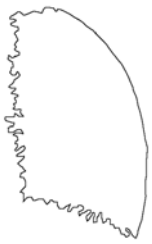

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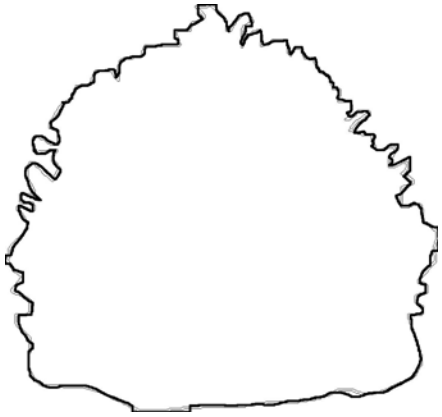

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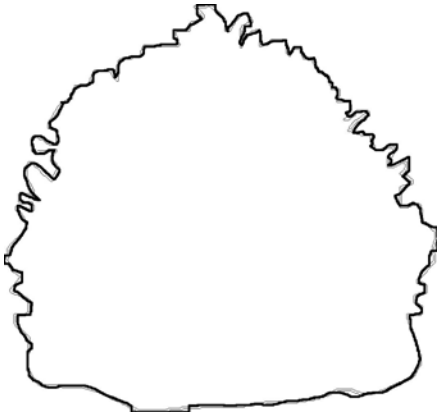

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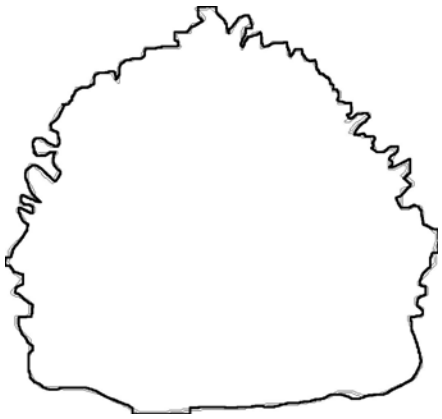

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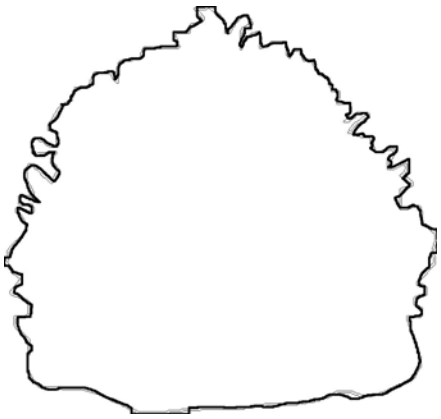

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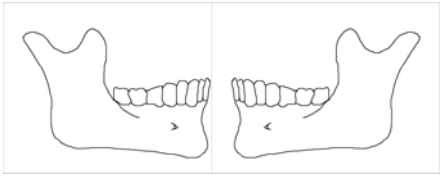

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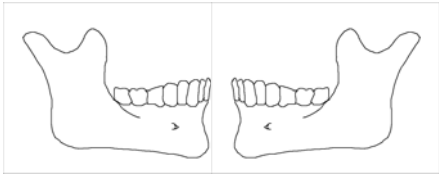

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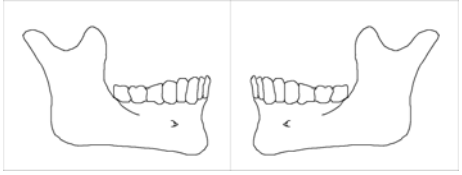

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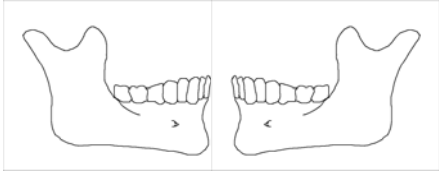

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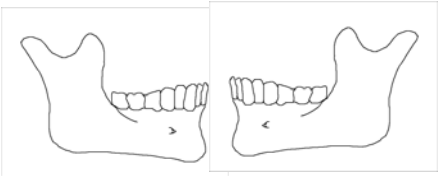

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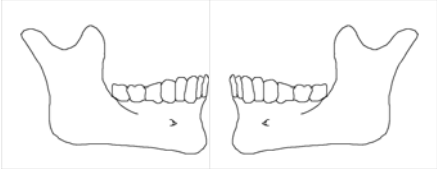

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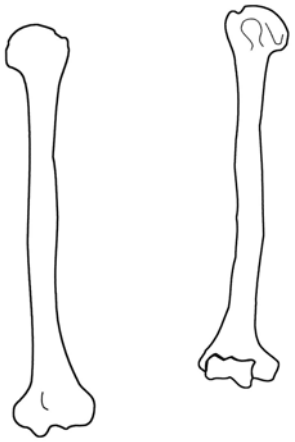

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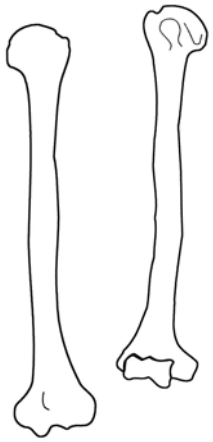

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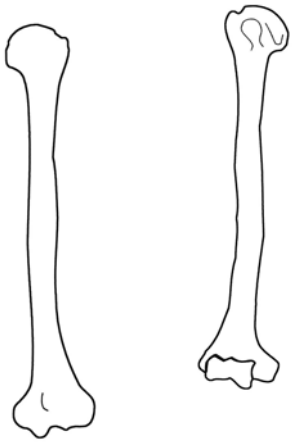

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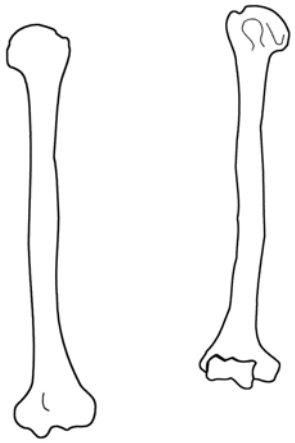

