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Implications of Vertebral Degenative Disease and Vertebral Ligamentous Ossification in Native Populations of the Lower Tennessee River Valley

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IMPLICATIONS OF VERTEBRAL DEGENERATIVE DISEASE AND VERTEBRAL LIGAMENTOUS OSSIFICATION IN NATIVE POPULATIONS OF THE LOWER TENNESSEE RIVER VALLEY

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Cervical vertebrae are an effective biomechanical proxy for understanding physical activities of a populace due to the osteological reactivity of nuchal muscle use to extensive weight and pressure. Differentiation in the distribution of osteophytosis (OPL), osteoarthrosis (OA), and ossification of the ligamentum flavum (OLF) along the cervical vertebrae may indicate particular biomechanical stresses and/or burden-bearing differences between subsistence strategies.

A collection of 287 pre-Columbian Native American individuals (N = 854 vertebrae) was analyzed for presence and severity of OPL, OA and OLF. The sample consists of remains from six archaeological sites located in the lower Tennessee River Valley: three sites (Cherry, Eva and Kays Landing) from the Archaic period (~2500-1000 BC) that reflect an intensive hunter-gatherer subsistence strategy; and three sites (Link, Slayden and Thompson Village) from the Mississippian period (~AD 1000-1200) that reflect an agriculturalist subsistence economy. A repeated measures ANOVA was employed to compare the 167 individuals viable for OPL analysis and 103 individuals viable for OLF analysis to determine frequency and distribution. While

degenerative changes are ultimately phenomena related to age and body size and are etiologically multifactorial, the results of this study, in conjunction with previous paleopathological studies of the shoulder joint, suggest a strong patterned co-association between reactive changes on the cervical spine and particular repetitive load-bearing movements (e.g., head balancing and head tumpline usage, weight bearing by the arms) and subsistence economy.

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S.A.B.

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CHAPTER I

INTRODUCTION

Determination of Native American daily life and activities from the Archaic and Mississippian periods present a unique situation for bioarchaeologists, particularly in southeastern North America. While extensive research has been conducted on pre-Columbian Native American peoples throughout recent history, relatively little is known about the health and living conditions of the populations in the western region of the lower Tennessee River Valley before contact. Cervical vertebrae possess the potential to provide invaluable information pertaining toward the anatomical consequences of different subsistence economies and their associated burden-bearing activities.

When functioning properly, the bone, ligaments and muscles operate simultaneously as an efficient lever-fulcrum system. Unfortunately, the complexity of the cervical structure makes it extremely difficult to understand the dynamics behind biomechanical stresses and failures. To extrapolate, over 50% of all spinal injuries occur within the cervical region and the mechanisms which create the injuries can result in different patterns in different situations (Mirza et.al, 2006). However, the contentious injuries do tend to congregate in certain areas where the stress is concentrated due to the transition of a load from a more rigid, constricted segment to a more flexible, moveable segment: the cranio-cervical junction (the occipital condyles to the axis vertebra) and the cervico-thoracic junction (the 7th cervical vertebra to the 1st thoracic vertebra) (Echarri and Forriol, 2002; Mirza et.al, 2006).

Due to this osteological sensitivity of the nuchal region to extensive weight and pressure, repetitive physical activities and biomechanical stresses frequently leave a permanent record that is forever written on the bone. Analysis of that record, particularly the manifestations and prevalence of apophyseal and marginal osteophytosis (OPL), osteoarthrosis (OA) and ossification of the ligamentum flavum (OLF), may provide sufficient proxies of biomechanical stress to elucidate on the elusive behavior differences of the peoples and/or communities within this region. As such, a wide range of mechanical injuries and pathological conditions were considered while attempting to reconstruct activity patterns and particular load-bearing stresses practiced by individual populations from different geographical and archaeological cultures in the Lower Tennessee River Valley. Each of these conditions were chosen for their stabilizing effects or reflection of compressive pressures.

CHAPTER II

ANATOMY OF CERVICAL VERTEBRAE

The human spinal column is comprised of three primary components: the cervical spine, the thoracic spine; and the lumbar spine. Unique both morphologically and functionally, each section is integral to the overall structural integrity of the body, providing both support for the musculoskeletal system and protection for the spinal cord and its radiating nervous tissues. This investigation focuses on the biomechanical and functional importance of the cervical spine, as well as its corresponding degenerative properties, with regards to stress from different subsistence economies and their possible associated repetitive movements.

Bone

Each cervical spine is composed of seven individual vertebrae. The first cervical vertebra, also referred to as the atlas, possesses a unique construction in that it is the only vertebra with no central body. This large, ovoid-shaped vertebra articulates with the occipital condyles of the cranium via two kidney bean – shaped superior articular facets, with two corresponding inferior articular facets. These articulations allow the head to execute sagittal-plane flexion and extension. Each set of articular facets are connected to a transverse process with foramina on their respective side via thin, bony arches which possess bony tubercles for muscular attachment. A secondary facet is located on the antero-interior surface of the vertebrae where it articulates with the dens of the second cervical vertebra.

The second cervical vertebra, also referred to as the axis, also possesses a distinctive body construction in that it is the only vertebra with a process projecting from the body. Said projection, known as the odontoid process or dens, rises superiorly from the body centrum to articulate with the atlas and provide structural support for axial-plane rotation. The axis also articulates with the atlas through the large superior articular facets, with two corresponding inferior articular facets. Each set of articular facets, attached to the centrum via bony pedicles, are bordered by a transverse process with foramina on their respective side. An additional distinctive feature of the axis is the spinous process. As the first in the vertebral column, the axis spinous process is quite robust with a bifurcated end characteristic of cervical vertebrae.

Features characteristic of a typical cervical vertebra can be found on the third through sixth cervical vertebrae shown in Figure 1. The body (centrum), considered as the largest part of the vertebra, is small but broad, possessing a transversely concave superior surface that appears shaped similar to a jelly bean from a supero-inferior perspective and saddle-shaped from an antero-posterior perspective. Each centrum is stacked directly above one another to provide structural support for the cranium. (Gray, 2003). Attached to the body via two short, thick pedicles emerging from the upper part of the posterior body are sets of round superior and inferior articular facets that are slanted at an angle that varies from 35-65 degrees depending on the location within the spine and the individual (Dutton, 2008). Each set of articular facets are bordered by a transverse process with foramina on their respective side. The articular facets are connected to the spinous process via broad plates of bone known as laminae, creating a circular connection designed to provide protection of the spinal cord in the canal, known

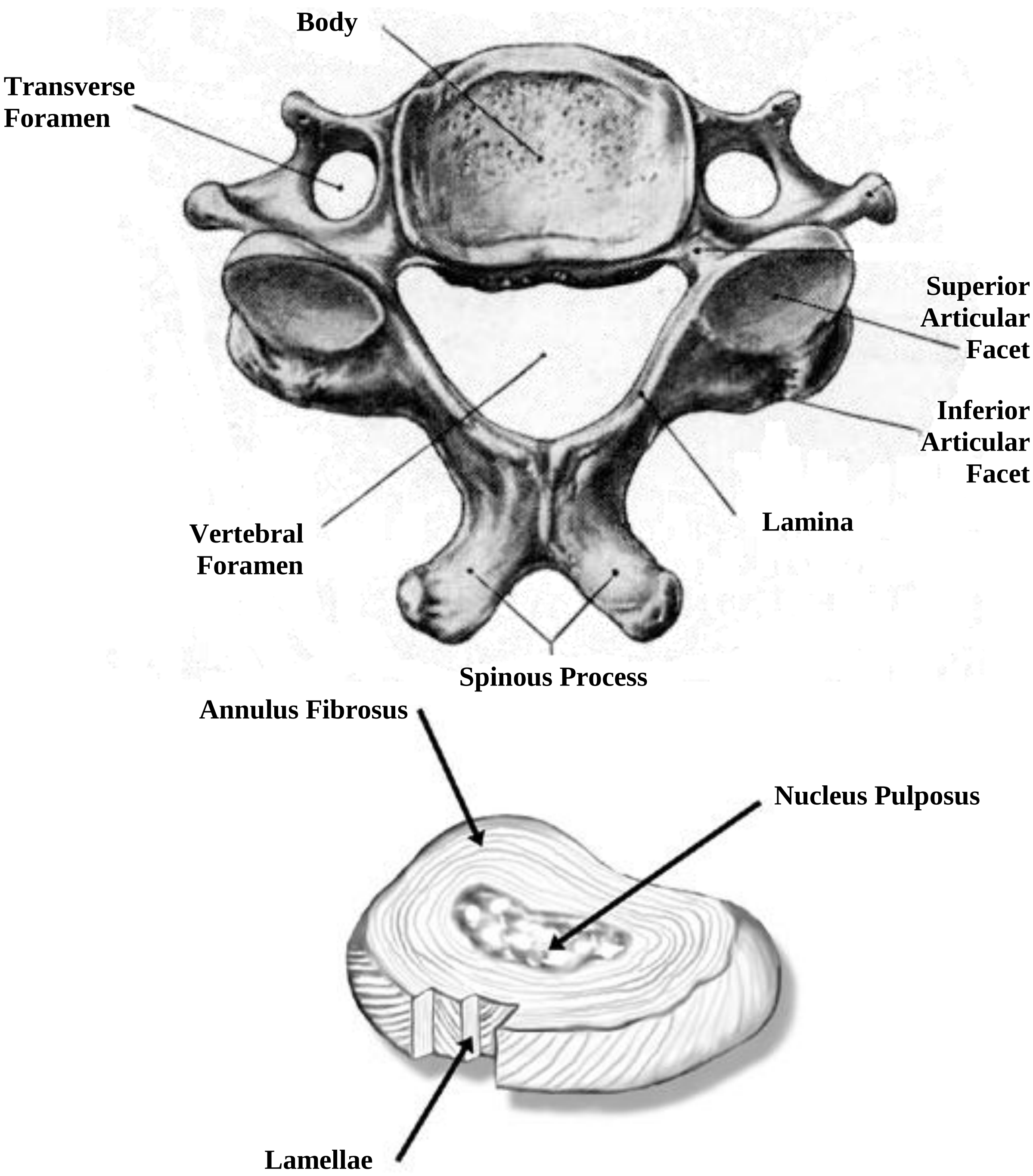

Figure 1. Anatomy of Typical Cervical Vertebra (upper) and Intervertebral Disc (lower) (adapted from Gray, 2003)

as the neural arch. All spinous processes are relatively short and characteristically bifurcated, with a downward angle that slowly elevates into a roughly perpendicular level by the seventh cervical vertebra.

Finally, the seventh cervical vertebra, also known as the Vertebra Prominens, possesses features both similar and atypical of a cervical vertebra. To elaborate, the body retains the characteristic saddle shape with slanted superior and inferior articular facets that are connected to the spinous process via laminae. However, the transverse processes on the seventh cervical vertebra do not contain foramina, a trait consistent with the thoracic vertebrae. Additionally, as mentioned in the previous paragraph, the spinous process of the last cervical vertebra is roughly perpendicular and not bifurcated, a characteristic also consistent with the thoracic vertebrae.

Joints

Joints, which provide the skeleton with both flexibility and movement, are classified by their structures and the quantity of allowable movement. Mainly composed of white fibrous tissues, joints are extremely strong and resilient, capable of sustaining extensive quantities of severely applied force. Within the 37 individual joints of the cervical vertebrae, there are two basic types and one specific type of joints located within the vertebral column: the pivotal joint found only in the atlantoaxial junction of the C1-dens articulation; the zygapophyseal joint of the articular facets; and the semi-movable, fibrocartilaginous joints of the intervertebral discs (Dutton, 2008). This allows for dramatically increased ranges of motion and flexibility while sacrificing stability. As such, this short but very complex segment of the spine is significantly vulnerable to trauma and injury.

According to Kotsenas (2012) and Meleger and Krivickas (2007), zygapophyseal facets are "true synovial hyaline diarthrodial joints" located on the superior and inferior portions of the vertebrae, posterior to the vertebral body on either side of the vertebral foramen. These posterior elements encompass a stable intervertebral bridge which affects the degree of spinal mobility, limiting twisting and vertebral slippage/dislocation, with the junctions of the 5th -7th cervical vertebrae possessing the most mobility (Meleger and Krivickas, 2007; Roberts, 2010). Anatomically, true synovial joints are composed of freely movable joints, lined with hyaline cartilage, separated by a capsule of lubricating fluid, known as the synovial membrane, designed to minimize friction (Roberts, 2010; Small, 2008). While the articular facets, like many other joints of the body, possess a great deal of mobility they are not as movable as angular (ball-in-socket) joints. As such, the synovial joints of the articular facets are classified as diarthrodial, capable of executing simple gliding motions of one bone over another, but prevent angular or rotary movements. Each articulation is encapsulated in thin ligamentous sacs, characteristically long and loose in the cervical spine, which connect the margins of the articulation facets for adjacent vertebrae.

In contrast, the semi-movable classification of the intervertebral joints denotes a much larger restriction in movement. Though capable of bending and twisting movements, the semi-movable joint is designed to contribute more to the structure strength and stability of the spine, forming approximately a quarter of the spine's total length and weight when alive. However, the true measure of the stability and resilience of the intervertebral joint is in its categorization as a fibrocartilaginous amphiarthroidal articulation. Anatomically, an amphiarthroidal joints consist of articulations united by broad, flattened fibrocartilaginous discs which adhere to a thin layer of hyaline cartilage covering the superior and inferior bodies of the adjacent bones. Said fibrocartilaginous discs are composed of alternating layers of a matrix with pink collagen fibers, creating a disc both extremely resilient as well as compressive. As such, these discs are adept at resisting tension and heavy pressure and absorbing shock from strenuous activities; however, said resilience and height of the discs do gradually decrease with age. Structurally, each intervertebral disc is comprised of two rings: an inner ring, known as the Nucleus Pulposus, and an outer ring, known as the Annulus Fibrosus. The Nucleus Pulposus is a gelatinous mass consisting of a "soft, pulpy, highly elastic yellow substance" (Gray, 2003) that lays in no concentric arrangement with a small synovial cavity in the center. Raised slightly higher than the surrounding tissue, the Nucleus Pulposus is all that remains of the ancestral chorda dorcalis seen in any other invertebrate animals. In contrast, the Annulus Fibrosus is constructed in concentric laminae of pink fibrous and white fibro-cartilage tissues that orient obliquely and interweave within the layers.

Musculature

Due to the extreme flexibility of the cervical spine and its tremendous susceptibility to traumatic injury, ligamentous and musculature integrity is crucial to the stability of this complex mechanical linkage. Over twenty separate ligaments and muscles control the degrees of freedom exerted by joint movement, of which 20% are controlled by the osseoligamentous tissues and 80% are controlled by the muscles. Each tissue has specific roles with ligaments utilized in stabilization and the muscles designed to provide "dynamic support for neutral and midrange activities." (Dutton, 2008).

There are several muscles which provide said "dynamic support" during specific flexion, extension, lateral flexion and rotation movements, each capable of exerting enough strain on the joint and/or the attachment sites to impart entheses or degenerative alteration. To elaborate, the trapezius, which attaches the skull and spine to the scapula and clavicle, allows for the neck to flex laterally while also drawing the head backward. The levator scapulae, which attaches from the cervical spine to the top of the scapula, also allows for the neck to flex laterally. The splenius capitis, semispinalis capitis and the semspinalis cervicis all work in conjunction draw the head and neck while the anterior scalene, which attaches from the cervical spine to the first rib, and the middle scalene, which attaches from the cervical spine to the ribs, function to flex the neck forward and laterally. Finally, the sternocleidomastoid serves to turn the head to the side (Roberts, 2010).

In contrast to the muscular tissues, there are numerous ligaments designed to connect specific articular extremities and bony elements together to assure stabilization. To elaborate, the atlanto-occipital joint seen in Figure 2 connects the atlas to the occipital condyles is secured via the anterior atlanto-occipital membrane, which is a continuation of the anterior longitudinal ligament that attaches the anterior arch of the atlas to the anterior portion of the foramen magnum, and the posterior atlanto-occipital membrane, which is reflective of the posterior aspect of the previously mentioned membrane. Additionally, the atlantoaxial joint seen in Figure 2 also consists of specific and unique ligamentous structures, such as: the apical ligament which secures the median aspect of the apex of the dens to the anterior foramen magnum; the dual/paired alar ligaments flank the apical ligament as it secures the dens to the medial sides of the occipital condyles; the cruciate ligament which consists of a transverse part, that connects the dens to the atlas via the inner aspect of the lateral atlas masses, and the vertical part, that connects that posterior body of the axis to the anterior foramen magnum; and the membrane tectoria which is a continuation of the posterior longitudinal ligament that envelops the posterior dens and the other three ligaments.

Once past the 2nd cervical vertebra, ligamentous attachments function within 5 specific structural units: the interbody joints; the laminae; the articular (zygapophyseal) processes; the transverse processes; and the spinous processes. The intervertebral disc joints are bound by two specific ligaments: the anterior and posterior longitudinal ligaments. Both continuous bands traverse down their respective portions of the spine from the skull to the sacrum in an effort to both retain movement flexibility while maintaining structural integrity. Structurally, each ligament is quite different. The anterior ligament is a strong, extremely dense band of interwoven longitudinal fibers that adhere to the intervertebral discs and body margins to smooth out the anterior portion of the spine. In contrast, the posterior ligament is a smooth, shining band of dense and compact longitudinal fibers that is very narrow and quite weak in comparison. All adjacent laminae are attached via the ligamentum flavum, which runs continuously from the axis vertebra to the sacrum in two lateral portions. Perhaps the most important aspect of the posterior element for the purposes of this research, these thin, highly broad expanses of yellow highly elastic tissue and collagen fibers run perpendicularly to maintain our upright posture and aid in recovery from spinal flexion. Different from all other cervical ligaments, the ligamentum flavum is designed to maintain tension despite the elasticity; an elasticity which can be compromised by scarring and/or infiltration of

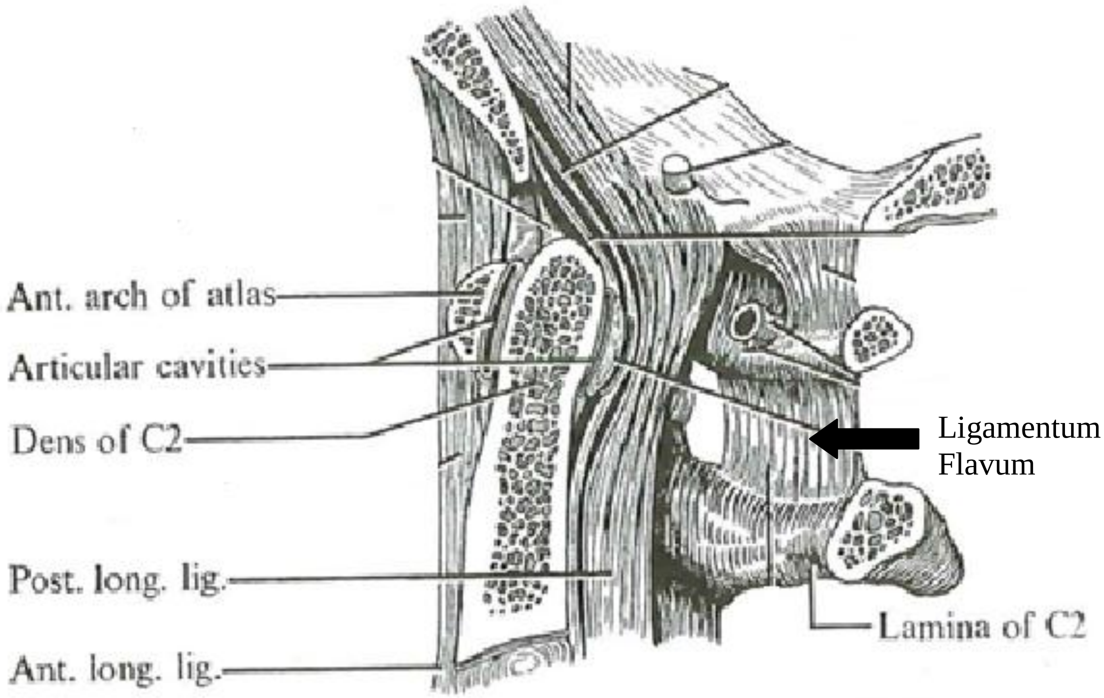

Figure 2. Sagittal Profile of Cranio-Cervical Junction (adapted from Small, 2008)

fatty tissues that increase the potential for compression. As previously mentioned, the articular processes are bound by the thin ligamentous sacs known as the capsular ligaments. Characteristically long and loose in the cervical spine, these ligamentous sacs secure the neighboring margins of the zygapophyseal facets and their corresponding synovial membranes. The transverse processes are controlled by the irregular, scattered fibers of the intratransverse ligaments. Finally, the spinous processes are held together via the supraspinous and interspinous ligaments. A strong, fibrous cord, the supraspinous ligament runs from the 7^{th} cervical vertebra to the sacrum via an inner and outer layer. In contrast, the thin and membranous structure of the interspinous ligament secures the adjacent margins of the spinous processes from the skull to the sacrum but is weakly developed in the cervical region.

With the cervical region capable of executing the greatest degree of movement of any region of the spine, the ligaments and muscles function simultaneously to perform the following actions demonstrated in Figure 3: flexion, considered to be the most extensive of all movements; extension, considered to be the least extensive; lateral flexion; circumduction; and rotation. When in flexion, the anterior longitudinal ligament relaxes while the ligamentum flavum, the supraspinous and interspinous ligaments stretch, resulting in a compression of the intervertebral disc. Flexion is produced by the actions of the longus cervicis, anterior scalene and the sternocleidomastoid muscles. In contrast the neck in extension stretches and is limited by the anterior longitudinal ligament and the spinous process. Extension is produced by the actions of the postvertebral muscles. When in lateral flexion, the respective side of the intervertebral disc is compressed and prevented from injury via the limitations of the transverse processes and their corresponding intratransverse ligaments. Lateral flexion is produced by the actions of the anterior and middle scalene, trapezius and the sternocleidomastoid muscles. Circumduction within the cervical spine is extremely limited and only created by a specific set of previous movements. Finally, rotation or twisting/torsion occur infrequently between immediately adjacent vertebrae but transpire regularly when executed as a whole. Rotation is produced by the actions of the sternocleidomastoid muscle on one side and the splenius muscle on the other side.

