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# DEGENERATIVE JOINT DISEASE AND CHANGING SUBSISTENCE ACTIVITIES IN THE ARKANSAS RIVER VALLEY

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# DEGENERATIVE JOINT DISEASE AND CHANGING SUBSISTENCE ACTIVITIES IN THE ARKANSAS RIVER VALLEY

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By

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**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

**CHAPTER ONE**

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**INTRODUCTION**

This research project is an examination of joint degeneration and its connection to subsistence-related activities. The patterns of joint degeneration were recorded for a population from the Arkansas River area of Oklahoma. It is postulated that this study population underwent a change in subsistence strategy, switching from foraging to horticulture (Rohrbaugh 1982). An attempt has been made to link changes in subsistence-related activities to possible changes in the joint degeneration pattern.

Other anthropological studies interested in the effects of changing subsistence strategies from foraging to agriculture have focused on dietary and nutritional implications and the resulting changes in health (Cassidy 1984, Cook 1984, Rose et al. 1984). Some anthropological studies have examined the biological effects of the subsistence activity, by studying the potential correlation of degenerative joint disease to activity-induced stress (Lallo 1973, Merbs 1983, Pickering 1979, 1984).

It has long been believed that wear and tear resulting from the use of joints, was one of the major causes for their degeneration (Goodfellow and Bullough 1967, Ettinger 1984). While degenerative joint disorders may be caused by many factors (Jurmain 1977), there is growing evidence that they are primarily a result of activity-induced stressors which affect bone growth and maintenance (Bridges 1983, Brodelius 1961, Lawrence 1955, 1961, Merbs 1983, Ortner 1968, Radin, Paul and Rose 1972).

By changing subsistence patterns, the activities required of an individual are modified, and the mechanical stressors placed on joints are altered. This mechanical stress may change in two ways: 1)it may change in severity and 2)it may change in the pattern of joints affected.

The research hypotheses developed within this study attempt to measure both types of change. Subsistence related activities have been inferred from the artifacts associated with the study site. Ethnographic analogy has also been used to infer possible activities. The main objective of this project is to determine if subsistence-related activities affect the patterns of joint degeneration.

Chapter Two reviews some of the methodological issues concerned with identifying degenerative joint disease (also known as osteoarthritis), and the theoretical issues regarding its association to activity-induced stress. A literature review of both clinical and anthropological material is provided.

Chapter Three presents an overview of the archaeology of eastern Oklahoma and of the specific site studied. The specific activities which may have contributed to joint degeneration within the population are also reviewed.

In Chapter Four, the methodology used to score the sample for joint degeneration is described. This chapter also discusses how the sample was selected and presents the research hypotheses being tested.

Discussion and analysis of the hypotheses are presented in Chapter Five. Associations are made regarding the observed patterns of degeneration and the potential subsistence-related activities.

Chapter Six concludes the thesis by summarizing what has been learned from this study, and what factors might be useful to consider in future studies.

## CHAPTER TWO

## LITERATURE REVIEW

Much research has been done regarding degenerative joint disease. Studies have focused on proper identification of the disease, causative factors of the disease, the specific path of the degenerative process, and the association between specific activities and joint degeneration.

This chapter describes the anatomy of the joint degeneration process, and reviews some of the traditional assumptions which have guided joint degeneration research. Some of the major medical and anthropological studies concerning activity-use and joint degeneration are also reviewed. First, a concise definition of degenerative joint disease is presented along with a list of potential causative factors.

### -----Classification / Etiology-----

Clinically, degenerative joint disease is classified under the larger medical heading of **Rheumatic Diseases**. These are diseases which cause stiffening in the musculo-skeletal system (Hollander 1966). If the stiffening affects the joints, then the term **Arthritis** is used to describe the disease. Degenerative joint disease is one of the many forms of arthritis (Resnick 1988).

Exactly how many types of arthritis there are is unclear. Various classification systems have been developed which subdivide joint degeneration based on several criteria (i.e., how many joints affected, unilateral vs. bilateral patterning, possible cause of degeneration, clinical evidence, radiologic evidence, etc.). In arthritis research, it has been very difficult to determine which criteria are more important.

For the purpose of this research project, degenerative joint disease is defined as a non-inflammatory disease of the synovial joints (Merbs 1983). This definition excludes arthritic degeneration of the vertebral bodies. These represent cartilaginous joints, and this type of degeneration is referred to as osteophytosis (Merbs 1983).

Understanding the etiology of degenerative joint disease is important in both identifying degenerative joint disease in archaeological populations and in determining its relation to activity-induced stress. Most degenerative joint disease research has focused on eight potentially causative factors. Systemic-predispositional factors include age, sex, metabolism, nutrition, hormones and heredity. Mechanical-functional factors are trauma and obesity (Davis 1988, Jurmain 1977). The predispositional factors have the potential to create an environment conducive to joint degeneration, whereas the functional factors have the potential to initiate degeneration.

While most researchers have studied these factors in isolation, it is apparent that these factors often interact with each other, creating a variety of causative environments. For example, an individual's metabolism may be conducive to joint degeneration, but this condition will not be triggered unless the individual experiences a traumatic event such as a broken hip, in which case only the hip is affected.

Metabolism, nutrition, hormones and heredity are thought to affect the integrity of the cartilage and/or subchondral bone (Hall 1983). Studies which focus on these causative factors are done with living tissue at the physiochemical and cellular level. Because this study is primarily interested in archaeological populations, we cannot measure the effects of these factors and must instead look at the organ system, the individual and the population (Mazees 1975).

In order to more fully understand the degeneration process, the following section describes the anatomy of bones and synovial joints.

## -----Anatomy of Degenerative Joint Disease-----

### Anatomy of Bone

Bones are composed of two components: compact cortical bone which comprises the exterior, and spongy cancellous bone on the interior. Within the body, the bone is covered by a thin layer of periosteum. Bones grow and develop through the actions of bone-forming osteoblast cells which line the bone just below this periosteal layer. Osteoblasts produce an osteoid matrix which develops into calcified bone. The osteoblasts transform themselves into osteocytes, cells which aid in bone maintenance by providing new bone tissue when needed (apposition). A third cell type, osteoclasts, also aid in bone maintenance by removing (resorption) damaged bone tissue (Ortner & Putschar 1981, Spence 1990, Steinbock 1976, White 1991).

As an organ tissue, bone is constantly responding to the stresses, strains, injuries and diseases which affect it. In this capacity, bone is limited to two types of response mechanisms. It can either be resorbed (osteoclastic) or laid down (osteocytic). These are also the response mechanisms responsible for normal bone growth and maintenance. Pathological conditions create an imbalance in the normal process of bone resorption and apposition. In degenerative joint disease, apposition outpaces resorption, and the bone expands into the joint cavity (Steinbock 1976).

By definition, degenerative joint disease affects only the synovial joints. Examples of synovial joints include the shoulder, the elbow, the hip, the knee, the fingers and toes. Although the vertebral joints themselves are not synovial joints (they lack a synovial membrane), the vertebral facets are synovial joints.

**Anatomy of Synovial Joints**

There are three types of joints in the human body: fibrous, cartilaginous, and synovial. Fibrous joints are not very moveable. They aid the skeleton in those areas where a high level of stability is needed. Cartilaginous joints are somewhat more moveable. These occur in areas where stability with some occasional movement is needed such as at the pubic symphysis. Synovial joints are the most moveable, and they function within the skeletal system to provide the organism with movement (Hollander 1966, Spence 1990).

In fibrous joints, bones are articulated by a fibrous connective tissue. Bones in cartilaginous joints are articulated with hyaline cartilage, to create articulations with a little more "give" than in fibrous joints. Unlike fibrous and cartilaginous joints where the cartilage serves to stabilize and restrict the movement of the bones being articulated, synovial joint movement is limited by ligaments, muscles, tendons, or adjoining bones, but not by cartilage. Synovial joints do include hyaline cartilage, but it is the unique arrangement and use of this cartilage which makes synovial joints moveable (Spence 1990).

In a synovial joint the bones are not directly connected by a cartilage strip, but are joined by cartilage to create a fluid-filled cavity (Figure 2.1). Hyaline cartilage, also called articular cartilage, lines the bone surfaces to be joined. The two opposing ends are encased in an articular capsule, a double-layered membrane that surrounds and encloses the joint. The inner layer of the articular capsule is called the synovial membrane. Within the articular capsule the bone ends do not touch, but a space is created between them which is filled with synovial fluid. The articular capsule creates joint flexibility, and synovial fluid nourishes the cartilage and lubricates the bone surfaces (Spence 1990).

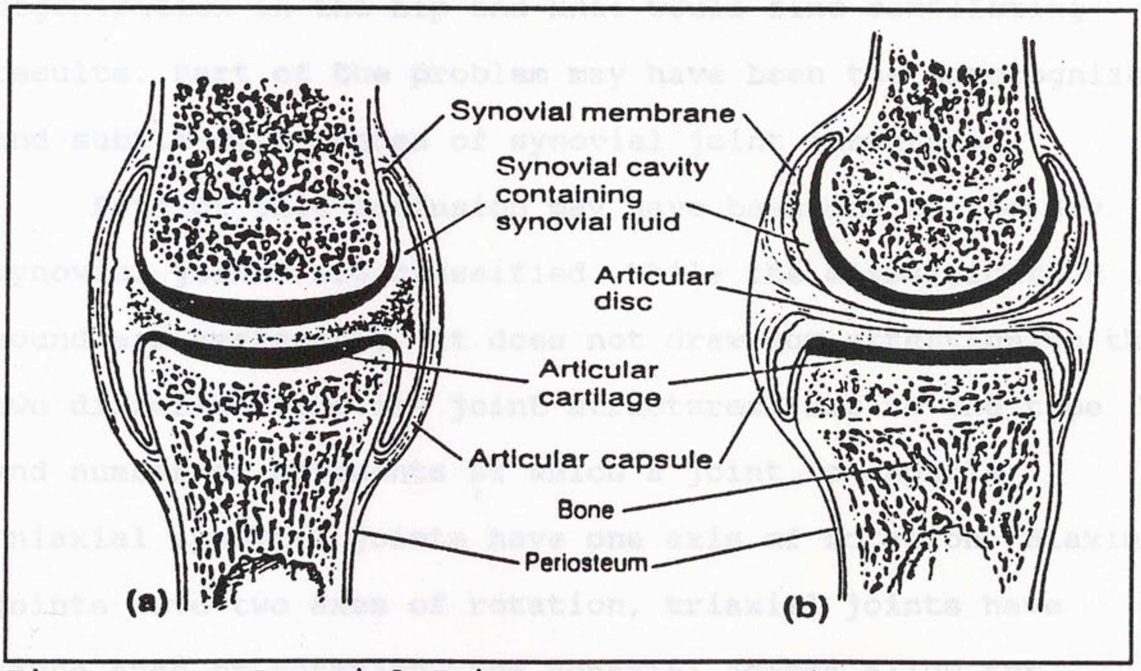



Figure 2.1: Synovial Joints (Spence 1990)

Although rarely mentioned in the literature, there are two types of synovial joints. The type described above and shown in Figure 2.1a, may be called a "true" synovial joint. It is the type most commonly referred to or thought of in joint research. Examples of this type of joint are the elbow and the hip. In the second type of synovial joint (Figure 2.1b), the joint capsule is divided, or partially divided, by a menisci (articulated disc) within the capsule. Examples of this type of synovial joint can be found in the sterno-clavicular joint, the radial-ulnar joint, and the knee joint (Spence 1990).

In early degenerative joint studies, researchers failed to take into account these anatomical differences and treated all synovial joints as being homogeneous. For example, a study which would attempt to identify causes of degeneration in the hip and knee would find conflicting results. Part of the problem may have been the unrecognized and subtle differences of synovial joint structure.

Part of this confusion may have been due to the way synovial joints are classified. While the classification is sound and systematic, it does not draw our attention to the two different synovial joint structures, but to the type and number of movements of which a joint is capable. Uniaxial synovial joints have one axis of rotation. Biaxial joints have two axes of rotation, triaxial joints have three axes of rotation, and nonaxial joints allow for movement in any direction. However, while both the knee and the ankle are uniaxial joints, the knee has a partial menisci which might affect its response to degeneration.

## Process of Joint Degeneration

Skeletally, osteoarthritis follows an identifiable pattern of degeneration (Figure 2.2). Initially, pitting appears on the surface of the articular cartilage and there is a decrease in the cartilage thickness. Simultaneously, cysts, appear in the subchondral bone. As the condition progresses, new bone forms along the surface undergoing stress. This new bone growth (lipping) expands into the cartilage, and, in the more severe stages, there is a complete erosion of the cartilage. The bones rub against each other and eburnation - a polishing of the bone surface - results. In very severe cases, grooves form on the bone surface parallel to the joint motion. (Hough and Sokoloff 1989, Johnson 1959, Steinbock 1976).

Problems in identifying degenerative joint disease arise because bone and cartilage have a limited number of ways in which to respond to stress. Many studies have addressed the issue of whether osteoarthritis begins in the cartilage or in the bone. Although Sokoloff (1966) states that the disorder can first appear in either the joint cartilage or the bone surface, theoretically he believes that pressure on the articular cartilage causes the cartilage to erode, thereby initiating the disease process.

On the other hand, Radin and collegues (1972) believe degeneration begins in the subchrondral bone. In the synovial joint, soft tissue and subchondral bone act as

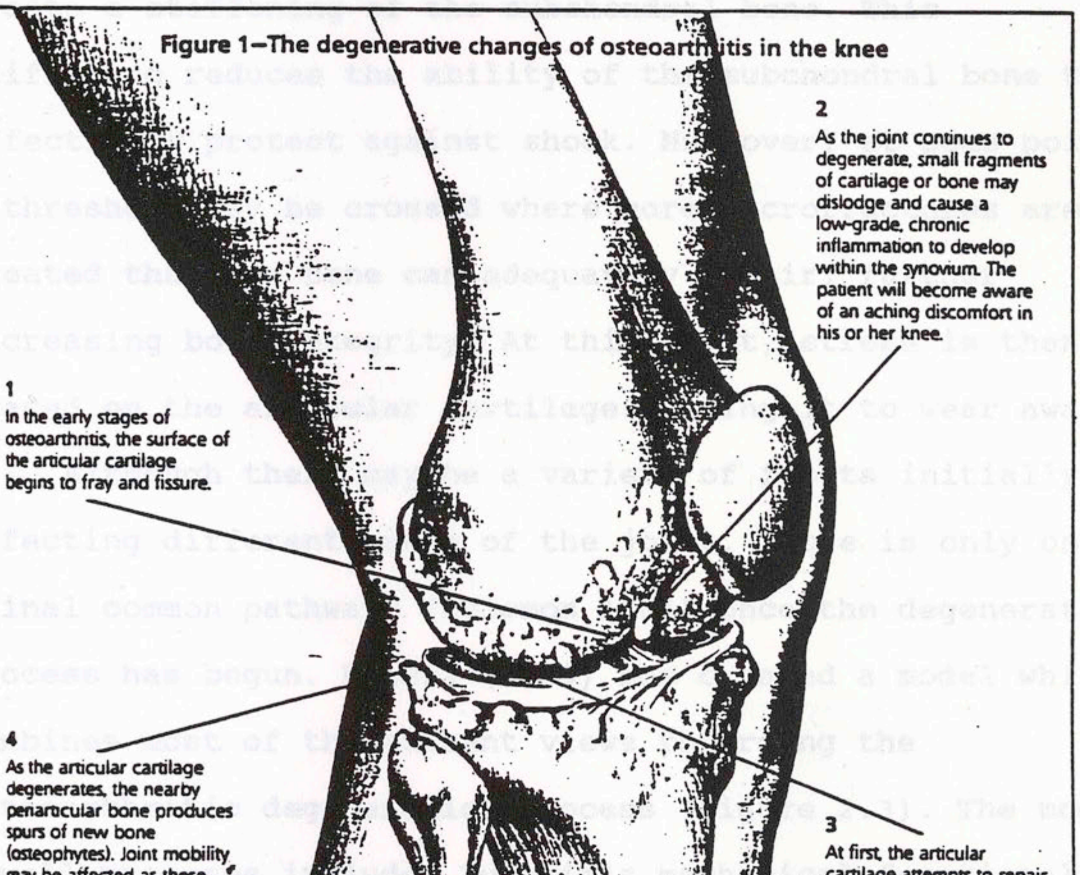



Figure 2.2: Degeneration in a Knee Joint (Hoaglund 1990)

shock absorbers against hyperflexion, hyperextension and heavy loading. These movements create microfractures in the subchondral bone which are then repaired. The repetition of these movements and their resulting fractures and repair, create a stiffening of the subchondral bone. This stiffening reduces the ability of the subchondral bone to effectively protect against shock. Moreover, at some point, a threshold may be crossed where more microfractures are created than the bone can adequately repair, further decreasing bone integrity. At this point, stress is then placed on the articular cartilage causing it to wear away.

Although there may be a variety of inputs initially affecting different parts of the joint, there is only one "final common pathway" (Solomon 1984) once the degeneration process has begun. Howell (1989) has created a model which combines most of the current views regarding the osteoarthritic degeneration process (Figure 2.3). The model Howell proposes includes Jurmain's mechanical-functional factors, along with Radin's microtraumas, on the left side of the diagram. Jurmain's predispositional factors are on the right.

These two groups of causative factors take into account two possible scenarios: either the cartilage is normal and receives some form of abnormal stress (functional-mechanical factors), or the cartilage is abnormal (predispositional factors) and breaks down even

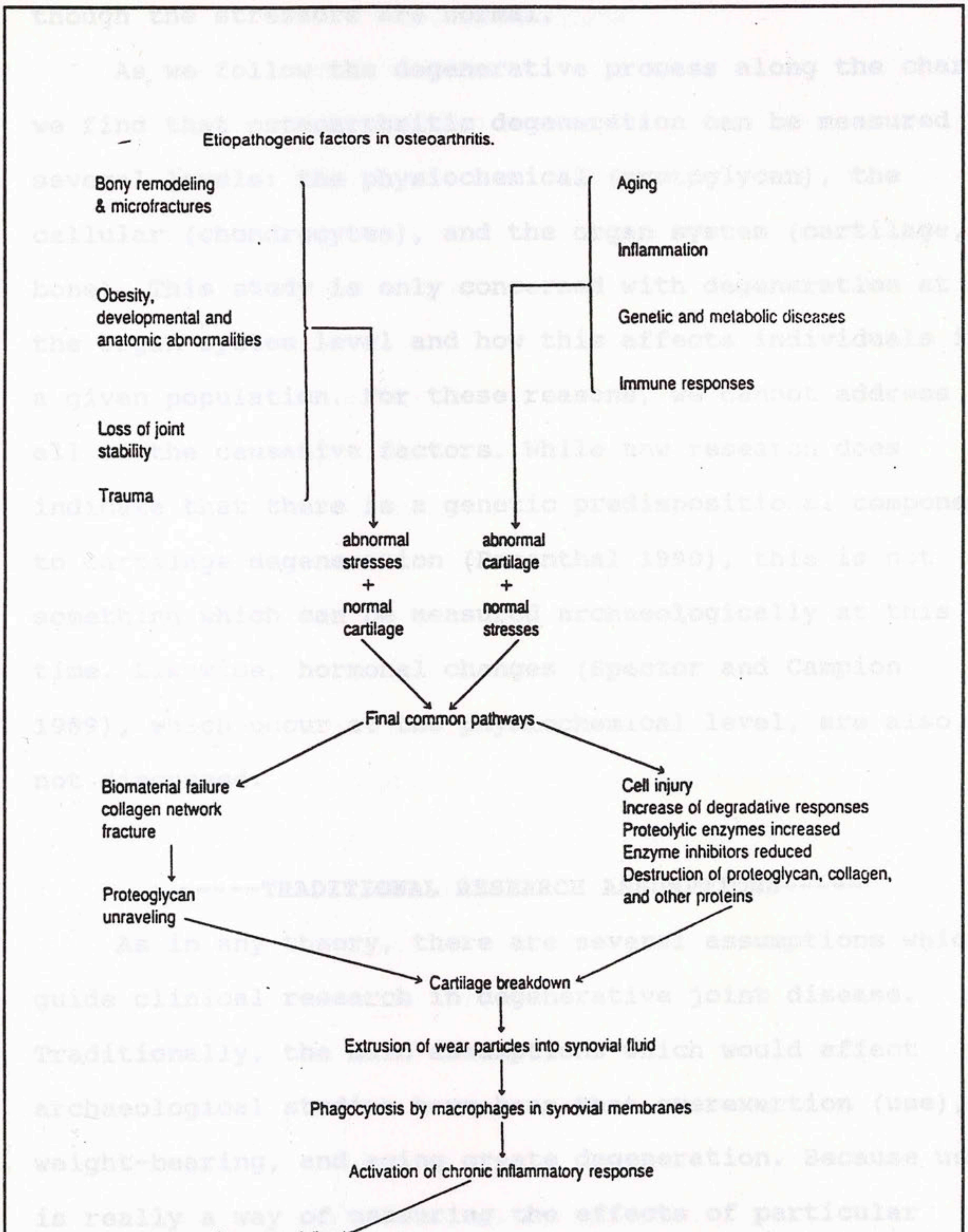


Figure 2.3: Osteoarthritic Process (Howell 1989)

though the stressors are normal.

As we follow the degenerative process along the chart, we find that osteoarthritic degeneration can be measured at several levels: the physiochemical (protoglycan), the cellular (chondrocytes), and the organ system (cartilage, bone). This study is only concerned with degeneration at the organ system level and how this affects individuals in a given population. For these reasons, we cannot address all of the causative factors. While new research does indicate that there is a genetic predispositional component to cartilage degeneration (Rosenthal 1990), this is not something which can be measured archaeologically at this time. Likewise, hormonal changes (Spector and Campion 1989), which occur at the physiochemical level, are also not discussed.