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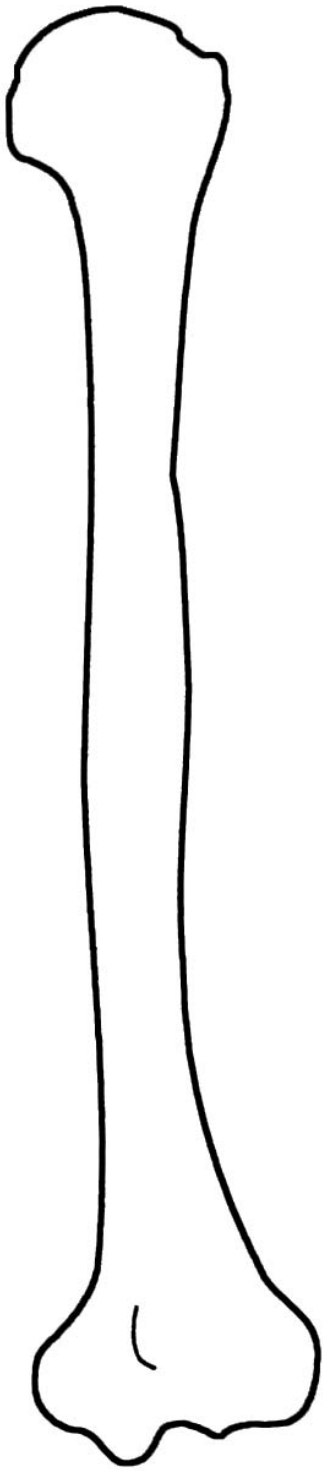

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PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

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PATHOLOGY:

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PATHOLOGY:

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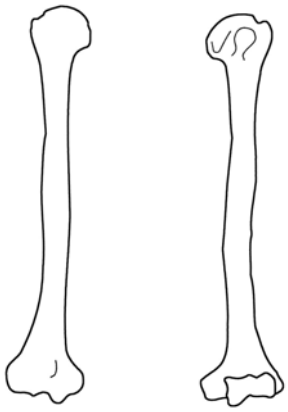

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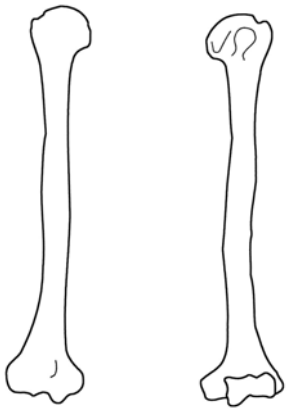

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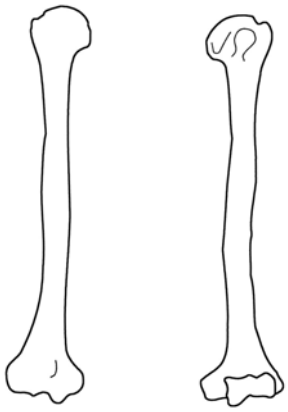

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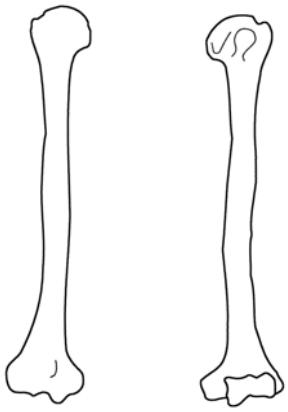

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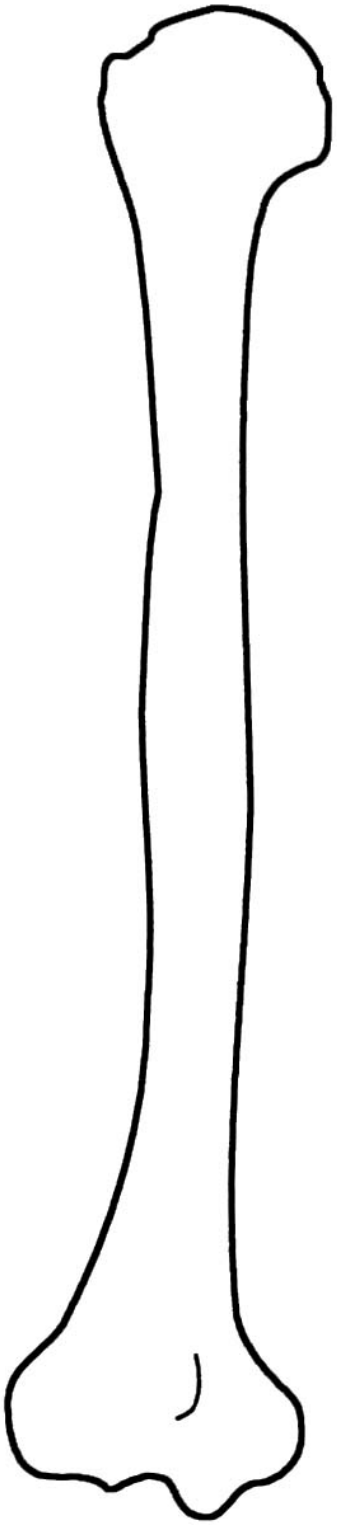

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DISTAL END PRESENT:

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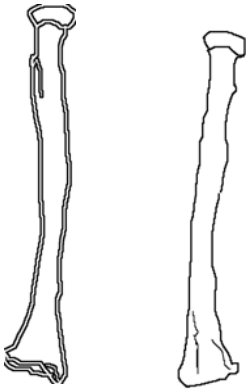

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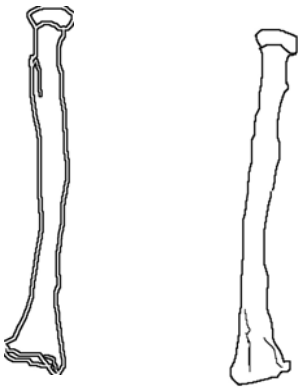

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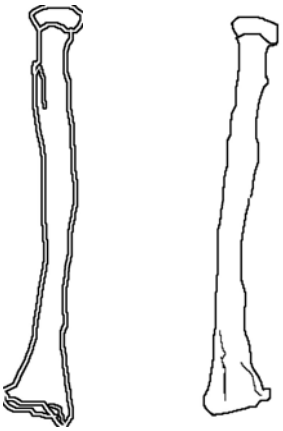