Biomechanics

According to Nigg (Nigg and Herzog, 1999), biomechanics is "the science that examines forces acting upon and within a biological structure and effects produced by such forces." To that end, biomechanics can be used to examine and comprehend the mechanisms behind the forces applied during injury events, as well as everyday physical activities which result in pathologic degeneration and osseous alteration. Said forces are defined as "the action that changes the state of motion of a body or the relative position of molecules composing the body," creating a push-pull effect (Pierce et al., 2004). Traditionally, there are three "pure" forms of force which are defined by their "magnitude, direction and point of application relative to a given body": compressive/compression, where a downward force is sent through the body in an axial manner; tension, where the force is also sent in an axial manner but results in stretching instead of compression; and shear, where one part of the bone is being forced to slide in the opposite direction from the adjacent bone. The term "load" is used to describe the application of this force on the bone and/or its resultant movements. These loads create

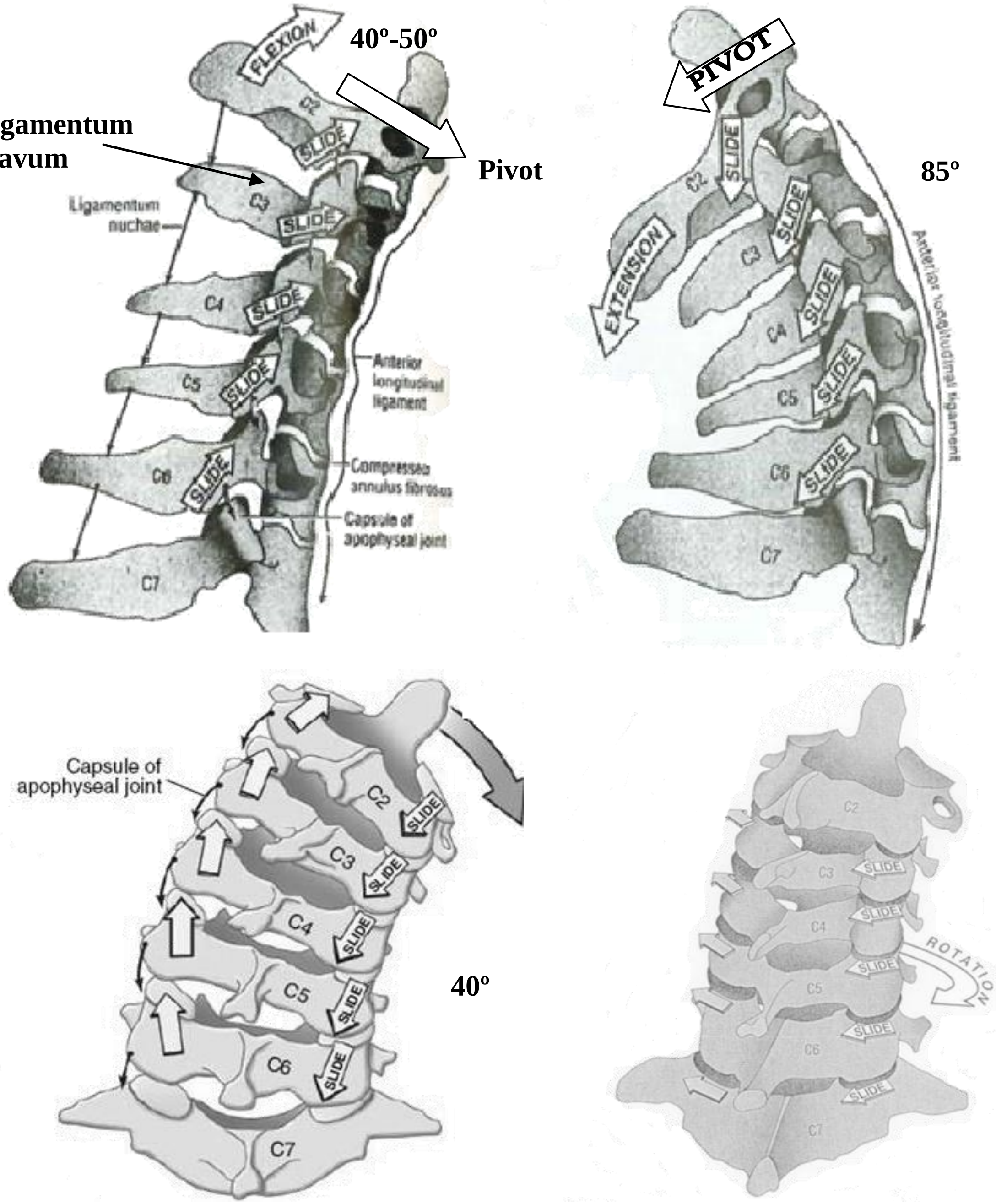

Figure 3. Biomechanical Motions of the Neck: Flexion (upper left), Extension (upper right), Lateral Flexion (lower left) and (lower right) (adapted from Dutton, 2008; Gray, 2003)

stress within the various tissues which respond in a particular distribution pattern depending on the type of force applied. To elaborate, a bending load results in tension on one side and compression on the other due to the offset, non-axial nature of the force applied. Torsional loading creates areas of both tension and compression where the tissues are undergoing shear due to any longitudinal twisting. Commonly, tissues undergo a combination of different load forms and are inversely reflective of the application site versus the extent to which the force spreads.

In certain instances where the stress of the applied force exceeds the tensile strength of the bone or hits a weak spot, a complete or incomplete fracture can occur. Where and what kind of fracture it is can provide invaluable information pertaining toward the type and magnitude of the force load applied. The likelihood of what kind of fracture and where it occurs on the bone is dependent upon both extrinsic and intrinsic factors. Extrinsic factors consist of the magnitude and direction of force, the impact and rate of the loading, certain influential environmental factors, how much the impact area can absorb the force and whether the load was dynamic or static. Intrinsic factors consist of the structural and material properties of the targeted tissues, such as bone biomechanics and strength.

CHAPTER III

LITERATURE REVIEW

Despite the plethora of pre-Columbian Native American human remains available from the WPA-TVA era in the southeastern United States and corresponding regions, there are few archaeological studies prior to the late 1970s which examined skeletal remains as population samples (Berryman, 1984; Bridges, 1989, 1994; Merb and Euler, 1985; Milner, 1992). Researchers frequently focused on the analysis of the ceramics, corresponding inorganic archaeological materials and cultural/ethnographic data for primary information and contextual support, relegating human remains to the position of secondary culturally relevant sources of information (Bass, 1985; Claassen, 1986; Haywood, 1823; Higgins, 1982; Jacobson, 2001; Jones, 1876; Kneberg, 1952; Lee and DeVore, 1968; Lewis and Kneberg, 1947, 1959; Lewis and Lewis, 1961; Lidberg, 1939; Magennis, 1977; Mason, 1980; Moore, 1915; Nash, 1968; Odom et al., 1953; Robertson, 1878; Schurr and Powell, 2005; Thruston, 1890; Turnbull, 1972).

While much more integrated into archaeological research when warranted (Brooks and Suchey, 1990; Iscan et al., 1984, 1985; Lovejoy et al., 1985; Milner, 1992; Phenice, 1969; Stewart, 1979; White and Folkens, 2005), modern researchers have historically trended toward addressing population-based questions. To elaborate, since the 1970s, the new paradigm of the biocultural approach (bioarchaeology) has the goal of reconstructing previous lifeways and their quality of life through the utilization of health status data such as nutritional status, non-specific infection/inflammation, and specific diseases (e.g. tuberculosis, treponemal disease) (Andrews, 2012; Bridges et al., 2000; Carter and Cobb, 1999; Crubézy et al., 2000; Ferguson, 1997; Gordon and Buikstra, 1981; Hawkey and Merbs, 1995; Henderson et al., 2010; Jurmain, 1990, 1991; Jurmain and Kilgore, 1995; Jurmain and Vilotte, 2009; Kennedy, 1989; Kramar et al., 1990; Larsen, 1997, 2000; Lovell and Lai, 1992; Milella et al., 2012; Molnar et al., 2011; Ortner, 2003; Resnick et al. 1975, 1978; Roberts and Manchester, 2005; Rogers and Waldron, 1995; Schurr and Powell, 2005; Turnbull, 1972; Waldron and Rogers, 1991; Weiss, 2007).

However, the application of degenerative alterations and biomechanics to the reconstruction of lifeways and specific physical activities is much more contentious. To elaborate, until the 1980s and early 1990s bony degenerative alterations and their associated pathological conditions were definitive remnants of specific activities, known scientifically as musculoskeletal markers (Berryman, 1984; Bridges, 1989, 1994; Bullough and Boachie-Adjei, 1988; Connor, 1990; Haas et al., 1994; Hawkey and Merbs, 1995; Hukuda et al., 1983; Jurmain, 1990, 1991; Jurmain and Kilgore, 1995; Kennedy, 1989; Kramar et al, 1990; Lai and Lovell, 1992; Lovell and Lai, 1992; Lovell, 1944; Merbs and Euler, 1985; Resnick et al, 1975, 1975; Rogers and Dieppe, 1990; Rogers and Waldron, 1995; Rogers et al., 1985; Sartoris et al., 1985; Suzuki, 1978; Waldron and Rogers, 1991; Williams et al., 1982). Unfortunately, studies emerged in the late 1980s and early 1990s which indicated multifactorial causes for reactive changes to the joints and joint margins, questioning the value for reconstructing physical activities from human remains (Bridges et al., 2000; Burt et al., 2013; Crubézy et al., 2002; Derevenski, 2000; Eshed et al., 2004; Ferguson, 1997; Henderson et al., 2010, 2012; Knüsel et al., 1997; Larsen, 1997, 2000; Molnar et al., 2011; Ortner, 2003; Roberts and Manchester, 2005; Rogers et al., 1997Rojas-Seplveda et al., 2008; Smith, 1996; Snodgrass, 2004; Waldron, 2009; Weiss, 2003, 2007, Williamson, 2000).

With that in mind, there is a new initiative to restore the explanatory power of degenerative changes, now referred to as entheseal changes, through the incorporation of biomechanical and modern medical principles and comparative research (Andrews, 2012; Jurmain and Vilotte, 2009; Kaki et al., 2011; Kim et al., 2013; Kotani et al., 2013; Lang et al., 2013; Milella et al., 2012; Novak and Šlaus, 2011; Sokiranski et al., 2011; and Knüsel, 2012). The problem with incorporating data from modern clinical trials is that physicians, physical therapists and biomechanical engineers tend to analyze primarily the reaction of the living skeleton to a specific situation or stress factor. While the resultant data is quite informative, the data available presents differently than dry bone. Moreover, features which are apparent on dry bone are often obscured from view via radiographical examination by living muscle and cartilage, resulting in an underrepresentation of degenerative issues during clinical studies (Bailey and Casamajor, 1911; Bellabarba et al., 2006; Bono, 2006; Dutton, 2008; EB Medicine, nd.; Geere et al., 2010; Gray, 2003; Hämäläinen, 1993; Heglund et al., 1995; Hoque et al., 2012; Huggare, 1998; Hussain et al., 2010; Inamasu and Bernard, 2006; Kaneda, et al., 1999; Kotsenas, 2012; Lloyd et al., 2010, 2010, 2011; Malville et al., 2001; McElhaney et al., 1976; McGill et al., 2009; Mirza et al., 2006; Naffziger et al., 1938; Nathan, 1959; Newman and Ostler, 2011; Oppenheimer, 1938; Pierce et al., 2004; Rao and Jones, 1975; Roberts, 2010; Small, 2008; Sokoloff, 1969; Valdes and Spector, 2009; Wald and Harrison, 1975; Weaker, 2014; Williams et al., 1982). Consequently, there is a need for specifically dry bone identification and quantification of mechanical stress, especially concerning the Native Americans of southeastern United States.

CHAPTER IV

ARCHAEOLOGICAL MATERIALS

In order to effectively evaluate the entheseal changes evident on the neck vertebrae between two subsistence economies with two presumably different patterns of work activities (hunter-gatherer versus agriculturalists), osteological samples from a single geographic context were examined for proliferative and resorptive bone change. The skeletal sample utilized in this research were recovered from six archaeological sites located within the lower Tennessee River Valley (shown in Figure 4): three sites (Cherry, Eva and Kays Landing) from the Late Archaic period (~2500-1000 BCE) that reflect intensive hunter-gatherer subsistence strategies; and three sites (Link, Slayden and Thompson Village) from the Mississippian period (~1100-1500 CE) that reflect an intensive agricultural subsistence economy (Chapman, 1980). Each site is located in the western portion of the Tennessee River Valley that is geographically identified today as west-central Tennessee. The remains are currently curated by the Frank H. McClung Museum at the University of Tennessee in Knoxville, Tennessee.

Cherry Site (40BN74)

Excavated in August and September of 1941, the Cherry site is the last excavation project funded by the Tennessee Valley Authority and the Works Project Administration in Benton County before the dam was flooded (Magennis, 1977). The Cherry site was located at 36°10’29”N and 88°08’45”W approximately 0.95mi east of the Big Sandy River and 22mi north of where the river meets the Tennessee River. Despite being

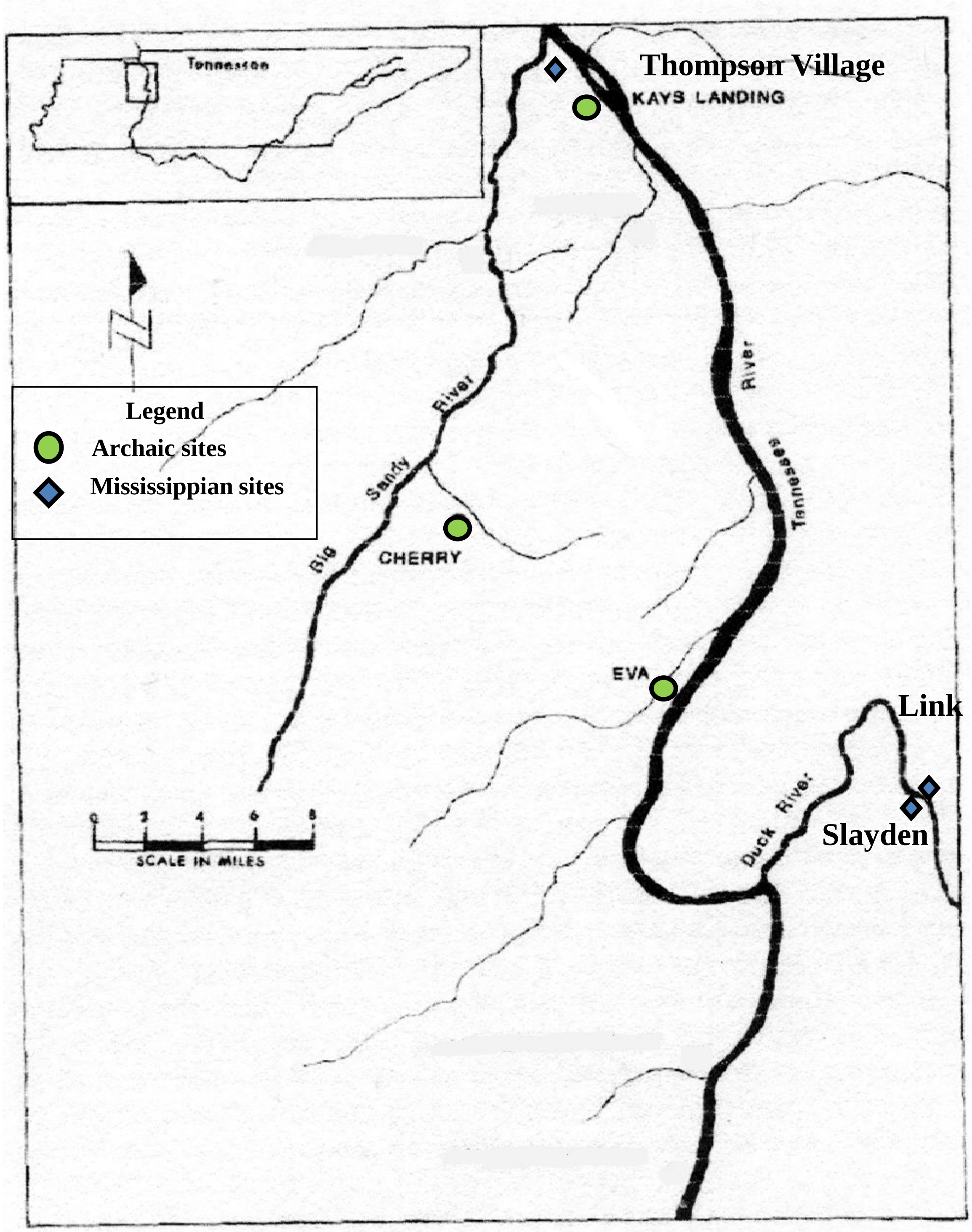

Figure 4. Map of Archaeological Sites (adapted from Magennis, 1977)

situated between two Big Sandy River tributaries, the Cherry site is considered the most remote of the west-central Tennessee River Valley Archaic sites. Positioned on a slight rise about 15-20ft above the lowest level of the bottom, the site covers approximately 2 acres with only one acknowledged stratum beyond the plow zone and clay subsoil (Magennis, 1977).

The spatial arrangement at Cherry is unique, a trait which is not corresponded at the nearby Eva site. The eastern portion of the site seems to have been the locale for burials and the main concentration of midden pits, of which there were three types of pits clearly defined at the Cherry site. Two types of pits potentially served a storage function, containing primarily midden refuse with some animal bone, some shells items and some artifacts. The third type of pit, however, was particularly interesting for its potential as a semi-subterranean structure, though the lack of associated evidence of post holes, hearths and other interior features does not support this theory. Regardless, these pits are large, shallow basin-shaped depressions which can span 13-20ft in diameter and were filled with midden. The western portion of the settlement contained the proposed habitation areas with a large number of post holes arranged in semi-circular and linear alignments to suggest the presence of structures (Magennis, 1977).

A total of 69 burials were recovered from the Cherry site (Magennis, 1977). Comparative chronological analysis of both the Eva and Cherry sites concur that the occupation of Cherry was contemporaneous with the Eva III phase defined by Lewis and Kneberg (1947, 1959, 1961). This phase, defined predominantly by Late Archaic projectile points, indicates an estimated duration of 2500-1000/500 BCE for occupation.

Eva Site (6BN12)

Excavation of the Eva site was conducted by the University of Tennessee and funded by the Tennessee Valley Authority and the Works Project Administration in 1940 preceding the flooding of the Kentucky Lake Dam (Herrman, 2002; Sassman and Anderson, 1996). Eva is located on a broad floodplain remnant terrace along the Tennessee River in Benton County, Tennessee where the highest elevation is around one mile west of the river (Buikstra and Charles, 1999). Midden deposits excavated in the area define the site to a little over an acre, with the shell mound portion confined to the central third region (Magennis, 1977). Though the exact relationship of the inhabitants to specific resources is as yet unknown, Eva is considered to be a classic Middle to late Shell Mound Archaic site, though the exact importance of shellfish within this region is highly debated. Despite the high numbers of remains within the middens, shellfish only amounted to a fifth of the overall diet, contributing a paucity of meat but numerous quantities of essential vitamins and minerals (Herrman, 2002). With such a wide and varied resource base, Smith postulates that the "continuously disturbed anthropogenetic habitat" of the Lower Tennessee River Valley provides ideal situations for the evolution of plant husbandry, demonstrated by the cultivation of chenopod, sumpweed and sunflowers (Smith, 1986, 1992).

According to Odom et al. (1953), Eva consists of 5 major strata which correspond to 3 major cultural phases. Eva I, also referred o as the Eva cultural phase, is comprised of Strata 4 and 5, denoting the earliest occupation of the site. A total of 17 burials were uncovered during this phase out of the total 177 burials excavated. Analysis of the material culture in stratum 5 suggests a date of the Early Archaic which is older than previously thought; however, this dating does compare relatively well with the early Middle Archaic radiocarbon date of 5200 BCE ± 500 years from an antler bone found in stratum 4 (Lewis and Lewis, 1961). It is therefore estimated that Eva I was occupied during 6000-5000 BCE. Since no radiocarbon dates were available for Eva II, also known as the Three Mile and/or Benton cultural phase, Lewis and Kneberg (1947, 1959) establish a date of 5000-3000 BCE through characteristic projectile points. According to Odom et al. (1953), Eva II is comprised of stratum 2 which represents the longest and most intense period of occupation through the large number of human (101 burials) and material remains recovered from this stratum. Eva III, also known as the Big Sandy and/or Ledbetter Landing cultural phase, consists predominately of Late Archaic projectile points discovered within stratum I and the plow zone, both of which varies significantly in depth, ranging from a thin line to 2.5ft. A total of 59 burials were recovered from this cultural phase and are approximately dated to 2500-1000/500 BCE (Magennis, 1977). Almost half of the adult individuals in this sample were recorded previously with some type of pathology while 22 individuals, including 1 subadult, were excavated with associated grave goods (Higgins, 1982).

Kays Landing Site (40HY13)

Though barely discernible from the surface, the archaeological occupation of Kays Landing is quite deep. Located along the Tennessee River, Kays Landing is comprised of three archaeological components: Kays I (approximately 2800 BCE ± 500 years); Kays II (approximately 1630 BCE ± 300 years); and Kays III (Lewis and Kneberg, 1959; Chapman, 1980). Kays I is comprised of Stratum 4 and 5, the lowest strata of the site. Stratum 5 contained 2 feet worth of numerous cultural materials such as a shell midden, fireplaces, burials, worked antler bone and other cultural materials; whereas Stratum 4 was comprised of alternating layers of "alluvium and occupational debris" (Chapman, 1980) that ranged from 1-2 feet in depth depending on the location. Kays II component is restricted to Stratum 2 only which lies above the sterile alluvial soil within Stratum 3. The stratum is comprised of various cultural material such as a shell mound "3 feet high at the apex and approximately 60 feet in diameter," fireplaces, burials and artifacts (Lewis and Kneberg, 1959) Kays III component is consisted of Stratum I and the surface plow zone which also contained small amounts of cultural artifacts. Radiocarbon dating of various antler fragments and shell samples provided the relative dates seen above for components Kays I and Kays II (Chapman, 1980).

Lewis and Kneberg (1959) postulated that the climate in this Archaic region was extremely conducive to the exploitation of the abundant surrounding natural resources, allowing the Native Americans in this region to maintain their way of life in small, relatively isolated villages. Furthermore, Lewis and Kneberg suggested that the archaeology and technology found within the Cherry, Eva and Kays Landing sites were indicative of two separate archaeological traditions within the Tennessee region of the Middle South culture: the Midcontinent and Eastern traditions. The Midcontinent tradition, encompassing the Cherry and Eva sites, existed during the Eva and Big Sandy cultural phases, thought to be primarily sedentary. In contrast, the Kays Landing site belonged to the Eastern archaeological tradition and existed during the Kays III phase, a much different Archaic tradition that reflected the changing climatic conditions and much less sedentism (Lewis and Kneberg, 1959). Later studies, such as Bowen (1975, 1977) and Higgins (1982), refuted this theory of both Archaic sedentism and multiple archaeological traditions. Bowen's analysis (1975, 1977) of 7 Duck River Valley sites, including the Cherry site, "exhibited locations and differences that could be attributed to a settlement pattern characterized by greater mobility – occupied seasonally and for short periods." Further analysis of activity indices corroborated Magennis (1977) and Higgins (1982) mortuary patterning conclusions of only one archaeological tradition, the Ledbetter Landing Phase of the Late Archaic (2500-1000 BCE).