**-----TRADITIONAL RESEARCH ASSUMPTIONS-----**

As in any theory, there are several assumptions which guide clinical research in degenerative joint disease. Traditionally, the main assumptions which would affect archaeological studies have been that overexertion (use), weight-bearing, and aging create degeneration. Because use is really a way of measuring the effects of particular activities, this review focuses on three factors associated with joint degeneration: 1)weight-bearing, 2)activity patterns, and 3)the aging process.

**Weight-Bearing**

Many traditional degenerative joint disease studies were based on the assumption that weight-bearing joints (hip, knee, and ankle) are more likely to be affected by degeneration than non-weight-bearing joints (Anderson & Felson 1988, Bullough, Goodfellow & O'Connor 1973, Kellgren 1961, Murray-Leslie et al. 1977). Their premise was that weight creates stress on the joints that will eventually lead to degeneration. Associated with this assumption is the idea that obesity would create even higher levels of stress and that, therefore, one would expect to find a correlation between obesity and joint degeneration.

Gofton (1971) dismissed such assumptions, claiming that the evidence was circumstantial. In a study done to support this claim, Gofton documented two varieties of hip degeneration. That which ocurred in the superolateral area of the joint was primarily unilateral, while patients suffering from degeneration in the medial area of the joint usually had degeneration in both joints. Clearly, obesity could not be a factor in unilateral joint degeneration, and for this reason, Gofton believed that other factors should be considered.

Kelgren and Lawrence (1958) reported a high association of obesity and knee degeneration in women. However, the association in men was not as significant. Spector and Campion (1989) attributed this difference in association to hormonal imbalances, particularly in estrogen. Apparently, high levels of estrogen predispose women to joint degeneration, thus explaining their higher levels of knee degeneration.

Interestingly enough, the same study by Kelgren and Lawrence (1958) found no correlation of obesity with hip degeneration. Likewise, the ankle is one of the joints least likely to be affected by degeneration (Blotzer 1984, Moskowitz 1967, Norkin & LeVangie 1983, Stauffer 1977). Other studies (Ortner 1968, Moskowitz 1967) have found that the elbow and fingers, both non-weight-bearing joints, are more highly affected by degeneration than any of the weight-bearing joints.

It may be that researchers have assumed weight-bearing to be stressful on the joints without understanding the biomechanics of specific joints. For example, the ankle is structurally designed to bear great amounts of stress caused from weight (Norkin & LeVangie 1983, Stauffer 1977). Before we can assume weight or obesity to be causative factors of joint degeneration, we need to know the biomechanical point where the joint's structural load limit is surpassed, and/or the point where permanent realignment of the bone structure occurs.

## Activity-Use

A better understanding of joint biomechanics might also help assumptions of degenerative joint disease based on activity-use. This category of causative factors relates to the specific activities one does with the joints. To understand how these activities affect the joints, researchers have looked primarily at the amount of joint use an activity involves. They are also beginning to realize that they need to understand the range of joint motion an activity requires.

## Range of Motion

Each joint has a normal range of motion; the distance for which it can be flexed, extended, rotated, etc. Any activity which extends the joint beyond this normal range of motion may lead to degeneration. This may happen because those areas of the joint beyond the normal range of motion are not adequately designed for consistent, repetitive, activity-use. This may be because 1)the bones are not properly aligned and therefore cannot support these structural changes, 2)the bones are not properly aligned and the cartilaginous surfaces actually come into contact where they rub against each other and erode, or 3)the cartilage in these extreme areas is not adequately lubricated and nourished when forced beyond the normal range of motion (Goodfellow and Bullough 1967).

Since movement, within the normal range of motion, is necessary for cartilage maintenance (Bullough, Goodfellow and O'Connor 1973, Goodfellow and Bullough 1967), Stulberg and Keller (1984) concluded that exercise (overuse) does not cause degeneration, but that it actually prevents degeneration. It would appear that compression and motion are good for cartilage; excessive compression and immobilization are detrimental (Albright 1983).

## Use vs. Overuse vs. Disuse

The idea that it is the range of a joint's motion which may trigger degeneration has arisen from studies which were initially concerned with joint use. Researchers believed that the constant, repetitive overuse of joints would lead to degeneration. In these studies, overuse did not mean that the joint was pushed beyond its normal range of motion; it meant that the joint was used too much.

In the case of the ankle joint, this belief led to studies involving ballet dancers (Andersson et al. 1989), soccer players (Klunder et al. 1980), parachutists (Murray-Leslie 1977), and other occupations which were seen as creating a high stress load on the joint. However, the results fluctuated and were often contradictory.

Looking at the data, a pattern does emerge. For example, Andersson et al. (1989) anticipated that professional ballet dancers would have a higher level of ankle degeneration than non-ballet dancers. While the professional ballet dancers did experience higher rates of degeneration, it did not appear while they were active dancers, but only occurred once they had retired, and heavy demands were no longer being placed on the joint. It would seem that the disuse of a joint is more of a causative factor than its use.

Looking at this evidence with the range of motion concept, the ankle joint of a practicing ballet dancer may have adapted itself to extreme ranges of motion while the dancer was a growing child. Once he or she stopped dancing, the ankle would only be used for "normal" ranges of motion; a range of motion for which the ballet dancer's joint may have been ill-suited.

Likewise, it was anticipated that parachutists (Murray-Leslie et al. 1977) would have higher levels of ankle degeneration. But this was not the case. First, parachuting does not place the ankle outside of its normal range of motion, and second, it is clear that the structural integrity of the ankle joint can withstand the compressive forces associated with parachuting.

## Aging

The conclusions in studies where degeneration begins only after the activity has ceased have a confounding causative factor - age. It has been accepted by researchers that degeneration will naturally occur as one ages (e.g. Peyron 1986). While this may be true, one must distinguish between degeneration which is part of the normal growth and development process, and degeneration which is related to any of the other causative factors (Moskowitz et al. 1967).

In the ballet study conducted by Andersson et al. (1989), the age association may be with retirement and not joint degeneration. It was retirement which led to disuse of the joint which, in turn, led to degeneration of the joints. In none of the dancers studied did they retire because of joint degeneration. If they had stopped dancing at an earlier age, their degeneration might have also begun at an earlier age.

Based on his studies of the articular cartilage and the articular bone surface, Sokoloff initially stated that the primary cause of degenerative joint disease was biological aging and the decrease in the ability of the cartilage to repair itself (Sokoloff 1966). Degenerative joint disease research in this tradition attempts to find a physiochemical cause for cartilage breakdown (e.g. Fassbender 1987, Hall 1983) However, even at this level, research has shown that age itself is not the causative factor, but, as Ettinger says, "[t]he increased prevalence of osteoarthritis in the elderly is thus due to prolonged exposure....(1984:811)."

It would appear that time, rather than age, should more accurately be considered a factor in joint degeneration. Although a large percentage of elderly people do suffer from joint degeneration, not **all** elderly people do, **and** not all arthritis sufferers are elderly. The age of onset for joint degeneration varies so greatly that Stewart (1958) had to reject degenerative changes in the joints as a skeletal predictor of age in archaeological/cadaver populations.

Until this issue is resolved, researchers might want to consider time ("prolonged exposure") rather than age as a contributing factor to degeneration. They should also consider time in connection with other predispositional factors such as genetic factors, hormonal factors, and biomechanical factors (Moskowitz 1967). In this study, biomechanical factors (i.e., joint function, range of motion and amount of use) are being considered through the activity-use of specific joints.

**-----CLINICAL STUDIES-----**

Clinical Studies of joint degeneration can be classified into three types: population based, activity based, and joint based. Joint based studies tend to focus on one joint and the potential causative factors for degeneration at that joint. Activity based studies examine the osteoarthritic pattern caused by a specific activity. These types of studies usually look at the effect of a specific activity on one particular joint, but some studies have attempted to look at the resultant overall joint patterning. Population based studies compare specific populations. They may be comparative joint studies (i.e., knees in blacks vs. whites) or comparative activity studies (i.e., black vs. white farmers).

In order to understand the relationship between activity-induced stress and patterns of osteoarthritic joint involvement, only those studies or portions of studies relating to activity correlated with joint degeneration will be discussed.

<u>Population Based Studies</u>

Two of the earliest researchers to look at activity and joint degeneration were Kellgren and Lawrence. In 1958 they studied an urban population in order to determine the overall prevalence of joint degeneration. Based on clinical examinations and X-rays, they found that the distal-interphalangeal joint and the proximal-interphalangeal joint of the hands, the knee joint, the cervical and lumbar joints of the spine, the joints of the feet, and the hip joint had a higher prevalence of joint degeneration than the wrist, elbow, shoulder, or ankle. They could not find an adequate explanation for these observations.

After this study, Kellgren and Lawrence continued to work independently on more focused studies of joint degeneration and occupation. As part of a larger study, Kellgren (1961) compared joint degeneration in males to females. He found females to be more highly affected in the extremities (i.e., hands, knees, ankles, and feet), while men were more highly affected in the trunk (i.e., spine, hips, and disks). He attributed the pattern of the women to diet and "inherited constitutional factors (1961:6)." The pattern for males was attributed to occupational stress and trauma.

Working on the assumption that climate had some connection to joint degeneration, Bremner et al. (1968) conducted a population based study comparing Jamaicans to Englishmen. They found that Jamaicans, in comparison to the English population, had a higher prevalence of cervical joint degeneration, a higher prevalence of joint degeneration in the knee, and a decreased prevalence of degeneration in the metatarsophalangeal joints. They attributed these prevalence rates to the Jamaican practices of carrying things on their head, walking on rough footpaths, and not wearing shoes. Interestingly enough, they drew no conclusions between joint degeneration and climate.

Activity Based Studies

Prior to the 1958 study with Kellgren, Lawrence (1955) conducted an activity based study of coal miners. He found they had a high prevalence of degeneration in the knee and elbow joints. Lawrence (1961) also found cotton workers (industrial weavers) to have a high prevalence of degeneration in the finger joints. He attributed this prevalence to the repetitive movements required of the fingers, and to the fact that their fingers were constantly banged against the weaving equipment (i.e., frames, bobbins, etc.).

Kellgren (1961) also conducted an activity based study comparing the lumbar region of the spine and the knee joints between miners, manual workers and office clerks. He found the miners to be more affected by joint degeneration than either the manual workers or the office clerks. Kellgren (1961) then looked specifically at the different types of mining jobs. He found that lifting was more likely to cause knee degeneration than stooping was to cause lower back degeneration.

In the tradition of Kellgren and Lawrence, Engel and Burch (1966) found a high prevalence of degeneration in the hand joints of craftsmen, and a low prevalence of degeneration in the hand joints of clerical workers. In a 1968 activity based study by Partridge et al., dockers were found to have a high prevalence of joint degeneration in the finger, elbow, and knee joints.

A study of pneumatic drill operators by Burke et al. (1977) found no significant association between degeneration of the elbow joint and occupation. Likewise, Eastmond et al. (1979) found no significant prevalence increase in degeneration of the knee joints among physical education teachers.

While a study by Klunder et al. (1980) found no association between degeneration in the knee joint and playing professional soccer, they did find that soccer players had an increased prevalence of degeneration in the hip joint. Two studies of runners (Lane et al. 1986, Puranen et al. 1975) found no significant indication that degeneration of the knee or hip joints could be associated with running.

## Joint Based Studies

Of the three types of clinical studies, there have been far fewer joint based studies of degenerative joint disease. This may be because this type of study is primarily descriptive and ill-designed to offer explanations for observed patterns of degeneration.

A 1970 study by Acheson et al. found the right hand to be more highly affected by joint degeneration than the left hand. Anderson and Felson (1988) attributed a high prevalence of degeneration in the knee to job-related knee bending, but did not look at specific occupations. Gunn (1973) found a low prevalence of degeneration in the hip joint of an Asian population.

## -----ANTHROPOLOGICAL STUDIES-----

There are two types of anthropological studies which deal with degenerative joint disease: descriptive and integrative (Pickering 1984). Descriptive studies, which are the predominant type, either list the occurrence of arthritis or describe extremely severe cases with no explanation as to their cause (e.g. Brues 1958, 1959, Buikstra 1971, Harn 1971, Kelley 1979). Integrative studies look at the "dynamic relationship between disease, human biology, and society" (Pickering 1984:41). These studies attempt to use the biocultural approach, linking cultural activities with biological joint degeneration.

### Early Skeletal Studies

Following the clinical tradition, Jurmain (1977) attempted to explain the causes of degenerative joint disease using an archaeological population. In his comparative study, Jurmain examined the knee, hip, and shoulder joints of four skeletal populations: American Blacks, American Whites, Pecos Indians, and Alaskan Eskimo. He found that the Eskimo were affected at an earlier age than any other group, and that they also had more severe degeneration than the other groups. Blacks were more affected in the knee, shoulder and elbow than Whites; and Pecos Indians were the least affected population. He attributed the differences between the Eskimo and the Pecos

Indians to differences in subsistence strategies; the Eskimo having a more "stressful" lifestyle than that of the Pecos Indians. He did not discuss specific cultural activities of either group.

While Jurmain was interested in the causes of joint degeneration, Ortner (1968) studied the elbow joint in two skeletal populations (one of Alaskan Eskimo and one of Peruvian Indians) in order to describe the process of degeneration. He chose to study only the elbow because it is a non-weight-bearing joint. Any degeneration, he reasoned, would be due to use-related activities such as handedness, strength, and activities involving the elbow joint. Specifically, he hypothesized that the spear-throwing activities of the Eskimo would create a different degeneration pattern than that of the Peruvians who used the bow and arrow.

In his study, Ortner considered the biomechanical functions of the joint as they relate to potential degeneration. He found four factors which would affect (although not necessarily cause) degeneration of the elbow: 1)the degree of motion to which the joint was exposed, 2)the efficiency of the joint to dissipate stress, 3)the duration of the stress to which the joint was exposed, and 4)the frequency with which the joint was exposed to the stressor.

Ortner found the Eskimo to have a higher prevalence of elbow degeneration than the Peruvians. He also observed the Eskimo elbow degeneration to be more severe on the right side; a fact he attributed to "atlatl elbow." Because his focus was more on documenting the observed degenerative changes of the elbow, Ortner did not discuss the biomechanics of spear-throwing or bow and arrow hunting.

## The Sadlermiut Eskimo

Merbs (1983) was one of the first anthropologists to attempt to systematically test his research hypotheses connecting degenerative joint disease to specific activities through the use of both ethnographic data and skeletal observations. Merbs observed patterns of degenerative joint disease in the Sadlermiut Eskimo skeletal population and then compared them to the known activities of this group.

After observing degeneration in the Sadlermiut skeletal population, Merbs (1983) made the following generalizations:
1) Sadlermiut males were affected more frequently and with greater intensity than females, 2) the right side was affected more than the left, and 3) the upper limb was affected more than the lower.

Based on the biomechanics involved in particular movements, Merbs was able to correlate some patterns of degeneration with specific activities. For example, in males, the combination of degeneration of the acromioclavicular joint, the olecranon fossa, and the right radial fossa was attributed to right-handed harpoon throwing. In females, degeneration of the trochlear joint of the elbow was attributed to scraping movements. Other patterns of degeneration were the results of kayak paddling, sewing and cutting. Merbs' determined that

> The activities which are most conducive to joint degeneration appear to be those which place normal stress upon cartilage for abnormally long periods of time, and those which place abnormal stress upon a joint, even for a brief period of time. (Merbs 1983: 159)

His assessment supports the earlier discussion of the traditional assumptions in degenerative joint disease research. It is not necessarily obesity, or age, or simple wear and tear which causes the joints to degenerate. Rather, he connected degeneration to normal joint stress which occurs for a long duration or frequency, and to abnormal joint stress which can occur for any length of time.

## The Illinois River Valley

Pickering's study of degenerative joint disease in the Illinois River Valley (1984) used a research approach similar to Merbs'. Rather than look at one population, as Merbs had done, Pickering (1984) compared the patterns of degenerative change in populations representing different subsistence strategies. Pickering used several sites from the Illinois River Valley area. The sites were grouped into three time periods:

1) Middle Woodland 100-400 AD (foraging);
2) Late Woodland 400-1000AD (transitional); and
3) Mississippian 1000-1200AD (agricultural).

Pickering chose six test hypothesis based on the expected outcomes regarding the association between activity-use and joint degeneration. These expected outcomes were based on previous studies and/or the untested assumptions of other researchers, both clinical and archaeological. Pickering's hypotheses were as follows:

1) Individuals having relatively small joints for their stature are going to have more evidence of degenerative joint disease than those with relatively large joints.
2) Age at onset of degenerative change will be earlier for females than for males.
3) Females are likely to have more severe degenerative change than males of the same age group.
4) In the Middle Woodland and early Late Woodland periods, severity scores of males are expected to be more asymmetrical than those of females in the same periods.

4a) During the Late Woodland and Mississippian periods, patterns of degenerative change in males and females should approximate symmetry.

5) Females of the late Late Woodland and Mississippian periods will evidence greater degenerative change in the upper spine than will females of the Middle Woodland and early Late Woodland.
6) Patterns of degenerative joint disease will vary more greatly between females representing the early periods (Middle Woodland and early Late Woodland) versus late periods (late Late Woodland and Mississippian) than between males representing early versus late periods (1984:126-130).

The first hypothesis stemmed from the assessment of the degeneration process made by Radin et al. (1972). If stress is measured as the force per unit area, a small joint will have less area in which to dissipate the stress, and will therefore be more susceptible to degeneration. Hypothesis 2 was based on the assumption that women were performing more "stressful" activities than men. Hypothesis 3 pertained to the impact of duration and frequency on degenerative joint changes. If females developed arthritis earlier, it would have a longer time to develop, and thus would become more severe than in males.

Hypotheses 4 and 4a were connected to expected activities. If males were throwing an atlatl, an asymmetrical pattern of joint degeneration would be expected. Using a bow and arrow would create stress on both arms. Hypothesis 5 was based on the assumption that the type of activities females were doing changed as subsistence strategies changed, and that horticulture placed greater stress on the upper back. According to the assumption of hypothesis 6, changing subsistence strategies would not only alter the joints affected, but would also alter the severity of the degeneration as well.

In conclusion, Pickering was unable to find any correlation between activity-use and degenerative joint disease in the populations he studied. Except for hypothesis number 5, each hypothesis was rejected. Because the severity scores of males did not change with changes in subsistence patterns (hypotheses 4 and 4a), Pickering concluded

> Since male severity scores are not changing, it is necessary to examine more closely the central assumptions concerning the use of hunting tools such as the atlatl and bow and arrow. (Pickering 1984:161)

The remaining hypotheses were rejected because of problems with sample size and/or sampling technique. For this reason, it is possible that the assumptions behind these hypothesis are still relevant.

**Northeastern Alabama**

Bridges (1991) also worked on issues of degeneration and activity-use using skeletal material from northeastern Alabama. She compared an Archaic foraging population (6000-1000 BC) to a Mississippian horticultural population (1200-1500 AD). Rather than test generalized hypotheses as Pickering had done, Bridges, like Merbs (1983), was more interested in correlating specific activities with joint degeneration.

Overall, Bridges found a high prevalence of degeneration in the shoulder, elbow and knee, and lower prevalences in the hip and ankle. Within the foraging population there was a fairly equal prevalence between males and females. Within the agricultural population she found males to have more severe degeneration than females.

The foraging population had a higher prevalence of degeneration over the agriculturists, but the difference was not statistically significant (Bridges 1991).

Bridges' study also found mixed results when comparing patterns of degeneration to specific activities. The high prevalence of degeneration in foraging females was attributed to the stress of processing collected nuts. Not only are nuts harder to process than corn, but the methods and materials used to process these foods also differed. The foraging population ground the nuts using a stone mano and metate, while the agriculturists ground corn using a wooden mortar and pestle. These involved two different types of biomechanical activities, and stone-grinding would have had a greater negative effect on the joints (Bridges 1991).

Bridges' data for elbow and shoulder degeneration in males shows no significant change in prevalence or in severity between foraging and agricultural populations. Her data, like Pickering's, does not support the assumption that "hunting techniques were a major cause of arthritis in these groups (1991:389)." Bridges reasoned that hunting, either with an atlatl or bow and arrow, was an infrequent activity of short duration (unlike nut or corn processing), and thus did not contribute to degenerative change.

In the final analysis, Bridges could not find a direct connection between the overall patterns of degeneration and changing subsistence strategies. Prevalence of osteoarthritis did not increase, as expected, with the change from foraging to agricultural patterns. Nor did it decrease. Rather, it remained the same, indicating that other factors need to be considered. For future research, Bridges suggested that the connection between cortical bone strength and degeneration should be examined.

The conflicting results of anthropological studies undertaken by Merbs (1983), Pickering (1984), and Bridges (1991) indicate that osteoarthritis may or may not be a result of activity-induced stress based on subsistence strategy. Merbs' (1983) study had a higher correlation between activity-use and joint degeneration than the studies by Pickering and Bridges for at least two reasons.

First, Merbs was not looking at subsistence strategy, but at specific activities and their biological impact. Second, Merbs had an ethnological advantage over Pickering and Bridges. Merbs was able to correlate specific activities with specific areas of joint degeneration based on ethnohistorical documentation of the skeletal population he studied, and based on observations he made of current Eskimo populations in the same area. Pickering and Bridges had only archaeological remains, a generalized idea of possible activities, and an overarching concept of subsistence strategy.

-----Conclusion-----

This chapter has discussed current trends, both clinical and archaeological, in the study of degenerative joint disease. Clinically, it is known that a correlation exists between activity-use and joint degeneration. In examining archaeological populations, these patterns are harder to ascertain. Archaeological studies have no control over sample size and preservation, and, except in the rare instance, activity-use can only be inferred from speculative tool identifications and leaps of faith into the ethnographic present.

In the next chapter, this archaeological leap regarding the inference of activity patterns is made.

## CHAPTER THREE

## PREHISTORIC SUBSISTENCE STRATEGIES & ACTIVITY PATTERNS IN EASTERN OKLAHOMA

This research study is based on skeletal material from the Moore site (Lf-31) in LeFlore County, Oklahoma. A determination of the subsistence mode of this population is based on the archaeological record of this area. The goal of this chapter is to place the study site in proper archaeological context, and to identify specific subsistence-related behaviors which may have affected joint degeneration.