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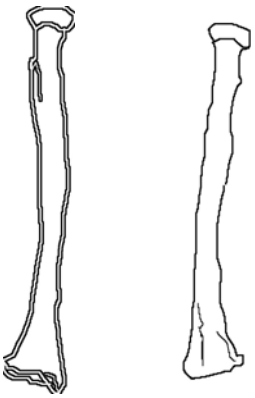
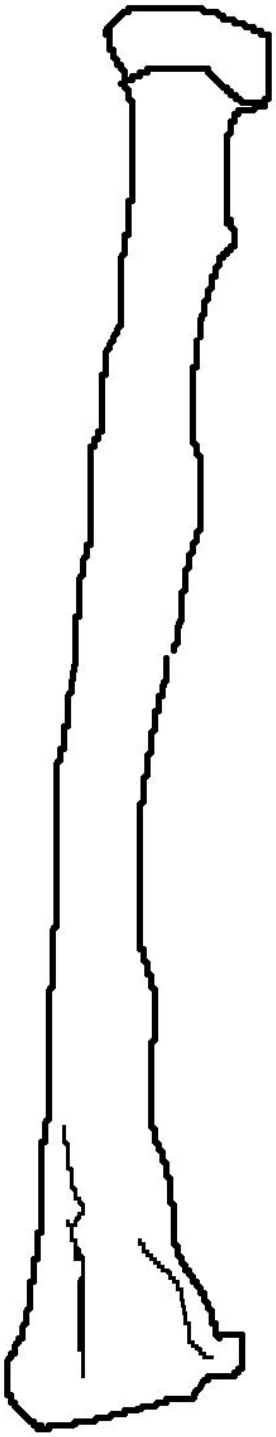


Cat #:
Path:

Notes:

COLLECTION NAME &LOC: DATE:

PROXIMAL END PRESENT:



PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

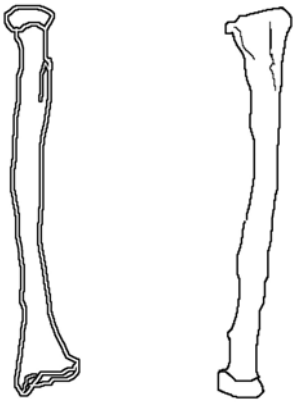
DISTAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

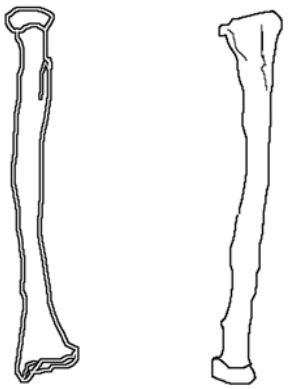
APPENDIX B Fragmentary Element Blank Data Form: Right Radius Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:



Cat #:
Path:

Notes:



Cat #:
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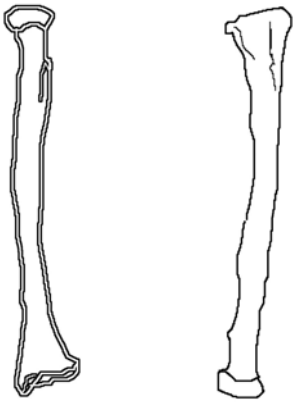
Notes:



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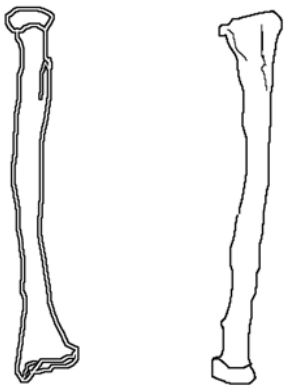

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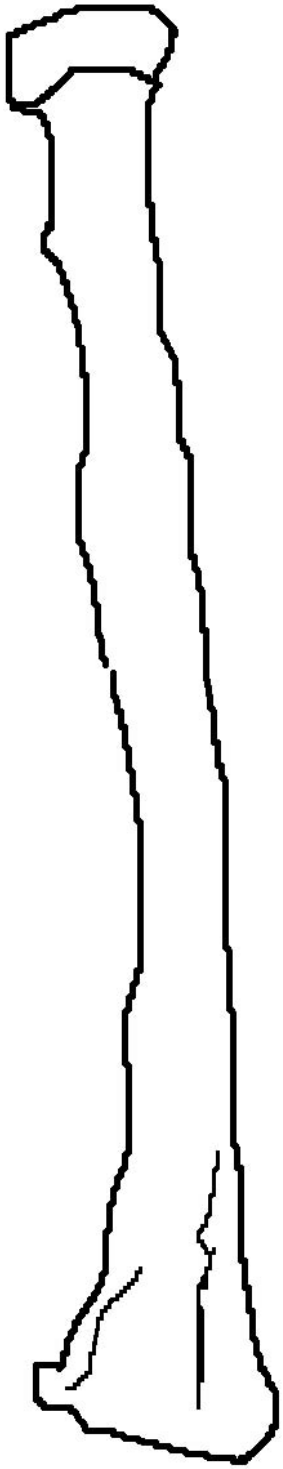
Notes:

COLLECTION NAME &LOC:

DATE:



PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

DISTAL END PRESENT:

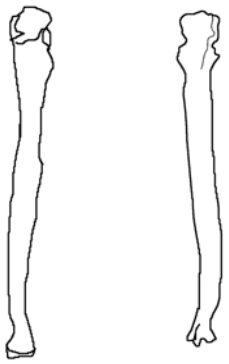
PATHOLOGY:

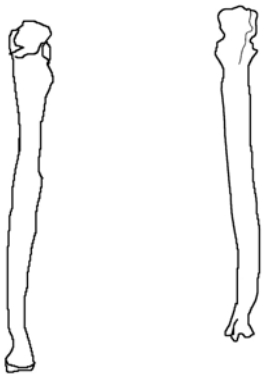
TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Left Ulna Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