Link Farm Site (19, 20 & 67HS6)

The Link Farm site is an extremely large Middle Mississippian period village comprised of multiple multi-function mounds that served as "ceremonial terraces, high status residences, and burial locale" (Nash, 1968). The mounds and surrounding residential area, encompassing an area of approximately 1 mile, are situated on the top of a steep bluff in Humphreys County overlooking the confluence of the Buffalo River, the Duck River and the Hurricane Creek. A narrow tributary created by this confluence resulted in a broad floodplain that was tremendously fertile for agricultural cultivation (Bass, 1985).

Excavations were carried out by Charles Nash and Georg Karl Neumann in 1935, 1936 and 1939 on behalf of the University of Tennessee (Kuemin-Drews, 2000). Unfortunately, the excavations conducted were extremely limited and asymmetrically sampled, primarily focused on the cemetery mounds and several of the residence mounds within the inner circle of mounds. The inner circle of mounds consisted of three conical mounds, a loaf-shaped mound, and two large pyramidal earth substructure mounds (Bass, 1985).

Despite the extensive looting, several of the burials managed to survive undisturbed in three locations: Unit 19, Unit 20 and the cemetery mound. Regrettably, any remains located within the large cemetery mound(s) were completely destroyed as a result of continuous agricultural cultivation (Kuemin-Drews, 2000); however, archaeologists were able to discern that the mound was approximately 30ft by 36ft, situated within the southeastern corner of the site between two undisturbed residential areas and bisected by a fence line (Bass, 1985).

Unit 19 was also positioned in the southeastern portion of the site adjacent to a Middle Mississippian period residential district. Encompassing approximately 120ft by 90ft, the mound was highly irregular in shape and significantly looted, with a majority of the 62 burials having been disturbed. Of the 62 burials, 21 were primary extended inhumations with 1 bundle burial. Numerous remains were positioned into burial clusters that cross-cut age and sex distinction, indicative of kin group funerary patterns (Bass, 1985). The discovery of stone box graves, all of which faced a west or southwest direction, indicates that the occupants of this site participated in the Middle Cumberland Cultural Complex (Berryman, 1984; Ferguson, 1972; Haywood, 1823; Kneberg, 1952).

Unit 20, the only excavated outer ring mound that encompassed an approximately 45ft by 33ft area, also contained stone box graves. Of the 45 individuals recovered, all but 2 were interred in stone boxes. Despite the damage from looting, 43 of the 45 individuals were able to be securely aged, sexed and placed primarily within five identified burial clusters or three multiple burials. In conjunction with Unit 19, each of these burial clusters and multiple burials cross-cut age and sex divisors, indicative of kin group funerary patterns (Bass, 1985).

Slayden Site (2HS1)

The Slayden site is actually a fission extension of the Link Farm site. Located directly across the Duck River, Slayden is also situated on a bluff crest overlooking the bottomland and was excavated contemporaneously with Link by Charles Nash on behalf of the University of Tennessee. According to research conducted by Bass (1985), both Link Farm and Slayden share common structural types which are contemporaneous in the Middle Mississippian period occupation. This demonstrates a continuation of hierarchical structure expressed in settlement and mortuary patterns (Bass, 1985).

According to Nash (1968), Slayden demonstrates three distinct vicinities of occupation: "upper" village; "village;" with several mound structures off the main "village" for residences and a cemetery. The "upper" village area was a roughly oval section encompassing approximately 450ft by 750ft of cultivated land on the bluff top. The "village" was an approximately 450ft by 150ft section of the narrower lower bench about 225ft to the east of the bluff. To the southeast of the "village" there were two areas of residence mounds located on the bluff crest projections. Finally, the cemetery mound was located on the point of the bluff crest about 450ft west of the "village" area. Unfortunately, in congruence with Link, many of the burials here were disturbed by looters (Nash, 1968). In fact, the 129ft by 45ft loaf-shaped mound of Unit 2 was almost completely looted, though archaeologists recovered 64 burials. All individuals faced toward the west and are aggregated in kin groups based upon the clusters of burials which cross-cut age and sex boundaries. An additional 5 burials were recovered from Unit 5 which were interred in stone boxes and mostly destroyed (Kuemin-Drews, 2000).

Thompson Village Site (7HY5)

Thompson Village is a site located on the western bank of the lower Tennessee River approximately 7mi south of the Tennessee-Kentucky border in Henry County, but about 4mi north of where the Benton County line meets the river. Situated 2mi north of the confluence of the Big Sandy River and the Tennessee River, Thompson Village is right next to Big Sandy Island which extends a half mile beyond the site in either direction (Moore, 1915). The confluence of the rivers created a broad, elevated floodplain that is approximately 1.5mi upriver and opposite the Gray site, suggesting that Thompson Village was considered a part of the Gray polity (Bass, 1985).

Excavation began on August 25, 1939 by George Lidberg on behalf of the University of Tennessee. The main area of the site extends 1,000ft north to south and 600ft deep, denoting 2 levels of occupation: Woodland and Middle Mississippian (Moore, 1915). Three cemeteries were uncovered on the outskirts of the village, though only two are relevant to this study as Middle Mississippian. A total of 183 burials were recovered with nearly all individuals placed in an extended position facing the southwest (Kuemin-Drews, 2000); however, the site did contain several bundle burials, cremations, semi-flexed burials and two (Burials 38 and 85) rare stone box burials made of limestone (Kneberg, 1952). The lack of stone box burials in this site suggest that these individuals were afforded greater effort in death as there is a lack of suitable construction materials on the western bank of the Tennessee River with which to participate in the Middle Cumberland Cultural Complex. A total of 4 burial clusters and 19 multiple burials, both of which contain individuals of varying sexes and ages ranging from infancy to senility, represent individual kin groupings (Bass, 1985). According to Lidberg's field notes

(1939), the presence of infants in the cemetery is quite unusual for this region and particularly this site as 23 of the 27 recovered infant burials were located within or underneath habitation structures, a trait which is duplicated at the Gray and Williams sites nearby. This mortuary pattern postulates that an individual typically had to reach 2 years of age before they could earn a spot within the cemetery (Bass, 1985).

CHAPTER V

RESEARCH METHODS

Reactive alteration was identified and quantified on 250 individuals of the combined collection of 287 pre-Columbian Native American burials (N=854 vertebrae). Each individual was examined primarily for the presence and severity of zygapophyseal and body OPL, zygapophyseal OA, IVDD and OLF, with secondary analysis pertaining toward additional degenerative and morphological changes such as asymmetry, Baastrup's syndrome, traumatic injury and Schmorl's nodes. Individual burials were excluded which did not contain cervical vertebrae, were too fragmentary to provide qualitative information or consisted of juveniles under the age of 17-years-old. Human remains utilized in this research were previously sexed and aged using standard techniques (Brooks and Suchey, 1990; Haas et al., 1994; Iscan et al., 1984, 1985; Lovejoy et al., 1985; Milner, 1992; Phenice, 1969; Stewart, 1979; White and Folkens, 2005). Ages were approximated into three categories for comparative analysis: young adult (17-25); mature adult (25-50); and old adult (50+). Each osteological condition was confirmed and quantified using previous comparative research and placed on a grading scale of 0 to 3, with 0 demonstrating absolute absence of reactivity and 3 being the most extreme cases present in the collection (Boncal, 2013; Bridges, 1994; Brown et al., 2008; Hukuda et al., 2000; Roberts and Manchester, 2005). Scores were further coalesced into one of three biomechanical regions: the upper region (1st and 2nd cervical vertebrae), which is responsible for 60-80% of the axial rotation of the neck; the middle region (3rd and 4th cervical vertebrae), which represents the peak of the cervical lordosis; and the lower region (5th-7th cervical vertebrae), which bears the brunt of the impact of neck extension and flexion. Potential individuals were excluded from further analysis based upon level of fragmentation. During the course of this research, several variables emerged which may have affected the results of this study, creating a potential sampling bias: the subjective methods used to age individuals; the capabilities of the SAS statistical model; and the number of individuals per sample.

Results of the 167 individuals viable for spinal OPL analysis and the 103 individuals viable for OLF analysis were incorporated into a repeated measures mixed model analysis of variance (ANOVA) in the SAS statistical program based upon the following criteria: site; burial number; sex; and age (Quinn and Keough, 2002). This test assumes a random and independent sampling where the epsilons are distributed as ~N(0,σ), the effects of α_j, β_k and $(\alpha\beta)_{jk}$ are fixed constants and additive, the groups j = 1 to a represent a random sample of the groups from a larger population and the variances will be equal. As such, the null hypothesis state that all the α_j, β_k and $(\alpha\beta)_{jk}$ are 0, represented symbolically as $H_0\!: all\ \alpha_j = 0$, $H_0\!: all\ \beta_k = 0$ and $H_0\!: all\ (\alpha\beta)_{jk} = 0$. Conversely, the alternative hypotheses state that some α_j, β_k and $(\alpha\beta)_{jk}$ will not be 0, represented symbolically as $H_A\!: some\ \alpha_j \neq 0, H_A\!: some\ \beta_k \neq 0$ and $H_A\!: some\ (\alpha\beta)_{jk} \neq 0$. The proposed biological hypothesis asserts that the combination of geographic region, age and sex, as well as their individual elements, will affect the quantity and severity of the degenerative spinal changes derived from the physical activity of the different subsistence economies. Categories with significant *p values* in the Type 3 Tests of Fixed

Effects, and Tests of Effect Slices, were further analyzed through pairwise comparisons of the least squares means, designed to compensate for the unbalanced nature of the data, in order to narrow down the locations of differentiation and corrected using a Bonferroni adjustment to lessen the chance of making a Type I error and wrongly rejecting the null hypothesis (Quinn and Keough, 2002).

Criteria for Spinal Degenerative Lesions (Vertebral and Apophyseal OPL, OA and IVDD)

Apophyseal and marginal osteophytosis, also known as osteophytic lipping, is an inherent condition of degeneration, recorded clinically as the most common form of spinal disease found radiographically and in autopsy (Bullough and Boachie-Adjei, 1988). As such, it must be treated cautiously when utilized in bioarchaeology, lest one mistake aging for pathology. While examining the skeletal material special attention was directed toward the evidence of osteophytosis and osteoarthrosis on the zygapophyseal facets and asymmetrical alignment of the cervical vertebrae as a whole. According to Kotsenas (2012), zygapophyseal facets are "true synovial hyaline diarthrodial joints" located on the superior and inferior portions of the vertebrae, posterior to the vertebral body on either side of the vertebral foramen and degeneration of this facet can begin around twenty years of age. Osteoarthrosis is the most common of joint pathologies and occurs due to aging and excessive wear of the joint (Jurmain and Kilgore, 1995). This disease occurs in synovial joints when the cartilage wears down causing the bones to be over stressed and rub against each other (Burt et al., 2013; Rogers and Waldron, 1995). Diagnosing osteoarthrosis on the bone includes eburnation, pitting on the joint surface, osteophytes, remodeling and boney growth around joints (Burt et al., 2013; Waldron and

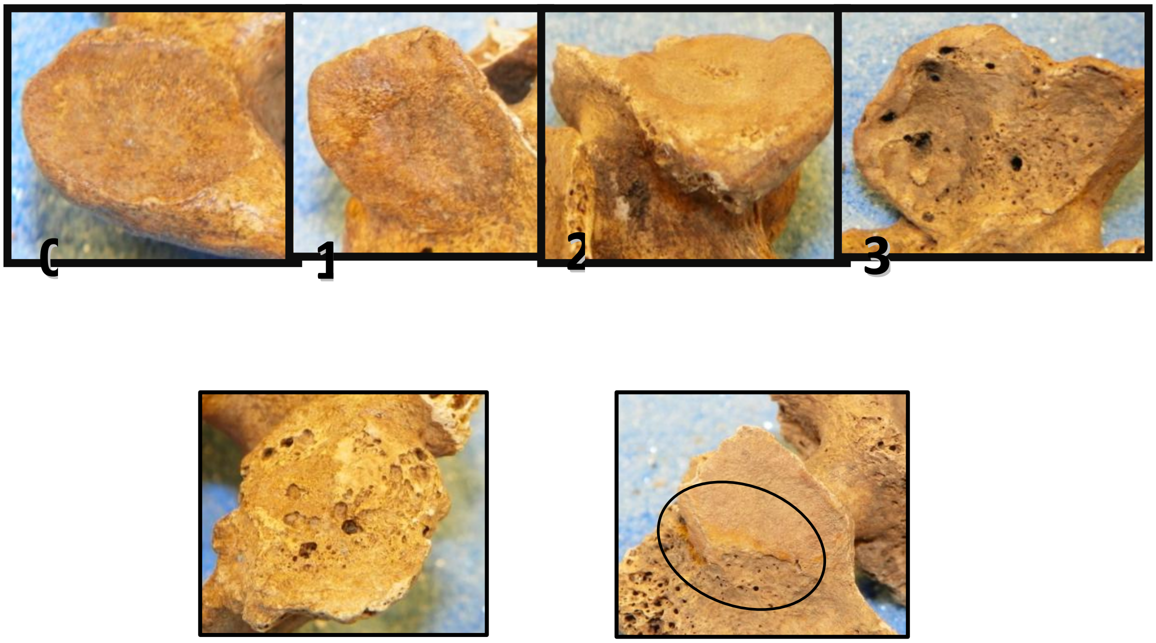

Figure 5. Grading Scale of Apophyseal OPL (upper) & Examples of OA (left) & Eburnation (right)

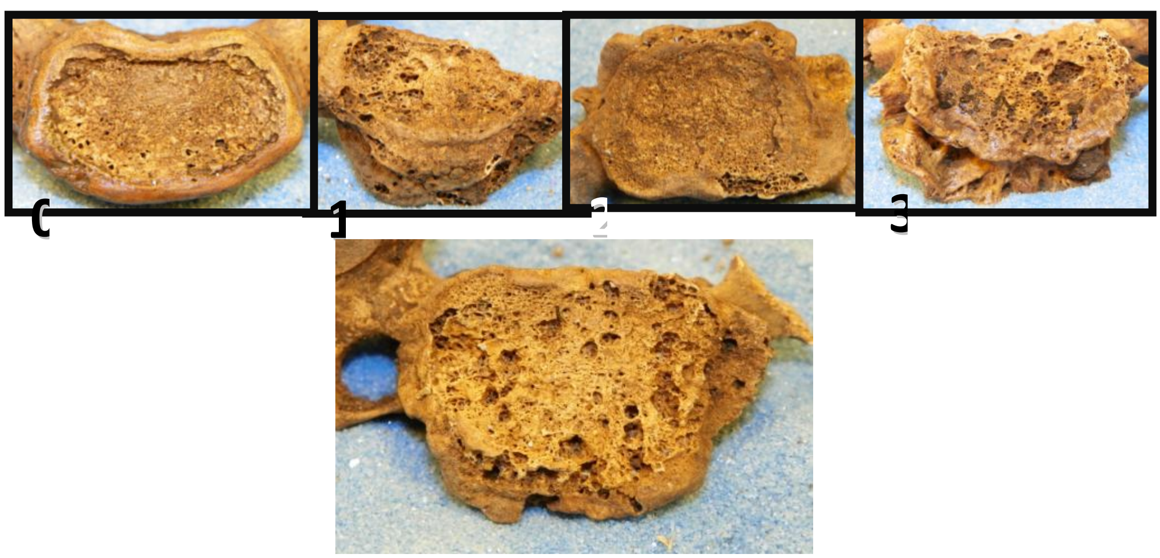

Figure 6. Grading Scale for Body OPL (above) & Example of IVDD (below)

Rogers, 1991). Eburnation occurs when the cartilage is destroyed and continued use of the joint causes bone on bone rubbing resulting on a shiny surface (Burt et al., 2013; Roberts and Manchester, 2005). Eburnation was scored as a presence-absence on the vertebrae that were found to have osteoarthrosis (there were no vertebrae that had evidence of eburnation that did not have osteoarthrosis); if there was evidence of eburnation on the facet it was marked as present, if there was no evidence of eburnation it was marked as absent. Individuals demonstrating levels 2 and 3 of OPL/OA severity, shown in Figure 5, were photographed for further analysis.

According to Roberts and Manchester (2005), vertebral osteophytosis is the result of damage to the annulus fibrosus of the intervertebral discs or the synovial joints of the zygapophyseal facets, displacing the disc anteriorly. This displacement places stress on the anchoring Sharpey's fibers which anchor the disc to the vertebral body margin, initiating the growth of osteophytes (Burt et al., 2013; Ortner, 2003). Osteophytes are growths of bone which diagnostically materialize on the margins of the vertebral body and/or the rims of the zygapophyseal facets; however, there are instances where osteophytic production transpires as a biological reaction to traumatic injury (Burt et al., 2013). In extreme cases of osteophytosis, the osteophytic growth can actually fuse adjoining vertebrae together (Roberts and Manchester, 2005). Consequently, the scale of grading employed in this study assessed the degree in which the osteophytic growth appeared on the vertebrae with a level of 0 possessing no apparent osteophytes and a level of 3 displaying subchondral destruction and/or rampant overgrowth that extends beyond the sphere of the vertebral body. Individuals demonstrating levels 2 and 3 of severity, shown in Figure 6, were photographed for further analysis.

Due to the similar processes which degrade both joints within the spine, intervertebral disc disease (IVDD) frequently presents with characteristics analogous to that of osteoarthrosis. Restricted to the superior and inferior surfaces of the vertebral body only, said characteristics include but are not limited to pitting on the joint surface, osteophytes, remodeling and boney growth around the joints. Since the intervertebral joints and their corresponding discs are fibrocartilaginous in nature and not subject to the same range of motion as synovial joints, eburnation is relatively rare, though exhibited in the samples utilized in this study. Individuals demonstrating levels 2 and 3 of OA severity, shown in Figure 6, were photographed for further analysis.

Criteria for Ossification of the Ligamentum Flavum

Though infrequent in the cervical spine (Kruse et al., 2000), ossification of the ligamentum flavum is a pathological condition that is typically encountered in adults age 40-60 of East Asian populations (Fotakopoulos et al., 2010; Inamasu et al., 2006) . Though the exact pathogenesis and significance of the role of hypertrophy is still unclear, OLF appears to be derived most commonly from mechanical stress, growth factors and trauma, resulting in neurological symptoms such as occipital headaches, neck pain, upper and lower extremities, gait disturbances, restriction of cervical movements and tetrapanesis (Fotakopoulos et al., 2010; Tatsuhito et al., 2000). Characteristically, OLF are defined as "well-defined ridge, from which thin spicules or plaques often extend upward" in order to ascertain a level of grading (Hukuda et al., 2000). Consequently, the scale of grading employed in this study (shown in Figure 7) assessed the degree in which the ossification appeared on the vertebral laminae with a level of 0 exhibiting absolutely no sign of degenerative alterations while level 3 exhibits the highest level of modification

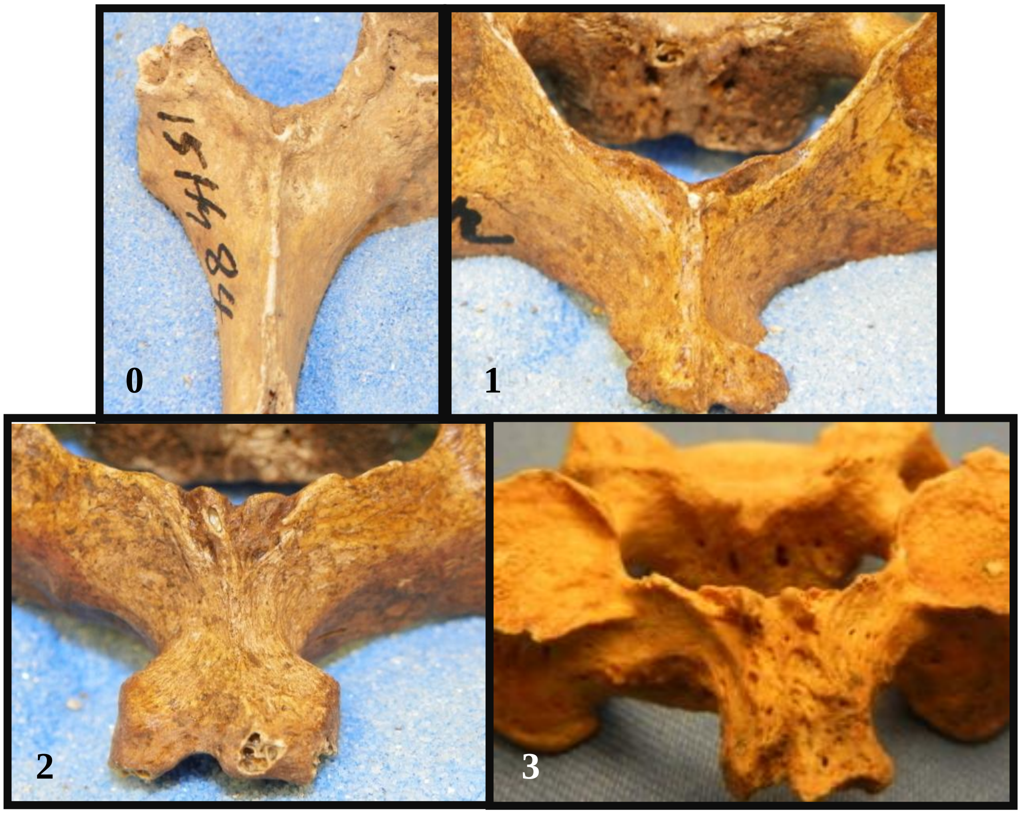

Figure 7. Grading Scale for OLF

Figure 8. Examples of Baastrup's Syndrome (left) and Deviated Spinous Process (right)

present among the entire cervical vertebrae collection. Individuals demonstrating levels 2 and 3 of severity were photographed for further analysis.

Criteria for Additional Morphological Alterations

Asymmetry occurs when differential pressure is placed on one side of the neck, forcing compression and increased degenerative changes of the diarthrodial joints in a consistent pattern on that corresponding side of the cervical vertebrae (Burt et al., 2013). As this characteristic is potentially indicative of repetitive behavior and/or biomechanical stress, analysis may elucidate on differential burden-bearing activities within the region. Presence and absence were recorded and photographed for the resulting anatomical side and the range of the affected vertebrae.

Baastrup's syndrome is a condition characterized by a posterior flattening of the spinous process due to repetitive extensive pressure. This pressure forces the neck into hyperextension, creating a pressure facet (otherwise known as a "kissing facet") as a result of the constant contact (EB Medicine, nd). Presence and absence were recorded and photographed for each individual, shown in Figure 8, as well as the location and range of the condition along the cervical spine.