### -----Area Synthesis-----

An understanding of the cultural chronology for the Arkansas River Basin area is necessary to differentiate between foraging, horticultural and agricultural subsistence strategies. Basically, there are five interpretations of this sequence: Wyckoff (1980), Galm (1981), Rohrbaugh (1982), Bell (1984), and the OAO Study Group (Sabo et al. 1990). While these interpretations overlap in many areas, there are key differences which will affect the interpretation of potential subsistence strategy identifications. This section provides a brief summary of the various cultural chronologies for the area and defines the cultural components for this sequence. Figure 3.1 shows the area under discussion.

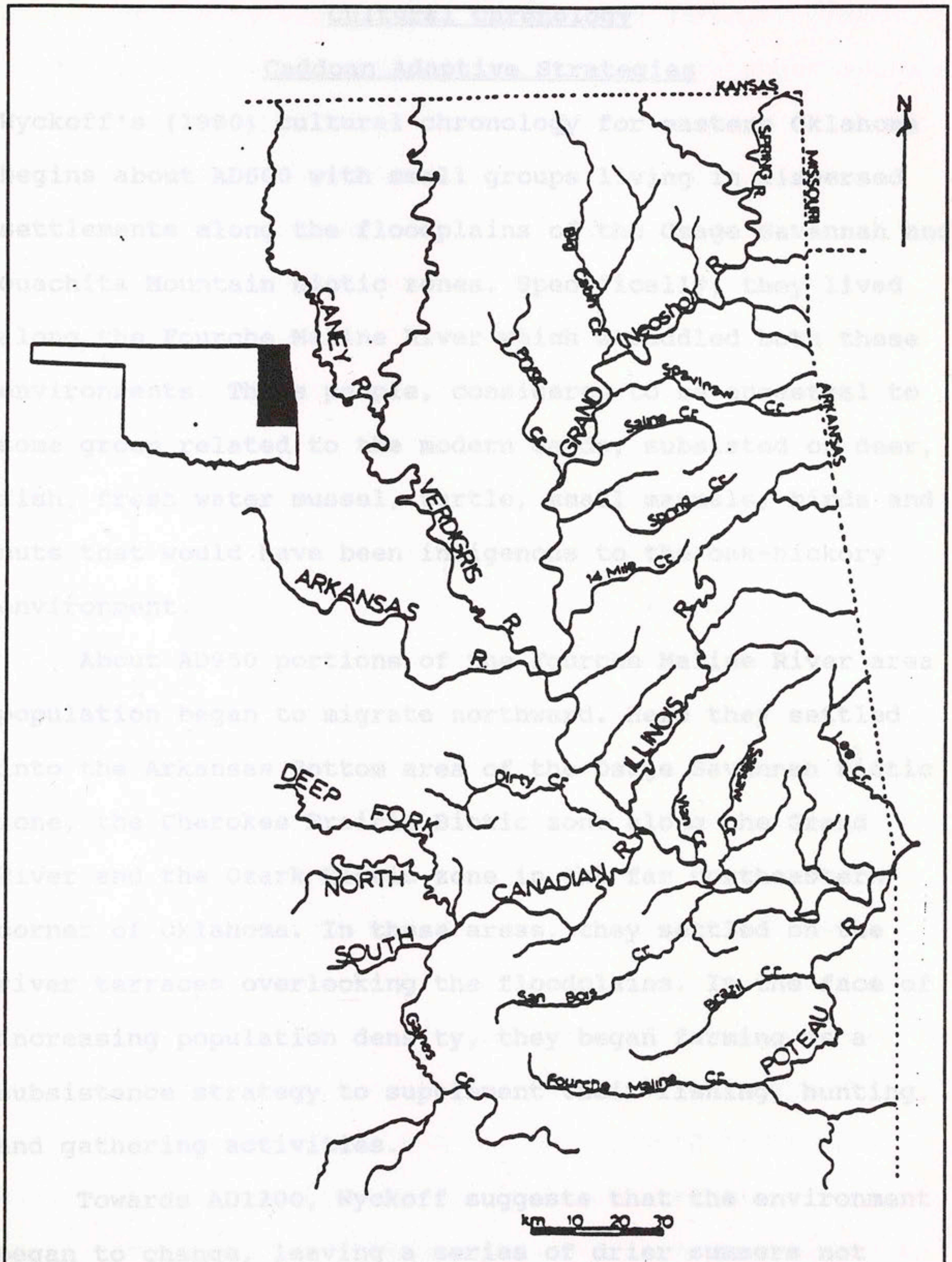



Figure 3.1: Eastern Oklahoma Study Area (Wyckoff 1980)

## Cultural Chronology

### Caddoan Adaptive Strategies

Wyckoff's (1980) cultural chronology for eastern Oklahoma begins about AD600 with small groups living in dispersed settlements along the floodplains of the Osage Savannah and Ouachita Mountain biotic zones. Specifically, they lived along the Fourche Maline River which straddled both these environments. These people, considered to be ancestral to some group related to the modern Caddo, subsisted on deer, fish, fresh water mussel, turtle, small mammals, birds and nuts that would have been indigenous to the oak-hickory environment.

About AD950 portions of the Fourche Maline River area population began to migrate northward. Here they settled into the Arkansas Bottom area of the Osage Savannah Biotic zone, the Cherokee Prairie Biotic zone along the Grand River and the Ozark Biotic zone in the far northeastern corner of Oklahoma. In these areas, they settled on the river terraces overlooking the floodplains. In the face of increasing population density, they began farming as a subsistence strategy to supplement their fishing, hunting, and gathering activities.

Towards AD1200, Wyckoff suggests that the environment began to change, leaving a series of drier summers not conducive to horticulture. This drying trend continued for several hundred years, moving west to east across the state. Around AD1200, as the western and northern areas began to dry, settlements in these areas were abandoned and the population contracted inward to the Arkansas River Bottoms. Wyckoff suggests that the abandoned areas were used as hunting grounds.

While the population was condensing in one area, it was increasing along the Arkansas River Bottom region, causing the population density to rise. To sustain this increasing population, horticultural activity increased, and a hierarchical social structure, which had started to form prior to this time, developed to accommodate the increasing complexity of the situation. Archaeologically, this system is represented by the many ceremonial centers found in the area.

As the drying trend continued, and moved east into the Arkansas River Basin, the social hierarchy, which could no longer be supported by the population base, collapsed and people once again returned to small settlements located primarily along the Arkansas River south of the Canadian River confluence. These environmental and social changes had many repercussions on the subsistence strategy. While the environment had been wet and moist, conditions were favorable for deer hunting and horticulture. The drying trend created an environment more favorable to bison, and as such, the population shifted to bison hunting. This switch required seasonal migrations in search of the bison, followed by semi-sedentary summers focused on farming. This new lifestyle, according to Wyckoff, resembled that of the plains groups further west.

Wister Valley Adaptations

While Wyckoff dealt with the entire eastern portion of Oklahoma, Galm's work (1984, 1981) emphasized only the Wister Valley (ie., Fourche Maline and Poteau Rivers). He also began his time sequence much earlier (1500BC vs. AD650).

Initially, Galm described the population as living in semipermanent base camps along the Fourche Maline and Poteau rivers. These populations fished, hunted, and gathered; sustaining themselves on nuts, deer, small game, mussels, and fish. Over time, Galm suggests that two important things happened. First, the population increased; and second, dependence on aquatic resources decreased. As the population increased, it shifted out of the Wister Valley and moved northward to the Arkansas River Bottom area.

This sequence follows exactly as the previous one presented by Wyckoff. However, while Wyckoff followed the population northward and focused on its development in the Arkansas River area, Galm continued to focus on the Wister Valley area for which a different developmental sequence is outlined.

Basically, the populations of the Wister Valley remained in a foraging subsistence mode with a decreased emphasis on fishing. Unlike their contemporaries to the north, they did not develop any type of horticultural subsistence pattern. However, they were affected by the drying environmental conditions, and around AD1400 people in the Wister Valley also switched to a plains-like bison hunting mode.

### Arkansas Valley Caddo

Bell (1984) focused on the Arkansas River Valley area between AD900-1200. During this time period, Wyckoff described the population as first arriving in the area, beginning small-scale horticulture and developing the rudiments of a social hierarchy. Bell, on the other hand, depicts the population as a highly stratified society participating in large scale agriculture in order to support the highly specialized ceremonial elite. Bell also suggests, based on house style changes, that societal changes may have been due to a population intruding into an already settled area, and not to a movement into an unoccupied area as claimed by Wyckoff.

### Cultural Complexes of the Caddo

Rohrbaugh (1984, 1982) focused on population development of the Arkansas River Valley at the end of the cultural time sequence, from about AD1200-1600. Much of his discussion supports Wyckoff's analysis. The early part of his sequence (about AD1200) is characterized by a seasonal mobility pattern supplementing slash and burn corn horticulture with deer hunting. Over time, this pattern was transformed into corn, sunflower and squash horticulture with bison hunting predominating over deer hunting.

The main difference with Rohrbaugh's analysis has to do with his more restricted understanding of the geographical boundaries constituting the Spiro region (Figure 3.2). While this definition has little effect on our understanding of the general cultural chronology for the area, it has a major effect on site placement issues, and the interpretation of possible subsistence strategies regarding the study site. This issue will be discussed in more detail later in this chapter.

## Ozark and Ouachita Mountain Adaptation

The final synthesis of the cultural chronology for this area comes from the Arkansas Archaeological Survey (Sabo et al. 1990). While this consortium draws heavily from Wyckoff, they offer some unique interpretations based primarily on their reliance upon secondary materials, specialized samples, and/or small sample sizes.

The OAO group describes a prehistoric cultural sequence for eastern Oklahoma fairly identical to those already discussed. However, while they note an increase in bison tools during the later periods, they do not identify them as hoes. In general, the OAO group recognizes that domesticated plants were used in the study area, but they do not believe that large-scale agriculture or intensive horticulture were ever practiced by these prehistoric populations.

## Time Sequence

Each of the cultural chronologies described above is based on a particular time sequence. Wyckoff's chronology divides time into four cultural periods: Caddo I-IV (1980). Brown (1984) uses a system in which the McKern Taxonomic System was modified into the Willey and Phillips system of phases. The phases recognized were Wister, Fourche Maline, Evans, Harlan, Spiro and Fort Coffee. However, in his modified system, Brown omitted the Evans phase and used only Wister, Fourche Maline, Harlan, Spiro and Fort Coffee. Galm (1981), and the OAO Study Group (Sabo et al. 1990) use the same sequence as Brown, also omitting the Evans phase. Rohrbaugh (1982) uses this same sequence, but he claims that many materials originally described as belonging to the original Fort Coffee focus should be placed in the new Spiro phase.

All the cultural chronologies are listed in Table 3.1 The discrepancies between the systems occur not in the time sequencing, but in the diagnostic characteristics of the phases and the placement of particular sites in a given phase. This report uses the dates and terminology of Galm and the OAO Study Group, while taking into account the diagnostic criteria of each researcher.

## Phase Diagnostics

Archaeologists have relied on such things as site types, house sizes, and artifact assemblages when establishing their cultural chronologies and time sequences. In dividing the eastern Oklahoma cultural sequence into subunits, most researchers have relied primarily on arrow points and ceramic typologies supplemented by various other criteria, depending on the refinement needed. This section discusses the diagnostic traits for each phase and the archaeological evidence each researcher has used to support his interpretation of the archaeological record.

### Wister Phase (1500 - 300 BC)

The Archaic period of eastern Oklahoma's prehistory is represented by the Wister phase. During this phase, sites are found along the Fourche Maline and Poteau rivers. Site patterns suggest that the population lived in dispersed, semi-permanent settlements along these streams (Galm 1981, Wyckoff 1980). Atlatls, points, chipped and ground stone artifacts suggest a foraging subsistence strategy of fishing, nut gathering, and deer hunting. Copper and marine shell artifacts suggest long distance trade with other groups in the lower Mississippi region, but there is no evidence for trade or other interaction with peoples associated with the Hopewellian culture of the northeastern United States (Galm 1984).

Fourche Maline Phase (300BC - AD800)

The Fourche Maline phase is similar to the Wister phase. It is distinguished archaeologically by the introduction of ceramics into the material culture. Two types of pottery are found during this phase: Williams Plain and LeFlore Plain.

Harlan Phase (AD800 - 1200)

During the Harlan phase, portions of the population moved north and settled along the floodplains of the Arkansas River Basin. While the foraging subsistence pattern continued in the south, it was supplemented in the north with small-scale horticulture (Galm 1981, Wyckoff 1980). Other changes included increased trade and import items, and the first appearances of Mississippian related trade items are found during this phase (Bell 1984).

Materially, there is an increase in the number and variety of artifacts found. New tools needed for

Table 3.1: Cultural Chronologies for Eastern Oklahoma

| | Wyckoff | Brown | Galm/ OAO | Rohrbaugh |
|---|---|---|---|---|
| 1880 AD | | | | |
| 1800 AD | | Historic | | Historic |
| 1700 AD | | | | |
| 1650 AD | | | | |
| 1600 AD | | | Fort Coffee Phase | Fort Coffee Phase |
| 1500 AD | | Fort Coffee Phase | | |
| 1450 AD | Caddo IV | | | |
| 1400 AD | | | | |
| 1300 AD | | | | Spiro Phase |
| 1250 AD | Caddo III | Spiro Phase | Spiro Phase | |
| 1200 AD | | | | |
| 1100 AD | | Harlan Phase | | |
| 1000 AD | Caddo II | | | Harlan Phase |
| 950 AD | | | Harlan Phase | |
| 900 AD | | | | |
| 800 AD | Caddo I | Evans Phase | | Evans Phase |
| 700 AD | | | | |
| 650 AD | | | | Woodland Period |
| 1 AD | | Fourche Maline Phase | Fourche Maline Phase | |
| 300 BC | | | | |
| | | Wister Phase | Wister Phase | |
| 1500 BC | | | | |

horticulture include deer-jaw sickles and shell hoes (Bell 1984). There are many more decorative items such as jewelry, hair ornaments, earspools, etc. The importance of decoration is also reflected in the ceramics, and there is an increase of decorated ceramic types. Woodward Plain also appears as a new type of plain ware.

The variety of artifacts and their elaboration, suggest status differentiation (Bell 1984). This idea is also supported by burial associations and placements. During the Harlan phase we see the introduction of mound-building, and there is clearly a distinction made between individuals buried in mounds versus those buried in non-mound sites. There is also status differentiation between the various burials within a specific site.

## Spiro Phase (AD1200 - 1450)

During the Harlan phase a hierarchical social structure had begun to develop. This system reached its peak during the Spiro phase. This phase is characterized by very elaborate ceremonial centers. Artifacts from the Spiro site indicate that it was involved in the trade system which connected most of the Temple Mound sites in the eastern United States (Brown 1984). Because Spiro was the main ceremonial/administrative center in the Arkansas River Basin at this time, artifacts found there are primarily of elite trade goods. Implements of everyday use are found in the many village sites surrounding the ceremonial center (Rohrbaugh 1984).

While most descriptions of Spiro phase artifacts focus on the elite items, artifacts related to subsistence strategy are unclear in regards to the prominence of horticulture. Corn has been found at some sites (Brown 1984), and some tools resembling hoes have been found, but the evidence is not conclusive. Stone manos and metates are found, and it is possible that foraging was still the primary subsistence mode supplemented with small amounts of horticulture.

## Fort Coffee Phase (AD1450 - 1650)

Towards the end of the Spiro phase, the elaborate social structure began to crumble. The reasons for this collapse are unclear, but it is evident that the populations in the Arkansas River Basin underwent several changes. Activity at the centralized ceremonial centers ended, and elite trade items virtually disappear from the archaeological record. In terms of subsistence strategy, it seems that more emphasis was placed on horticulture (Rohrbaugh 1984). There is an increase in bison bone artifacts, such as bison scapula hoes (Rohrbaugh 1982). Populations may have begun a seasonal mobility pattern similar to that found in the historic period.

## -----Study Site-----

### Site Description & Excavation History

Lf-31, the Moore site, is a non-mound cemetery site probably representing the end of the Spiro phase and the beginning of the Fort Coffee phase. It is located approximately 4 miles SW of the Spiro Mound site in LeFlore County and about one mile NE of the town of Spiro (Figure 3.2)

The Moore site (Figure 3.3) is a large cemetery divided by a railroad track. Some associated houses and pits were located about 1000 feet north of the cemetery. The extent of the site is unknown, and only portions were professionally excavated. The site was first discovered sometime between 1880 and 1890 when the Kansas City Southern Railroad put a track through the middle of the site (Newkumet 1939, Orr 1939, 1946, Unknown 1939). Approximately 100 burials were destroyed by the railroad crew (Newkumet 1939, Orr 1939). In the early 1900's the site was visited by pot-hunters and at least one professional scientist -- Dr. James Thoburn curator of the Oklahoma Historical Museum. No official reports were made about the site according to Orr (1939).

The site was selected for excavation by the WPA Archaeological Projects Team in 1938. The Oklahoma WPA Archaeological Projects were directed by Forrest Clements chair of the Anthropology Department at the University of

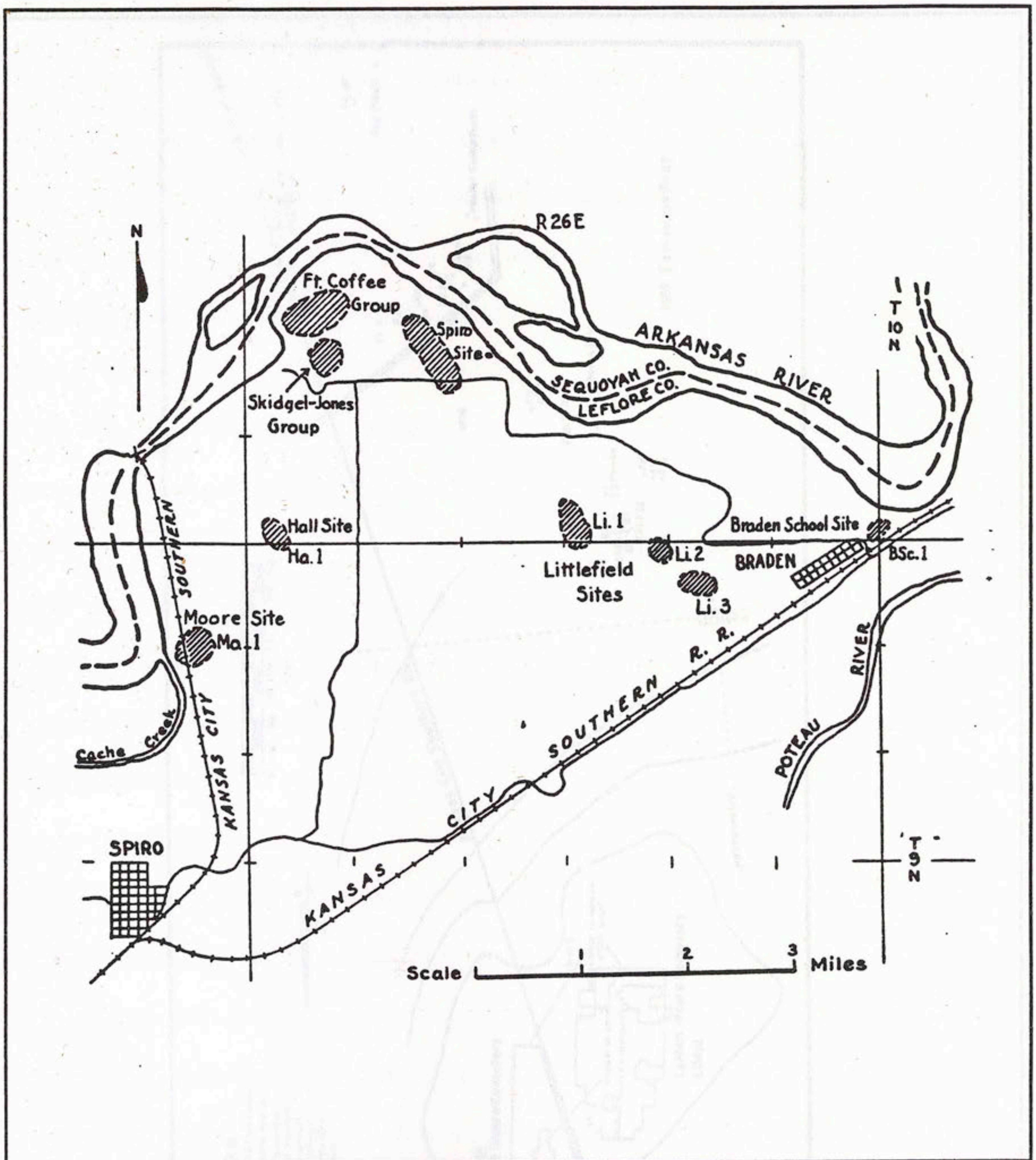



Figure 3.2: The Spiro Region (Orr 1946)

Oklahoma (Rogers 1978). The LeFlore County excavations were directed by Kenneth G. Orr (Rohrbaugh 1984). Because the purpose of WPA projects was to employ as many people as possible, the site was probably chosen based on size rather than for any specific archaeological reason (Rogers 1978).