LEFT ULNA PATHOLOGIES





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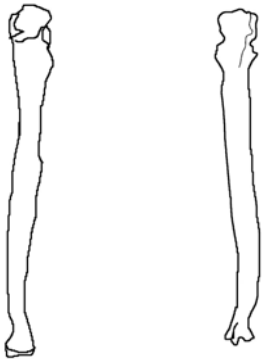
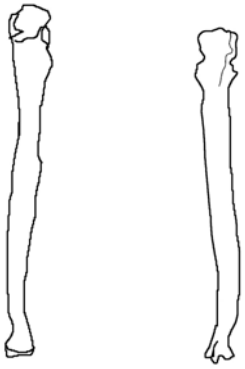
Notes:

Cat #:
Path:

Notes:





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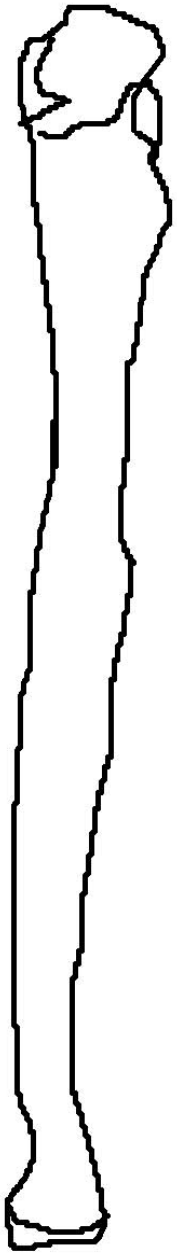
Notes:

Cat #:
Path:

Notes:

COLLECTION NAME &LOC:
LEFT ULNA



DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

DISTAL END PRESENT:

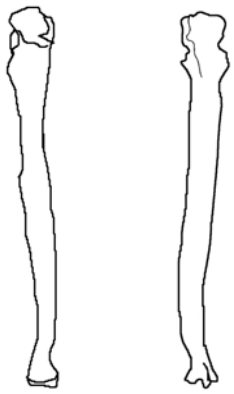
PATHOLOGY:

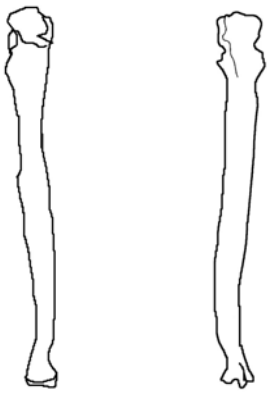
TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Right Ulna Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

RIGHT ULNA PATHOLOGIES





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Cat #:
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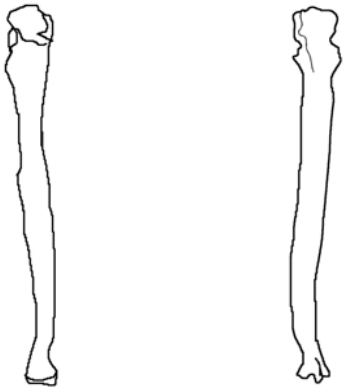

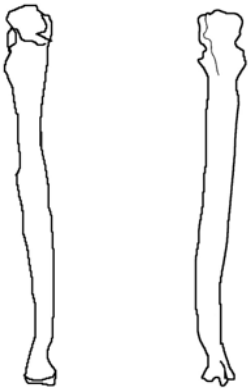

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Path:

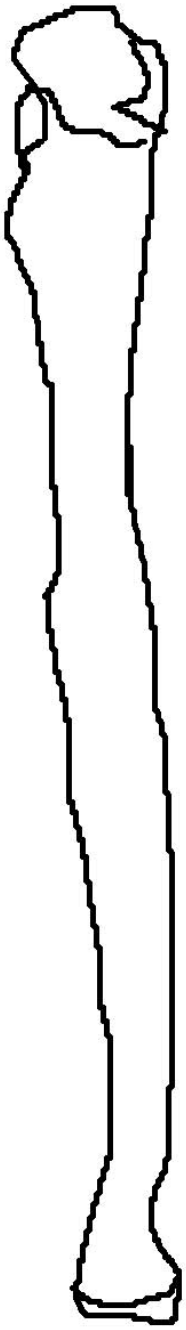
Notes:

Cat #:
Path:

Notes:

COLLECTION NAME &LOC: DATE:

RIGHT ULNA



PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

DISTAL END PRESENT:

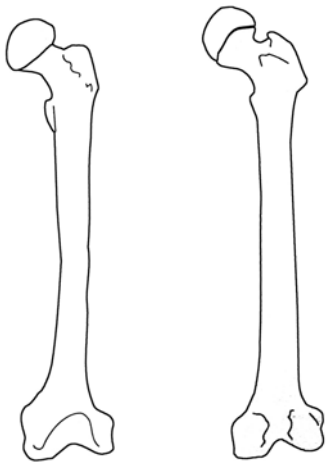
PATHOLOGY:

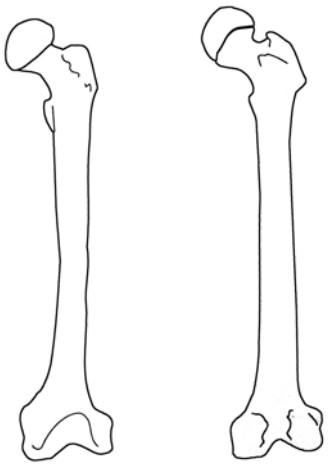
TOTAL NUMBER :
TOTAL NUMBER PATH

APPENDIX B Fragmentary Element Blank Data Form: Left Femur Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

LEFT FEMUR PATHOLOGIES PAGE #:





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Photo(s)#:
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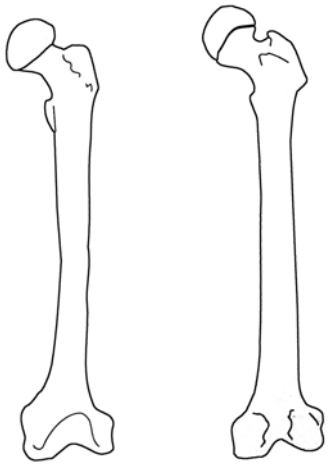