Traumatic injuries are potentially suggestive of certain biomechanical stresses and repetitive physical activities depending on the location and severity of the injury. These injuries are frequently accompanied by rampant secondary osteological reactivity, such as osteoarthrosis and osteophytosis (Burt et al., 2013). Presence and absence were recorded and photographed for traumatic injuries, such as Porter's neck which results from extensive hyperflexion that forces the alar ligaments to shear the odontoid process from the body of the second cervical vertebra, as well as the location and resultant osteological reactivity (Waldron, 2009). Another common, though as yet under-studied, condition and/or injury is the deviation of the spinous process, shown in Figure 8. Though the specific etiology is currently unknown, it is theorized that a deviation of the spinous process may be indicative of a displacement or improper placement and weight distribution of heavy loads on the back during burden bearing. Depending on the condition of the bone and the resultant remodeling, this injury may have developed during adolescence through repetitive physical activities or more recently due to extreme biomechanical stress.

Schmorl's nodes occur as the result of a rupture of the nucleus pulposus within the annulus fibrosis of the intervertebral disc (Burt et al., 2013). Release of fluid from within the nucleus pulposus causes a necrotic interaction with the surrounding bone tissue, creating depressions in the vertebral body surface (Ortner, 2003). Such ruptures are thought to be a consequence of heavy neck-loading and back-loading, signifying extensive biomechanical stress placed on the spine of archaeological populations (Burt et al., 2013; Lai and Lovell, 1992; Üstündağ, 2009). Schmorl's nodes typically target the middle and lower thoracic and lumbar vertebrae where the cartilaginous endplate is weakest and the former notochord has resorbed (Burt et al., 2013; Waldron 2009). Though previous studies quantify the size of the Schmorl's node (Andrews, 2012), the condition is recorded and subsequently photographed strictly on presence, absence and location due to the relative paucity of the condition within the cervical spine.

CHAPTER VI

RESULTS

Cherry Site (40BN74)

Spinal degenerative lesions (OPL, OA and IVDD). A total of 25 individuals out of a sample of 69 were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 1. Examination of the apophyseal facets, consisting of 12 males and 13 females, demonstrated several cases of level 3 severity with osteoarthritic tendencies, though only 2 sets of remains contained evidence of eburnation. Investigation of the OPL of the vertebral body yielded 23 burials possible for further statistical analysis, consisting of 12 males and 11 females. 10 of the 23 individuals further presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, indicative of intervertebral disc disease (IVDD).

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 2-3. For this of Fixed Effects, testing differences between the means for both apophyseal and vertebral OPL were part of the ANOVA and are shown in Tables 2 and 3 respectively. The non- significant p value *0.8833* for the Type 3 Test of Fixed Effects of the apophyseal OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 9. According to the results, the only main effect that was significant was the

Table 1. Summary and Frequency/Prevalence of the Cherry site

Cherry site						
	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**35 (51%)**	**69**
29= Apop OPL/OA Overall					**83%**	**42%**
25 = stat viable:					71%	36%
Male	2 (8%)	8 (32%)	0	2 (8%)	12 (48%)	
Female	6 (24%)	4 (16%)	0	3 (12%)	13 (52%)	
Unknown	0	0	0	0	0	
Eburnation	2					
28 = Body OPL Overall					**80%**	**41%**
23 = stat viable:					66%	33.00%
Male	2 (8.7%)	8 (34.8%)	0	2 (8.7%)	12	
Female	5 (21.7%)	3 (13%)	0	3 (13%)	11	
Unknown	0	0	0	0	0	
8 = IVDD:					23%	11.00%
Male	0	4 (50%)	0	0	4	
Female	1 (12.5%)	1 (12.5%)	0	2 (25%)	4	
Unknown	0	0	0	0		
Eburnation	0					
Vert range	C3-C7					
25 = OLF Overall					**71%**	**36%**
21 = stat viable:					60%	30%
Male	2 (9.5%)	6 (28.6%)	0	2 *8.7%)	10	
Female	4 (19%)	4 (19%)	0	3 (14.3%)	11	
Unknown	0	0	0	0	0	
Vert range	C3, C5-C7					

Table 2. ANOVA Apophyseal OPL/OA Results for the Cherry site

Apop OPL/OA Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	19	3.73	0.0429
sex	1	19	0.04	0.8420
age	2	19	0.13	0.8829
region*sex	2	19	0.22	0.8077
region*age	4	19	0.50	0.7373
sex*age	2	19	0.15	0.8645
region*sex*age	4	19	0.29	0.8833

Apop OPL/OA Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	19	0.31	0.9019
region*sex*age	**MIDDLE**			5	19	0.10	0.9899
region*sex*age	**UPPER**			5	19	0.29	0.9150
region*sex*age		**F**	**?**	2	19	1.87	0.1820
region*sex*age		**F**	**MA**	2	19	1.16	0.3358
region*sex*age		**F**	**Y**	2	19	1.64	0.2194
region*sex*age		**M**	**?**	2	19	0.37	0.6949
region*sex*age		**M**	**MA**	2	19	3.39	0.0550
region*sex*age		**M**	**Y**	2	19	0.02	0.9833

Table 3. ANOVA Vertebral Body OPL Results for the Cherry site.

Vert Body OPL Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	17	0.44	0.6531
sex	1	17	1.26	0.2768
age	2	17	0.14	0.8724
region*sex	2	17	1.14	0.3417
region*age	4	17	1.20	0.3487
sex*age	2	17	0.71	0.5052
region*sex*age	4	17	0.97	0.4485

Vert Body OPL Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	17	0.74	0.6020
region*sex*age	**MIDDLE**			5	17	0.69	0.6387
region*sex*age	**UPPER**			5	17	0.68	0.6439
region*sex*age		**F**	**?**	2	17	0.97	0.3980
region*sex*age		**F**	**MA**	2	17	1.91	0.1792
region*sex*age		**F**	**Y**	2	17	0.31	0.7358
region*sex*age		**M**	**?**	2	17	0.05	0.9547
region*sex*age		**M**	**MA**	2	17	1.49	0.2531
region*sex*age		**M**	**Y**	2	17	1.59	0.2318

region (*p value 0.0429*). Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, also produced similarly non-significant results which failed to reject the null hypothesis that the means are 0. However, the test did yield a three-way interaction for mature males which was approaching significance (*p value 0.055*) but was excluded because the overall main effects are non-significant.

The non-significant p value *0.4485* for the Type 3 Test of Fixed Effects of the vertebral OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 10. According to the results, none of the main effects produced significance. Tests of the Effect Slices also produced similarly non-significant results which failed to reject the null hypothesis that the means are 0.

OLF. A total of 23 individuals were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 1. Examination of the laminae of the neural arch, consisting of 10 males and 11 females, demonstrated several cases of level 3 severity. All instances of higher severity were isolated to either the 3^{rd} cervical vertebra alone or ranged between the 5^{th}-7^{th} cervical vertebrae in the lower biomechanical region.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 4. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. Type 3 Test of Fixed Effects, testing differences between the means were part of the ANOVA and are shown in Tables 6 and 7 respectively. The non-significant p value *0.6427* for the Type 3 Test of

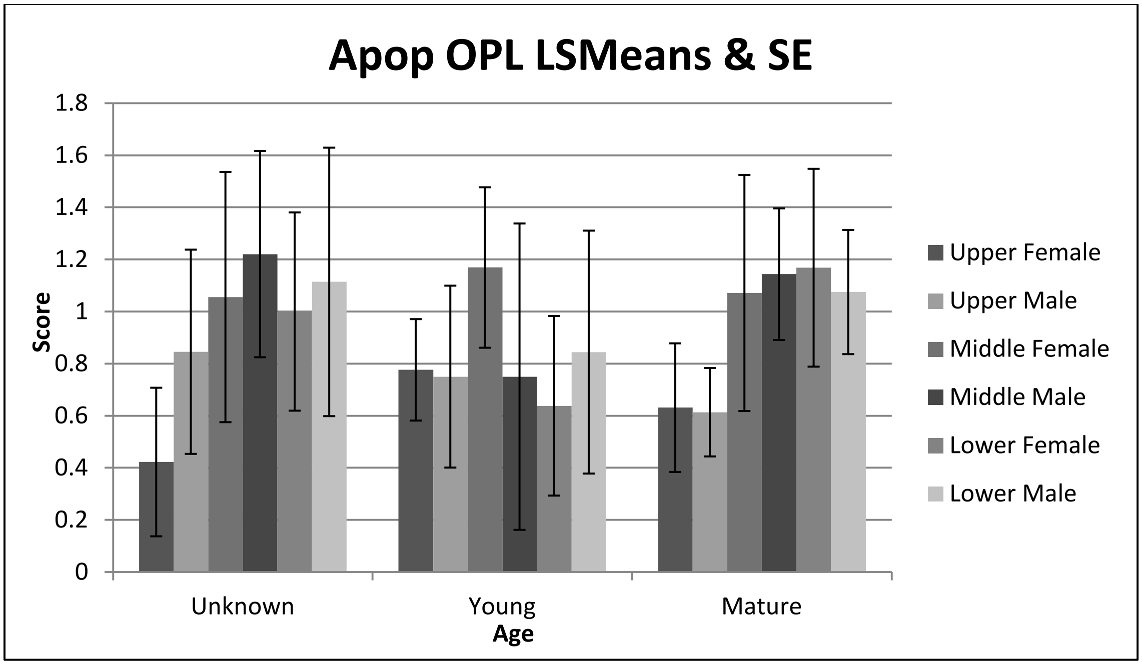

Figure 9. Cherry Apophyseal OPL LSMeans and SE

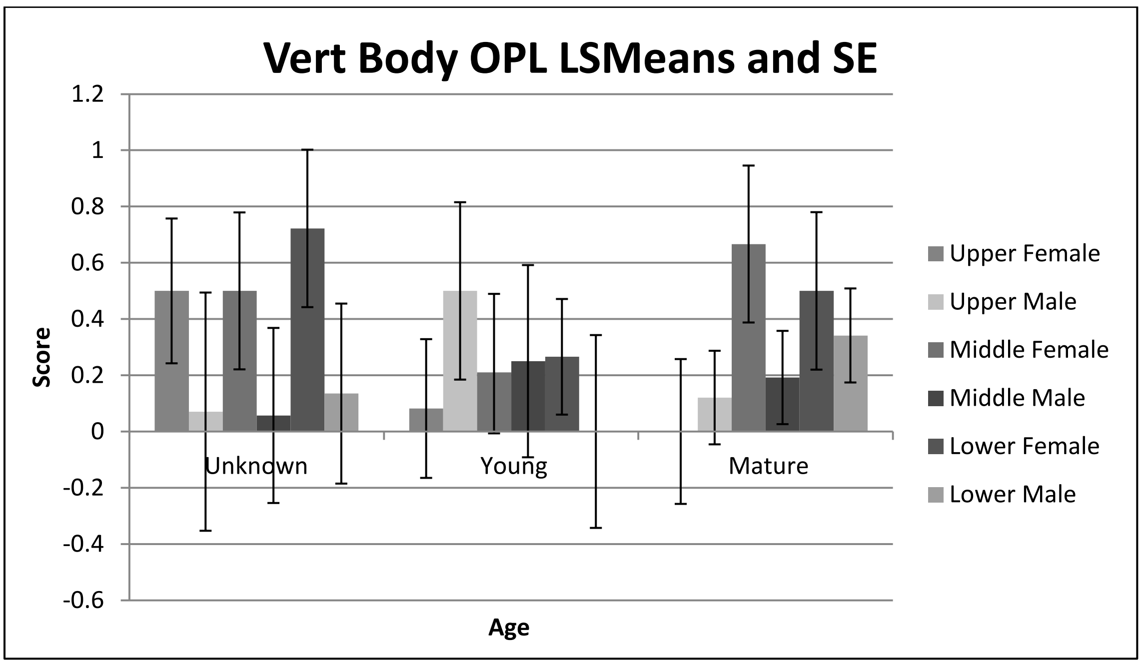

Figure 10. Cherry Vertebral Body OPL LSMeans and SE

Fixed Effects fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 110. According to the results, the only main effect that was significant was the region (*p value 0.0102*). Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded significant results for the three-way interaction for mature males (*p value 0.0152*), indicating a rejection of the null hypothesis that the means are 0. Additionally, the test did yield a three-way interaction for mature females which was approaching significance (*p value 0.0524*) but was excluded.

Additional morphological alterations. The Cherry site presented with a total of 6 cases which demonstrated some sort of alteration of bilateral asymmetry, consisting of 3 left side and 3 to the right side. Also, there were a total of 4 instances of Baastrup's syndrome present within the sample population, consisting of 3 mature males and 1 mature female. However, 1 individual showed evidence of a complete fracture of the odontoid process, indicative of Porter's neck. Finally, 2 individuals within the Cherry sample yielded deviated spinous processes in the 7^{th} cervical vertebrae, both of which deviated in a leftward direction.

Eva Site (6BN12)

Spinal degenerative lesions (OPL, OA and IVDD). A total of 26 individuals out of a sample of 59 were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 5. Examination of the apophyseal facets, consisting of 11 males and 15 females, demonstrated several cases of level 3 severity with osteoarthritic tendencies, though only 2 sets of remains contained evidence of

Table 4. ANOVA OLF Results for the Cherry site

OLF Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	15	6.32	0.0102
sex	1	15	0.01	0.9098
age	2	15	2.24	0.1406
region*sex	2	15	0.72	0.5021
region*age	4	15	0.76	0.5667
sex*age	2	15	1.48	0.2598
region*sex*age	3	15	0.57	0.6427

OLF Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	15	0.90	0.5040
region*sex*age	**MIDDLE**			4	15	1.52	0.2465
region*sex*age	**UPPER**			5	15	1.38	0.2877
region*sex*age		**F**	**?**	2	15	2.26	0.1386
region*sex*age		**F**	**MA**	2	15	3.61	0.0524
region*sex*age		**F**	**Y**	1	15	1.48	0.2422
region*sex*age		**M**	**?**	2	15	1.06	0.3705
region*sex*age		**M**	**MA**	2	15	5.60	0.0152
region*sex*age		**M**	**Y**	2	15	0.79	0.4709

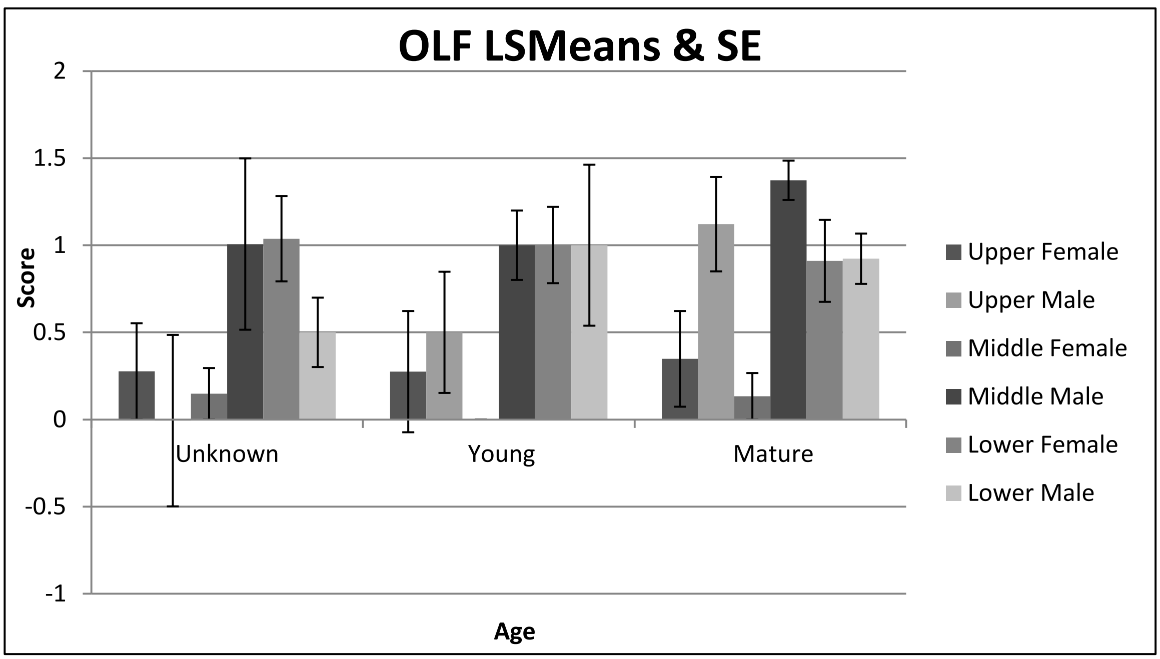

Figure 11. Cherry OLF LSMeans and SE

eburnation. Investigation of the OPL of the vertebral body yielded 25 burials possible for further statistical analysis, consisting of 11 males and 14 females. 14 of the 25 individuals further presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, indicative of intervertebral disc disease (IVDD). Two additional cases presented with IVDD that possessed no confirmed age or sex and therefore were not included in the statistical analyses but were factored in here for overall prevalence. Of the 16 total OA cases, each instance ranged between the 2^{nd} and 7^{th} vertebrae and only 1 case was identified with eburnation.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 6-7. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. Type 3 Test of Fixed Effects, testing differences between the means for both apophyseal and vertebral OPL were part of the ANOVA and are shown in Tables 6 and 7 respectively. The non-significant p value *0.0769* for the Type 3 Test of Fixed Effects of the apophyseal OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 12. According to the results, the only main effect that was significant was the region (*p value 0.0014*). Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded significant results for the three-way interaction for mature males (*p value 0.0010*). Additionally, the test produced a three-way interaction for females of an unknown age which was approaching significance (*p value 0.0516*) but was excluded because the overall main effects are non-significant.

Table 5. Summary and Frequency/Prevalence of the Eva site

Eva site	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**30 (51%)**	**59**
30 = Apop OPL/OA Overall					**100%**	**51%**
26 = stat viable:					87%	44%
Male	4 (15.4%)	4 (15.4%)	0	3 (11.5%)	11	
Female	2 (7.7%)	9 (34.6%)	0	4 (15.4%)	15	
Unknown	0	0	0	0	0	
Eburnation	2					
28 = Body OPL Overall					**83%**	**47%**
25 = stat viable:					83.00%	42%
Male	4 (16%)	4 (16%)	0	3 (12%)	11	
Female	2 (8%)	9 (36%)	0	3 (12%)	14	
Unknown	0	0	0	0	0	
14 = IVDD:					47%	24%
Male	1 (7.1%)	3 (21.4%)	0	2 (14.3%)	6	
Female	0	5 (35.8%)	0	1 (7.1%)	6	
Unknown	0	0	0	2 (14.3%)	2	
Eburnation	0					
Vert range	C3-C7					
24 = OLF Overall					**80%**	**41%**
22 = stat viable:					73%	37%
Male	4 (18.2%)	3 (13.6%)	0	2 (9.1%)	9	
Female	2 (9.1%)	7 (31.8%)	0	4 (18.2%)	13	
Unknown	0	0	0	0		
Vert range	C3, C5-C7					

Table 6. ANOVA Apophyseal OPL/OA Results for the Eva site

Apop OPL/OA Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	20	9.32	0.0014
sex	1	20	0.02	0.8857
age	2	20	2.25	0.1316
region*sex	2	20	0.37	0.6965
region*age	4	20	1.39	0.2730
sex*age	2	20	0.87	0.4335
region*sex*age	4	20	2.48	0.0769

Apop OPL/OA Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	20	1.49	0.2375
region*sex*age	**MIDDLE**			5	20	1.91	0.1369
region*sex*age	**UPPER**			5	20	0.83	0.5461
region*sex*age		**F**	**?**	2	20	3.45	0.0516
region*sex*age		**F**	**MA**	2	20	1.29	0.2975
region*sex*age		**F**	**Y**	2	20	0.68	0.5165
region*sex*age		**M**	**?**	2	20	2.61	0.0984
region*sex*age		**M**	**MA**	2	20	9.95	0.0010
region*sex*age		**M**	**Y**	2	20	0.00	0.9988

Table 7. ANOVA Vertebral Body OPL Results for the Eva site

Vert Body OPL Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	19	1.71	0.2072
sex	1	19	0.61	0.4438
age	2	19	0.88	0.4316
region*sex	2	19	0.19	0.8295
region*age	4	19	0.40	0.8035
sex*age	2	19	0.14	0.8664
region*sex*age	4	19	0.55	0.7019

Vert Body OPL Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	19	0.88	0.5162
region*sex*age	**MIDDLE**			5	19	0.32	0.8976
region*sex*age	**UPPER**			5	19	0.48	0.7849
region*sex*age		**F**	**?**	2	19	0.86	0.4395
region*sex*age		**F**	**MA**	2	19	0.97	0.3968
region*sex*age		**F**	**Y**	2	19	0.04	0.9580
region*sex*age		**M**	**?**	2	19	0.14	0.8672
region*sex*age		**M**	**MA**	2	19	1.48	0.2526
region*sex*age		**M**	**Y**	2	19	0.98	0.3943

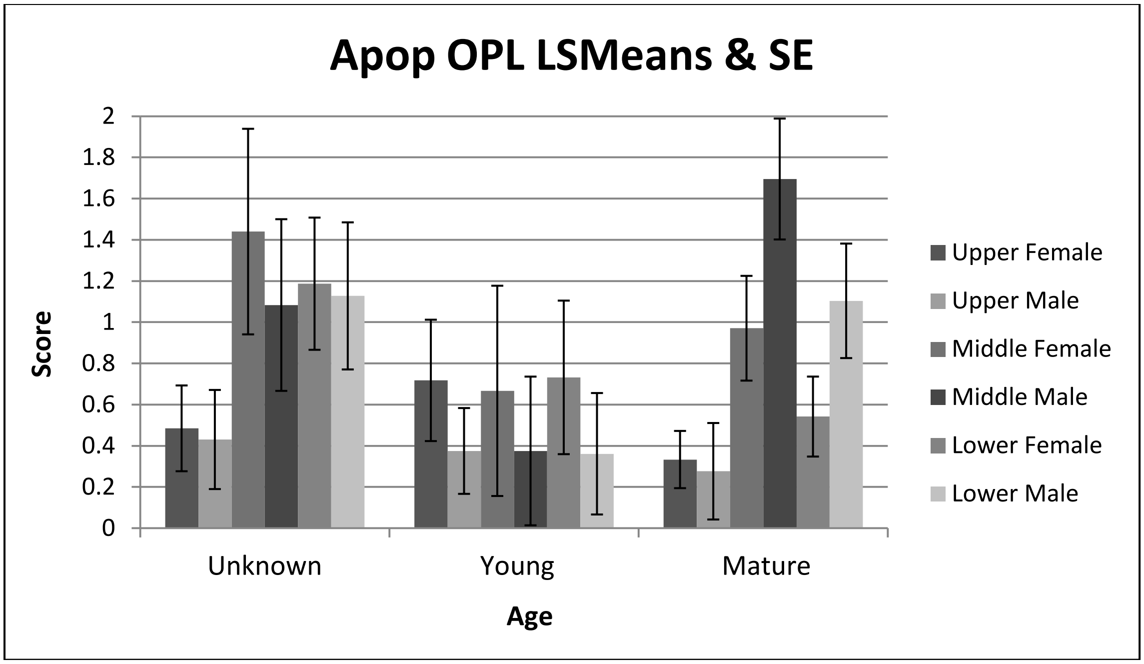

Figure 12. Eva Apophyseal OPL LSMeans and SE

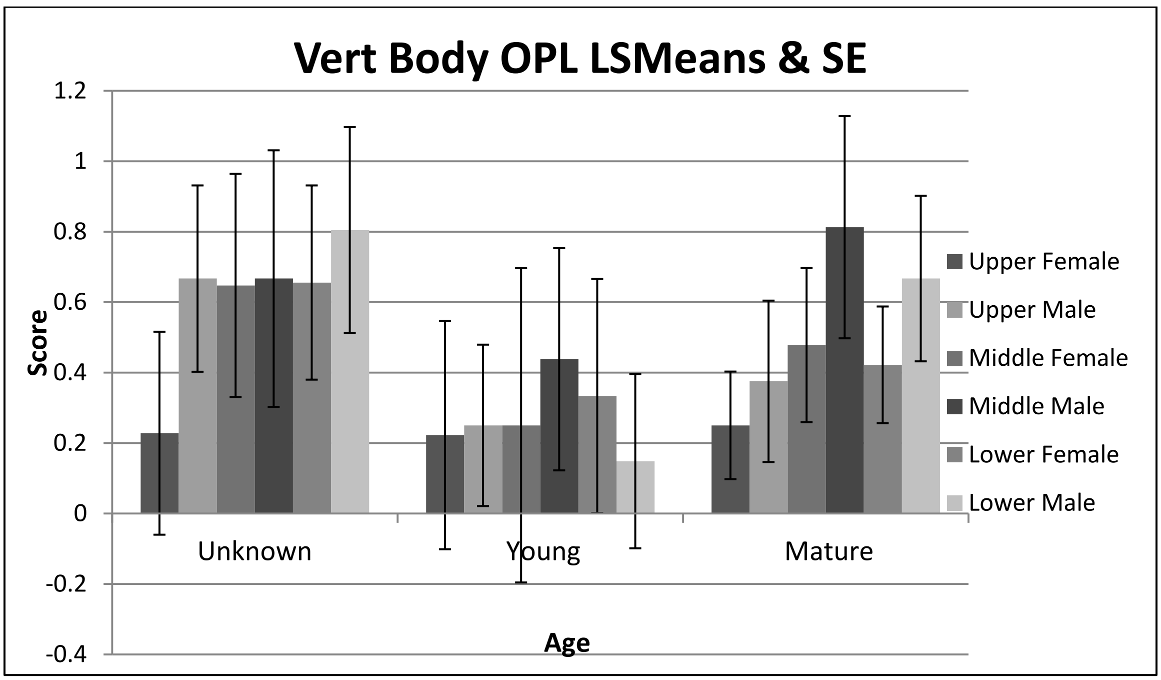

Figure 13. Eva Vertebral Body OPL LSMeans and SE

The non-significant p value *0.7019* for the Type 3 Test of Fixed Effects of the vertebral OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 13. According to the results, none of the main effects produced significance. Tests of the Effect Slices also produced similarly non-significant results which failed to reject the null hypothesis that the means are 0.