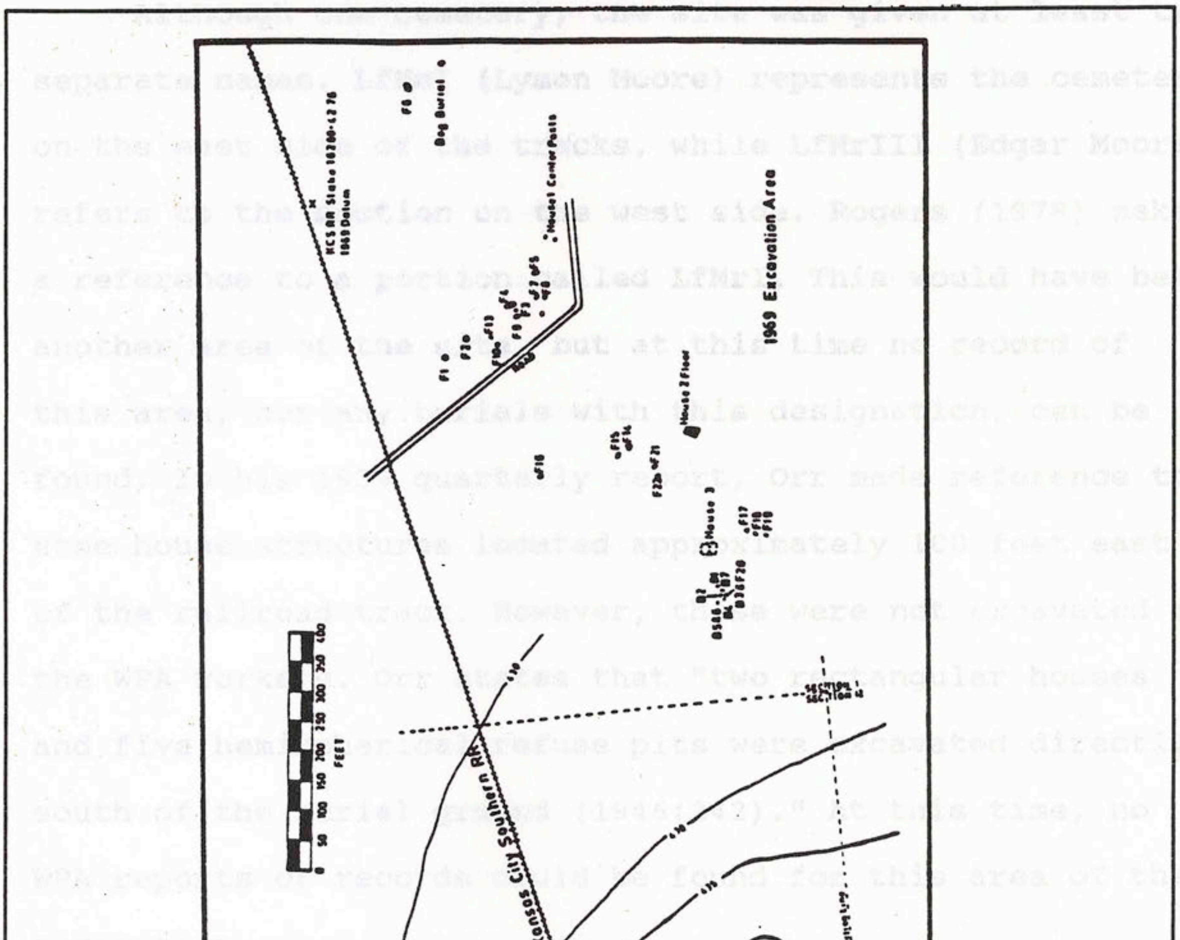


Figure 3.3: The Moore Site (34Lf31) (Rohrbaugh 1982)

Although one cemetery, the site was given at least two separate names. LfMoI (Lymon Moore) represents the cemetery on the east side of the tracks, while LfMrIII (Edgar Moore) refers to the section on the west side. Rogers (1978) makes a reference to a portion called LfMrI. This would have been another area of the site, but at this time no record of this area, nor any burials with this designation, can be found. In his 1939 quarterly report, Orr made reference to some house structures located approximately 100 feet east of the railroad track. However, these were not excavated by the WPA workers. Orr states that "two rectangular houses and five hemispherical refuse pits were excavated directly south of the burial ground (1946:242)." At this time, no WPA reports or records could be found for this area of the excavation.

The WPA team worked from approximately mid-November to mid-December during 1938 on the Lymon Moore portion of the cemetary where roughly 54 burials were excavated. The Edgar Moore portion was excavated during March 1939, and approximately 81 burials were recovered. Materials were measured, recorded, and photographed in situ, then bagged and sent to the lab for further processing and analysis. The majority of the material from WPA excavations was never completely processed nor analyzed, and this was true of the Moore site. Some of it was processed and analyzed; and some was not.

In 1969 an Oklahoma Archaeological Survey team excavated some of the house and pit structures associated with the cemetery. These were located about 1000 feet north of the WPA excavation area. Seven burials were found in this new area. These houses may or may not be the same structures that were identified (but unexcavated) by the WPA team. They certainly could not be the houses Orr says were excavated by the WPA team, as these houses were said to have been south of the cemetery site.

## Site Placement

Some confusion has arisen over the placement of the Moore site into an appropriate phase. Rohrbaugh (1982, 1984) contends that the site was incorrectly labeled as Fort Coffee phase because of the misleading site typologies used to identify the different phases. His dissertation is primarily concerned with correcting this classification error which he claims occurred when archaeologists switched from the atemporal McKern Classification System (foci) to the temporally structured Willey and Phillips system (phases). When archaeologists made this switch, they simply imposed a time sequence over the foci classifications.

Rohrbaugh's premise is that several of the sites placed in the Fort Coffee phase are contemporaneous with the Spiro site and, thus, should be placed in the Spiro phase. The McKern system classifies sites based on artifact types. Rohrbaugh suggests that Fort Coffee **focus** sites are the non-ceremonial sites of the population connected to the Spiro ceremonial center. Because artifact types would differ, elite goods versus everyday goods, the sites appear different.

Using the Moore site as his main study site, Rohrbaugh examined burial artifacts and orientations, house artifacts and orientations, and refuse from trash pits. He compared his findings at Moore with the Spiro site and other village/cemetery sites located within a 36 square mile radius around the Spiro site. Rohrbaugh concluded that the Moore site represented one cemetery used over time by the same population.

Based on his final analysis of artifact distributions in houses, pits, and burials, Rohrbaugh divided the Moore site into two phases. LfMrIII (the Edgar Moore portion of the cemetery), burials 1-5 of LfMoI (the Lymon Moore portion of the cemetery), and House #3 were assigned to the Spiro phase. All of the refuse pits, the 1969 burials, and the remaining burials of LfMoI were assigned to the Fort Coffee phase.

Rohrbaugh's division of the Moore site is very important to this study, as earlier burials (Spiro phase) are associated with a subsistence strategy which may have primarily emphasized foraging, and later burials (Fort Coffee phase) with a subsistence strategy that may have begun to emphasize horticulture. This difference might have affected degeneration patterns.

**Associated Tools & Activities**

Many of the artifacts found at the Moore site are suggestive of specific activities performed by the population. Using the concepts of functional tool categories and associated activities as described by Ahler and McMillan (1976), inferences regarding subsistence activities of the Moore population can be made.

Ahler and McMillan created 31 tool categories based on the artifacts found at the Rodgers Shelter site in the Ozark Uplands of Missouri. They then created a list of associated activities for which these tools would have been used. As created, the tool and activity categories are site specific to Rodgers Shelter. In applying this methodology to the Moore site, a new set of tool and activity categories was generated based on the specific artifacts found at the study site.

Since the goal of this study is to measure the impact of subsistence strategy on the skeleton, the artifact analysis of the Moore site focuses only on subsistence related activities. The methodology of Ahler and McMillan has been modified to reflect this goal. First, two activity areas were isolated for study: horticultural/foraging related activities, and hunting related activities. Next, a brief ethnographic review was made of groups who appear similar and/or related to the prehistoric study population. The point of this review was to determine 1)the processes involved in horticultural, foraging, and hunting activities, 2)how these specific processes were performed, and 3)the tools associated with these activities. Next, a list of functional tool categories was created based on the artifacts found at the study site. While all the artifacts were categorized, only those related to the specific subsistence activities are discussed. Finally, based on the ethnographic analogies and the site-specific tool categories, a list of potential subsistence-related activities was created. It is these activities which will be considered in relation to the patterns of degeneration which are described in Chapter 5.

Based on ethnographic and archaeological reviews, it is proposed that the people associated with the Moore site engaged in three major types of subsistence activities: foraging, horticulture, and hunting. What proportion each of these had in the overall subsistence strategy is unclear. Hunting was certainly an important activity, although which animals were emphasized during a hunt may have changed over time. Likewise, horticulture and foraging activities were probably practiced by the population. However, it is unclear whether foraging was supplementing horticulture, whether horticulture was supplementing foraging, or whether equal amounts of foraging and horticulture were being practiced. Artifacts associated with all of these strategies are found at the site, although their proportions and distributions would indicate some change in subsistence behaviors (Rohrbaugh 1982).

Horticultural and foraging activities can be divided into two subgroups: the processes associated with either growing or collecting the foodstuffs, and the actual processing of the foodstuffs. Gilbert (1987) and Cash and Wolff (1974) described agricultural practices for the Hidatsa, Mandan and Arikara. These plains groups farmed along the river bottoms because the soil was fertile and easier to till than the upland areas. Farming activities were primarily performed by the women, but occasionally old men helped with the planting (Gilbert 1987). The Moore site is located along the Arkansas River bottom, and a brief survey of the burial data reveals that the majority of the agricultural related artifacts are found with women. Based on accounts described by Gilbert (1987), Cash and Wolf (1974) and Swanton (1946), a general picture of the agricultural cycle is presented. First, a garden plot was cleared and burned. In the southeast, trees were being felled and cleared (Swanton 1946). In the plains, tall grasses were being removed (Gilbert 1987).

Next, the soil was tilled using either digging sticks or buffalo scapula hoes. Corn, along with other domesticated plants such as beans, was planted. The corn was left to grow and the plot was often hoed for weeds. When mature, the corn was harvested and processed. Deer jaw sickles, which might have been used to clear grass, and bison-scapula hoes are found at the study site.

Foraging would have involved several activities depending on what was being collected. Swanton (1946) lists the following wild foods as being eaten by Caddo populations: chestnuts, hickory nuts, acorns, persimmons, plums, pond lilies, and walnuts. Certainly other plants were collected and used for non-dietary purposes. Rohrbaugh (1982) lists all the regional flora around the Moore site and cites excerpts from Swanton showing how other plant material was used. For the most part, foraging related to diet was performed by women, and probably involved picking things up either from a standing, stooped, squatting or kneeling position. It may have also involved plucking things from vines or branches and/or digging up roots, probably with a digging stick.

Food processing techniques might also play a role in joint degeneration. Both nuts, a foraged item, and corn, a horticultural item, would have involved strenuous processing techniques. In the Southeast, nuts were processed by being ground on a stone basin (Bridges 1983), whereas corn was pounded using a wooden mortar and pestle (Wright 1985). Gilbert (1987) also records corn pounding for the Hidatsa, a plains group. In ethnographic accounts (Gilbert 1987, Swanton 1946), corn processing was done in a standing or sitting position, using both arms to lift the pestle and pound the corn.

This activity creates a potential for wear at both the shoulder and elbow joints. Nut processing also creates the potential for wear at these same joints. However, the anatomical motions involved in grinding are different from those involved in pounding. It is also unclear whether grinding involved one or both hands.

To further complicate the analysis, we can only infer how the study population processed these food items. It is possible that they ground both nuts and corn rather than pounding their corn as suggested by the ethnographic accounts of related populations. Archaeologically, stone grinding basins are found at the study site, as are items identified as hand held hammerstones which might indicate one-handed grinding. Evidence of wooden mortars and pestles is not found, but this lack of evidence does not indicate the processing preference.

To summarize foragers would be grinding nuts with either one or two hands; horticulturalists would also be grinding nuts, and they would also be processing corn, either by pounding or by grinding.

Hunting can be divided into three activity areas: 1) manufacture of the necessary tools, 2) the actual process of hunting, and 3)the processing of animals, specifically their hides.

There are two main tools necessary for hunting: the bow and the arrow. Bow and arrow manufacture require some similar activities (Beesley 1990). First the wood must be acquired and prepared (i.e., chopped and the bark removed). Next the wood must be shaped. Once shaped, bows are decorated and strung. Arrows, however, also require the preparation of feathers, points, and binding materials. Once prepared, these are attached to the arrow shaft. Preparation of bows requires using an axe or axe-like tool to cut the wood and peel the bark. The bark from arrows is peeled using a small hand-knife. The chopping and peeling are done with one hand, probably the right in right-handed individuals, while the wood is held stationary in the left. Shaping bows and arrowshafts is also done with one hand, while the wood is held in the other.

Movements associated with prepartion of the wood primarily involve the elbow, while the "whittling" movements associated with shaping primarily involve the wrist. Likewise, the fine movements required for feather and point making also involve the wrist. A shaping technique associated only with bow manufacturing involves scraping the wood with a very large knife. This knife requires the use of two arms, with the primary movement occurring at the elbow.

Hunting probably required a lot of walking, and this may have had an impact on the hip and knee joints. The arm joints, specifically the elbow and shoulder, would be stressed during the actual process of shooting arrows. The amount of stress placed on these joints probably differed depending on the type of game being hunted. It is assumed, based on the artifacts found at the site, that deer and bison were both hunted by the study population. Both deer and bison bone tools are found at the site, although the possibility remains that these could have been trade items.

Hide-processing involves four general steps: fleshing, scraping, braining and working (Schultz 1992a). How these were actually done depended on whether a deer or bison hide was being processed.

Deer hides were fleshed by stretching the hide across an upright, angled log, kneeling over it and scraping it with a "beamer." This activity involved both arms in a back-and-forth scraping motion, and creates a potential for degeneration of the elbow and shoulder joints. A beamer was made from a long bone of a bison or other animal. Bison rib bones might have also been used. A portion of the shaft was removed on one side of the bone to create two sharp edges which were then used to flesh the hide. Inevitably, the process of fleshing would break the weakened midshaft, leaving a polish around the broken edges (Bell 1980). Tools identified in the WPA reports by the descriptive phrase "polished split long bone" may have been beamers.

Bison hides were fleshed by either stretching them on the ground or stretching them in a suspended vertical manner and working them with a stone scraper. The scraper was hafted to a short shaft and held in such a way as to keep the wrist from moving during the fleshing process. Movement would have occurred at the shoulder and elbow. Scraping, braining and working were the same for both deer and bison hides. Scraping involved stretching the hide on the ground, standing over it and scraping it with a stone tool mounted on a long shaft. Braining was done by rubbing the hide with a smooth stone to work in tanning material. This involved one hand moving in a circular motion. Hides were worked and stretched by pulling them back and forth across a taught rope or other item such as specialized bison scapula. This activity involved both elbows in rapidly alternating back and forth movements.

In these steps, differences between deer and bison hide processing would have been in the amount of time and effort required to perform each step. Bison hide-processing was more time and energy consuming than deer hide-processing. Schultz (1992b) estimates that it took approximately 8 hours of work for 1 person to process a deer-hide. Bison hides, however, required about 50 people/hours of work per hide and often required more than one person to perform the necessary steps.

Archaeologically, only beamers, indicative of deer-hide processing, are found at the study site. Many stone tool scrapers are found which might have been used in hide processing. Also, the many handstones found around the site might have been used for either nut processing as suggested earlier, or as braining tools for processing either deer or bison hides.

The specific activities under consideration, the joints which may have been affected, the associated tools and their potential phase distribution within the site, and the preferred gender division of labor for each activity are listed in Table 3.2. Interestingly enough, the one artifact specifically associated with horticulture (bison scapula hoe) is found only in areas attributed to the Fort Coffee phase.

## -----Conclusion-----

Archaeologists face many problems in interpreting the archaeological record. Interpretations can be highly biased based on where sites were excavated, what artifacts and features were preserved, and what artifacts and features were or were not excavated at the site. In attempting to understand the cultural behaviors associated with the study site, one must take into account these limitations and realize that speculation and assumption are a major factor in any analysis.

Table 3.2: Activity, Joint & Tool Associations

| ACTIVITY | GENDER | JOINTS | TOOLS | PHASE |
|---|---|---|---|---|
| **Horticulture:** | | | | |
| Clearing | ♀ | elbow, flexion; shoulder; elbow, rotation | sickle | Ft. Coffee |
| Hoeing | ♀ | elbow, flexion; shoulder; elbow, rotation | hoe | Ft. Coffee |
| Corn Processing | ♀ | elbow, flexion; elbow, rotation | mortar/pestle (wood) | Not found |
| **Foraging:** | | | | |
| Walking | ♀ | hip; knee; shoulder | | |
| Collecting | ♀ | elbow, flexion; shoulder; hip; knee; elbow, rotation | sickle | Ft. Coffee |
| Nut Processing | ♀ | elbow, flexion; elbow, rotation; shoulder | grinding basins (stone) | Ft. Coffee |
| **Hunting:** | | | | |
| Tool-Making | ♂ | elbow, flexion; elbow, rotation; shoulder | | |
| Walking | ♂ | hip; knee; shoulder | | |
| Shooting | ♂ | elbow, flexion; shoulder; elbow, rotation | points | Both |
| **Hide-Processing:** | | | | |
| Deer fleshing | ♀ | elbow, flexion; elbow, rotation; shoulder | beamer | Ft. Coffee |
| Bison fleshing | ♀ | elbow, rotation; shoulder | scraper | Both |
| Scraping | ♀ | elbow, flexion; shoulder; elbow, rotation | scraper | Both |
| Braining | ♀ | shoulder | handstones | Ft. Coffee |
| Working | ♀ | elbow, flexion; elbow, rotation; shoulder | | |

Initially populations in eastern Oklahoma relied upon a foraging subsistence strategy of hunting, gathering and fishing. Because there are several different biotic zones in this region, we find slight modifications in the actual foods consumed from zone to zone. Population increases along the Arkansas River resulted in increased social complexity and the possible adoption of a horticultural subsistence strategy. With the collapse of the social hierarchy, changes in subsistence strategy may have once again occurred. Perhaps, the population of the study site switched to a bison hunting and more plains-like subsistence strategy as suggested by Wyckoff (1980). However, the increase in agricultural related tools found at the study site would suggest that horticulture was important in the late period. Perhaps the study population engaged in a subsistence pattern similar to that described by Weltfish (1965) for the Pawnee: a seasonal pattern of corn planting and bison hunting.

Artifact distribution from the study site would also indicate that horticulture was introduced after the collapse of the Spiro social system. The results of the OAO study (Sabo et. al 1990) regarding horticulture in the Arkansas valley are skeptical. They claim that populations in eastern Oklahoma never participated in horticultural subsistence activities; however, along with the agricultural tools, charred corn is found in one of the trash pits at the study site.

While there are many alternative explanations for the materials used to infer subsistence activities of the study site population, the hypotheses of this study regarding joint degeneration will be based on the following conclusions concerning subsistence and activity: 1)there is a potential difference in subsistence pattern between the late (Ft. Coffee) and early (Spiro) burials of the site, and 2)based on this difference, horticulture enters during the late (Ft. Coffee) phase.

# CHAPTER FOUR

# METHODOLOGY

This chapter introduces the specific research hypotheses under consideration and the methodology used to score joint degeneration in the study population. The criteria used to select the study site and the study sample are also presented.

## -----Research Hypotheses-----

One objective of this study is to correlate joint degeneration with known activity patterns. Hypotheses were developed with this goal in mind, and two sets of hypotheses were generated. The two hypotheses of Set I were developed to test the association between gender-related divisions of labor and the specific activities being performed. The two hypotheses of Set II were developed to test whether or not subsistence strategy within the Moore site actually did change over time.

The four hypotheses are as follows:

Set I
Patterns of degeneration will differ between males and females.

A. Because men and women engage in different activities, the patterns of degeneration (percent affected) will differ between men and women.

B. Comparing the two phases, patterns of degeneration (percent affected) in women will change, but patterns of degeneration (percent affected) in men will remain the same.

Set II
Patterns of degeneration will change from Spiro phase (early) to Fort Coffee phase (late) burials as activity patterns changed.

A. Comparing all joints, if subsistence strategy changed from foraging to horticulture, then the percent affected for each joint will increase from the Spiro (early) to Fort Coffee (late) phases.

B. Comparing all joints, if subsistence strategy changed from foraging to horticulture, then the severity will be greater in the Fort Coffee (late) burials.

Set I includes assumptions regarding the differential distribution of activities between men and women. Specifically, hypothesis IB recognizes that men were hunting throughout both periods, and that it was probably the activities of women which changed. Set II assumes that activities related to horticulture were more stressful on the body, and that horticulture was primarily practiced during the Fort Coffee phase.

In order to test the hypotheses, four joints were examined: the shoulder, elbow, hip and knee. The elbow was divided into two components - flexion and rotation - because different articular surfaces are involved in the two motions. For purposes of analysis, the study was concerned with only two scores - percent affected, and severity level. The following sections describe the methodology used to select the sample and determine the final scores.

## -----Sample Selection-----

### Site Selection

Before selecting a specific site, an investigation of all available sites in eastern Oklahoma was conducted. Initially, the research project called for two sites, one from a foraging subsistence strategy and one from a horticultural subsistence strategy. Sites were checked for the number of skeletons present, the condition of the skeletal remains, previous osteological analysis such as aging and sexing, and previous archaeological analysis and determination of temporal location and/or subsistence strategy.

There are many small sites throughout eastern Oklahoma that have been subject to detailed osteological and archaeological analyses. Unfortunately, most of these are sites with very few burials and not enough material to obtain a representative sample size for this type of study. Rather than use several small sites where spatial and temporal continuity could not be guaranteed, one large site was selected to ensure integrity of the sample.

The Moore site was chosen as the study site for several reasons. It is a large site with over 100 burials. Based on museum records and a cursory examination of the material, it was thought that skeletal preservation was fairly good. Also, there had been some previous osteological and archaeological work done on the site by Rohrbaugh (1982). Based on this previous work, it was also thought that the site represented two identifiable subsistence strategies as discussed in Chapter Three.

Once the site was chosen and the materials were brought to the lab, several problems developed. First, it was found that prior researchers had removed and destroyed much of the material necessary for a study of joint degeneration. Evidently Rohrbaugh had taken many long bones to use for radiocarbon analysis, and inevitably he had taken material from the most well-preserved skeletons.

Many of the skeletons which, according to burial records, should have provided a complete set of well-preserved joints were no longer complete. Many of these burials were missing several bones. For example, the entire left side had been removed, or a left leg and a right arm, or both legs, etc. The site was also left with the less-well preserved material still intact, but its condition limited its use in the study.