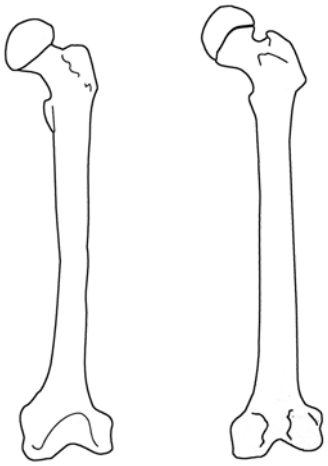

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Path:

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Notes:

LEFT FEMUR

COLLECTION NAME & LOC:

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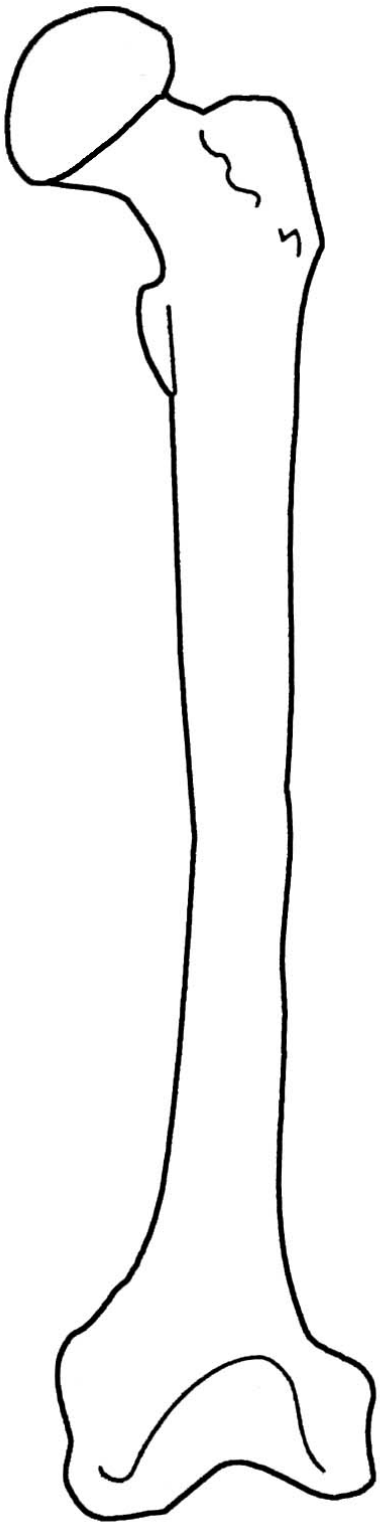


DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

PATHOLOGY:

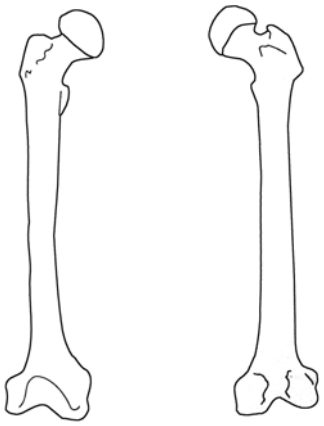
NOTES:

TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Right Femur Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

RIGHT FEMUR PATHOLOGIES PAGE #:



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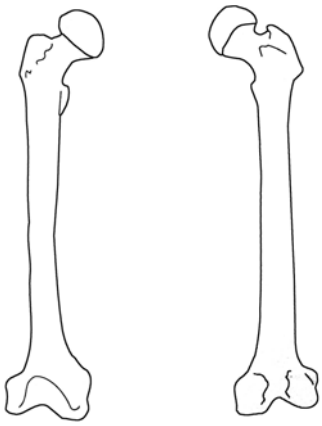

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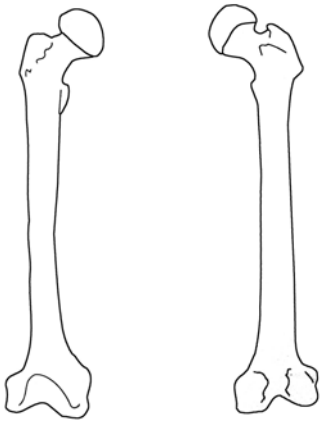

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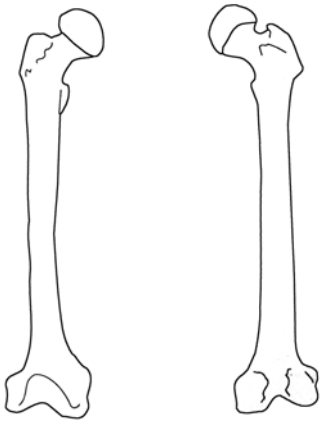
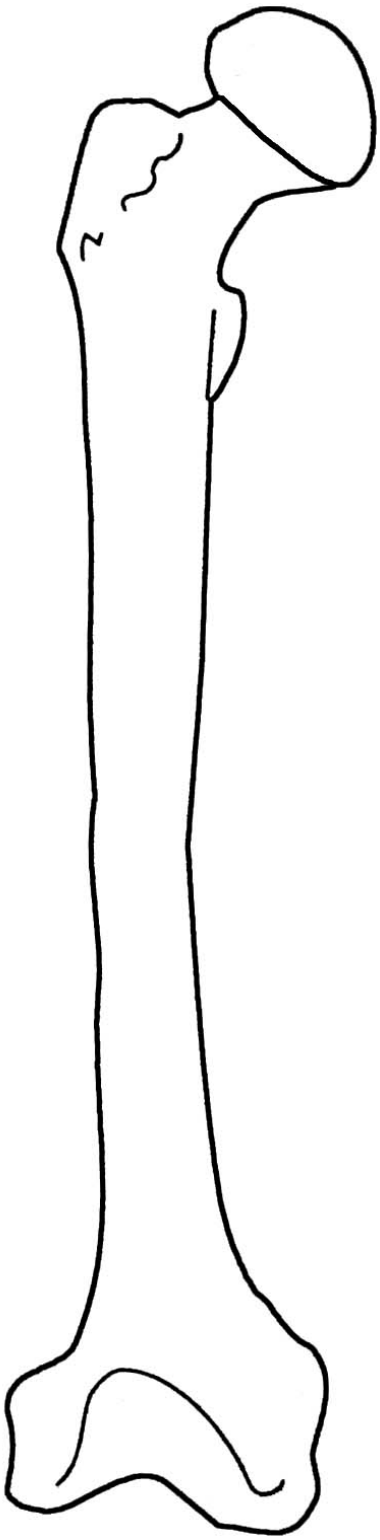