OLF. A total of 22 individuals were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 5. Examination of the laminae of the neural arch, consisting of 9 males and 13 females, demonstrated several cases of level 3 severity. All instances of higher severity were isolated to a range between the 2nd and 3rd and the 5th and 6th cervical vertebrae. OLF was unable to be analyzed statistically due to infinite likelihood.

Additional morphological alterations. The Eva site presented with no cases which demonstrated some sort of alteration of bilateral asymmetry. In contrast, there were a total of 4 instances of Baastrup's syndrome present within the sample population, consisting of 2 mature males and 2 mature females. However, no individuals showed evidence of a shorn odontoid process, indicative of Porter's neck. Finally, 3 individuals within the Eva sample yielded deviated spinous processes in the 7th cervical vertebrae, both of which deviated in a right direction.

Kays Landing Site (40HY13)

Spinal degenerative lesions (OPL, OA and IVDD). A total of 34 individuals out of a sample of 64 were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 8. Examination of the apophyseal facets,

Table 8. Summary and Frequency/Prevalence of the Kays Landing site

Kays Landing site	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**39 (61%)**	**64**
38 = Apop OPL/OA Overall					**97%**	**59%**
34 = stat viable:					87%	53%
Male	0	12 (35.7%)	3 (8.8%)	1 (2.9%)	16	
Female	7 (20.6%)	10 (29.4%)	0	1 (2.9%)	18	
Unknown	0	0	0	0	0	
Eburnation	2					
35 = Body OPL Overall					**90%**	**55%**
27 = stat viable:					69%	42%
Male	0	10 (35.7%)	1 (3.7%)	0	11	
Female	5 (18.5%)	10 (35.7%)	0	1 (3.7%)	16	
Unknown	0	0	0	0	0	
14 = IVDD:					36%	22%
Male	2 (14.3%)	5 (35.7%)	1 (7.1%)	0	8	
Female	1 (7.1%)	5 (35.7%)	0	0	6	
Unknown	0	0	0	0	0	
Eburnation	1					
Vert range	C4-C7					
29 = OLF Overall					**74%**	**45%**
28 = stat viable:					72%	44%
Male	0	10 (35.7%)	2 (7.1%)	0	12	
Female	5 (17.9%)	11 (39.3%)	0	0	16	
Unknown	0	0	0	0	0	
Vert range	C2-C3, C5-C6					

consisting of 16 males and 18 females, demonstrated several cases of level 3 severity with osteoarthritic tendencies, though only 2 sets of remains contained evidence of eburnation. Investigation of the OPL of the vertebral body yielded 27 burials possible for further statistical analysis, consisting of 11 males and 16 females. 17 of the 27 individuals further presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, indicative of intervertebral disc disease (IVDD); however, several cases presented with IVDD that possessed no confirmed age or sex and therefore were not included in the statistical analyses but were factored in here for overall prevalence. Each instance was isolated to between the 4^{th}-7^{th} cervical vertebrae, though only 1 case was identified with eburnation.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 9-10. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. Type 3 Test of Fixed Effects, testing differences between the means for both apophyseal and vertebral OPL were part of the ANOVA and are shown in Tables 9 and 10 respectively. The non-significant p value *0.4035* for the Type 3 Test of Fixed Effects of the apophyseal OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 14. According to the results, there were no significant effects. Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded significant results for the three-way interaction for the Lower cervical region (*p value 0.0286*), indicating a rejection of the null hypothesis that the means are 0.

Table 9. ANOVA Apophyseal OPL/OA Results for the Kays Landing site

Apop OPL/OA Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	27	0.30	0.7418
sex	1	27	0.12	0.7272
age	3	27	0.55	0.6537
region*sex	2	27	0.09	0.9187
region*age	4	27	0.67	0.6198
sex*age	2	27	0.88	0.4271
region*sex*age	1	27	0.72	0.4035

Apop OPL/OA Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			5	27	2.98	0.0286
region*sex*age	**MIDDLE**			2	27	1.16	0.3276
region*sex*age	**UPPER**			6	27	0.53	0.7771
region*sex*age		**F**	**?**	1	27	0.89	0.3535
region*sex*age		**F**	**MA**	2	27	1.44	0.2538
region*sex*age		**F**	**Y**	2	27	0.90	0.4195
region*sex*age		**M**	**?**	0	.	.	.
region*sex*age		**M**	**MA**	2	27	2.09	0.1433
region*sex*age		**M**	**O**	1	27	0.63	0.4355
region*sex*age		**M**	**Y**	1	27	0.00	1.0000

Table 10. ANOVA Vertebral Body OPL Results for the Kays Landing site

Vert Body OPL Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	22	3.47	0.0488
sex	1	22	0.46	0.5057
age	3	22	1.32	0.2937
region*sex	2	22	3.53	0.0469
region*age	5	22	0.19	0.9640
sex*age	0	.	.	.
region*sex*age	0	.	.	.

Vert Body OPL Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			4	22	0.86	0.5035
region*sex*age	**MIDDLE**			4	22	1.39	0.2697
region*sex*age	**UPPER**			3	22	0.99	0.4155
region*sex*age		**F**	**?**	1	22	0.00	1.0000
region*sex*age		**F**	**MA**	2	22	0.66	0.5281
region*sex*age		**F**	**Y**	2	22	0.78	0.4701
region*sex*age		**M**	**MA**	2	22	10.15	0.0008
region*sex*age		**M**	**O**	2	22	0.92	0.4132

The Type 3 Test of Fixed Effects of the vertebral OPL was unable to estimate a value for a three-way interaction, making it impossible to ascertain if the test fails to reject the null hypothesis that the means are 0. Therefore, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 15. According to the results, the only effects that were significant were the main effect of region (*p value 0.0488*) and the interaction effect of region*sex (*p value 0.0469*). Tests of the Effect Slices yielded significant results for the three-way interaction for mature males (*p value 0.0008*), indicating a rejection of the null hypothesis that the means are 0.

OLF. A total of 28 individuals were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 8. Examination of the laminae of the neural arch, consisting of 12 males and 16 females, demonstrated several cases of level 3 severity. All instances of higher severity were isolated to the 2^{nd} – 3^{rd} cervical vertebra and the 5^{th} – 6^{th} cervical vertebrae.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 11. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. The Type 3 Test of Fixed Effects of the vertebral OPL was unable to estimate a value for a three-way interaction, making it impossible to ascertain if the test fails to reject the null hypothesis that the means are 0. Therefore, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 16. According to the results, the only effects that were significant were the main effect of region (*p value <.0001*) and sex (*p value 0.0319*) and the interaction effect of region*age (*p value <.0001*). Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded

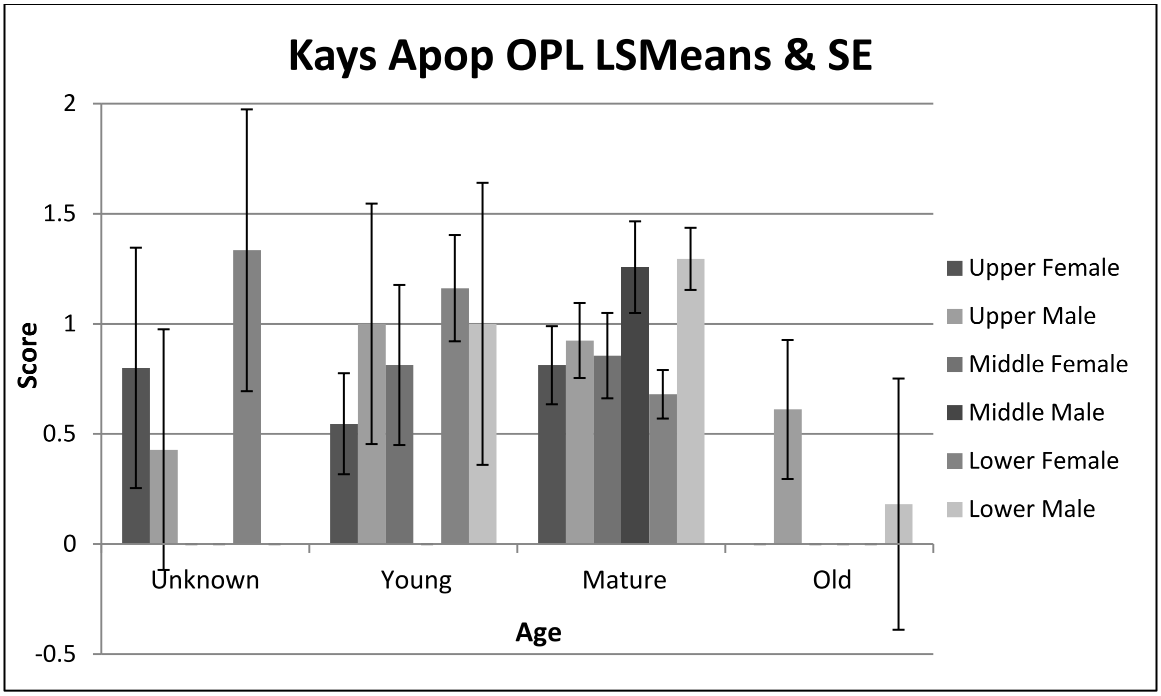

Figure 14. Kays Landing Apophyseal OPL LSMeans and SE

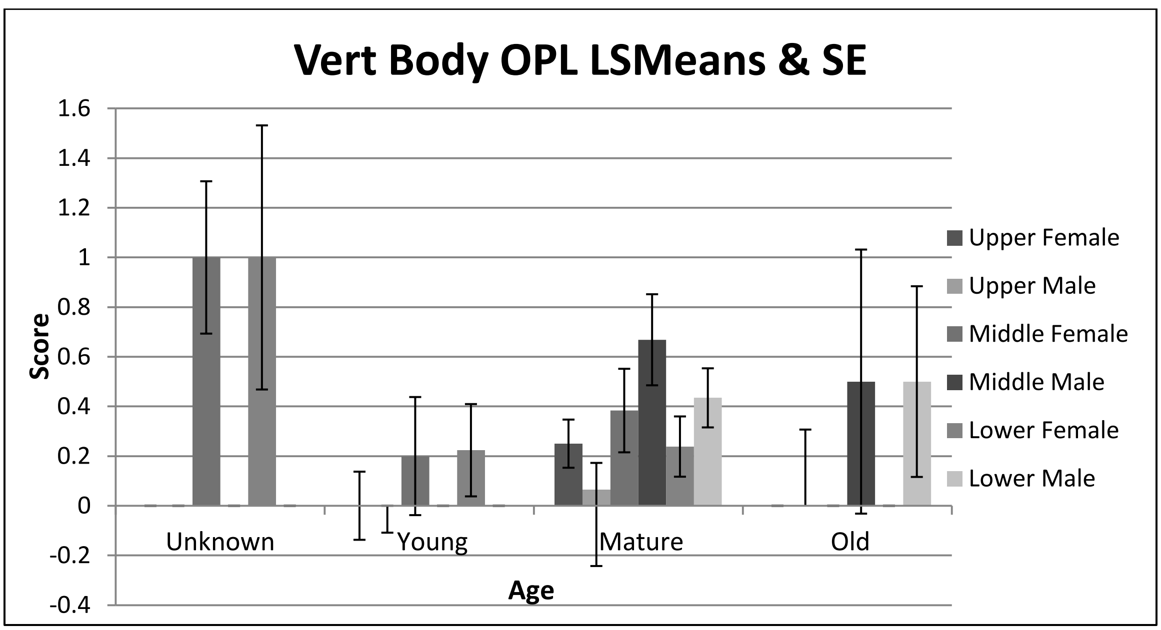

Figure 15. Kays Landing Vertebral Body OPL LSMeans and SE

Table 11. ANOVA OLF Results for the Kays Landing site

OLF Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	24	15.46	<.0001
sex	1	24	5.19	0.0319
age	2	24	2.76	0.0834
region*sex	2	24	1.27	0.2996
region*age	3	24	22.77	<.0001
sex*age	0	.	.	.
region*sex*age	0	.	.	.

OLF Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			2	24	2.30	0.1219
region*sex*age	**MIDDLE**			3	24	3.27	0.0385
region*sex*age	**UPPER**			3	24	9.13	0.0003
region*sex*age		**F**	**MA**	2	24	1.64	0.2144
region*sex*age		**F**	**Y**	2	24	46.43	<.0001
region*sex*age		**M**	**MA**	2	24	2.94	0.0719
region*sex*age		**M**	**O**	1	24	0.03	0.8638

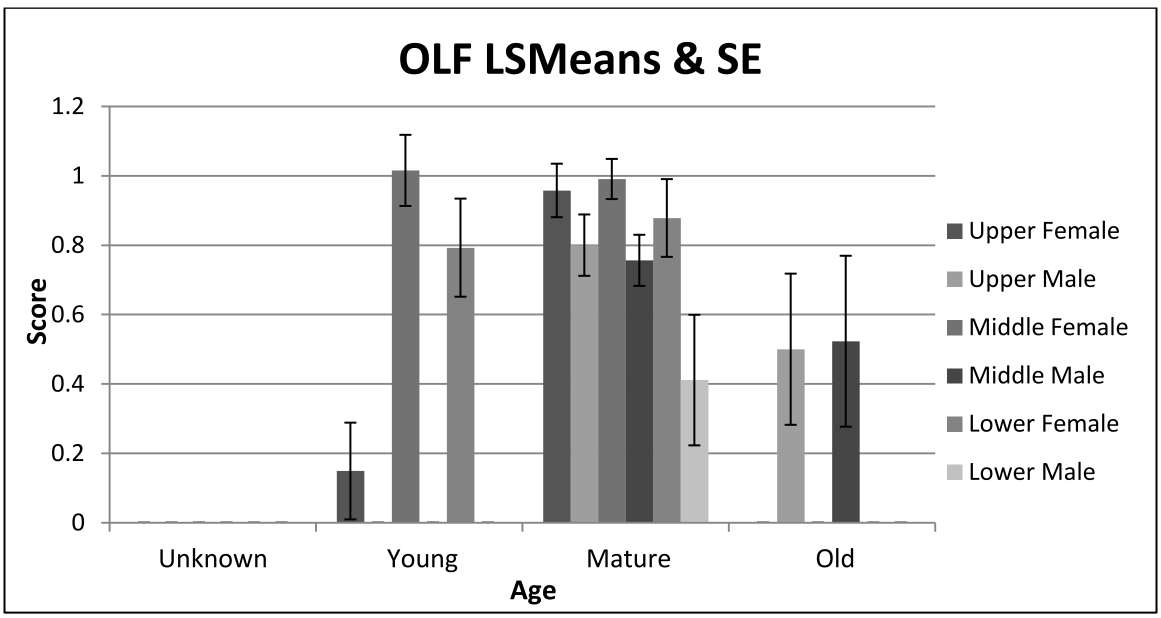

Figure 16. Kays Landing OLF LSMeans and SE

significant results for the three-way interaction for young females (*p value <.0001*), indicating a rejection of the null hypothesis that the means are 0. Additionally, the test did yield significant three-way interactions for the Upper (*p value 0.0003*) and Middle (*p value 0.0385*) biomechanical regions, indicating a rejection of the null hypothesis that the means are 0.

Additional morphological alterations. The Kays Landing site presented with no instances which demonstrated some sort of alteration of bilateral asymmetry. In contrast, there were absolutely no instances of Baastrup's syndrome present within the sample population. However, 2 individual showed evidence of a shorn odontoid process, indicative of Porter's neck. This condition results from the application of extensive pressures on the odontoid process and the upper biomechanical region of the neck with shears the process from the body of the 2nd cervical vertebrae, suggestive of a traumatic injury. Finally, no individuals within the Kays Landing sample yielded deviated spinous processes in the 7th cervical vertebrae.

Link Farm Site (19, 20 & 67HS6)

Due to the fragmentary nature of the remains from this site, the bioarchaeological material consisted of a sample population that was too small to analyze statistically with any certainty. Therefore, the only data collected at this time were frequency/prevalence rates. Each set of remains were further examined for additional morphological alterations.

Spinal degenerative lesions (OPL, OA and IVDD). A total of 15 individuals out of a sample of 31 potential adults were complete enough to age, sex and place the vertebrae with any certainty for analysis. Results for the frequency and/or prevalence are presented

Table 12. Summary and Frequency/Prevalence of the Link Farm site

Link Farm site	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**19 (61%)**	**31**
15 = Apop OPL/OA:					79%	48%
Male	1 (7.1%)	0	0	1 (2.9%)	2	
Female	2 (14.3%)	5 (35.7%)	0	1 (7.1%)	8	
Unknown	1 (7.1%)	0	0	4 (28.6%)	5	
Eburnation	2					
15 = Body OPL:					79%	48%
Male	0	0	0	1 (6.7%)	1	
Female	2 (13.3%)	5 (33.3%)	0	1 (6.7%)	8	
Unknown	1 (6.7%)	0	0	5 (33.3%)	6	
1 = IVDD:					5%	3%
Male	0	0	0	0	0	
Female	0	0	0	0	0	
Unknown	0	0	0	1 (100%)	1	
Eburnation	1					
Vert range	C4-C7					
13 = OLF:					68%	42%
Male	0	0	0	0	0	
Female	1 (7.7%%)	4 (30.8%)	0	3 (23.1%)	8	
Unknown	1 (7.7%%)	0	0	4 (30.8%)	5	
Vert range	C4-C7					

in Table 12. Examination of the apophyseal facets, consisting of 2 male and 8 females with 5 additional burials unable to be confidently assigned an age and/or sex range, demonstrated no cases of level 3 severity with osteoarthritic tendencies or evidence of eburnation. Investigation of the OPL of the vertebral body yielded 15 burials possible for further analysis, consisting of 1 male and 8 females with 6 additional burials unable to be confidently assigned an age and/or sex range. 1 of the 15 individuals further presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, isolated to between the 4^{th} – 7^{th} cervical vertebrae, which is indicative of intervertebral disc disease (IVDD).

OLF. A total of 13 individuals were feasible for further analysis. Results for the frequency and/or prevalence are presented in Table 12. Examination of the laminae of the neural arch, consisting of 8 females and 5 individuals unable to be assigned an age and/or sex with any confidence, demonstrated no cases of level 3 severity. All instances of OLF were isolated to the 4^{th} – 7^{th} cervical vertebrae.

Additional morphological alterations. Despite the fragmentary nature of the remains and an unidentified disease which results in hole formation within the bone tissue that hinders accurate observations and undoubtedly biasing the results, the Link Farm site produced some credible results. No cases presented with some sort of alteration of bilateral asymmetry, indicative of a consistent pattern of forced compression and increased degenerative change in the diarthrodial joints (i.e. zygapophyseal joints). Correspondingly, there were absolutely no instances of Baastrup's syndrome present within the sample population, suggesting a lack of forced hyperextension of the neck required to create a pressure facet. Similarly, no individuals showed evidence of a shorn odontoid process, indicative of Porter's neck. This condition results from the application of extensive pressures on the odontoid process and the upper biomechanical region of the neck with shears the process from the body of the 2nd cervical vertebrae, suggestive of a traumatic injury. In contrast, 1 individual within the Link Farm sample yielded deviated spinous processes in the 7th cervical vertebrae, both of which deviated in a leftward direction.

Slayden Site (2HS1)

Due to the fragmentary nature of the remains from this site, the bioarchaeological material consisted of a sample population that was too small to analyze statistically with any certainty. Therefore, the only data collected at this time were frequency/prevalence rates. Though the remains were examined for additional morphological alterations, no instances could be ascertained at this time.