In 1990 J. Daniel Rogers removed samples for a radioisotope analysis project, but these were usually rib fragments, or small pieces not relevant to this study.

The biggest problem, it was discovered, involved the many misplaced and mislabeled bones. For example, a box labeled as containing only one burial had three upper arm bones inside.

Prior to selecting the sample and beginning the actual research project, the site was sorted, inventoried and labeled.

**Pre-Analysis Preparation**

The skeletal material from the Moore site had been housed at the Oklahoma Museum of Natural History. It was stored in cardboard boxes, usually one skeleton per box. A few exceptions were poorly preserved materials that were stored several skeletons per box. The boxes were labeled according to the bag labels in which the bones had originally been stored.

During the WPA excavations, skeletal material was placed in brown paper bags as it was removed from the ground. Sometimes entire skeletons were put in one bag, but usually one skeleton was placed in several bags. The bones from each skeleton were placed in the bags in the order in which they were removed. When the bag was full, another bag was started. Usually, the skull and the cervical bones were placed in the same bag. Sometimes the cervical bones were placed with the other bones of the body, but the skull always had a separate bag.

On each bag was recorded the burial number, the contents of the bag (skull or bone), the depth, and the row and alley grid numbers. The bags were then given a bag number, and this was also recorded. When the bags were sent to the lab for analysis, some of the material was processed and the bag numbers were written directly on the bones from that bag. However, not all the material was processed, and therefore not all the bones were labeled.

The materials were then stored in these bags for many years. Sometime in the recent past, the material was restored and moved from bags to boxes. Although most of the original bags were thrown away, the portion with the bag number and other pertinent information was cut out and stored in the box with the skeletal material. The site number and burial number from the bag were then recorded on the outside of the box.

Because the original bags were decaying and the ink was fading, it was apparent that some boxes had been labeled incorrectly. As the material was used for other research studies and shuffled around, some bones were returned to the wrong box. This mixing occurred because not all the bones were labeled, and because some numbers were misidentified due to changing writing styles (fives were often missing the top line and thus looked like sixes, sixes often looked like zeros, and sevens sometimes looked like fours).

Using the original burial forms, WPA field notes, catalog pages, the bag labels and those bones which had been processed, an inventory was made. All relevant information regarding burial numbers, bag labels, skeletal labels, etc. was recorded and input into a database program. Using the computer, a list of catalog numbers was generated and matched with the appropriate burial number. The bones were then sorted into their appropriate boxes.

There were still many bones that could not be identified. Some of these had been labeled, but clearly did not belong with the associated burial (e.g. a juvenile humerus with an adult). There were still a few unlabeled skeletons which had too many long bones, and so educated guesses were made as to what belonged and what did not. The few remaining unlabeled, unmatched bones were added to the box started by other researchers labeled "unidentified miscellaneous bones."

Once the bones had been properly sorted, they were given new labels according to the new museum cataloging system. After labeling, the bones to be used in this study were put in plastic bags and grouped separately for analysis. All other material was returned to its appropriate box and stored until the project was completed.

## Sample Selection Criteria

Because of the confusion regarding skeletal identification, this study used only material that could be identified as belonging to a specific skeleton.

Unidentifiable bones, while in excellent condition, were discarded from the sample, as were entire skeletons when reliable identification was not possible. These factors, along with the radiocarbon removals discussed earlier, severely limited the actual research sample.

The seven skeletons from the 1960 excavation were not included in the sample. They were over 1000 feet from the edge of the area excavated by the WPA, and were associated with houses rather than with the cemetery proper.

If a skeleton was too fragmentary to accurately identify specific bones, that skeleton was not included in the sample. If an individual bone from an otherwise useable skeleton was too fragmentary to identify its side, that specific bone was not included in the sample. In the remaining skeletons, all bones which were present and applicable to the study were scored for degeneration according to the methodology discussed later in this chapter.

## -----Scoring Methodology-----

### Literature Review

In his study of the Inuit Eskimo, Merbs (1983) outlined the system he used for scoring joint degeneration. Merbs was concerned with the patterns of degeneration of specific joints and their relationship to particular activities. He observed degeneration in all the synovial joints (i.e., temporomandibular, shoulder, elbow, wrist, hand, vertebral column, ribs, hip, knee, ankle, and foot), and developed the basic methodology used by most anthropological researchers involved in degeneration and activity-use studies.

First, individual articular surfaces were seriated and scored for lipping (osteophyte development), pitting/porosity (erosion, cysts) and eburnation (polishing). The scale Merbs used to score for severity is shown in Table 4.1. Next, a second researcher seriated and scored the same articular surface. Any discrepancies in scoring were discussed by the two observers until a consensus score was reached. When all relevant articular surfaces had been scored, a final joint score was determined.

Table 4.1: Severity Scale Used by Merbs (1983)

| | |
|---|---|
| X | = observation not possible |
| 0 | = no degeneration |
| ± | = trace degeneration |
| + | = mild degeneration |
| ++ | = moderate degeneration |
| +++ | = severe degeneration |

In his analysis section, Merbs used this final joint score to calculate the percent affected for each joint, and a score he called the Intensity value. These calculations were made for each joint in four ways: female right, female left, male right, male left.

In his dissertation study, Pickering argued that Merbs' method is a "subjective scale [based on] relative severity (1984:10)" Merbs (1992) later confirmed this statement and agreed that the values for each score were population-specific. Severe degeneration (+++) was defined as the most severe form observed in a given sample. Pickering attempted to devise a more standardized scale where each severity level was clearly defined and not population-specific.

Pickering's research strategy differed in other ways as well. He was not studying the relationship between joint degeneration and specific activities as Merbs had done. Pickering was studying the overall effects of subsistence strategy and testing for connections between changing subsistence patterns and degeneration. As such, Pickering proposed that the individual was the unit of analysis rather than the joint. Pickering scored individual articular surfaces, combined them into the appropriate joint scores, and then combined these into eight body segment scores. However, he did not create one score for each individual, recognizing that by doing so he would sacrifice valuable data (Pickering 1984).

## Research Procedure

Since this project was looking for patterns of joint degeneration and connections to specific activities, comparisons were made on a joint by joint basis. Individuals were not reduced to a single score for degeneration. Nor, for example, was one score calculated for all females affected by joint degeneration. Rather, a series of scores reflecting the pattern of joint involvement has been presented. For example, Table 5.18 shows the pattern of joint involvement for Spiro phase females.

In a study done to determine the association between health at death and burial status, Tainter (1980) examined degeneration in three joints: the shoulder, elbow, and knee. He divided these joints into eighteen joint surfaces for analysis (Table 4.2). This research project modified Tainter's eighteen surfaces in order to include the hip joint, and thus initially yielded twenty joint surfaces for analysis (Table 4.3).

An initial scoring was done once the joints and surfaces to be scored were determined. This procedure utilized the scoring system designed by Merbs (1983) and discussed in the previous section. Each joint surface was simultaneously scored for lipping, pitting, and eburnation.

For example, all the glenoid cavities from the sample were laid on the table. One at a time, they were simultaneously scored for lipping, pitting, and eburnation. Once all the glenoid cavities had been scored, the next joint surface was scored, and so on down the line. This procedure used only one observer, and was done to familiarize the researcher with the scoring methodology and the reliability of the technique.

Table 4.2: Joint Surfaces Used by Tainter (1980)

| | |
|---|---|
| Acromial facet of clavicle | Head of radius |
| Glenoid fossa of scapula | Olecranon process of Ulna |
| Humeral head | Radial notch of Ulna |
| Capitulum | Lateral condyle of femur |
| Medial border of trochlea | Medial condyle of femur |
| Lateral border of trochlea | Lateral condyle of tibia |
| Coronoid fossa | Medial condyle of tibia |
| Radial fossa | Lateral aspect of patella |
| Olecranon fossa | Medial aspect of patella |

Table 4.3: Joint Surfaces Used in Initial Analysis

| | |
|---|---|
| Humerus,head | Radial fossa |
| Glenoid fossa | Olecranon fossa |
| Clavicular facet | Olecranon process |
| Acromial facet | Acetabulum |
| Capitulum | Femur, head |
| Radial head | Femur, medial condyle |
| Radial margin | Femur, lateral condyle |
| Radial notch | Tibia, medial condyle |
| Trochlea, medial | Tibia, lateral condyle |
| Trochlea, lateral | Patella, medial |
| Coronoid fossa | Patella, lateral |

Based on the experience of this initial procedure, several modifications were made to the scoring technique. First, the joint surfaces were revised, yielding 23 areas for analysis. These are listed on the data-collection form in the Appendix. Next, each area was given finite boundaries for which degeneration was to be observed. Again, each joint surface was scored for degeneration, but a more stringent technique was used in order to minimize the subjectivity of the observer.

Each joint surface was independently seriated and scored for lipping, pitting, and eburnation. For example, beginning with lipping of the glenoid cavity, the sample was divided into three categories: lipping unobservable, no lipping present, and lipping present. This last category was then seriated according to the degree of observed lipping. The scores for lipping were then recorded, and the sample was reseriated for pitting of this joint surface, and then for eburnation. The process was then repeated for all other joint surfaces.

Rather than use the + system designed by Merbs, scores were recorded using a 0-4 scale in order to facilitate computer analysis of the results. The scoring scale is presented in Table 4.4.

Table 4.4: Severity Scale Used for Analysis

| | |
|---|---|
| X | = unobservable |
| 0 | = no degeneration |
| 1 | = trace degeneration |
| 2 | = mild degeneration |
| 3 | = moderate degeneration |
| 4 | = severe degeneration |

Using this scale to score for joint degeneration can be a subjective process. The difference between no lipping (0) and severe lipping (4) is usually obvious. But what about the difference between mild (2) and moderate (3), or moderate (3) and severe (4)? Also, once a series of joint surfaces have been scored, would the researcher be able to assess the same joint surfaces with the same scores? Would a second observer assess the same scores to the joint surfaces? The first problem refers to intra-observer error (the subjectivity of the same observer), and the second to inter-observer error (the subjectivity between different observers).

To reduce the chance for inter-observer error, two other researchers were enlisted to verify the seriations of the initial observer. Because the second observers, two graduate students in the Anthropology program, had limited time and could not do an entire seriation (to score an entire series of joint surfaces took at least two hours), they were used to corroborate the seriation done by the initial researcher. For example, upon seriating the glenoid cavity for lipping, a second observer was called in to verify the seriation. Often there were differences in where individual joint surfaces should be categorized. The surfaces in question would be discussed by the observers and a consensus reached as to where the joint belonged.

After all scores for lipping, pitting, and eburnation had been recorded, each joint surface was given a maximum score equivalent to the highest score recorded for any one of the three categories. These maximum joint surface scores were then used to give a final degeneration score for the entire joint. This score was equivalent to the highest maximum score attributed to any bone area comprising that joint. This final joint score indicated the severity of degeneration for that joint.

Maximum scores - for either joint surfaces or entire joints - were assigned the highest score recorded for that area rather than an average of all the recorded scores. Averages were not assigned because of the way degeneration may differentially affect specific components of joints and joint surfaces, and because of the differential degeneration rates of its three component processes. For example, Merbs (1983) notes that within the shoulder joint the humeral head will show evidence of degeneration before it appears on the glenoid cavity, and that consequently the humeral head will have more severe degeneration than the glenoid cavity.

As it impacts the individual's health, degeneration of the shoulder joint will be as severe as its most severe component. Mobility of this joint will not be limited to an average between the humeral head and the glenoid cavity, but will be limited to the severity of the joint as a whole. Because lipping, pitting and eburnation progress somewhat independently of each other, the severity of the degeneration is regarded as equivalent to the severity of the most severe disease component.

Degenerative joint disease is a complex process that is not yet fully understood. Based on what is known about this disease process skeletal researchers (Merbs 1983, Pickering 1984) have accepted the practice of recording the highest scores rather than the averages. This study follows this trend.

Both the initial and final data collections were done "blind" in that the age and sex of each individual was not known until after all the data had been collected. Because individuals were never observed *in toto*, assessments of age and sex were nearly impossible to make during the scoring process. Age and sex were recorded after the fact in order to eliminate the tendency to score "old" individuals as more severe, and "young" individuals as less severe.

The age and sex information for the study population were obtained from Rohrbaugh (1982). Because the study sample was chosen prior to knowledge of age and sex, three individuals were removed from the study sample after joint degeneration data had been collected because either their age and/or sex were not known. The joint degeneration data for all other individuals remaining in the sample is presented and analyzed in the next chapter.

# CHAPTER FIVE

# DATA & ANALYSIS

In this chapter the research data are presented and analyzed. Connections between the observed patterns of degeneration and subsistence related activities are discussed. First an overview of the sample and the population from which it was drawn is provided.

## -----Demography-----

The mortality distribution for adults (18 and over) of the Moore site population is presented in Figure 5.1. The data for the population includes only those individuals for whom both age and sex were given. Because of the way in which the population was aged, the data were divided into four age groups: sub-adults (under 18 years of age), 18-25 year olds (Age Group 1), 25-35 year olds (Age Group 2), and 35 years and over (Age Group 3).

Within the cemetery population, there are 34 adult females and 26 adult males. There is a fairly equal number of males and females within Age Group 3, but over twice as many females as males in the Age Group 1. Age Group 2 has twice as many males as females (Figure 5.1).

The 47 children and sub-adults found at the site are not included in the analysis nor are they shown in Figures

5.1, 5.2 and 5.3. The majority of these children and subadults (n = 38), were found within the Spiro phase of the cemetery. Based on the total number of individuals who were aged, children and subadults represented 53% of the Spiro phase population and 25% of the Fort Coffee phase population.

Figures 5.2 and 5.3 show the mortality distributions when the cemetery is divided into two phases. Of importance is the fact that there are no young males (Age Group 1) in the Spiro phase, and only 1 Age Group 2 female in the Fort Coffee phase. These numbers have affected the sample distributions and statistical tests as is evident in Figures 5.4, 5.5 and 5.6.

Within the study sample (Table 5.1, Figure 5.4), it is evident that there is an uneven distribution of males and females by age group. The majority of the females are between the ages of 18-25, and the majority of the males are in the older two age groups. The mortality distributions by phase show that the sample distribution is biased in several ways (Figures 5.5 and 5.6). First, there are no males in Age Group 1 for the Spiro phase, and second, there are no females in the Fort Coffee phase Age Groups 2 and 3. This distribution could not have been foreseen prior to analysis, and its effect has been considered in the testing of the various hypotheses.

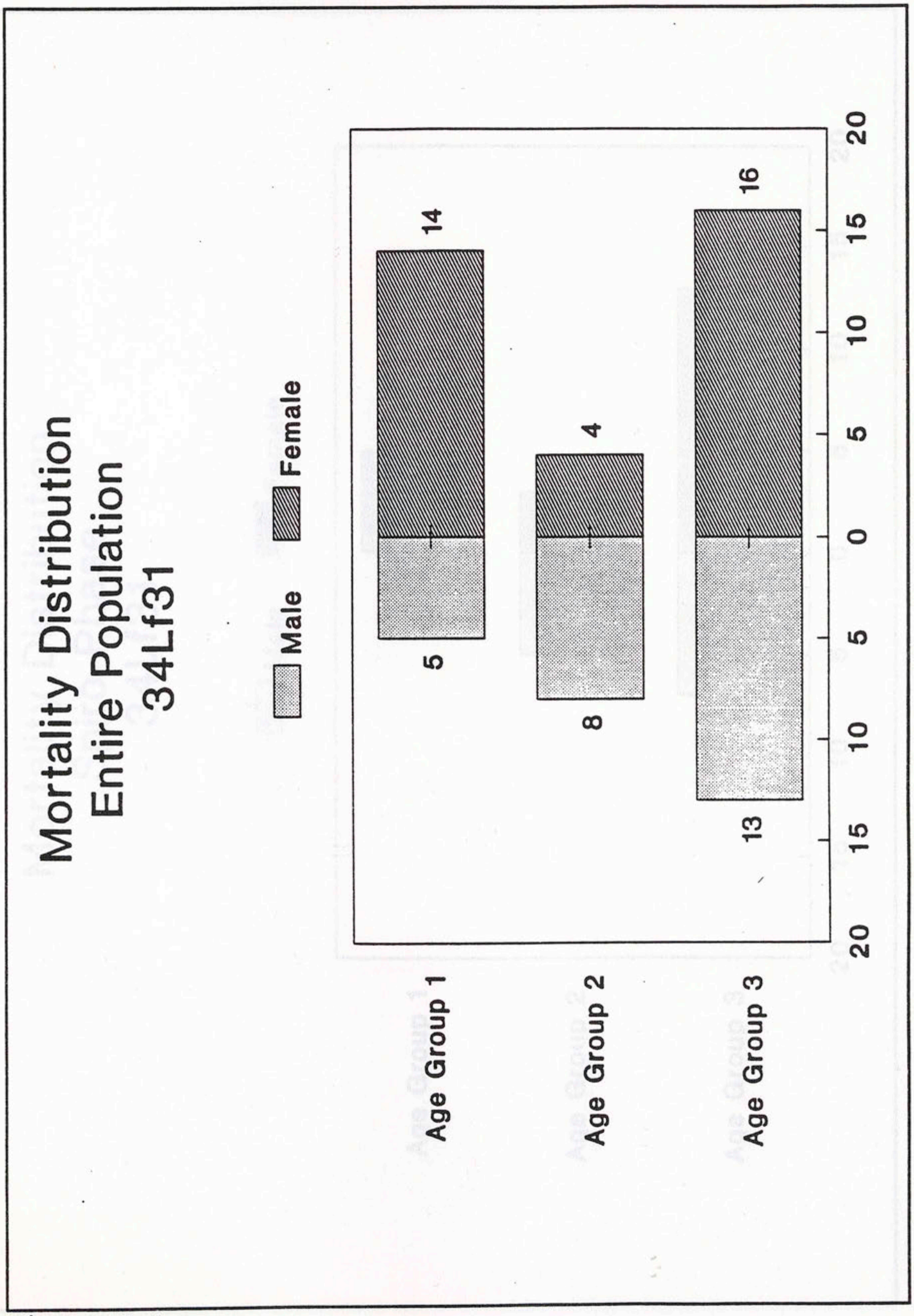

Mortality Distribution
Entire Population
34Lf31
Male
Female
Age Group 1
Age Group 2
Age Group 3
5
14
8
4
13
16
20
15
10
5
0
5
10
15
20

Figure 5.1

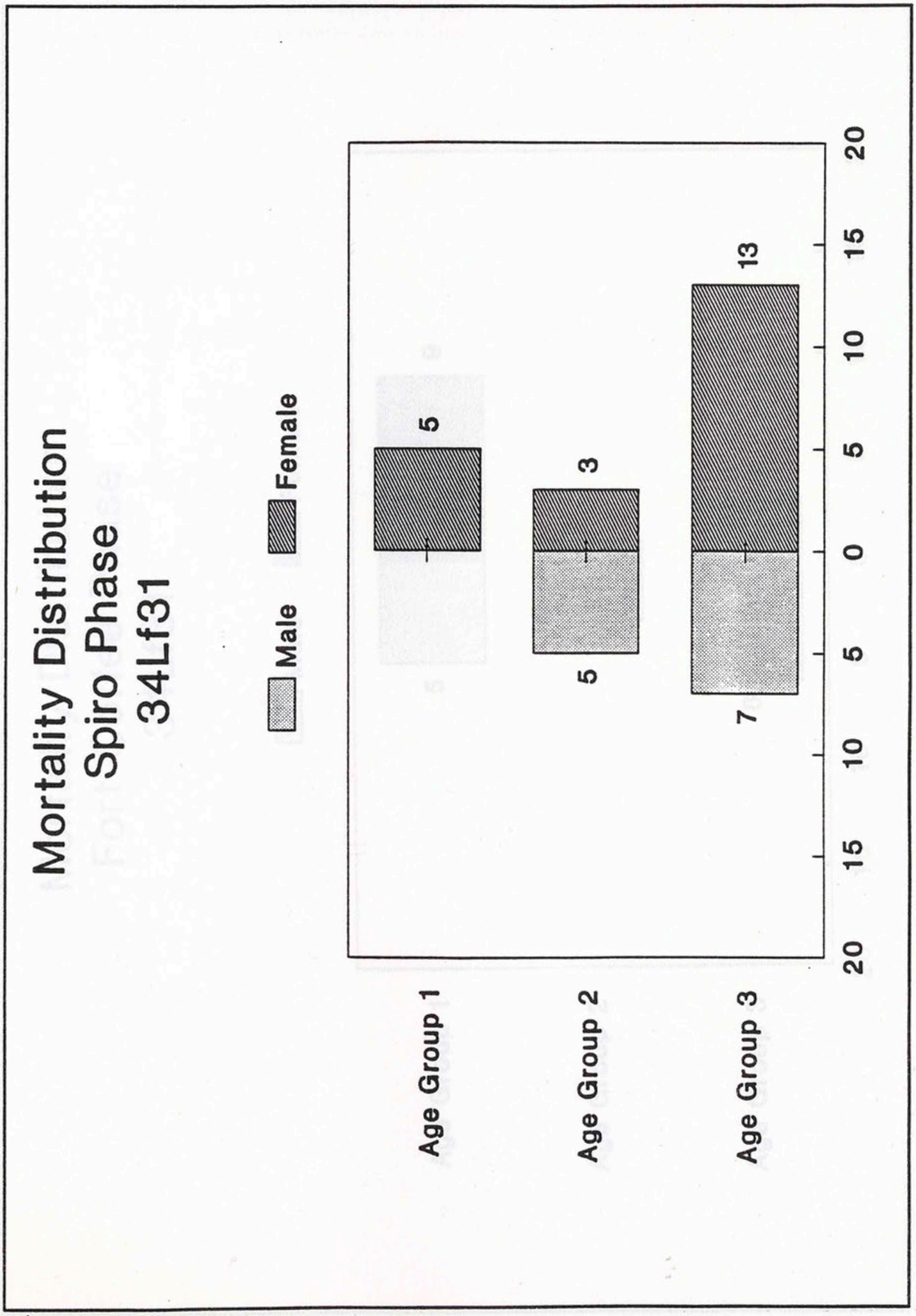

Mortality Distribution
Spiro Phase
34Lf31
Male
Female
Age Group 1
Age Group 2
Age Group 3
5
5
3
7
13
20
15
10
5
0
5
10
15
20