Cat #:
Path:

Photo(s)#:
Notes:

RIGHT FEMUR
COLLECTION NAME & LOC:



DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

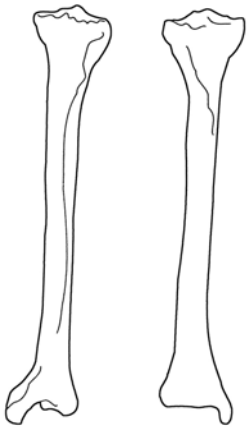
PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:
NOTES:

APPENDIX B Fragmentary Element Blank Data Form: Left Tibia Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

LEFT TIBIA PATHOLOGIES PAGE #:



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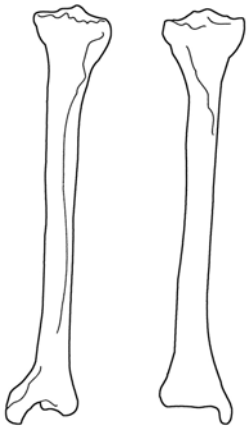

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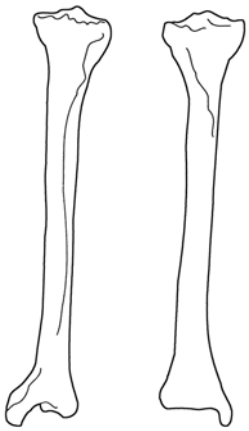

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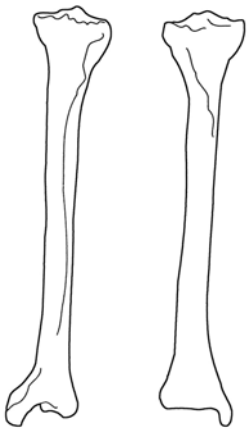


Cat #:
Path:

Photo(s)#:
Notes:

LEFT TIBIA

COLLECTION NAME & LOC:

:

DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

PATHOLOGY:

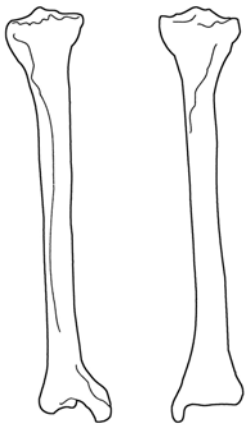
NOTES:

TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Right Tibia Pathology and Data Collection Forms

COLLECTION NAME & LOC: DATE:

RIGHT TIBIA PATHOLOGIES PAGE #:



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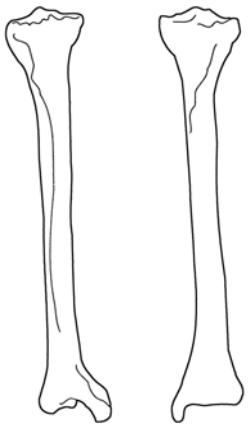

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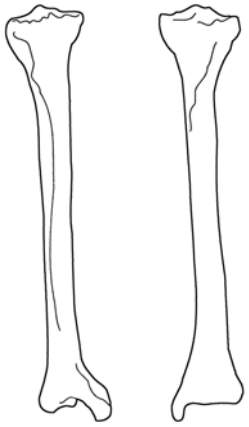

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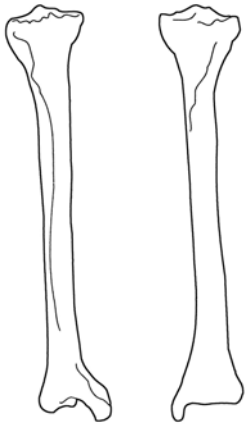

Cat #:
Path:

Photo(s)#:
Notes:

RIGHT TIBIA

COLLECTION NAME & LOC:

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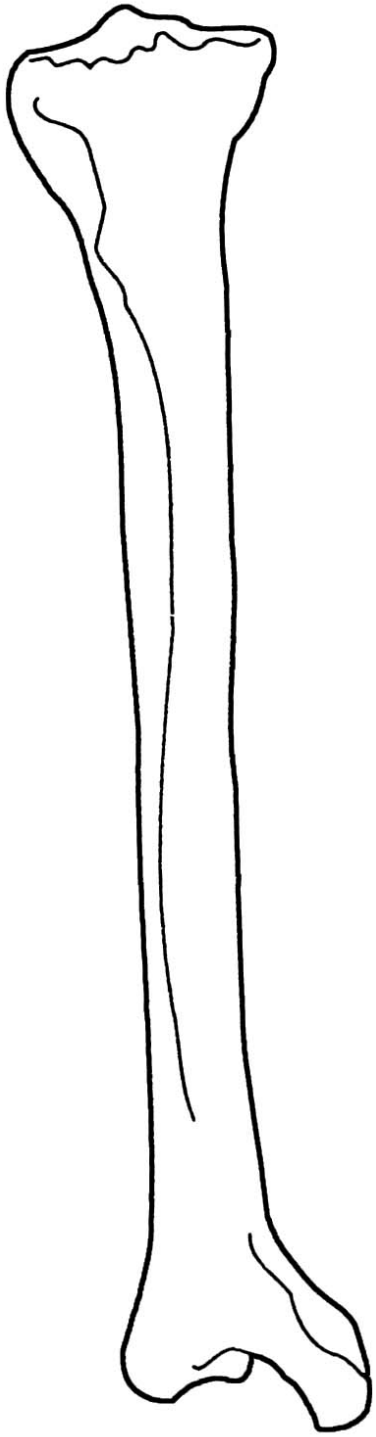


DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

PATHOLOGY:

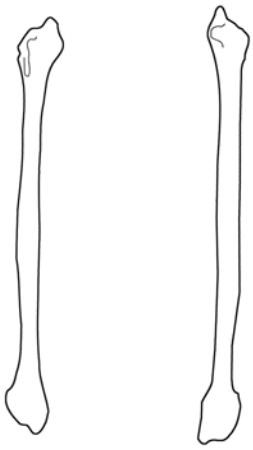
NOTES:

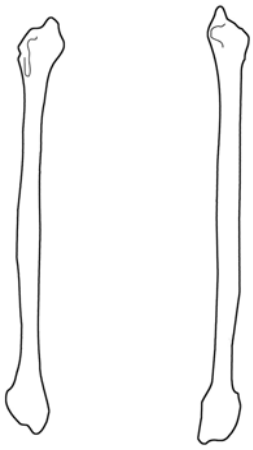
TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Left Fibula Pathology and Data Collection Form

COLLECTION NAME & LOC: DATE:

LEFT FIBULA PATHOLOGIES PAGE #:





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Path:

Photo(s)#:
Notes:

Cat #:
Path:

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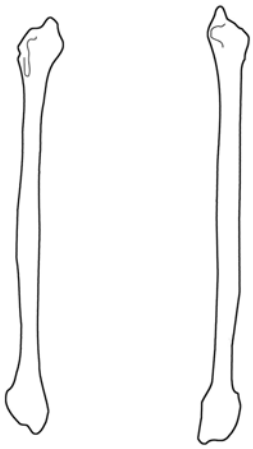

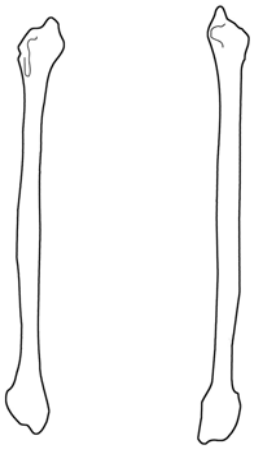

Cat #:
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Notes:

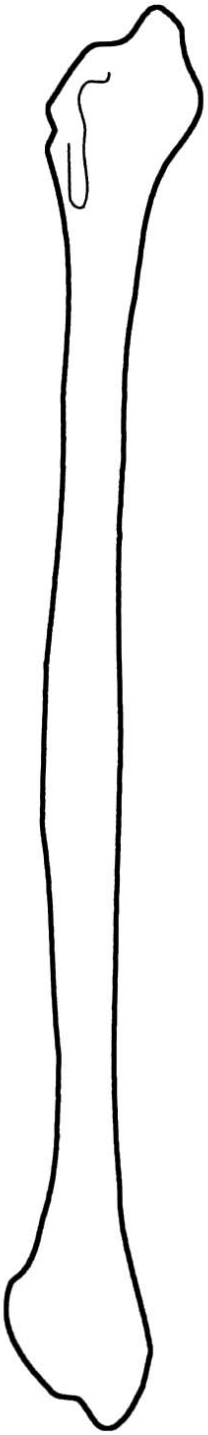
Cat #:
Path:

Photo(s)#:
Notes:

LEFT FIBULA

COLLECTION NAME & LOC:

:



DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

PATHOLOGY:

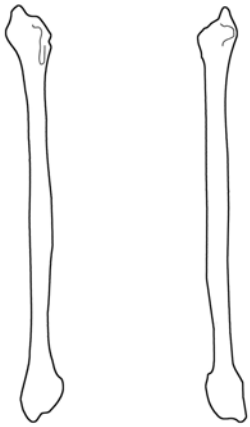
NOTES:

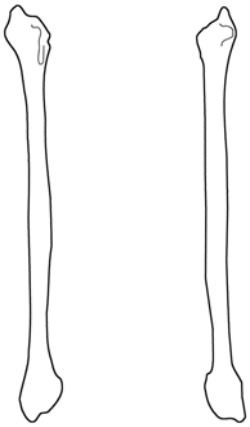
TOTAL NUMBER :
TOTAL NUMBER PATH:

APPENDIX B Fragmentary Element Blank Data Form: Right Fibula Pathology and Data Collection Form

COLLECTION NAME & LOC: DATE:

RIGHT FIBULA PATHOLOGIES PAGE #:





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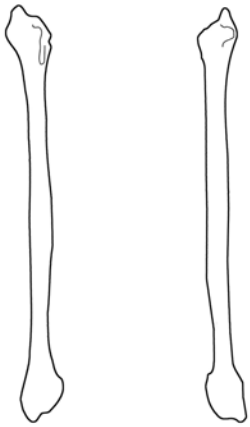
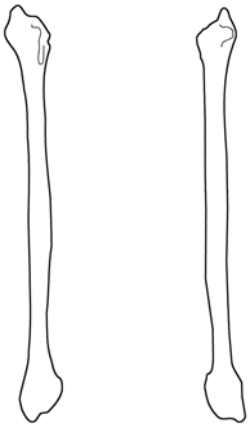




Cat #:
Path:

Photo(s)#:
Notes:

Cat #:
Path:

Photo(s)#:
Notes:

RIGHT FIBULA

COLLECTION NAME & LOC:

DATE:

PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

MIDSECTION PRESENT:

PATHOLOGY:

TOTAL NUMBER :
TOTAL NUMBER PATH:

NOTES:

DISTAL END PRESENT:

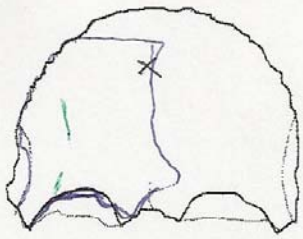
PATHOLOGY:

NOTES:

TOTAL NUMBER :
TOTAL NUMBER PATH:

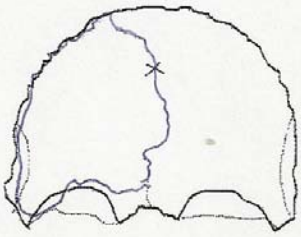
APPENDIX C Sample Data Forms: Crania

COLLECTION NAME & LOC: Aljubarota, Coimbra PT DATE: 13 March 2002

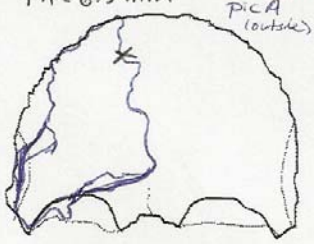


Cat #: ALJ.1.706
Path: No Path
crib orb = 0 / gr –
Notes: Right side only (fairly complete)
A couple of v. shallow lines of taph damage
Th = 6.0mm

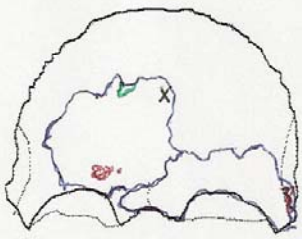
Cat #: ALJ.1.75
Path: Inside surface: depression [lesion?] @ 48.8mm from top cond; 8.3mm from metopic
Oval-shaped (7.0x4.5mm)
Not traumatic - could be non-path lrg arachn granulations
crib orb = 0 ; mild/Ale brow gr I
Notes: present metopic suture - R side only present
Taph square (4.3x4.2 mm) depression near coronal suture (canine tooth?)
Th = 6.5 mm
pic A (outside)



Cat #: ALJ.1.70
Path: No path
Notes: Fairly complete R part of frontal
Th = 5.9mm



Cat #: ALJ.1.172
Path: No path
Notes: Partly complete R side of frontal
Th = 7.7mm



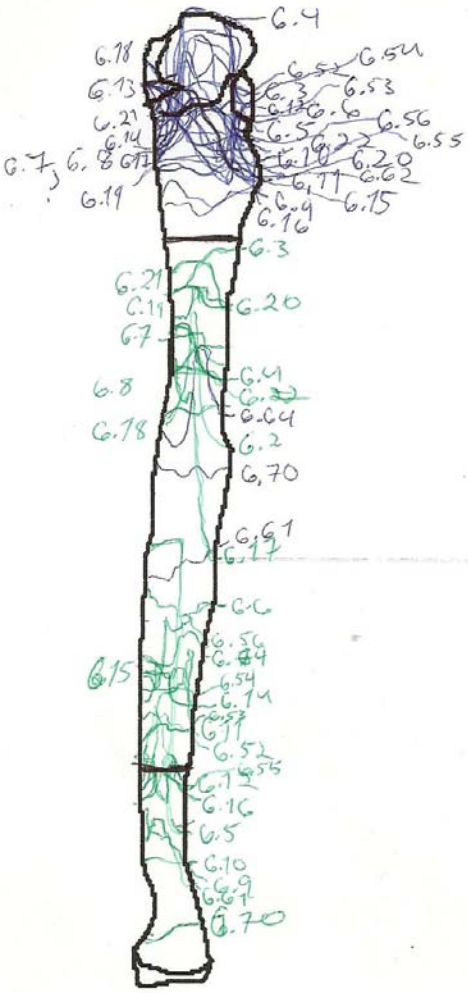
Cat #: ALJ.1.72
Path: Non-traumatic (probably) osteophyte over development @ above R brow
11.0mm
sat temporal margin → some lipping
Area 6mm x 7.7mm
Notes: crib orb = 0 gr I
Mild P.H.
L 15.7mm from midline
Area above & including L browridge/orbit
part of squama above R brow
Some perforation (partial) on piece of R-squama
TH = 7.65mm
pic A

Cat #: ALJ.1.148
Path: No Path
crib orb = 0.5 / gr I
Notes: Partly complete R side frontal
Some taph root damage
Th = 4.2mm

APPENDIX C Sample Data Forms: Post-Crania Collection

COLLECTION NAME &LOC: Aljubarrota, Comba PT DATE: 7 May 2003

LEFT ULNA



PROXIMAL END PRESENT:

PATHOLOGY:

TOTAL NUMBER :

TOTAL NUMBER PATH:

MIDSECTION PRESENT:

PATHOLOGY:

Taph? 6.17 - Ant, med sahe damage (could be taph b/c)

6.53 Damage to ~~post~~ ant distal end

6.62 Distal end damage = path? perforatn?

TOTAL NUMBER :

TOTAL NUMBER PATH:

DISTAL END PRESENT:

PATHOLOGY:

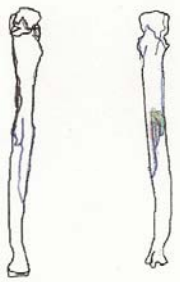
TOTAL NUMBER :

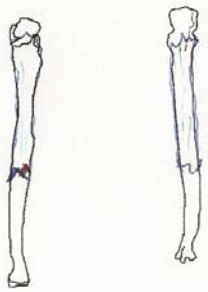
TOTAL NUMBER PATH:

APPENDIX C Sample Data Forms: Post-Crania Pathology

Page 1.

COLLECTION NAME & LOC: Aljubarrota, Combra PT DATE: 7 May 2003
LEFT ULNA PATHOLOGIES



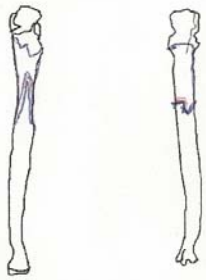


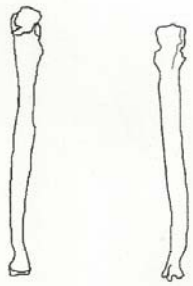
Cat #: ALJ 6.17
Path:

Cat #: ALJ.6.53
Path: Triangle shaped (5.8mm 4.0mm) perforation @ distal lateral end of anterior side

Photo: 0542
Notes: Ulna frag - damage (Post?) on Posterio-lateral side
Probably erosion post-mort

Photo: 0543
Notes: middle shaft fragment fairly weathered & fairly robust





Cat #: ALJ.6.62
Path: Full perforation ant distal side
Partial perf posterio-lateral

Photo: 544 (Ant), 545 (A), 546 (P), 547 (L)
Notes: Small middle fragment of gracile ondividual

Cat #:
Path:

Notes:

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