Table 13. Summary and Frequency/Prevalence of the Slayden site

Slayden site	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**3**	**13**
3 = Apop OPL/OA:					100%	23%
Male	0	1 (33.3%)	0	0	1	
Female	1 (33.3%)	0	0	1 (33.3%)	2	
Unknown	0	0	0	0	0	
Eburnation	0					
3 = Body OPL:					100%	23%
Male	0	1 (33.3%)	0	0	1	
Female	1 (33.3%)	0	0	1 (33.3%)	2	
Unknown	0	0	0	0	0	
3 = OLF:					100%	23%
Male	0	1 (33.3%)	0	0	1	
Female	1 (33.3%)	0	0	1 (33.3%)	2	
Unknown	0	0	0	0		
Vert range	C2-C7					

Spinal degenerative lesions (OPL, OA and IVDD). A total of 3 individuals out of a sample of 13 potential adults were complete enough to age, sex and place the vertebrae with any certainty. Results for the analysis frequency and/or prevalence are presented in Table 13. Examination of the apophyseal facets, consisting of 2 male and 2 females, yielded evidence of OPL development on almost every individual with no instance of level 3 severity or osteoarthritic characteristics. Investigation of the OPL of the vertebral body yielded 3 burials possible for further statistical analysis, consisting again of 1 male and 2 females. No individuals presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, indicative of intervertebral disc disease (IVDD).

OLF. A total of 2 individuals were complete enough to age, sex and place the vertebrae with a certainty for analysis. Results for the frequency and/or prevalence are presented in Table 13. Examination of the laminae of the neural arch, consisting of 1 male and 1 female, demonstrated no case of level 3 severity. All instances of OLF ranged between the 2^{nd} – 7^{th} cervical vertebrae.

Thompson Village Site (7HY5)

Spinal degenerative lesions (OPL, OA and IVDD). A total of 57 individuals out of a sample of 71 were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 14. Examination of the apophyseal facets, consisting of 23 males and 34 females, demonstrated several cases of level 3 severity with osteoarthritic tendencies, though only 3 sets of remains contained evidence of eburnation. Investigation of the OPL of the vertebral body yielded 50 burials possible for further statistical analysis, consisting of 20 males and 30 females. 8 of the 50 individuals

Table 14. Summary and Frequency/Prevalence of the Thompson Village site

Thompson Village site	Young adult	Mature adult	Old adult	Unknown	Total w/ verts	Overall Total
Sample Adults					**71 (55%)**	**129**
70 = Apop OPL/OA Overall					**99%**	**54%**
57 = stat viable:					80%	44%
Male	2 (3.4%)	16 (28.1%)	0	5 (8.8%)	23	
Female	8 (14%)	16 (28.1%)	5 (8.8%)	5 (8.8%)	34	
Unknown	0	0	0	0	0	
Eburnation	3					
64 = Body OPL Overall					**90%**	**50%**
50 = stat viable:					70%	39%
Male	2 (4%)	13(26%)	0	5 (10%)	20	
Female	5 (10%)	15 (30%)	5 (10%)	5 (10%)	30	
Unknown	0	0	0	0	0	
7 = IVDD:						
Male	0	0	1 (14.3%)	0	1	
Female	0	1 (14.3%)	0	3 (42.9%)	4	
Unknown	0	0	0	2 (28.5%)	2	
Eburnation	0					
Vert range	C5-C7					
53 = OLF Overall					**75%**	**41%**
43 = stat viable:					61%	33.30%
Male	1 (2.4%)	13 (30.9%)	0	2 (8.7%)	17	
Female	5 (11.9%)	14 (33.4%)	5 (11.9%)	1 (2.4%)	25	
Unknown	0	0	0	0	0	
Vert range	C2-C4					

further presented with osteoarthritic characteristics on the superior and inferior surfaces of the vertebral body, indicative of intervertebral disc disease (IVDD). Two additional cases presented with body osteoarthrosis that possessed no confirmed age or sex and therefore were not included in the statistical analyses but were factored in here for overall prevalence. Of the 10 total OA cases, each instance was isolated to between the 5^{th} and 7^{th} vertebrae. Vertebral body OPL was unable to be analyzed statistically due to infinite likelihood.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 15-16. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. Type 3 Test of Fixed Effects, testing differences between the means for both apophyseal and vertebral OPL were part of the ANOVA and are shown in Tables 2 and 3 respectively. The non-significant p value *0.1173* for the Type 3 Test of Fixed Effects of the apophyseal OPL fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 17. According to the results, the test yielded no significant results; however, the test did produce a result for the main effect of region that was approaching significance (*p value 0.0589*) but was excluded because the overall main effects are non-significant. Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded significant results for the three-way interaction for mature males (*p value <.0001*), indicating a rejection of the null hypothesis that the means are 0.

Table 15. ANOVA Apophyseal OPL/OA Results for the Thompson Village site

Apop OPL/OA Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	50	3.00	0.0589
sex	1	50	0.42	0.5216
age	3	50	1.34	0.2710
region*sex	2	50	0.32	0.7249
region*age	6	50	0.66	0.6825
sex*age	2	50	0.12	0.8913
region*sex*age	4	50	1.95	0.1173

Apop OPL/OA Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			6	50	1.57	0.1749
region*sex*age	**MIDDLE**			6	50	1.31	0.2717
region*sex*age	**UPPER**			6	50	1.80	0.1177
region*sex*age		**F**	**?**	2	50	1.56	0.2200
region*sex*age		**F**	**MA**	2	50	0.33	0.7240
region*sex*age		**F**	**O**	2	50	1.04	0.3605
region*sex*age		**F**	**Y**	2	50	1.15	0.3233
region*sex*age		**M**	**?**	2	50	0.18	0.8381
region*sex*age		**M**	**MA**	2	50	14.37	<.0001
region*sex*age		**M**	**Y**	2	50	0.05	0.9539

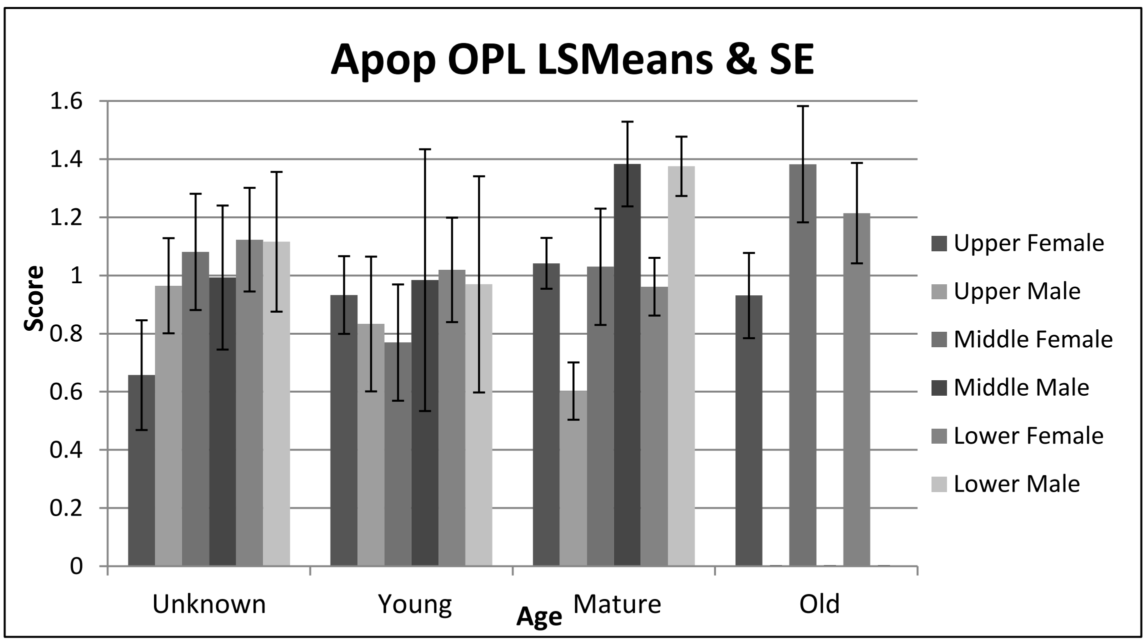

Figure 17. Thompson Village Apophyseal OPL LSMeans & SE

OLF. A total of 43 individuals were feasible for further statistical analysis. Results for the frequency and/or prevalence are presented in Table 14. Examination of the laminae of the neural arch, consisting of 17 males and 25 females, demonstrated several cases of level 3 severity. All instances of higher severity were isolated to a range between the 2^{nd}-4^{th} cervical vertebrae in the upper and middle biomechanical regions.

Results for the repeated measures mixed model ANOVA test analyzed employing the PROC MIXED procedure are presented in Table 17. For this initial test, the α (threshold of significance) was conventionally set to $\alpha < 0.05$. Type 3 Test of Fixed Effects, testing differences between the means were part of the ANOVA and are shown in Tables 17 respectively. The non-significant p value *0.6160* for the Type 3 Test of Fixed Effects fails to reject the null hypothesis that the means are 0. Though the tests were non-significant, I plotted a graphical representation of the least squares means estimates with standard errors in Figure 18. According to the results, there were no significant effects. Tests of the Effect Slices, designed to segregate the different ages, sexes and biomechanical regions, yielded significant results for the three-way interaction for old females (*p value 0.0152*), indicating a rejection of the null hypothesis that the means are 0. It is important to note in this instance that Thompson Village was the only sample which contained older adult individuals from which to analyze, which may results and interpretations of this sample.

Additional morphological alterations. The Thompson Village site presented with a total of 5 cases which demonstrated some sort of alteration of bilateral asymmetry, consisting of 3 left and 2 right In contrast, there were a total of 3 instances of Baastrup's syndrome present within the sample population, consisting of 1 mature male and 2 mature females.

Table 16. ANOVA OLF Results for the Thompson Village site

OLF Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region	2	36	2.08	0.1396
sex	1	36	0.26	0.6106
age	3	36	0.82	0.4933
region*sex	2	36	0.69	0.5086
region*age	6	36	0.70	0.6501
sex*age	2	36	0.14	0.8695
region*sex*age	1	36	0.26	0.6160

OLF Tests of Effect Slices							
Effect	**region**	**sex**	**age**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
region*sex*age	**LOWER**			6	36	0.17	0.9831
region*sex*age	**MIDDLE**			5	36	0.76	0.5861
region*sex*age	**UPPER**			4	36	0.89	0.4779
region*sex*age		**F**	**?**	1	36	0.04	0.8505
region*sex*age		**F**	**MA**	2	36	0.41	0.6697
region*sex*age		**F**	**O**	2	36	4.00	0.0270
region*sex*age		**F**	**Y**	2	36	0.73	0.4883
region*sex*age		**M**	**?**	2	36	0.45	0.6438
region*sex*age		**M**	**MA**	2	36	2.45	0.1001
region*sex*age		**M**	**Y**	0	.	.	.

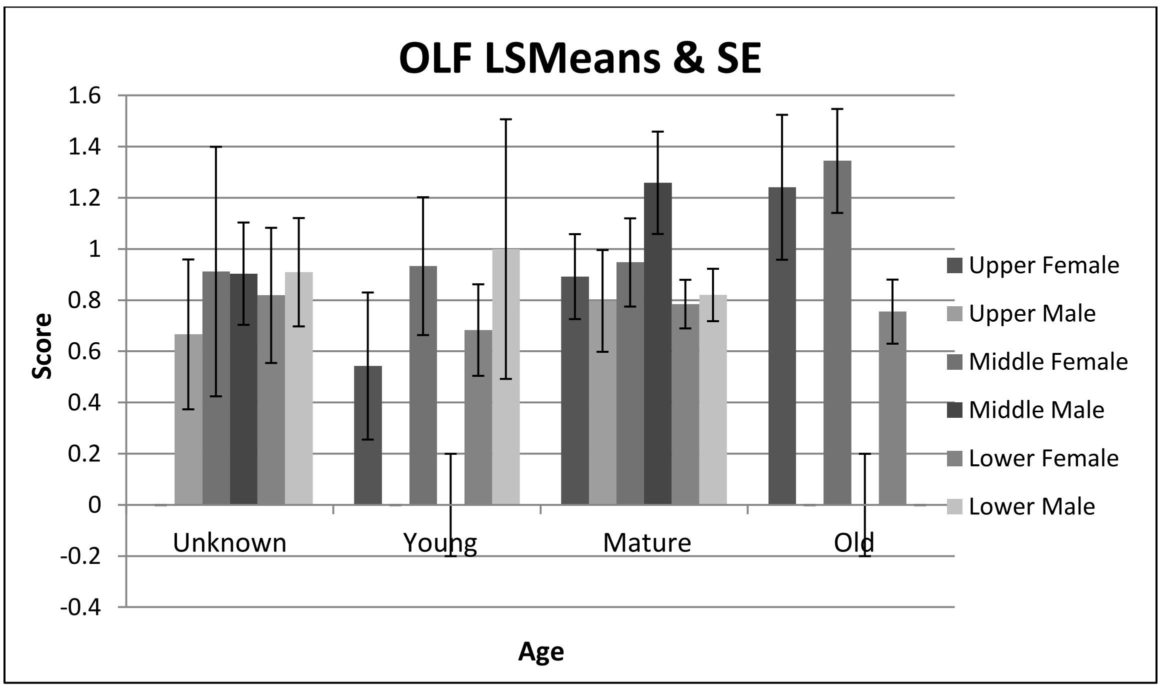

Figure 18. Thompson Village OLF LSMeans & SE

However, 3 individuals showed evidence of a shorn odontoid process, indicative of Porter's neck. Finally, no burials within the Thompson Village sample yielded deviated spinous processes in the 7th cervical vertebrae; however, 1 mature female presented with a broken spinous process that may have been the result of a more recent traumatic injury or a continuing pseudoarthrosis (i.e. false joint).

CHAPTER VII

DISCUSSION

Cherry Site (40BN74)

Spinal degenerative lesions (OPL, OA and IVDD). A significant result in the zygapophyseal OPL/OA tests generated for region indicates a pattern of different levels of use within the biomechanical regions. Unfortunately, this test only reveals that there is a pattern of differential use, not which cervical region was under the most strain nor what activity created that change. Additionally, the 8 individuals who presented with IVDD upon examination of the vertebral bodies were localized to the middle and lower cervical regions, indicating that an axially directed force degraded the intervertebral discs in this region, possibly from the back.

OLF. Isolation of the highest levels of severity to the 3rd cervical vertebra and the 5th-7th cervical vertebrae suggests extended periods of aggressive flexion in these regions, resulting in a stretch of the ligamentum flavum beyond its typical load-bearing capacity. This flexion, initiated by the longus cervicis, the anterior scalene and the sternocleidomastoid muscles, could possibly have resulted from a repetitive activity that consistently forced the neck and/or head forward while placing strain on the posterior neck, pushing the biomechanical limits of stabilization in the lower cervical region and the cervical at the extent of the lordosis curve. Correspondingly, these extended periods of flexion would exert compressive forces on the intervertebral discs, explaining the 43.5% prevalence of IVDD within the Cherry sample (Kim et al., 2013). A significant result in the OLF tests generated for region supports the qualitative pattern of different levels of use within the biomechanical regions. Finally, an additional significant result yielded for mature males would suggest a differential susceptibility for this particular age and sex, implying a more consistent pattern of heavy burden-bearing and physical stress than in younger men or in women.

Additional morphological alterations. The presence of 6 cases of bilateral asymmetry within the Cherry sample, 3 trending leftward and 3 trending toward the right, indicates a consistent pattern of lateral flexion that resulted in compression and increased degenerative changes in the zygapophyseal joints on that particular side (Bono et al., 2006). Additionally, the 4 instances of Baastrup's syndrome, consisting of 3 mature males and 1 mature female, suggest forced hyperextension of the neck required to create a pressure facet (Clifford, 2007; Kaki et al., 2011; Pinto et al., 2004). However, the presence of a case of complete dens fracture is consistent with the application of extensive flexion pressures on the odontoid process and the upper biomechanical region of the neck which forces the transverse atlantal ligaments to shear the process from the body of the 2nd cervical vertebrae. As flexion accounts for 80% of all dens fractures in modern biomechanical studies, this injury may be suggestive of a traumatic injury (Bellabarba et al., 2006; Hoque et al., 2012). Finally, while the etiology of a deviated spinous process is not definitively established as of yet, the presence of 2 cases which both deviate in a leftward direction is indicative of a heavy burden fracturing the spinous process, with repetitive loads forcing the bone out of alignment (Bono et al., 2006).

Eva Site (6BN12)

Spinal degenerative lesions (OPL, OA and IVDD). A significant result in the zygapophyseal OPL/OA tests generated for region and the interaction of region*age*sex indicates a pattern of different levels of use within the biomechanical regions that is positively dependent upon a specific age and sex. The additional significant results for mature males supports this theory, implying differential susceptibility for this particular age and sex with a more consistent pattern of heavy burden-bearing and physical stress than in younger men or in women. Additionally, the 16 individuals who presented with IVDD upon examination of the vertebral bodies ranged the entire length of the cervical spine which possess vertebral bodies (2^{nd}-7^{th} cervical vertebrae), indicating that the axially directed force which degraded the intervertebral discs ranged across the entire cervical spine.

OLF. Despite the lack of quantitative data to statistically analyze the OLF data, the qualitative numbers does provide some valuable information. Isolation of the highest levels of severity to the junctions of the 2^{nd} and 3^{rd} and the 5^{th} and 6^{th} cervical vertebrae suggests extended periods of forcible flexion in these specific connections, resulting in a stretch of the ligamentum flavum beyond its load-bearing capacity. This flexion, similar to the Eva sample, could possibly have resulted from a repetitive activity that consistently pushed the biomechanical limits of parts of the lower cervical region and the transition zone which starts the lordosis curve. Correspondingly, these extended periods of flexion would exert compressive forces on the intervertebral discs, explaining the 64% prevalence of IVDD within the Eva sample.

Additional morphological alterations. The absence of bilateral asymmetry within the

Eva sample indicates a lack of consistent lateral flexion that compressed and increased degenerative changes in the zygapophyseal joints on that particular side (Bono et al., 2006). Additionally, the 4 instances of Baastrup's syndrome, consisting of 2 mature male and 2 mature females, suggest forced hyperextension of the neck required to create a pressure facet (Clifford, 2007; Kaki et al., 2011; Pinto et al., 2004). Moreover, the absence of a complete dens fracture is consistent with a lack of extensive flexion pressures on the odontoid process and the upper biomechanical region of the neck to force the transverse atlantal ligaments to shear the process from the body of the 2nd cervical vertebrae (Bellabarba et al., 2006; Hoque et al., 2012).. Finally, while the etiology of a deviated spinous process is not definitively established as of yet, the presence of 3 cases which both deviate towards the right is indicative of a heavy burden fracturing the spinous process, with repetitive loads forcing the bone out of alignment (Bono et al., 2006).

Kays Landing Site (40HY13)

Spinal degenerative lesions (OPL, OA and IVDD). A significant result in the zygapophyseal OPL/OA tests generated for the lower cervical region indicates a pattern of differential axial loading within this region. Significant results in the vertebral body OPL tests generated for region and the interaction of region *sex indicates a pattern of different levels of use within the biomechanical regions that is positively dependent upon a specific sex. The additional significant results for mature males supports this theory, implying differential susceptibility for this particular age and sex with a more consistent pattern of heavy burden-bearing and physical stress than in younger men or in women. Additionally, the 17 individuals who presented with IVDD upon examination of the vertebral bodies were localized to the 4th-7th cervical vertebrae, indicating that an axially directed force degraded the intervertebral discs in this region.

OLF. Isolation of the highest levels of severity to the junctions of the 2nd and 3rd and the 5th and 6th cervical vertebrae suggests extended periods of forcible flexion in these regions, resulting in a stretch of the ligamentum flavum beyond its load-bearing capacity. This flexion, initiated by the longus cervicis, the anterior scalene and the sternocleidomastoid muscles, could possibly have resulted from a repetitive activity that consistently pushed the biomechanical limits of the lower cervical region and the cervical at the extent of the lordosis curve. Correspondingly, these extended periods of flexion would exert compressive forces on the intervertebral discs, explaining the approximately 63% prevalence of IVDD within the Kays Landing sample. A significant result in the OLF tests generated for region supports the qualitative pattern of different levels of use within the biomechanical regions, with a further significant results of the three-way interaction of the Upper and Middle biomechanical regions isolating the areas more differentially susceptible. Finally, an additional significant result yielded for region*age and young females would suggest a strong correlation between region and age, with young females more susceptibility, implying a more consistent pattern of heavy burden-bearing and physical stress than in mature women or men.

Additional morphological alterations. The absence of bilateral asymmetry within the Kays Landing sample indicates a lack of consistent lateral flexion that compressed and increased degenerative changes in the zygapophyseal joints on that particular side (Bono et al., 2006). Additionally, the complete absence of Baastrup's syndrome suggests a lack of forced hyperextension of the neck required to create a pressure facet (Clifford, 2007;

Kaki et al., 2011; Pinto et al., 2004). However, the presence of 2 cases of complete dens fracture is consistent with the application of extensive flexion pressures on the odontoid process and the upper biomechanical region of the neck which forces the transverse atlantal ligaments to shear the process from the body of the 2nd cervical vertebrae. As flexion accounts for 80% of all dens fractures in modern biomechanical studies, this injury may be suggestive of a traumatic injury or a fall while carrying a heavy load on the head (Bellabarba et al., 2006; Hoque et al., 2012).. Finally, the absence of deviated spines possibly suggests a lack of a heavy burden which might fracture the spinous process or a different method of carrying the load, preventing the bone from being forced out of alignment (Bono et al., 2006).

Thompson Village Site (7HY5)

Spinal degenerative lesions (OPL, OA and IVDD). A significant result in the zygapophyseal OPL/OA tests generated for mature males implies a differential susceptibility for this particular age and sex with a more consistent pattern of heavy burden-bearing and physical stress than in younger men or in women. Additionally, the 10 individuals who presented with IVDD upon examination of the vertebral bodies were localized to the lower cervical regions, indicating that an axially directed force degraded the intervertebral discs in this region.

OLF. Isolation of the highest levels of severity to the 2nd through 4th cervical vertebra suggests extended periods of forcible flexion in this particular area, resulting in a stretch of the ligamentum flavum beyond its load-bearing capacity. This flexion, initiated by the longus cervicis, the anterior scalene and the sternocleidomastoid muscles, could possibly have resulted from a repetitive activity that consistently pushed the biomechanical limits of the Upper and Middle cervical regions. Correspondingly, these extended periods of flexion focused on the upper and middle neck would exert limited compressive forces on the intervertebral discs, explaining the 20% prevalence of IVDD within the Thompson Village sample. A significant result in the OLF tests generated for old females would suggest a differential susceptibility for this particular age, which may or may not imply a more consistent pattern of heavy burden-bearing and physical stress than in younger women or men due to the advanced age and lack of comparative older adults in other samples.