Figure 5.2

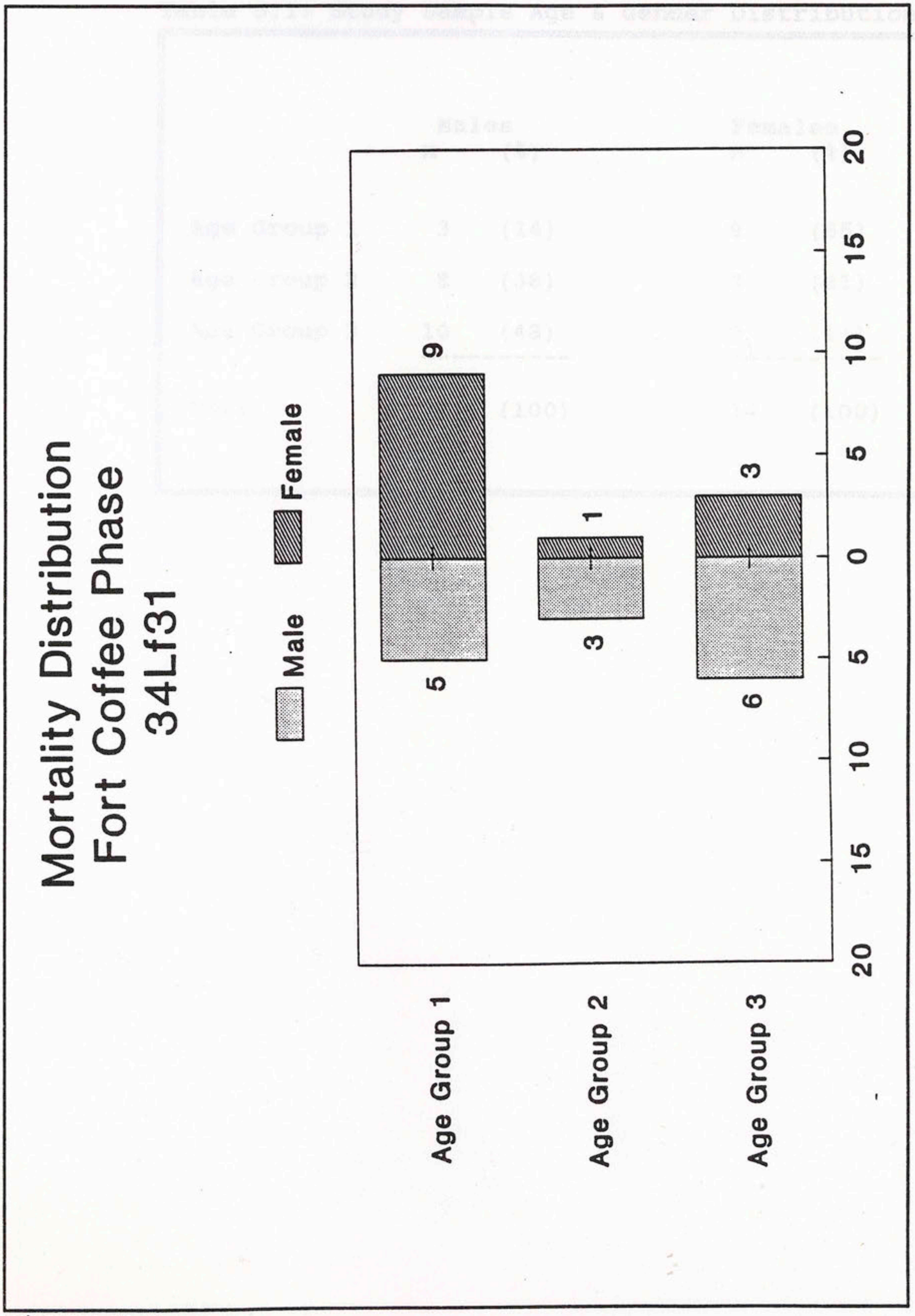

Mortality Distribution
Fort Coffee Phase
34Lf31
Male
Female
Age Group 1
Age Group 2
Age Group 3
5
9
3
1
6
3
20
15
10
5
0
5
10
15
20

Figure 5.3

Table 5.1: Study Sample Age & Gender Distribution

| | Males n | Males (%) | Females n | Females (%) |
|---|---|---|---|---|
| Age Group 1 | 3 | (14) | 9 | (65) |
| Age Group 2 | 8 | (38) | 3 | (21) |
| Age Group 3 | 10 | (48) | 2 | (14) |
| Total | 21 | (100) | 14 | (100) |

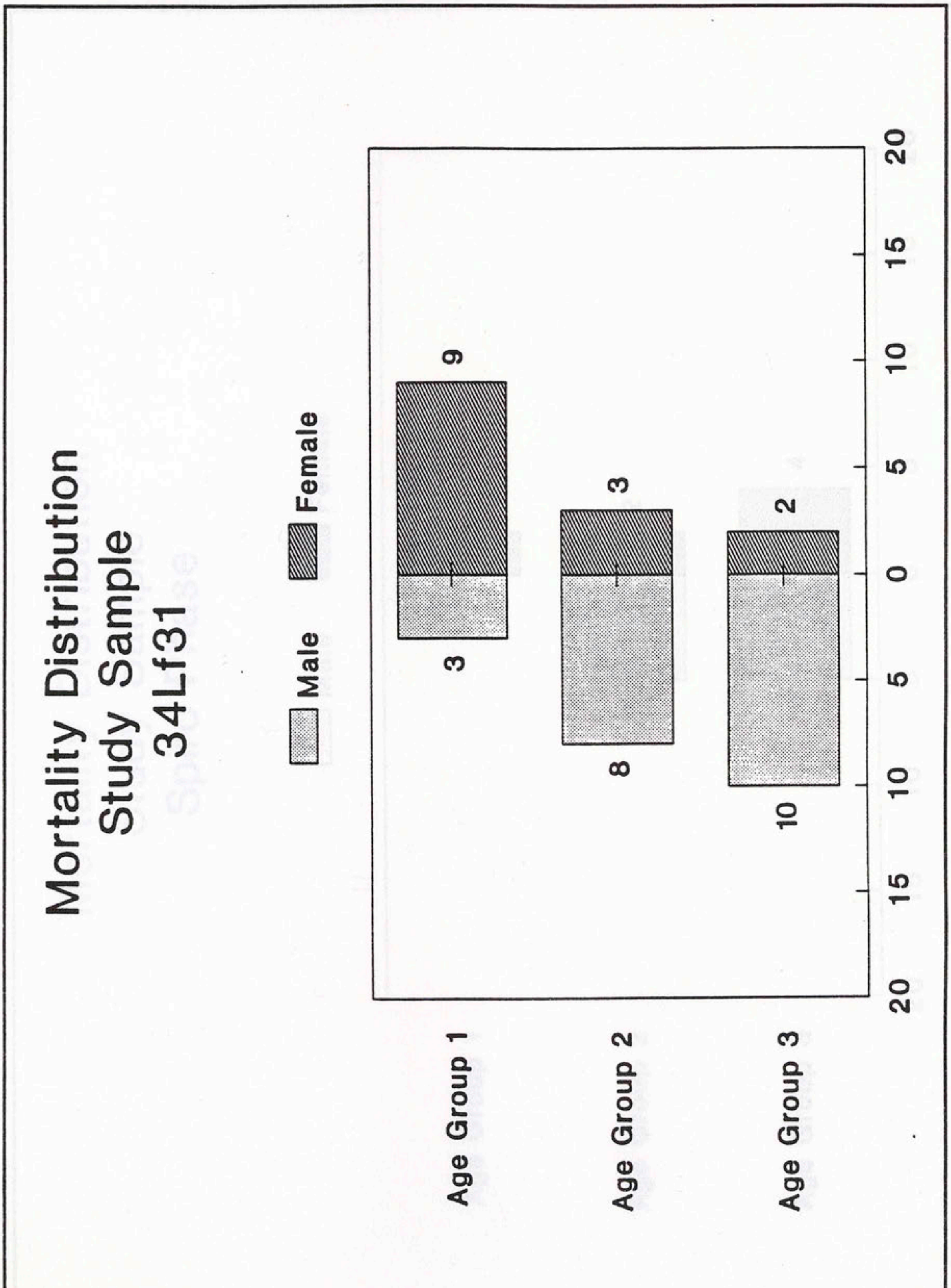

Mortality Distribution
Study Sample
34Lf31
Male
Female
Age Group 1
Age Group 2
Age Group 3
3
9
8
3
10
2
20
15
10
5
0
5
10
15
20

Figure 5.4

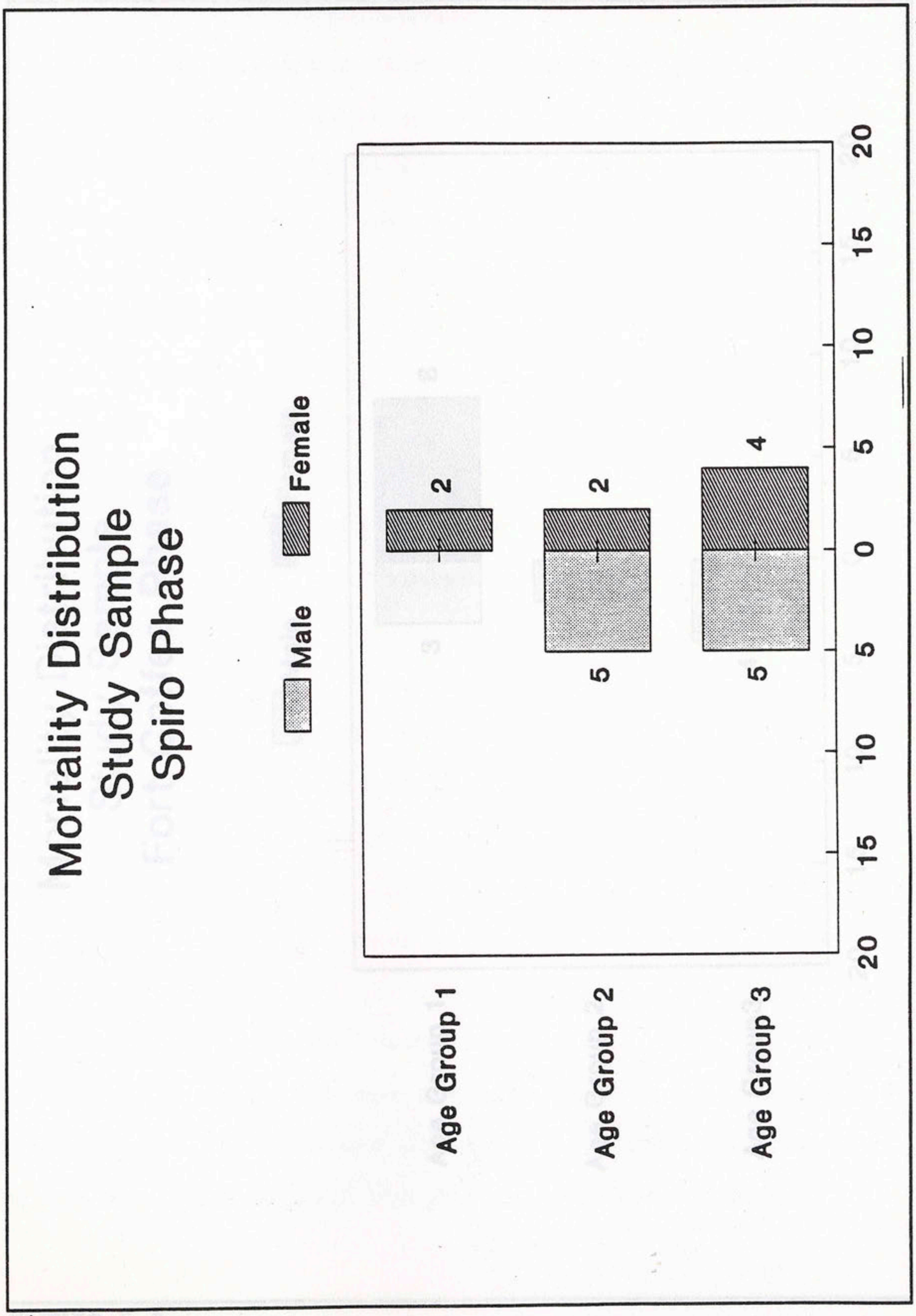

Mortality Distribution
Study Sample
Spiro Phase
Male
Female
Age Group 1
Age Group 2
Age Group 3
2
2
5
4
5
20
15
10
5
0
5
10
15
20

Figure 5.5

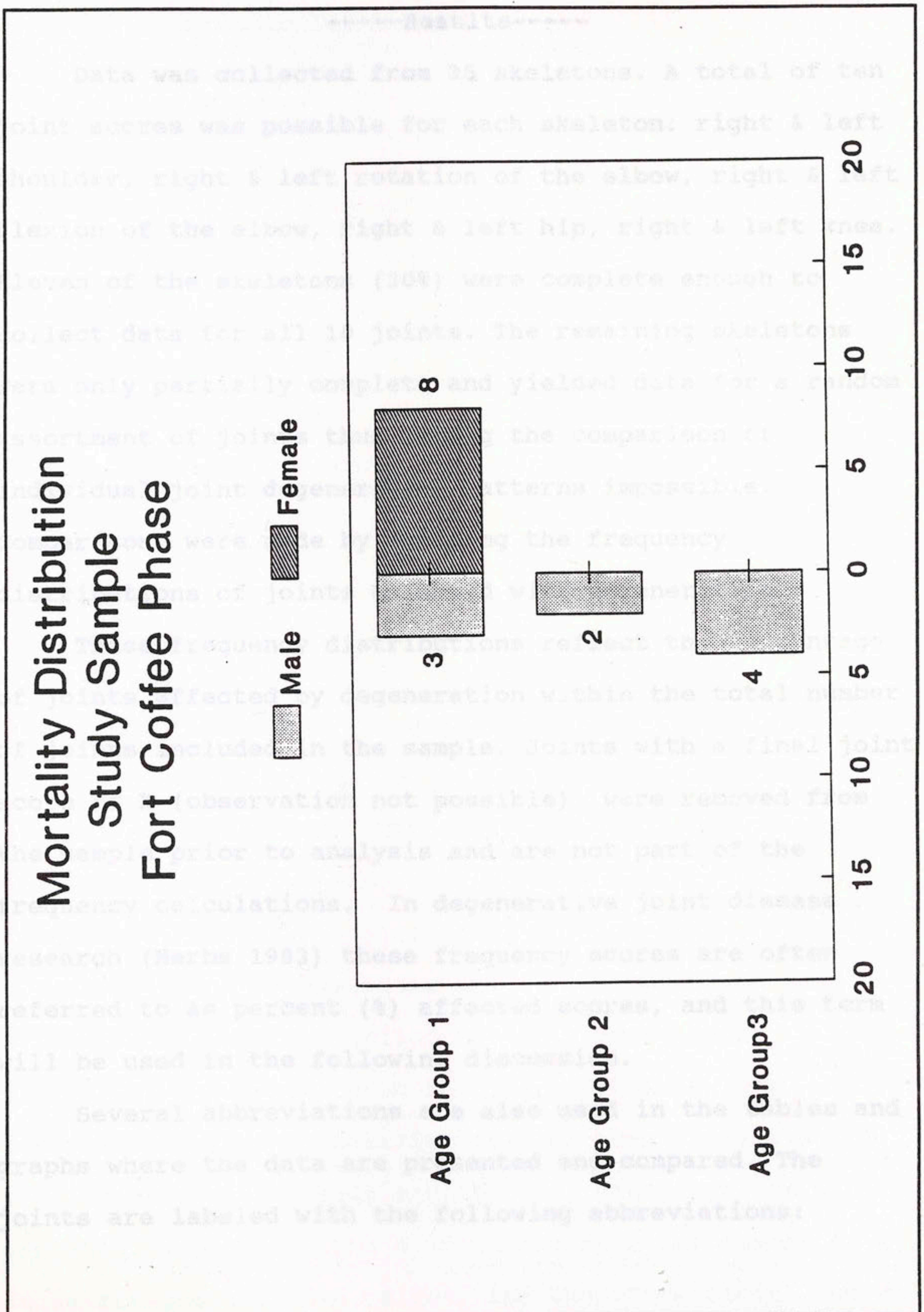

Mortality Distribution
Study Sample
Fort Coffee Phase
Male
Female
Age Group 1
Age Group 2
Age Group3
3
8
2
4
20
15
10
5
0
5
10
15
20

Figure 5.6

## -----Results-----

Data was collected from 35 skeletons. A total of ten joint scores was possible for each skeleton: right & left shoulder, right & left rotation of the elbow, right & left flexion of the elbow, right & left hip, right & left knee. Eleven of the skeletons (30%) were complete enough to collect data for all 10 joints. The remaining skeletons were only partially complete and yielded data for a random assortment of joints thus making the comparison of individual joint degeneration patterns impossible. Comparisons were made by studying the frequency distributions of joints affected with degeneration.

These frequency distributions reflect the percentage of joints affected by degeneration within the total number of joints included in the sample. Joints with a final joint score of X (observation not possible), were removed from the sample prior to analysis and are not part of the frequency calculations. In degenerative joint disease research (Merbs 1983) these frequency scores are often referred to as percent (%) affected scores, and this term will be used in the following discussion.

Several abbreviations are also used in the tables and graphs where the data are presented and compared. The joints are labeled with the following abbreviations:

SJ = shoulder joint
EJR = rotation of the elbow joint
EJF = flexion of the elbow joint
HJ = hip joint
KJ = knee joint

Probability values (p) are also listed in the tables. Fisher's exact test was used to calculate the probabilities in all tables except one (Table 5.3: Joint Degeneration by Age Group). This table uses a chi-square ($X^2$ probability instead. Fisher's exact test was used because of the small sample sizes. A chi-square test was used when three populations were being compared as illustrated in Table 5.3.

These probabilities (both Fisher's exact and chi-square) indicate how likely it is that the data distributions are due to chance. A one-tailed Fisher's exact was used when the related hypothesis was one-directional (i.e., Ft. Coffee phase will have a higher % affected than Spiro phase). Non-directional hypothesis (i.e., there will be a difference in the percent affected scores), or data comparisons not related to a specific hypothesis used a two-tailed Fisher's exact test.

Alpha was set at 0.10 for all hypotheses. Any comparison with a probability greater than alpha was not considered statistically significant. Distributions with a probability greater than 0.10 do not rule out chance as a cause for the observed values, and therefore limit (but do not prohibit) the possibility of the research hypothesis to be correct. Distributions with a probability value less than 0.10 are considered to have ruled out chance and to lend support (but do not prove) the validity of the research hypothesis.

The abbreviation RR, which is also used in the data tables, stands for risk ratio. Risk ratio is a statistical measure of the association between two groups which are being compared. The risk ratio is a ratio of two percentages. It compares the number of affected joints between two groups while also considering the number of unaffected joints in the two groups.

For example, the RR value of 1.26 for the right knee joint (KJ) in Table 5.4 indicates a 26% increase in the number of females affected with knee degeneration as compared to the number of males affected with knee degeneration. For every four males affected with knee degeneration, there will be approximately five females affected with knee degeneration. This risk ratio was calculated by dividing 62% (the percentage of females affected) by 50% (the percentage of males affected).

The RR value of 0.85 for the right hip joint (HJ) in Table 5.4 was calculated by dividing 58% (% of females affected) by 68% (% of males affected). It indicates a 15% decrease in the number of females affected with degeneration of the right hip as compared to males affected with degeneration of the right hip. In other words, for every four males affected with degeneration, there are approximately three females affected with degeneration.

$RR_{mh}$ refers to a risk ratio adjusted for a potential confounder using the Mantel-Haenszel technique. Age was the only potential confounder for which the risk ratio was adjusted. A significant difference between the unadjusted risk ratio (RR) and the age adjusted risk ratio ($RR_{mh}$) would indicate that age is a confounder of the observed distribution.

Analyses of variance (ANOVA) were also calculated in order to measure the interactions between several variables. Three tests were run for each of the 10 joints. The first test measured the effect of age while controlling for phase and gender; the second test measured the effect of phase while controlling for age and gender; and the third test measured the effect of gender while controlling for age and phase. The second and third tests yielded no significant results, indicating that phase and gender do not confound any of the comparisons. The age analysis yielded the same results as the chi-square ($X^2$) probability values reported in Table 5.3.