Additional morphological alterations. The presence of 5 cases of bilateral asymmetry within the Thompson Village sample, 3 trending leftward and 2 trending toward the right, indicates a consistent pattern of lateral flexion that resulted in compression and increased degenerative changes in the zygapophyseal joints on that particular side (Bono et al., 2006). Additionally, the 3 instances of Baastrup's syndrome, consisting of 1 mature male and 2 mature females, suggest forced hyperextension of the neck required to create a pressure facet (Clifford, 2007; Kaki et al., 2011; Pinto et al., 2004). However, the presence of 3 cases of complete dens fracture is consistent with the application of extensive flexion pressures on the odontoid process and the upper biomechanical region of the neck which forces the transverse atlantal ligaments to shear the process from the body of the 2nd cervical vertebrae. As flexion accounts for 80% of all dens fractures in modern biomechanical studies, this injury may be suggestive of a traumatic injury (Bellabarba et al., 2006; Hoque et al., 2012).. Finally, the absence of deviated spines possibly suggests a lack of a heavy burden which might fracture the spinous process or a different method of carrying the load, preventing the bone from being forced out of alignment (Bono et al., 2006).

Archaic Site Comparison

These results denote some interesting implications. Overall, it appears that biomechanical region and mature age in males are important factors in apophyseal OPL/OA, with the corresponding importance of the areas of the 3rd cervical vertebra and the lower cervical region in OLF. This would indicate that there is a pattern in the Archaic sites, with mature males exhibiting the highest level of expression regarding the long-term consequences of the force exerted by a particular posture or burden-bearing activity. Correspondingly, said posture or activities appear to be straining the neck repetitively in a manner which targeted the same region repeatedly. However, the lack of consistency in significance between the three Archaic samples suggests that there is something else at play here which is affecting degenerative manifestations. This factor may be an effect of preservation or geographical.

Geographically, all three Archaic were located in relatively close proximity to sources of water but existed in different conditions. Cherry, the most isolated of the sites off the Big Sandy River, was located at a higher elevation than its contemporaries (Magennis, 1977). To that end, the Cherry site was the only Archaic sample which contained evidence of bilateral asymmetry as the result of persistent lateral flexion. Additionally, the Cherry sample possessed an appreciably lower prevalence of IVDD per capita in comparison to Eva or Kays Landing. Eva, on a similar latitudinal plane as Cherry, inhabited a broad floodplain on the much larger Tennessee River (Lewis and Kneberg, 1947, 1959; Lewis and Lewis, 1961; Magennis, 1977; Odom et al., 1953).

Interestingly, Eva was the only which presented with no instances of odontoid process fracture. Both sites displayed evidence of Baastrup's syndrome and deviated spinous processes but yielded no significant results for the vertebral body OPL. Kays Landing also was also situated on a floodplain farther north near the confluence of the Big Sandy and Tennessee rivers (Lewis and Kneberg, 1959; Wojcinski, 2011). Both floodplain sites exhibited higher levels of prevalence of IVDD per capita than the Cherry site; however, Kays Landing demonstrated no instances of Baastrup's syndrome in the sample.

This location farther north may explain the exceptions Kays Landing poses to the aforementioned overall degenerative pattern. In fact, Kays Landing appears to be an almost complete outlier, inconsistent with many other findings from Cherry and Eva. The only significant result for Kays Landing's zygapophyseal OPL/OA was for the lower cervical region instead of just region, suggesting that a great deal of pressure and force was being applied specifically to the lower region of the neck instead of just indicating a differential distribution of and susceptibility to stress. Likewise, Kays Landing is the only Archaic site which yielded significant results of region and the interaction of region and sex for vertebral body OPL, indicating a pattern of different levels of use within the biomechanical regions that is positively dependent upon a specific sex. Finally, Kays is the only site in which OLF produces significant results for young females, the upper cervical region and the middle cervical region. This suggests a higher level of flexional and extensional force being applied to the upper and middle neck with young females being affected more than any other age or sex.

It is this information which permits certain educated conclusions to be derived. Though the exact etiology is as yet unknown, one of the factors known to result in Baastrup's syndrome is repetitive physical stress and activities which cause excessive flexion and extension, activities such as tumpline usage across the head (Kaki et al., 2011; Meleger and Krivickas, 2007). Tumplines, utilized by numerous societies across the globe and illustrated in Figure 19, are broad bands of cloth or leather attached to a sack on the back that either go across the shoulders or, in this case, the forehead in order to provide support (Gerszten et al., 2001). Clinical studies, conducted by Kaneda et al. (1999) on the consequences of different methods of haulage techniques still consistently employed by porters in Nepal, recorded that the haulage porters who practiced back loading with tumplines across the forehead exerted a posture that hardly moved vertically, with the knee acting as a fulcrum. Furthermore, back loading with tumpline usage continuously increases pressure exerted on the cervical vertebrae over the entire time the object is being carried, increasing the individual's susceptibility to cervical degeneration and spondylosis (Gerszten et al., 2001; Kaneda et al., 1999). As noted by modern canoe experts (Jacobson, 2001; Mason, 1980), use of this method is quite strenuous yet efficient, and inappropriate application of this technique has injurious consequences. These osteological consequences can be seen in the severe degeneration of the spines of ancient mummies from southern Peru and northern Chile, who practiced back loading with forehead tumplines with capacho baskets (Gerszten et al., 2001). Fur traders from the Fort Edmonton cemetery in Alberta, who were required to carry multiple packs (ranging 40-100 lb) on their back that were supported by forehead tumplines, resulting in 39% to manifest both marginal and apophyseal OPL with a further 22% that exhibited surface pitting, articular surface modification and hemi-circumferential lesions on the anterior superior vertebral bodies from disc displacement (Lai and Lovell, 1992; Lovell and Dublenko, 1999). Archaic and Mississippian Native American populations follow similar patterns with 65% of all individuals over 30-years-old, resulting in peak OPL and OA involvement of the 5^{th} and 6^{th} vertebrae due to the maximum lordotic curve (Bridges, 1994). The effects of tumpline usage across the head are also consistent with the lack of differential susceptibility in vertebral body OPL and the extent of flexion stress exhibited by OLF, as well as the lack of odontoid process fracture caused by hyperflexion (Bellabarba et al., 2006; Jacobson, 2001; Mason, 1980). Finally, the presence of deviated spinous processes within the samples are also consistent with back loading and heavy spinal burden bearing. Therefore, it is logical to posit that the individuals living at both the Cherry and Eva sites were participating in activities consistent with head tumpline burden bearing, as demonstrated in Figure 19.

Contrastingly, the amount of axial pressure and force exhibited by the zygapophyseal and vertebral statistics would suggest significant axial compression, consistent with head loading. Head loading, employed by the porters of Nepal and woodbearers of the Congolese, consists of numerous smaller items in a conical basket or fashioned into a pack that is separated from the head via a circle of bound cloth (Kaneda et al., 1999; Lloyd et al., 2010, 2011; Malville et al., 2001). While Heglund et al. (1995) and Kaneda et al. (1999) agree that this particular method of hauling saves energy due to a posture that rarely moves vertically and a waist that acts as a fulcrum, head loading increases the spine's susceptibility to injury, as confirmed by clinical studies conducted by Levy (1968). Levy also noticed that x-rays of the porters during head loading denoted a straightening of the vertebral bodies and discs into a somewhat vertical pillar in order to bear the weight straight down, resulting in disc compression and a narrowing of the intervertebral space. This relieved some of the stress exerted on the ligaments and muscles and separates the spinous processes, preventing the occurrence of Baastrup's syndrome which corresponds to the absence of Baastrup's syndrome in the Kays Landing sample (Levy, 1968). In conjunction , multiple instances of complete odontoid process fracture which is primarily the result of traumatic hyperflexion, lack of deviated spines and significant OLF results in the Upper and Middle cervical spine are also consistent with head loading activities (Echarri and Forriol, 2002; Jumah and Nyame, 1994). Consequently, it is logical to postulate that the individuals living at the Kays Landing site were participating in activities compatible with head loading.

These conclusions are further supported by the work of Neidich (2013, 2014; Neidich and Smith, N.D.) on the humeral imprint, a non-pathological mechanical marker indicative of habitual arm positions, clavicle degenerative rate/alteration and entheseal changes for the teres minor muscle. Her research suggests that the people of Cherry and Eva habitually rotated the arm posteriorly as if to steady a heavy load on the back. Furthermore, Neidich's work demonstrates none of this posterior habitual rotation of the arm, but exhibits a high rate of degeneration at the clavicle, a condition associated with muscular and/nerve impingement that is consistent with raising the arm for long periods of time, possibly to steady a heavy load balanced on the head (Neidich, 2014).

Archaic versus Mississippian Sites

With the Mississippian site of Thompson Village, this would suggest that, like the Archaic samples, there is an interesting differential distribution of location along the

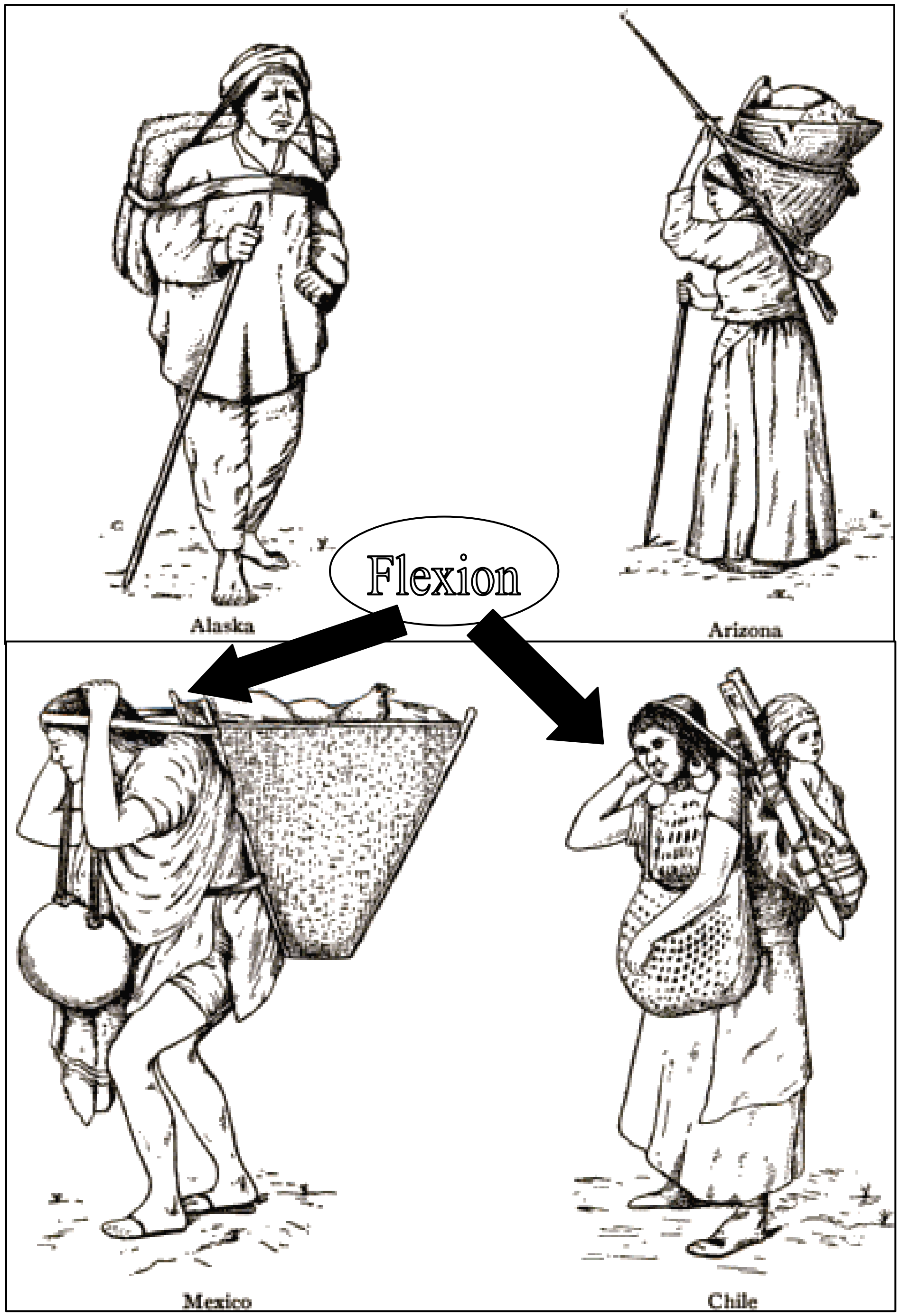

Figure 19. Forms of tumpline usage involving the head (adapted from Lee and DeVore, 1968)

cervical spine, with mature males perhaps under the most stress from the mechanical force, perhaps burden-bearing activities. Reminiscent of the Cherry and/or Eva sites, Thompson Village generated significant results for mature males in the zygapophyseal OPL/OA, yielded OLF values similar to the Cherry site as shown in Figure 20, demonstrated multiple instances of bilateral asymmetry, multiple instances of Baastrup's syndrome and exhibited a relatively low prevalence of IVDD that were entirely isolated to the lower cervical region. Nevertheless, Thompson Village does present with some results more consistent with the head loading activities postulated for Kays Landing such as: multiple individuals with complete odontoid fractures; no confirmed cases of deviated spines; and OLF results which are significant for females, albeit older females. With such contentious and ambivalent data, it is necessary to examine contemporary and comparable research in order to draw any conclusions. Correspondingly, Neidich (2014) discovered characteristic degenerative changes in both rate and location, though in a much more extensive quantity per capita, comparable to the Cherry and Eva sites. Therefore, based on the statistics and Neidich's (2014) work on the arm, it is reasonable to posit that the individuals of Thompson Village participated in activities more consistent with tumpline usage across the head than head loading in and of itself, demonstrated in Figure 19.

Therefore, on the surface the results show that there doesn't appear to be any significant difference in degeneration linked to subsistence economy. Mature males continue to be an important factor for zygapophyseal OPL/OA and inferences concerning the vertebral body OPL were unable to be drawn due to non-significance or lack of statistical data due to infinite likelihood. Frequency/prevalence rates continue to follow

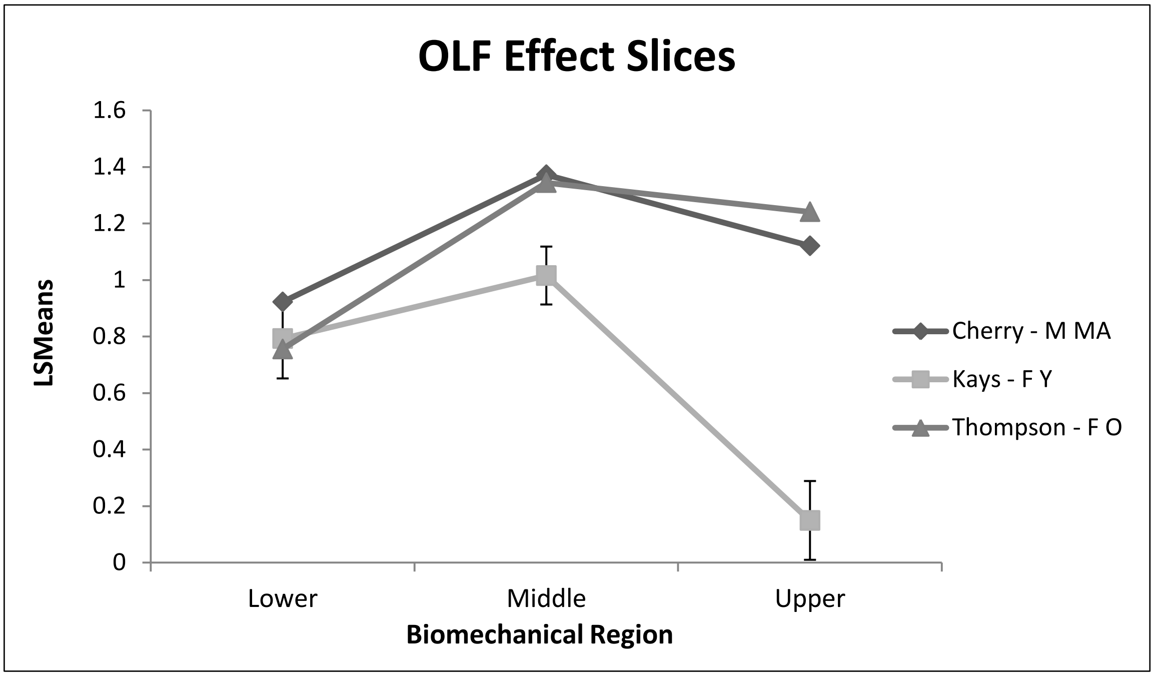

Figure 20. Cross-site Comparison of Significant OLF Results

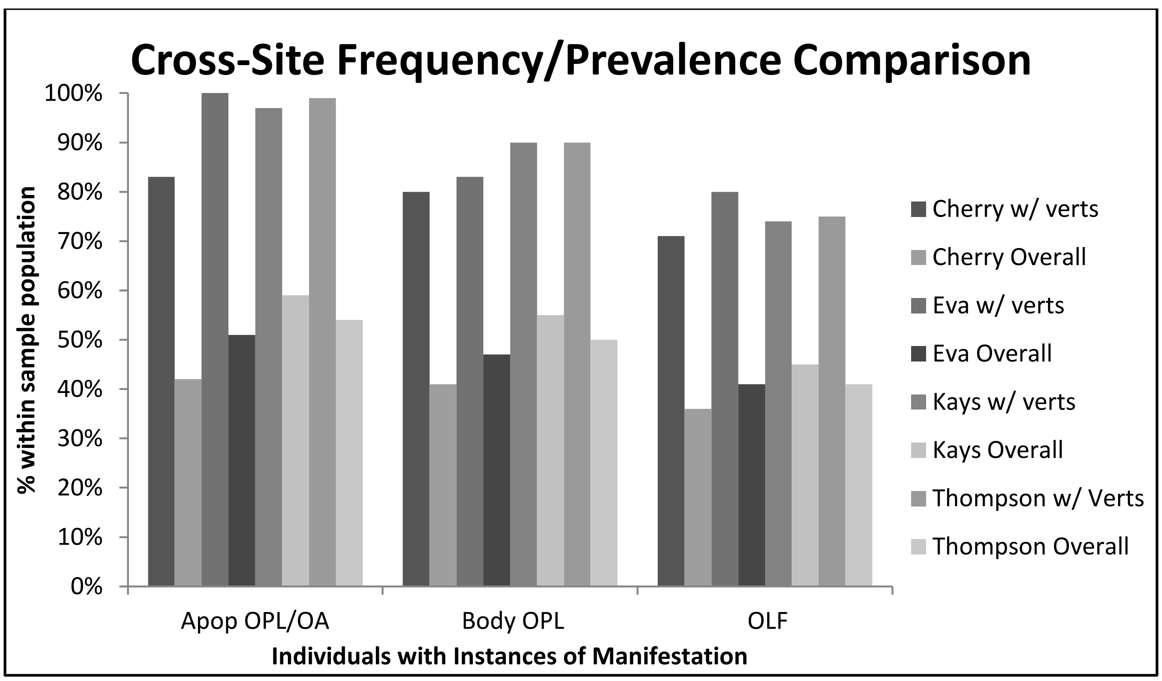

Figure 21. Cross-site Comparison of Frequency/Prevalence Rates

the same pattern, shown in Figure 21, with Kays Landing demonstrating the highest frequency/prevalence of degenerative and ligamentous manifestation across all four sites and all three scored traits. IVDD continues to follow an overall pattern across all four sites of targeting primarily the middle and lower cervical biomechanical regions, with the exception of Eva which encompassed the entire cervical spine. The presentation of OLF is perhaps the only exception to this overall pattern and the reasons for this are unclear. Such a localization of cases of severe OLF to the 2^{nd}-4^{th} cervical vertebrae is inconsistent with the data extrapolated here, but is consistent with previous research conducted on the Late Woodland sample of Schroeder Mounds in Illinois concerning vertebral degeneration and OLF (Boncal and Smith, 2013, 2014). Additionally, significant OLF results for older females would parallel the same sex distinctions at Kays Landing, but this result must be analyzed with a great deal of scrutiny due to the lack of burials of a comparable age in the Archaic sites.

However, if the theory that Thompson Village did participate in tumpline usage on the head, then there would indeed be a difference based upon subsistence economy when isolated to one geographical area. To elaborate, the Archaic Kays Landing and Mississippian Thompson Village are virtually neighboring sites with very little distance for separation (Bass, 1985; Kuemin-Drews, 2000; Moore, 1915). Since Kays Landing had a different archaeological tradition which may account for the differences in subsistence economy activities, it is rational to conclude that there is indeed a subsistence economy difference depending on geographical location. However, this conclusion is only a theory due to lack of comparable site data in close proximity to the Cherry and Eva sites.

While this study strives to adhere to Molleson's mandates to "use methodological approach . . . in attempt to reconstruct physical activity that might have made these changes via biomechanics," establishing a differential diagnosis of a particular activity or suite of activities via a cluster of morphological signs is very hard to assemble (Molleson, 2007). Bone is remarkably pliable, and pressures can easily distort the vertebral bone form and robusticity. It is this pliability which arouses great concern in numerous researchers. According to Waldron (2009), the identification of OPL, OA or similar degenerative changes are quite easy to recognize, but the identification of the etiology behind in the proliferative or erosive lesion is inconclusive and/ too variable due to its multifactorial origins. A sentiment shared by many other researchers (such as Bridges, 1991; 1994; Hukuda et al., 2000; Jurmain, 1990; Jurmain and Kilgore, 1995; Knüsel et al., 1997; Lane et al., 1986; Ortner, 2003; Rogers and Waldron, 1995; Rojas-Sepulveda et al). Jurmain (1990) further contends that it is "difficult if not impossible to isolate the *specific* behaviors that most influenced degenerative disease," particularly due to the lack of definitive information known concerning prehistoric behavior. Yet, Jurmain concedes that comparisons of the pattern and frequency of degenerative alterations can illuminate on the overall paleoepidemiology and life-style reconstruction. Therefore, one must always extend caution when approaching this kind of research (Jurmain, 1990).

CHAPTER VIII

CONCLUSION

Due to the biomechanical complexity of the human body and particularly the neck, reconstructing human lifeways and activities will never be a simple process. There are numerous extrinsic and intrinsic factors which affect the location, severity and extent of degenerative change and ligamentous ossification, despite the remnants which repetitive physical stress and burden-bearing activities inevitably leave behind. Such factors include age and sex of the individual, geographic location , topography, culture and even subsistence strategies. Therefore, differentiating between degeneration as an inherent consequence of aging from degeneration as a pathological alteration within an archaeological context is problematic at best, frequently prone to misinterpretation and/or over-interpretation of the data. Problematic, but not impossible.

The research within this thesis demonstrates with a good degree of confidence that it is possible to potentially identify physical activities indicative of certain subsistence economies through the examination of zygapophyseal and vertebral body OPL, OA and OLF, as well as numerous supportive mechanical injuries and pathological conditions. By interpreting these characteristics as proxies for biomechanical stress and employing biostatistical analyses, I have been able to postulate that the sample populations of Cherry, Eva and Thompson Village were participating in movements consistent with back loading burden-bearing activities that placed tremendous flexional and extension al strain on the neck, such as tumpline usage across the head. Furthermore, it appears that the sample population of Kays Landing was exceedingly different, taking part in movements consistent with head loading burden-bearing activities that placed extensive axial compressive force on the cervical spine.

Future Research

While the conclusions drawn in this thesis are reasonable, they are by no means absolute and incontrovertible. Behaviors are variable and overlapping; therefore, it is only logical that this pilot study should result in more questions than answers for it is these questions which suggest a causality within the patterns. If given my druthers, I would increase the amount of sample populations examined within the Lower Tennessee River Valley, striving to isolate sites that are in close spatial proximity to one another. This would effectively reduce the chances of drawing the wrong conclusions due to extrinsic factors, such as geographic and topographic influences, thereby imparting much more confidence in the results. It is further necessary to control for sex and age factors. Many societies throughout history segregate physical activities based upon sex and/or age, thereby biasing the results of the sample. Age further complicates the situation since degenerative alteration is an inherent condition of aging, as previously mentioned. To elaborate, every person acquires some degree of osteophytosis of the vertebral body margin or the apophyseal facets by the age of 40. Controlling for age could allow for the differentiation between what is aging and what is pathological. Furthermore, the criteria and methodologies utilized by the original researchers who aged the human remains were subjective and not objective, possibly resulting in sampling bias and result error. Unfortunately, the lack of comparative cohesive and informative neck research puts this research at a slight disadvantage, hindering the ability to draw differential diagnosis. Very little modern medical and biomechanical data addresses the consequences of haulage techniques for comparative research. One of the more prevalent areas of modern focus seem to highlight the anatomical consequences of neck muscle strain and injury suffered by air craft pilots under high G forces (Hamalainen, 1993; Newman and Ostler, 2011). While this data is informative, this research does not highlight the specific results of protracted haulage methodologies via degeneration and biomechanical stress, as well as nuchal reactive and entheseal change. Finally, as there are many ways in which to carry burdens and we know practically nothing about the physical activities conducted by the Archaic Native Americans of the Lower Tennessee River Valley, more research into the etiology of Baastrup's syndrome, as well as the directionality of deviated spinous processes, is undeniably required in order to better identify a differential diagnosis.

Although the research can be designed to be more reliable and informative, nothing can replace the fact that these conclusions are all theoretical until more research is conducted which addresses this issue, particularly with prehistoric Native American inhabitants of the southeastern United States. It is only through extensive research on the significance of degenerative change and biomechanical stress, employing standardized collection and analytical methods, will we be able to someday definitively attribute certain physical characteristics to particular burden-bearing activities.

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APPENDIX A

CHERRY SITE LSMEANS AND SE RESULTS

Apop OPL/OA

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.0000	0.3807	19	2.63	0.0166
region*sex*age	**LOWER**	**F**	**MA**	1.1680	0.3797	19	3.08	0.0062
region*sex*age	**LOWER**	**F**	**Y**	0.6381	0.3448	19	1.85	0.0799
region*sex*age	**LOWER**	**M**	**?**	1.1137	0.5153	19	2.16	0.0437
region*sex*age	**LOWER**	**M**	**MA**	1.0747	0.2383	19	4.51	0.0002
region*sex*age	**LOWER**	**M**	**Y**	0.8442	0.4663	19	1.81	0.0861
region*sex*age	**MIDDLE**	**F**	**?**	1.0556	0.4803	19	2.20	0.0406
region*sex*age	**MIDDLE**	**F**	**MA**	1.0711	0.4531	19	2.36	0.0289
region*sex*age	**MIDDLE**	**F**	**Y**	1.1690	0.3081	19	3.79	0.0012
region*sex*age	**MIDDLE**	**M**	**?**	1.2203	0.3958	19	3.08	0.0061
region*sex*age	**MIDDLE**	**M**	**MA**	1.1434	0.2528	19	4.52	0.0002
region*sex*age	**MIDDLE**	**M**	**Y**	0.7500	0.5882	19	1.28	0.2177
region*sex*age	**UPPER**	**F**	**?**	0.4222	0.2851	19	1.48	0.1551
region*sex*age	**UPPER**	**F**	**MA**	0.6310	0.2469	19	2.56	0.0194
region*sex*age	**UPPER**	**F**	**Y**	0.7761	0.1948	19	3.98	0.0008
region*sex*age	**UPPER**	**M**	**?**	0.8455	0.3920	19	2.16	0.0441
region*sex*age	**UPPER**	**M**	**MA**	0.6135	0.1698	19	3.61	0.0019
region*sex*age	**UPPER**	**M**	**Y**	0.7500	0.3492	19	2.15	0.0449

Vert Body OPL

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	0.7222	0.2800	17	2.58	0.0195
region*sex*age	**LOWER**	**F**	**MA**	0.5000	0.2800	17	1.79	0.0920
region*sex*age	**LOWER**	**F**	**Y**	0.2656	0.2056	17	1.29	0.2138
region*sex*age	**LOWER**	**M**	**?**	0.1348	0.3201	17	0.42	0.6790
region*sex*age	**LOWER**	**M**	**MA**	0.3415	0.1672	17	2.04	0.0570
region*sex*age	**LOWER**	**M**	**Y**	-278E-18	0.3429	17	-0.00	1.0000
region*sex*age	**MIDDLE**	**F**	**?**	0.5000	0.2791	17	1.79	0.0910
region*sex*age	**MIDDLE**	**F**	**MA**	0.6667	0.2791	17	2.39	0.0288
region*sex*age	**MIDDLE**	**F**	**Y**	0.2103	0.2170	17	0.97	0.3461
region*sex*age	**MIDDLE**	**M**	**?**	0.05704	0.3113	17	0.18	0.8568
region*sex*age	**MIDDLE**	**M**	**MA**	0.1920	0.1659	17	1.16	0.2630
region*sex*age	**MIDDLE**	**M**	**Y**	0.2500	0.3418	17	0.73	0.4745
region*sex*age	**UPPER**	**F**	**?**	0.5000	0.2575	17	1.94	0.0689
region*sex*age	**UPPER**	**F**	**MA**	-278E-18	0.2575	17	-0.00	1.0000
region*sex*age	**UPPER**	**F**	**Y**	0.08167	0.2467	17	0.33	0.7447
region*sex*age	**UPPER**	**M**	**?**	0.07055	0.4236	17	0.17	0.8697
region*sex*age	**UPPER**	**M**	**MA**	0.1207	0.1664	17	0.73	0.4782
region*sex*age	**UPPER**	**M**	**Y**	0.5000	0.3154	17	1.59	0.1313

OLF

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.0376	0.2447	15	4.24	0.0007
region*sex*age	**LOWER**	**F**	**MA**	0.9103	0.2352	15	3.87	0.0015
region*sex*age	**LOWER**	**F**	**Y**	1.0013	0.2189	15	4.57	0.0004
region*sex*age	**LOWER**	**M**	**?**	0.5000	0.1992	15	2.51	0.0240
region*sex*age	**LOWER**	**M**	**MA**	0.9224	0.1444	15	6.39	<.0001
region*sex*age	**LOWER**	**M**	**Y**	1.0000	0.4620	15	2.16	0.0470
region*sex*age	**MIDDLE**	**F**	**?**	0.9632	0.1475	15	6.53	<.0001
region*sex*age	**MIDDLE**	**F**	**MA**	1.2187	0.1332	15	9.15	<.0001
region*sex*age	**MIDDLE**	**M**	**?**	1.0068	0.4919	15	2.05	0.0586
region*sex*age	**MIDDLE**	**M**	**MA**	1.3726	0.1128	15	12.17	<.0001
region*sex*age	**MIDDLE**	**M**	**Y**	1.0000	0.1992	15	5.02	0.0002
region*sex*age	**UPPER**	**F**	**?**	0.3148	0.2762	15	1.14	0.2722
region*sex*age	**UPPER**	**F**	**MA**	0.3759	0.2745	15	1.37	0.1910
region*sex*age	**UPPER**	**F**	**Y**	0.5000	0.3478	15	1.44	0.1711
region*sex*age	**UPPER**	**M**	**?**	-0.00676	0.4919	15	-0.01	0.9892
region*sex*age	**UPPER**	**M**	**MA**	1.1209	0.2708	15	4.14	0.0009
region*sex*age	**UPPER**	**M**	**Y**	0.5000	0.3478	15	1.44	0.1711

APPENDIX B

EVA SITE LSMEANS AND SE RESULTS

Apop OPL/OA

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.1869	0.3209	20	3.70	0.0014
region*sex*age	**LOWER**	**F**	**MA**	0.5419	0.1941	20	2.79	0.0112
region*sex*age	**LOWER**	**F**	**Y**	0.7321	0.3727	20	1.96	0.0635
region*sex*age	**LOWER**	**M**	**?**	1.1277	0.3570	20	3.16	0.0049
region*sex*age	**LOWER**	**M**	**MA**	1.1038	0.2779	20	3.97	0.0008
region*sex*age	**LOWER**	**M**	**Y**	0.3614	0.2948	20	1.23	0.2344
region*sex*age	**MIDDLE**	**F**	**?**	1.4399	0.4990	20	2.89	0.0091
region*sex*age	**MIDDLE**	**F**	**MA**	0.9707	0.2542	20	3.82	0.0011
region*sex*age	**MIDDLE**	**F**	**Y**	0.6667	0.5103	20	1.31	0.2063
region*sex*age	**MIDDLE**	**M**	**?**	1.0833	0.4167	20	2.60	0.0171
region*sex*age	**MIDDLE**	**M**	**MA**	1.6951	0.2935	20	5.78	<.0001
region*sex*age	**MIDDLE**	**M**	**Y**	0.3750	0.3609	20	1.04	0.3111
region*sex*age	**UPPER**	**F**	**?**	0.4848	0.2082	20	2.33	0.0305
region*sex*age	**UPPER**	**F**	**MA**	0.7176	0.1389	20	5.17	<.0001
region*sex*age	**UPPER**	**F**	**Y**	0.3333	0.2946	20	1.13	0.2713
region*sex*age	**UPPER**	**M**	**?**	0.4306	0.2406	20	1.79	0.0886
region*sex*age	**UPPER**	**M**	**MA**	0.2765	0.2342	20	1.18	0.2516
region*sex*age	**UPPER**	**M**	**Y**	0.3750	0.2083	20	1.80	0.0870

Vert Body OPL

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	0.6555	0.2757	19	2.38	0.0281
region*sex*age	**LOWER**	**F**	**MA**	0.4217	0.1658	19	2.54	0.0199
region*sex*age	**LOWER**	**F**	**Y**	0.3333	0.3323	19	1.00	0.3285
region*sex*age	**LOWER**	**M**	**?**	0.8042	0.2926	19	2.75	0.0128
region*sex*age	**LOWER**	**M**	**MA**	0.6667	0.2350	19	2.84	0.0105
region*sex*age	**LOWER**	**M**	**Y**	0.1483	0.2474	19	0.60	0.5560
region*sex*age	**MIDDLE**	**F**	**?**	0.6472	0.3167	19	2.04	0.0551
region*sex*age	**MIDDLE**	**F**	**MA**	0.4777	0.2188	19	2.18	0.0418
region*sex*age	**MIDDLE**	**F**	**Y**	0.2500	0.4461	19	0.56	0.5817
region*sex*age	**MIDDLE**	**M**	**?**	0.6667	0.3642	19	1.83	0.0829
region*sex*age	**MIDDLE**	**M**	**MA**	0.8125	0.3154	19	2.58	0.0185
region*sex*age	**MIDDLE**	**M**	**Y**	0.4375	0.3154	19	1.39	0.1815
region*sex*age	**UPPER**	**F**	**?**	0.2277	0.2882	19	0.79	0.4393
region*sex*age	**UPPER**	**F**	**MA**	0.2222	0.1527	19	1.45	0.1620
region*sex*age	**UPPER**	**F**	**Y**	0.2500	0.3240	19	0.77	0.4498
region*sex*age	**UPPER**	**M**	**?**	0.6667	0.2645	19	2.52	0.0208
region*sex*age	**UPPER**	**M**	**MA**	0.3750	0.2291	19	1.64	0.1181
region*sex*age	**UPPER**	**M**	**Y**	0.2500	0.2291	19	1.09	0.2888

OLF

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	0.6555	0.2757	19	2.38	0.0281
region*sex*age	**LOWER**	**F**	**MA**	0.4217	0.1658	19	2.54	0.0199
region*sex*age	**LOWER**	**F**	**Y**	0.3333	0.3323	19	1.00	0.3285
region*sex*age	**LOWER**	**M**	**?**	0.8042	0.2926	19	2.75	0.0128
region*sex*age	**LOWER**	**M**	**MA**	0.6667	0.2350	19	2.84	0.0105
region*sex*age	**LOWER**	**M**	**Y**	0.1483	0.2474	19	0.60	0.5560
region*sex*age	**MIDDLE**	**F**	**?**	0.6472	0.3167	19	2.04	0.0551
region*sex*age	**MIDDLE**	**F**	**MA**	0.4777	0.2188	19	2.18	0.0418
region*sex*age	**MIDDLE**	**F**	**Y**	0.2500	0.4461	19	0.56	0.5817
region*sex*age	**MIDDLE**	**M**	**?**	0.6667	0.3642	19	1.83	0.0829
region*sex*age	**MIDDLE**	**M**	**MA**	0.8125	0.3154	19	2.58	0.0185
region*sex*age	**MIDDLE**	**M**	**Y**	0.4375	0.3154	19	1.39	0.1815
region*sex*age	**UPPER**	**F**	**?**	0.2277	0.2882	19	0.79	0.4393
region*sex*age	**UPPER**	**F**	**MA**	0.2222	0.1527	19	1.45	0.1620
region*sex*age	**UPPER**	**F**	**Y**	0.2500	0.3240	19	0.77	0.4498
region*sex*age	**UPPER**	**M**	**?**	0.6667	0.2645	19	2.52	0.0208
region*sex*age	**UPPER**	**M**	**MA**	0.3750	0.2291	19	1.64	0.1181
region*sex*age	**UPPER**	**M**	**Y**	0.2500	0.2291	19	1.09	0.2888

APPENDIX C

KAYS LANDING SITE LSMEANS AND SE RESULTS

Apop OPL/OA

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.3333	0.6401	27	2.08	0.0468
region*sex*age	**LOWER**	**F**	**MA**	0.6797	0.1101	27	6.17	<.0001
region*sex*age	**LOWER**	**F**	**Y**	1.1611	0.2411	27	4.82	<.0001
region*sex*age	**LOWER**	**M**	**MA**	1.2951	0.1412	27	9.17	<.0001
region*sex*age	**LOWER**	**M**	**O**	0.1811	0.5703	27	0.32	0.7532
region*sex*age	**LOWER**	**M**	**Y**	1.0000	0.6401	27	1.56	0.1299
region*sex*age	**MIDDLE**	**F**	**MA**	0.8554	0.1943	27	4.40	0.0002
region*sex*age	**MIDDLE**	**F**	**Y**	0.8131	0.3631	27	2.24	0.0336
region*sex*age	**MIDDLE**	**M**	**MA**	1.2565	0.2084	27	6.03	<.0001
region*sex*age	**UPPER**	**F**	**?**	0.8000	0.5459	27	1.47	0.1543
region*sex*age	**UPPER**	**F**	**MA**	0.5456	0.1772	27	3.08	0.0047
region*sex*age	**UPPER**	**F**	**Y**	0.8112	0.2293	27	3.54	0.0015
region*sex*age	**UPPER**	**M**	**?**	0.4286	0.5459	27	0.79	0.4392
region*sex*age	**UPPER**	**M**	**MA**	0.9241	0.1698	27	5.44	<.0001
region*sex*age	**UPPER**	**M**	**O**	0.6111	0.3152	27	1.94	0.0630
region*sex*age	**UPPER**	**M**	**Y**	1.0000	0.5459	27	1.83	0.0780

Vertebral Body OPL

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.0000	0.5318	22	1.88	0.0733
region*sex*age	**LOWER**	**F**	**MA**	0.2383	0.1214	22	1.96	0.0625
region*sex*age	**LOWER**	**F**	**Y**	0.2236	0.1859	22	1.20	0.2418
region*sex*age	**LOWER**	**M**	**MA**	0.4345	0.1190	22	3.65	0.0014
region*sex*age	**LOWER**	**M**	**O**	0.5000	0.3840	22	1.30	0.2064
region*sex*age	**MIDDLE**	**F**	**?**	1.0000	0.3068	22	3.26	0.0036
region*sex*age	**MIDDLE**	**F**	**MA**	0.3833	0.1682	22	2.28	0.0327
region*sex*age	**MIDDLE**	**F**	**Y**	0.2000	0.2378	22	0.84	0.4094
region*sex*age	**MIDDLE**	**M**	**MA**	0.6684	0.1834	22	3.64	0.0014
region*sex*age	**MIDDLE**	**M**	**O**	0.5000	0.5318	22	0.94	0.3573
region*sex*age	**UPPER**	**F**	**MA**	0.2500	0.09703	22	2.58	0.0172
region*sex*age	**UPPER**	**F**	**Y**	-222E-18	0.1372	22	-0.00	1.0000
region*sex*age	**UPPER**	**M**	**MA**	0.06400	0.1085	22	0.59	0.5612
region*sex*age	**UPPER**	**M**	**O**	5.55E-17	0.3068	22	0.00	1.0000

OLF

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**MA**	0.8783	0.1121	24	7.84	<.0001
region*sex*age	**LOWER**	**F**	**Y**	0.7927	0.1414	24	5.61	<.0001
region*sex*age	**LOWER**	**M**	**MA**	0.4110	0.1882	24	2.18	0.0390
region*sex*age	**MIDDLE**	**F**	**MA**	0.9907	0.05790	24	17.11	<.0001
region*sex*age	**MIDDLE**	**F**	**Y**	1.0155	0.1025	24	9.90	<.0001
region*sex*age	**MIDDLE**	**M**	**MA**	0.7562	0.07369	24	10.26	<.0001
region*sex*age	**MIDDLE**	**M**	**O**	0.5230	0.2464	24	2.12	0.0443
region*sex*age	**UPPER**	**F**	**MA**	0.9577	0.07713	24	12.42	<.0001
region*sex*age	**UPPER**	**F**	**Y**	0.1489	0.1394	24	1.07	0.2961
region*sex*age	**UPPER**	**M**	**MA**	0.8000	0.08844	24	9.05	<.0001
region*sex*age	**UPPER**	**M**	**O**	0.5000	0.2179	24	2.30	0.0308

APPENDIX D

THOMPSON VILLAGE SITE LSMEANS AND SE RESULTS

Apop OPL/OA

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	1.1234	0.1783	50	6.30	<.0001
region*sex*age	**LOWER**	**F**	**MA**	0.9616	0.09926	50	9.69	<.0001
region*sex*age	**LOWER**	**F**	**O**	1.2146	0.1727	50	7.03	<.0001
region*sex*age	**LOWER**	**F**	**Y**	1.0194	0.1796	50	5.68	<.0001
region*sex*age	**LOWER**	**M**	**?**	1.1161	0.2403	50	4.64	<.0001
region*sex*age	**LOWER**	**M**	**MA**	1.3757	0.1020	50	13.48	<.0001
region*sex*age	**LOWER**	**M**	**Y**	0.9696	0.3718	50	2.61	0.0120
region*sex*age	**MIDDLE**	**F**	**?**	1.0813	0.2338	50	4.62	<.0001
region*sex*age	**MIDDLE**	**F**	**MA**	1.0301	0.1250	50	8.24	<.0001
region*sex*age	**MIDDLE**	**F**	**O**	1.3829	0.2153	50	6.42	<.0001
region*sex*age	**MIDDLE**	**F**	**Y**	0.7694	0.2357	50	3.26	0.0020
region*sex*age	**MIDDLE**	**M**	**?**	0.9931	0.2477	50	4.01	0.0002
region*sex*age	**MIDDLE**	**M**	**MA**	1.3835	0.1457	50	9.50	<.0001
region*sex*age	**MIDDLE**	**M**	**Y**	0.9841	0.4502	50	2.19	0.0335
region*sex*age	**UPPER**	**F**	**?**	0.6573	0.1887	50	3.48	0.0010
region*sex*age	**UPPER**	**F**	**MA**	0.9330	0.08742	50	10.67	<.0001
region*sex*age	**UPPER**	**F**	**O**	1.0420	0.1466	50	7.11	<.0001
region*sex*age	**UPPER**	**F**	**Y**	0.9311	0.1336	50	6.97	<.0001
region*sex*age	**UPPER**	**M**	**?**	0.9649	0.1637	50	5.89	<.0001
region*sex*age	**UPPER**	**M**	**MA**	0.6026	0.09855	50	6.11	<.0001
region*sex*age	**UPPER**	**M**	**Y**	0.8333	0.2318	50	3.59	0.0007

OLF

Least Squares Means								
Effect	**region**	**sex**	**age**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
region*sex*age	**LOWER**	**F**	**?**	0.8191	0.2642	36	3.10	0.0037
region*sex*age	**LOWER**	**F**	**MA**	0.7850	0.09496	36	8.27	<.0001
region*sex*age	**LOWER**	**F**	**O**	0.7556	0.1252	36	6.04	<.0001
region*sex*age	**LOWER**	**F**	**Y**	0.6836	0.1788	36	3.82	0.0005
region*sex*age	**LOWER**	**M**	**?**	0.9096	0.2117	36	4.30	0.0001
region*sex*age	**LOWER**	**M**	**MA**	0.8207	0.1024	36	8.02	<.0001
region*sex*age	**LOWER**	**M**	**Y**	1.0000	0.5073	36	1.97	0.0564
region*sex*age	**MIDDLE**	**F**	**?**	0.9121	0.4876	36	1.87	0.0696
region*sex*age	**MIDDLE**	**F**	**MA**	0.9478	0.1724	36	5.50	<.0001
region*sex*age	**MIDDLE**	**F**	**O**	1.3445	0.2032	36	6.62	<.0001
region*sex*age	**MIDDLE**	**F**	**Y**	0.9333	0.2694	36	3.46	0.0014
region*sex*age	**MIDDLE**	**M**	**?**	0.9039	0.3720	36	2.43	0.0202
region*sex*age	**MIDDLE**	**M**	**MA**	1.2591	0.1822	36	6.91	<.0001
region*sex*age	**UPPER**	**F**	**MA**	0.8924	0.1660	36	5.38	<.0001
region*sex*age	**UPPER**	**F**	**O**	1.2416	0.2832	36	4.38	<.0001
region*sex*age	**UPPER**	**F**	**Y**	0.5430	0.2874	36	1.89	0.0670
region*sex*age	**UPPER**	**M**	**?**	0.6667	0.2929	36	2.28	0.0289
region*sex*age	**UPPER**	**M**	**MA**	0.7975	0.1989	36	4.01	0.0003