Patterns of joint degeneration for both right and left sides were first compared. This comparison used the entire joint sample and did not differentiate for age, gender, or phase (Table 5.2, Figure 5.7). The ANOVA which considered the effect of these variables did not find them to have a

Table 5.2: Joint Degeneration by Side

| | SJ | | EJR | | EJF | | HJ | | KJ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) |
| Right | 58 | (15) | 56 | (15) | 68 | (21) | 65 | (20) | 55 | (12) |
| Left | 48 | (12) | 48 | (13) | 74 | (20) | 57 | (16) | 33 | (8) |
| RR | 1.20 | | 1.15 | | .91 | | 1.13 | | 1.64 | |
| Fisher's | .58 | | .79 | | .77 | | .60 | | .23 | |
| **Adjusted for Age:** | | | | | | | | | | |
| $RR_{mh}$ | 1.27 | | 1.17 | | .91 | | 1.10 | | 1.62 | |
| Fisher's | .30 | | .55 | | .60 | | .64 | | .16 | |

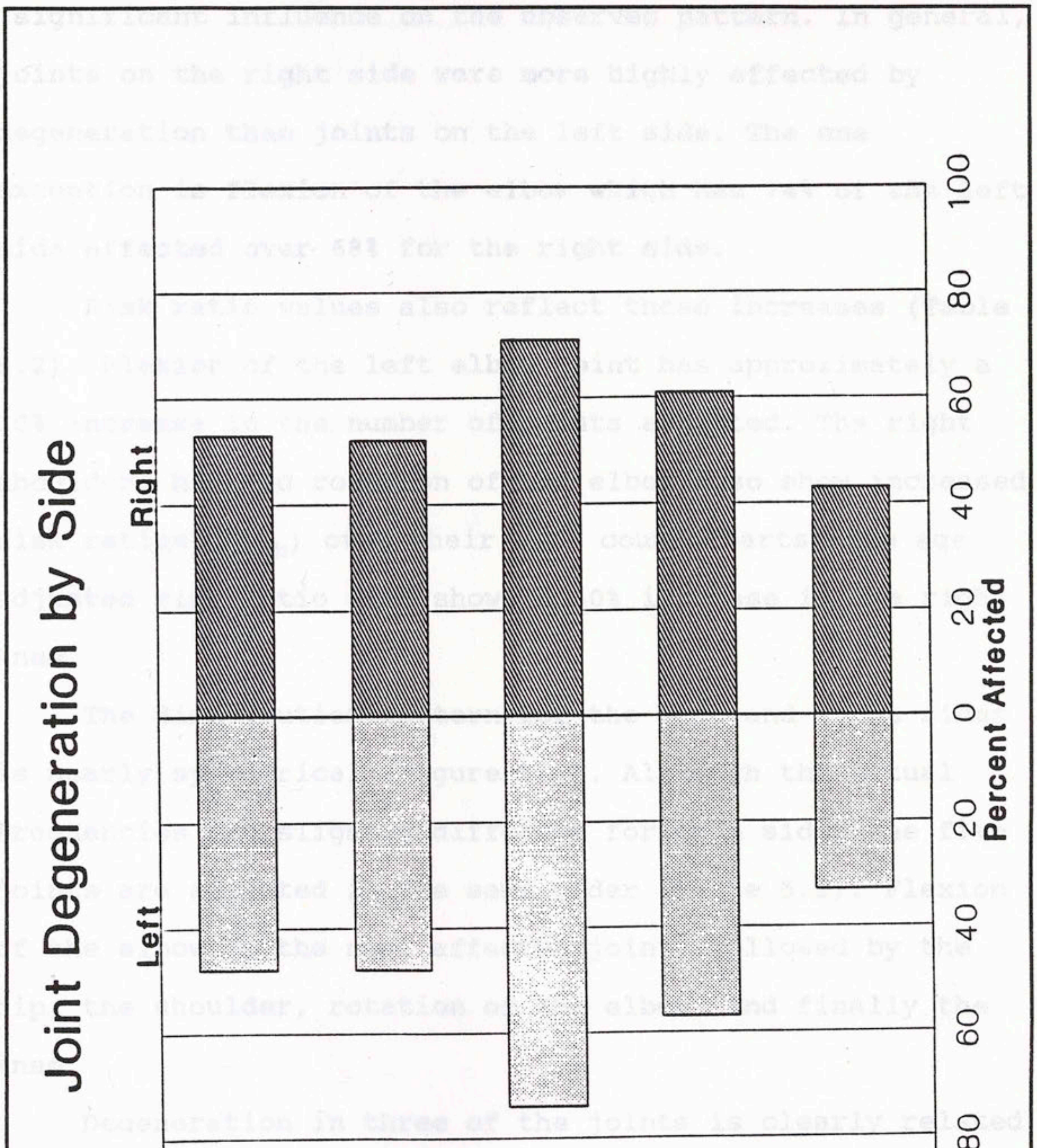

Joint Degeneration by Side
Left
Right
SJ
EJR
EJF
HJ
KJ
100 80 60 40 20 0 20 40 60 80 100
Percent Affected

Figure 5.7

significant influence on the observed pattern. In general, joints on the right side were more highly affected by degeneration than joints on the left side. The one exception is flexion of the elbow which has 74% of the left side affected over 68% for the right side.

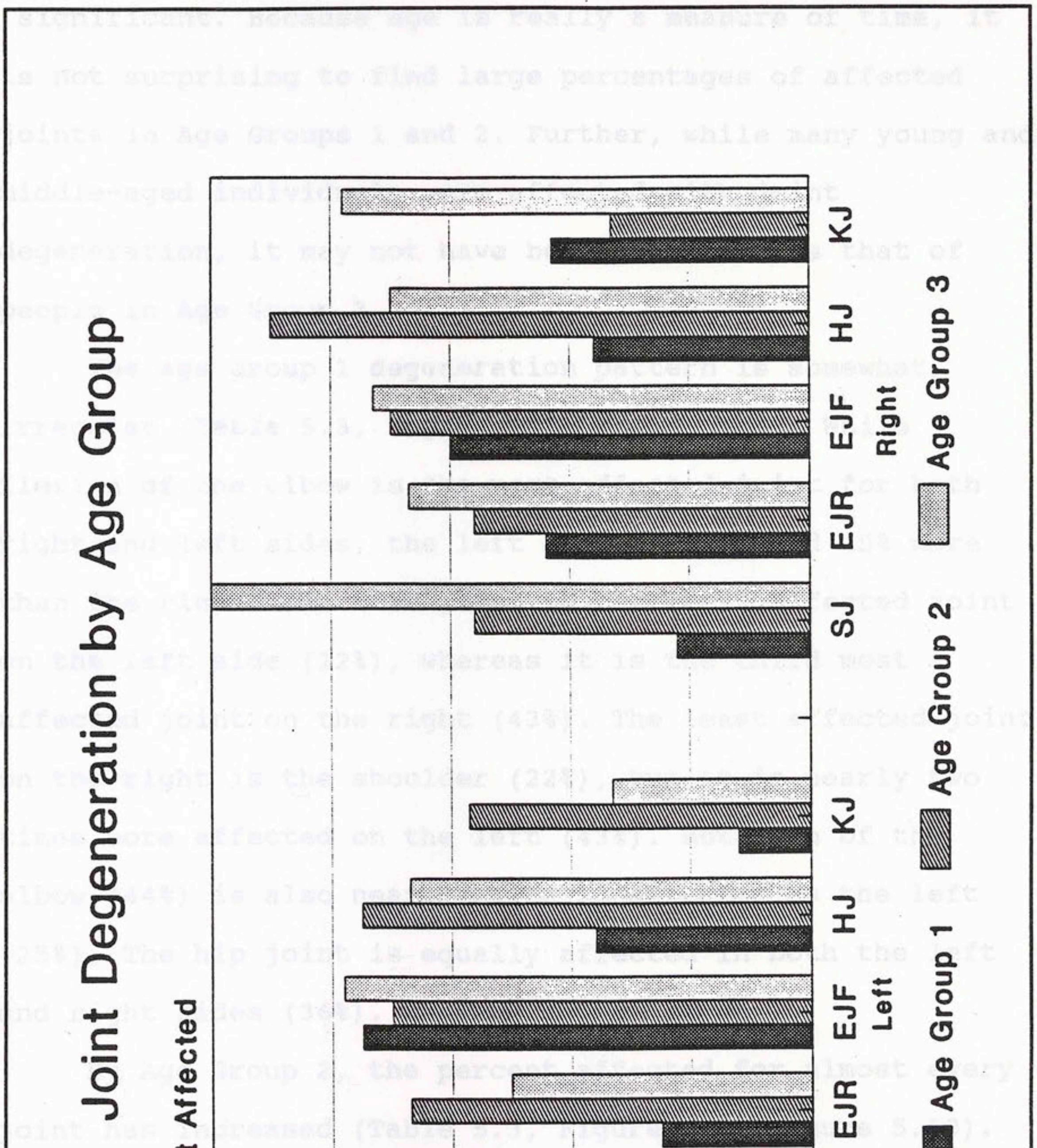
Risk ratio values also reflect these increases (Table 5.2). Flexion of the left elbow joint has approximately a 10% increase in the number of joints affected. The right shoulder, hip and rotation of the elbow also show increased risk ratios ($RR_{mh}$) over their left counterparts. The age adjusted risk ratio also shows a 60% increase in the right knee.

The distribution pattern for the left and right sides is nearly symmetrical (Figure 5.7). Although the actual frequencies are slightly different for each side, the five joints are affected in the same order (Table 5.2). Flexion of the elbow is the most affected joint, followed by the hip, the shoulder, rotation of the elbow, and finally the knee.

Degeneration in three of the joints is clearly related to age (Table 5.3, Figure 5.8). 78% of the individuals in Age Group 3 were affected with degeneration of the left shoulder joint and everyone in this same age group had degeneration in the right shoulder. The right hip joint was affected with degeneration in 90% of the individuals in Age Group 2. All three of these differences are statistically

**Table 5.3: Joint Degeneration by Age Group**

| | LEFT | | | | | | | | | | RIGHT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SJ | | EJR | | EJF | | HJ | | KJ | | SJ | | EJR | | EJF | | HJ | | KJ | |
| | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) |
| Age Group 1 | 43 | (3) | 25 | (2) | 75 | (6) | 36 | (4) | 12 | (1) | 22 | (2) | 44 | (4) | 60 | (6) | 36 | (4) | 43 | (3) |
| Age Group 2 | 22 | (2) | 67 | (6) | 70 | (7) | 75 | (6) | 57 | (4) | 56 | (5) | 56 | (5) | 70 | (7) | 90 | (9) | 33 | (2) |
| Age Group 3 | 78 | (7) | 50 | (5) | 78 | (7) | 67 | (6) | 33 | (3) | 100 | (8) | 67 | (6) | 73 | (8) | 70 | (7) | 78 | (7) |
| RR(1-2) | 2.00 | | 0.37 | | 1.07 | | 0.48 | | 0.21 | | 0.39 | | 0.79 | | 0.86 | | 0.40 | | 1.30 | |
| RR(2-3) | 0.28 | | 1.34 | | 0.89 | | 1.12 | | 1.73 | | 0.56 | | 0.84 | | 0.96 | | 1.29 | | 0.42 | |
| RR(1-3) | 0.55 | | 0.50 | | 0.96 | | 0.54 | | 0.36 | | 0.22 | | 0.66 | | 0.82 | | 0.51 | | 0.55 | |
| $x^2$ | 5.67 | | 2.97 | | 0.15 | | 3.31 | | 3.35 | | 10.52 | | 0.90 | | 0.42 | | 6.78 | | 3.43 | |
| p | 0.06* | | 0.23 | | 0.93 | | 0.19* | | 0.18 | | 0.005* | | 0.64 | | 0.81 | | 0.03* | | 0.18 | |



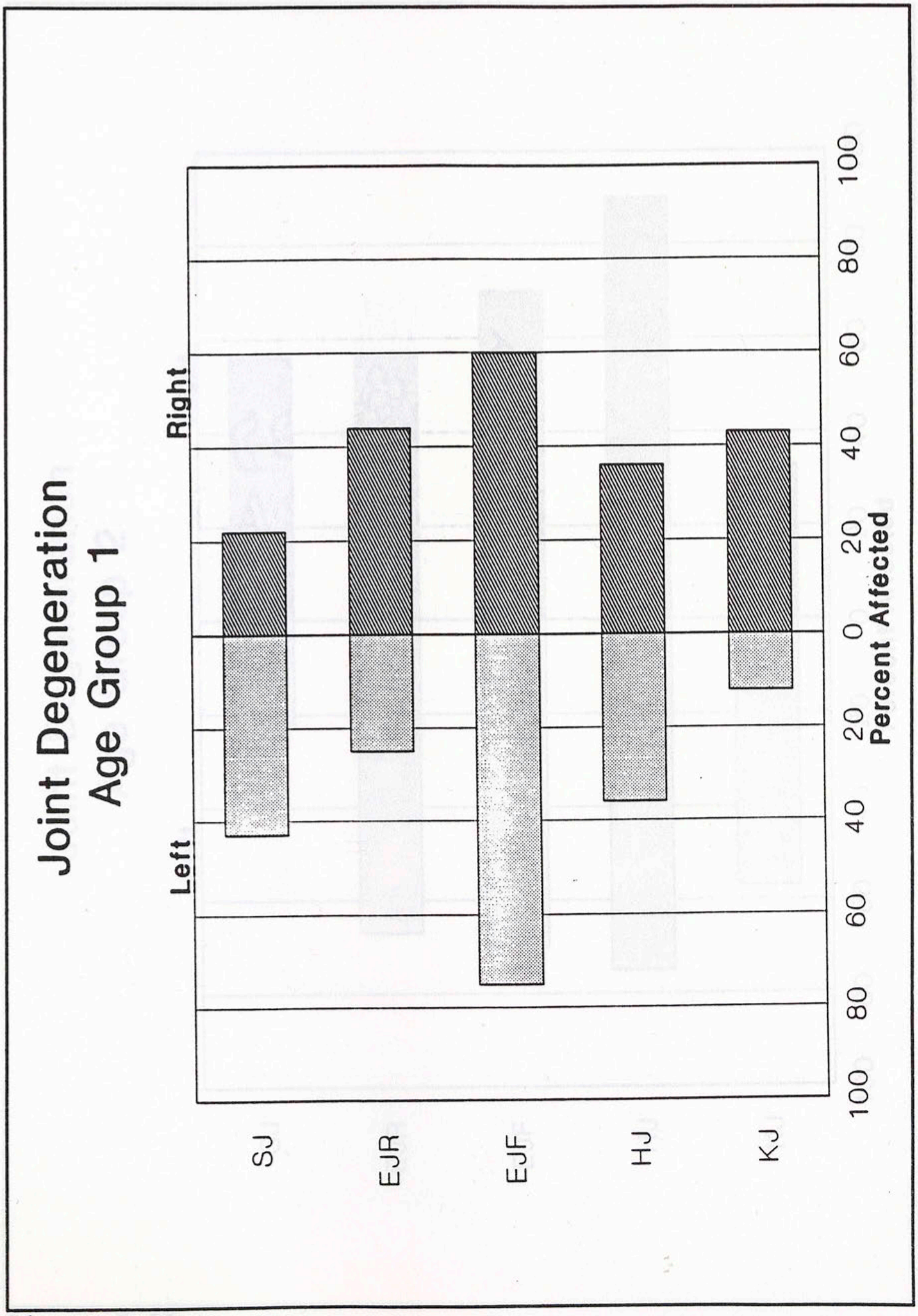
Joint Degeneration by Age Group
Percent Affected
100
80
60
40
20
0
SJ
EJR
EJF
HJ
KJ
Left
Right
Age Group 1
Age Group 2
Age Group 3


Figure 5.8

significant. Because age is really a measure of time, it is not surprising to find large percentages of affected joints in Age Groups 1 and 2. Further, while many young and middle-aged individuals were affected with joint degeneration, it may not have been as severe as that of people in Age Group 3.

The age group 1 degeneration pattern is somewhat irregular (Table 5.3, Figure 5.8, Figure 5.9). While flexion of the elbow is the most affected joint for both right and left sides, the left side is affected 15% more than the right. The knee joint is the least affected joint on the left side (12%), whereas it is the third most affected joint on the right (43%). The least affected joint on the right is the shoulder (22%), but it is nearly two times more affected on the left (43%). Rotation of the elbow (44%) is also nearly twice as affected as the left (25%). The hip joint is equally affected in both the left and right sides (36%).

By Age Group 2, the percent affected for almost every joint has increased (Table 5.3, Figure 5.8, Figure 5.10). The two exceptions are the left shoulder, which is only half as affected (22%) as it was in Age Group 1; and the right knee which has decreased from 43% in Age Group 1 to 33% in Age Group 2. The hip, both right and left, is the most affected joint in this age group, with the right side (90%) being somewhat more affected than the left (78%).


Joint Degeneration
Age Group 1
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected
Figure 5.9

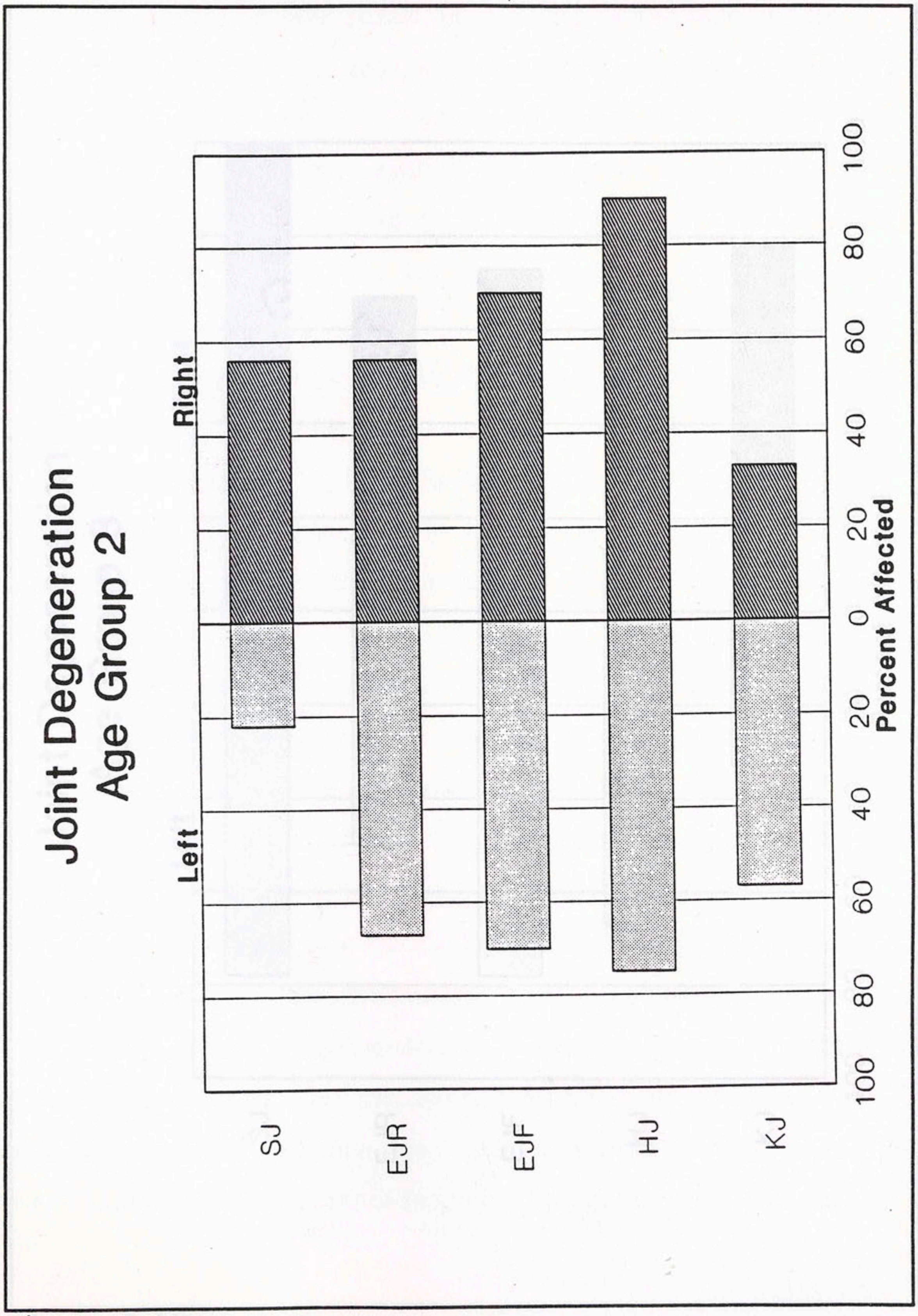

Joint Degeneration
Age Group 2
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected

Figure 5.10

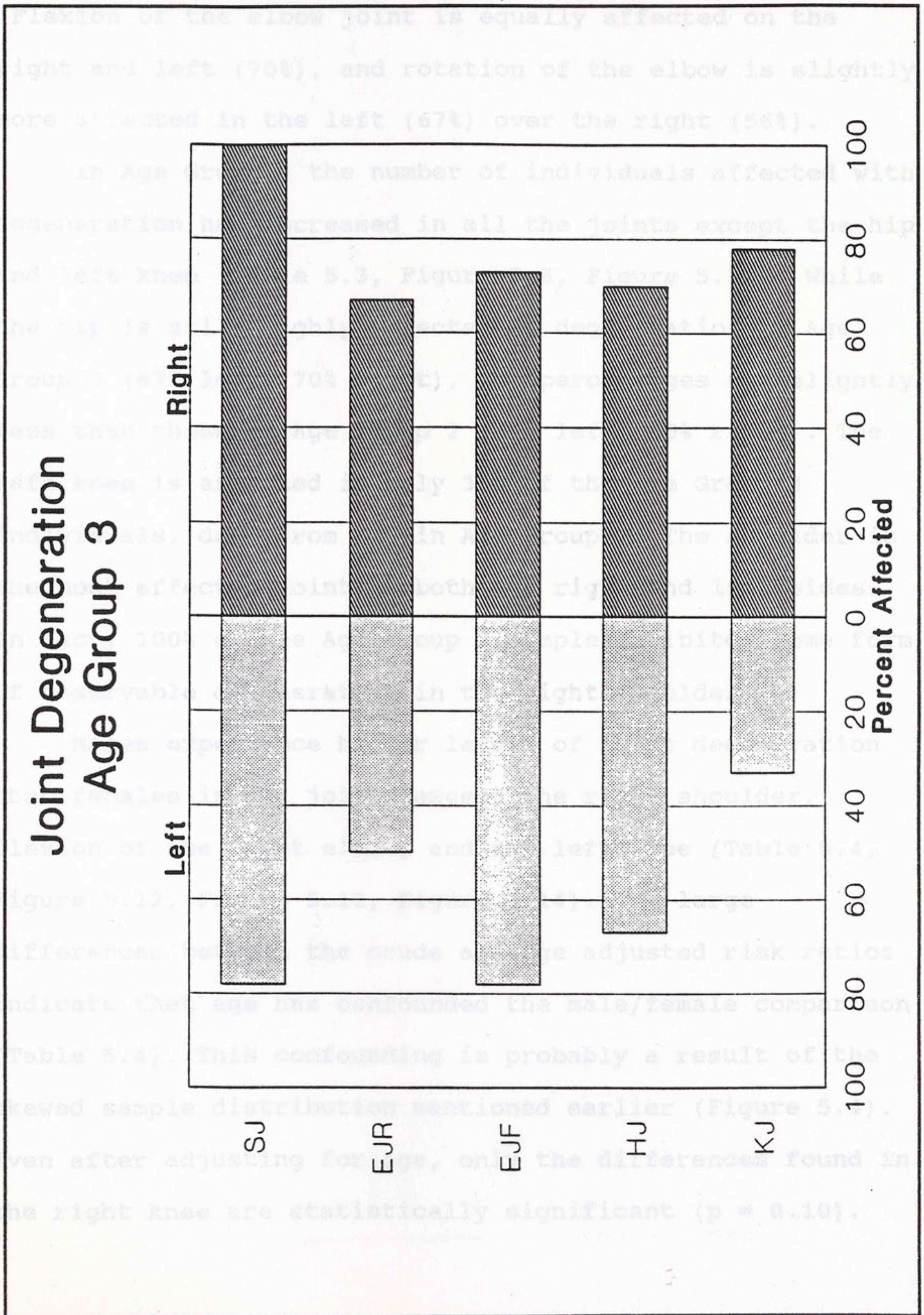

Joint Degeneration
Age Group 3
Left
Right
SJ
EJR
EJF
HJ
KJ
100 80 60 40 20 0 20 40 60 80 100
Percent Affected

Figure 5.11

Flexion of the elbow joint is equally affected on the right and left (70%), and rotation of the elbow is slightly more affected in the left (67%) over the right (56%).

In Age Group 3 the number of individuals affected with degeneration has increased in all the joints except the hip and left knee (Table 5.3, Figure 5.8, Figure 5.11). While the hip is still highly affected by degeneration in Age Group 3 (67% left; 70% right), the percentages are slightly less than those of Age Group 2 (75% left; 90% right). The left knee is affected in only 33% of the Age Group 3 individuals, down from 57% in Age Group 2. The shoulder is the most affected joint on both the right and left sides. In fact, 100% of the Age Group 3 sample exhibited some form of observable degeneration in the right shoulder.

Males experience higher levels of joint degeneration than females in all joints except the right shoulder, flexion of the right elbow, and the left knee (Table 5.4, Figure 5.12, Figure 5.13, Figure 5.14). The large differences between the crude and age adjusted risk ratios indicate that age has confounded the male/female comparison (Table 5.4). This confounding is probably a result of the skewed sample distribution mentioned earlier (Figure 5.4). Even after adjusting for age, only the differences found in the right knee are statistically significant ($p = 0.10$).

Table 5.4: Joint Degeneration by Gender

| | LEFT | | | | | | | | | | RIGHT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SJ | | EJR | | EJF | | HJ | | KJ | | SJ | | EJR | | EJF | | HJ | | KJ | |
| | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) |
| Female | 56 | (5) | 40 | (4) | 80 | (8) | 55 | (6) | 25 | (2) | 40 | (4) | 45 | (5) | 67 | (8) | 58 | (7) | 63 | (5) |
| Male | 44 | (7) | 53 | (9) | 71 | (12) | 59 | (10) | 38 | (6) | 69 | (11) | 63 | (10) | 68 | (13) | 68 | (13) | 50 | (7) |
| RR | 1.27 | | 0.75 | | 1.13 | | 0.93 | | 0.66 | | 0.58 | | 0.71 | | 0.99 | | 0.85 | | 1.26 | |
| Fisher's | 0.69 | | 0.70 | | 0.68 | | 1.00 | | 0.68 | | 0.23 | | 0.45 | | 1.00 | | 0.71 | | 0.68 | |
| Adjusted for Age: | | | | | | | | | | | | | | | | | | | | |
| $RR_{mh}$ | 1.42 | | 1.09 | | 1.17 | | 1.41 | | 4.56 | | 1.00 | | 0.83 | | 1.06 | | 1.26 | | 2.58 | |
| Fisher's | 0.39 | | 0.88 | | 0.59 | | 0.38 | | 0.17 | | 1.00 | | 0.69 | | 0.84 | | 0.48 | | 0.10* | |

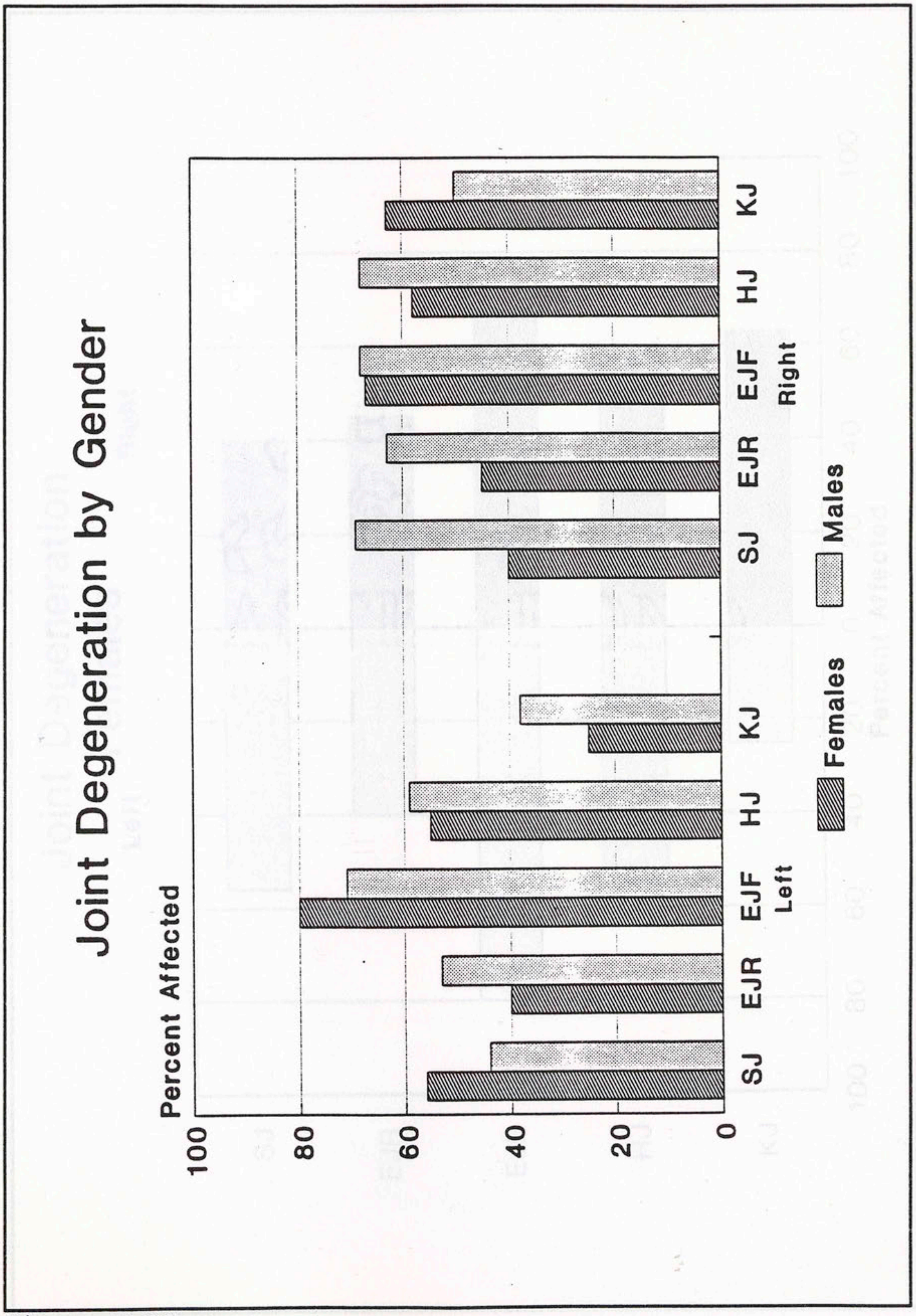
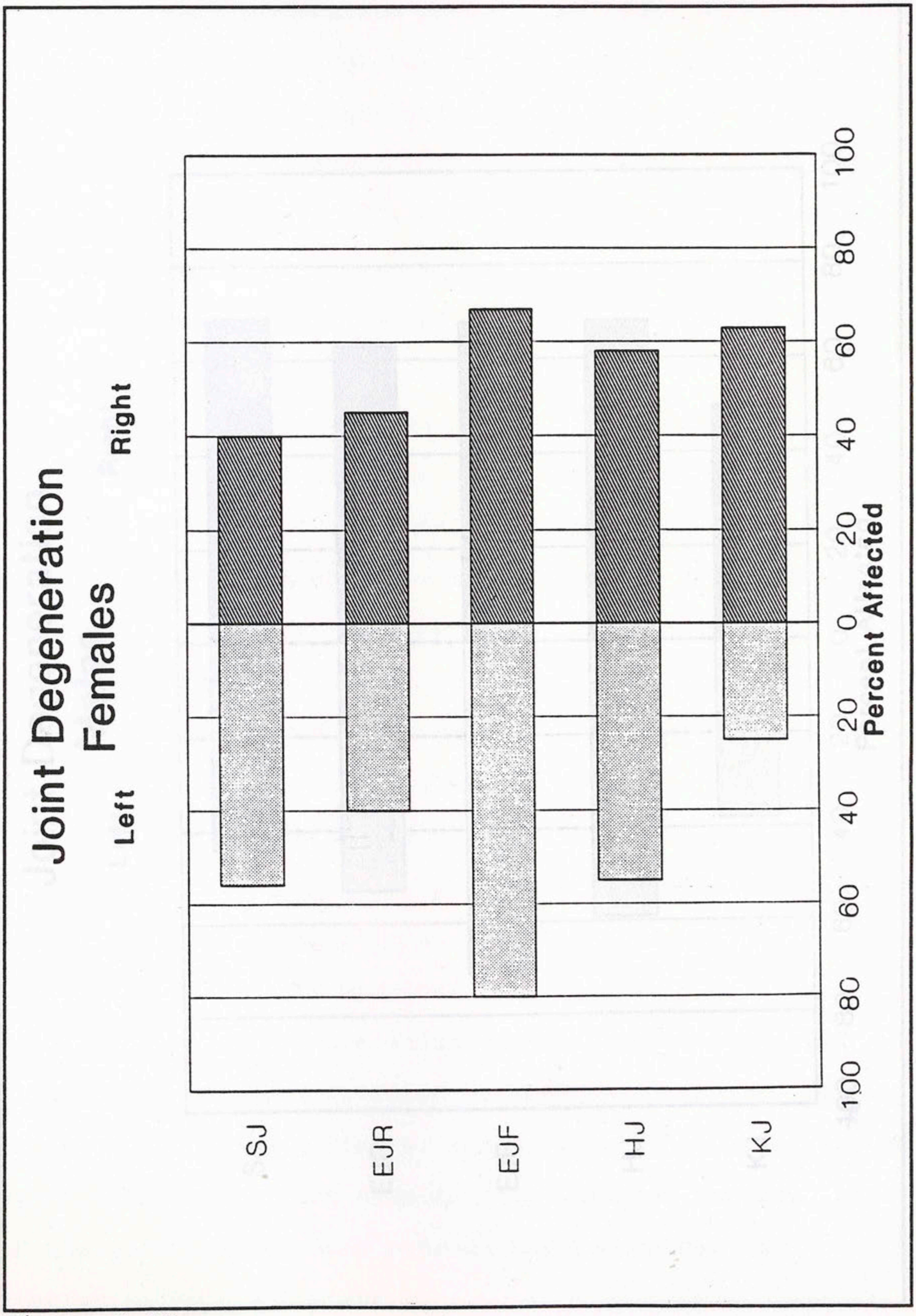

Joint Degeneration by Gender
Percent Affected
100
80
60
40
20
0
SJ
EJR
EJF
HJ
KJ
Left
SJ
EJR
EJF
HJ
KJ
Right
Females
Males

Figure 5.12


Joint Degeneration
Females
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected
Figure 5.13

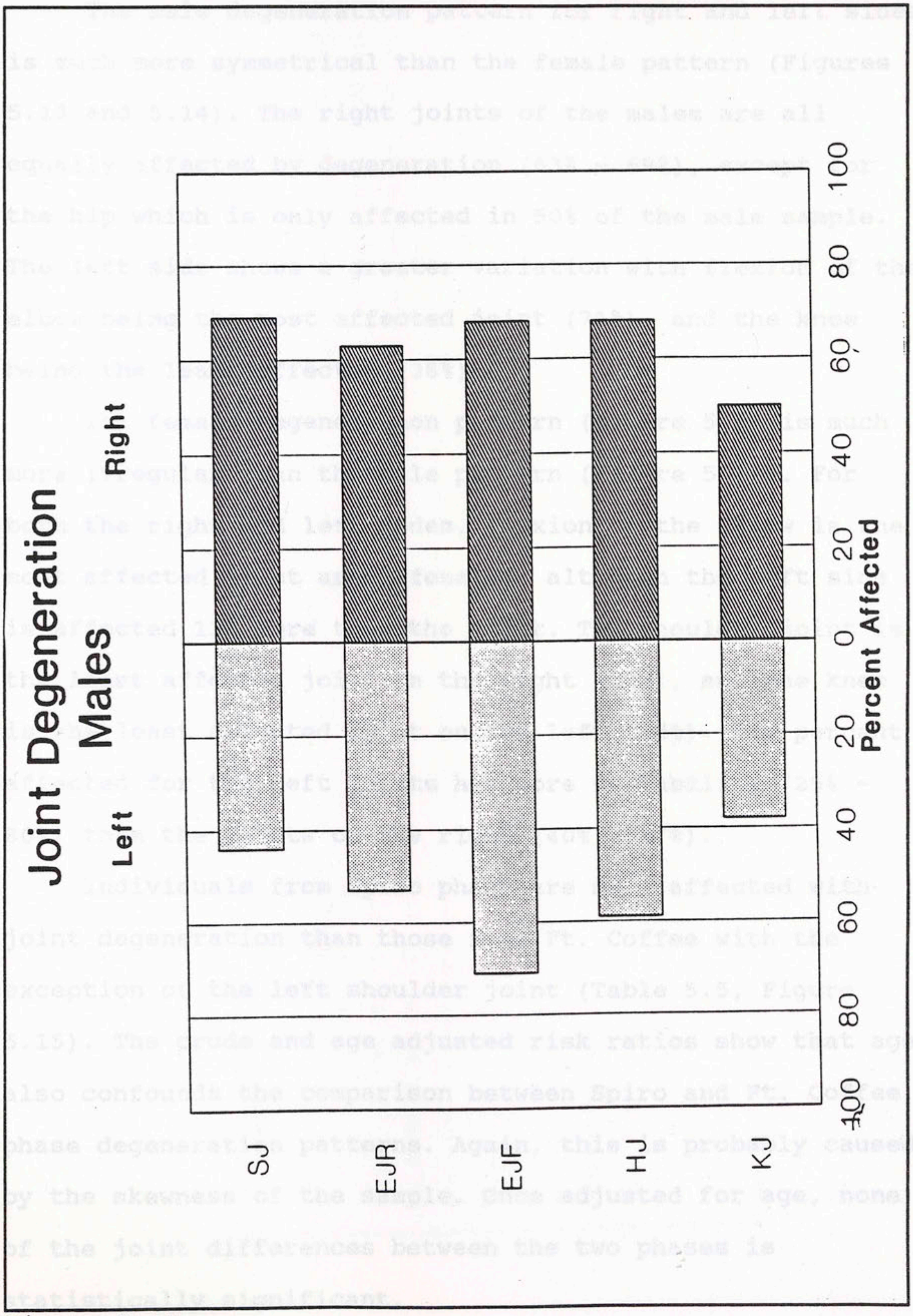

Joint Degeneration
Males
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected

Figure 5.14

The male degeneration pattern for right and left sides is much more symmetrical than the female pattern (Figures 5.13 and 5.14). The right joints of the males are all equally affected by degeneration (63% - 69%), except for the hip which is only affected in 50% of the male sample. The left side shows a greater variation with flexion of the elbow being the most affected joint (71%), and the knee being the least affected (38%).

The female degeneration pattern (Figure 5.13 is much more irregular than the male pattern (Figure 5.14). For both the right and left sides, flexion of the elbow is the most affected joint among females, although the left side is affected 13% more than the right. The shoulder joint is the least affected joint on the right (40%), and the knee is the least affected joint on the left (25%). The percent affected for the left joints has more variability (25% - 80%) than the joints on the right (40% - 67%).

Individuals from Spiro phase are more affected with joint degeneration than those from Ft. Coffee with the exception of the left shoulder joint (Table 5.5, Figure 5.15). The crude and age adjusted risk ratios show that age also confounds the comparison between Spiro and Ft. Coffee phase degeneration patterns. Again, this is probably caused by the skewness of the sample. Once adjusted for age, none of the joint differences between the two phases is statistically significant.

Table 5.5: Joint Degeneration by Phase

| | LEFT | | | | | | | | | | RIGHT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SJ | | EJR | | EJF | | HJ | | KJ | | SJ | | EJR | | EJF | | HJ | | KJ | |
| | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) | % | (n) |
| Spiro | 46 | (6) | 62 | (8) | 79 | (11) | 75 | (9) | 45 | (5) | 77 | (10) | 62 | (8) | 69 | (11) | 80 | (12) | 60 | (6) |
| Ft. Coffee | 50 | (6) | 36 | (5) | 69 | (9) | 44 | (7) | 23 | (3) | 38 | (5) | 50 | (7) | 67 | (10) | 50 | (8) | 50 | (6) |
| RR | 0.92 | | 1.72 | | 1.14 | | 1.70 | | 1.96 | | 2.02 | | 1.24 | | 1.03 | | 1.60 | | 1.20 | |
| p | 0.50 | | 0.13 | | 0.34 | | 0.07* | | 0.20 | | 0.06* | | 0.35 | | 0.50 | | 0.07* | | 0.35 | |
| Adjusted for Age: | | | | | | | | | | | | | | | | | | | | |
| $RR_{mh}$ | 0.90 | | 1.18 | | 1.34 | | 1.30 | | 1.28 | | 5.00 | | 1.20 | | 0.92 | | 1.06 | | 1.17 | |
| p | 0.40 | | 0.38 | | 0.20 | | 0.23 | | 0.37 | | 0.13 | | 0.38 | | 0.39 | | 0.41 | | 0.37 | |

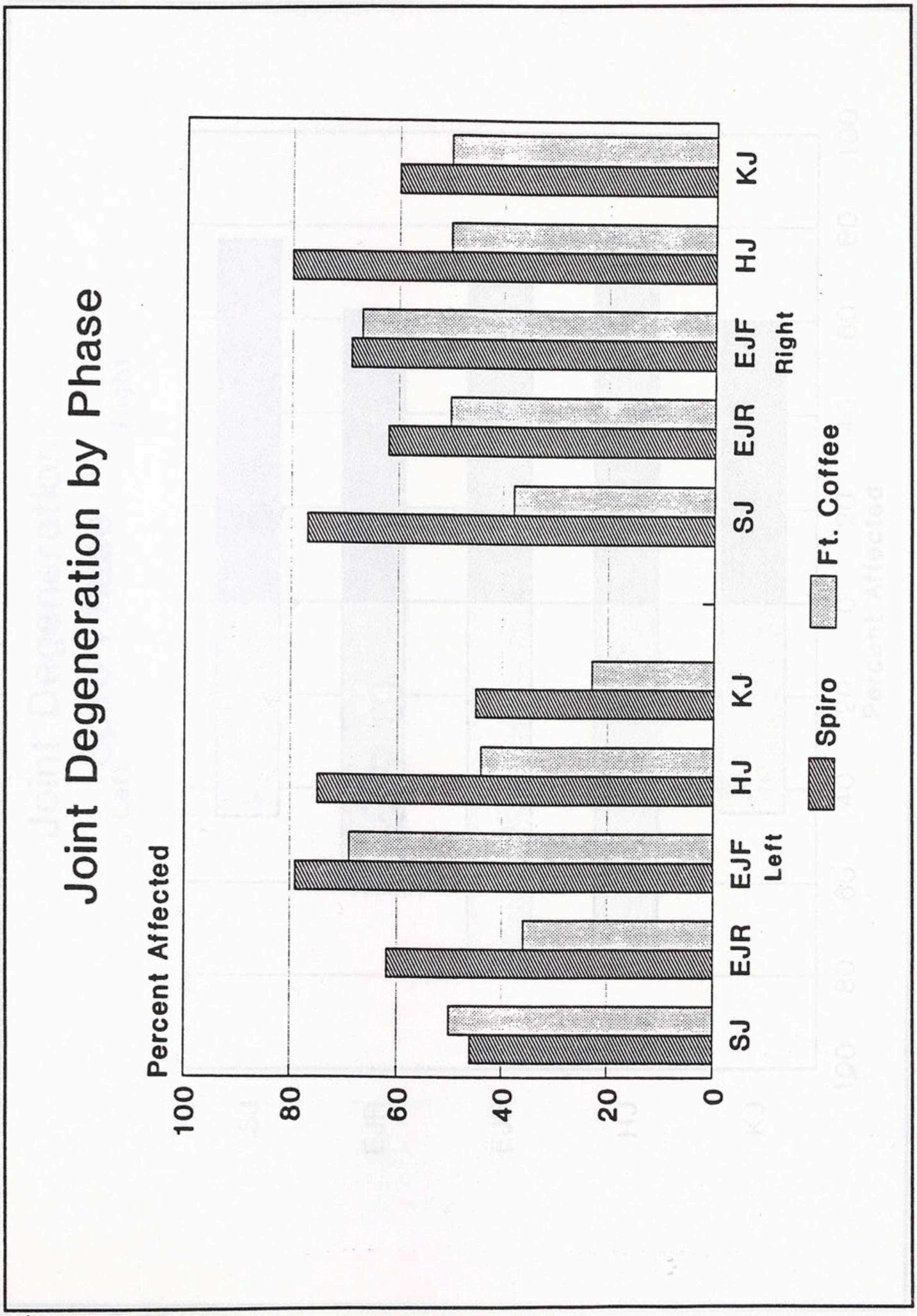
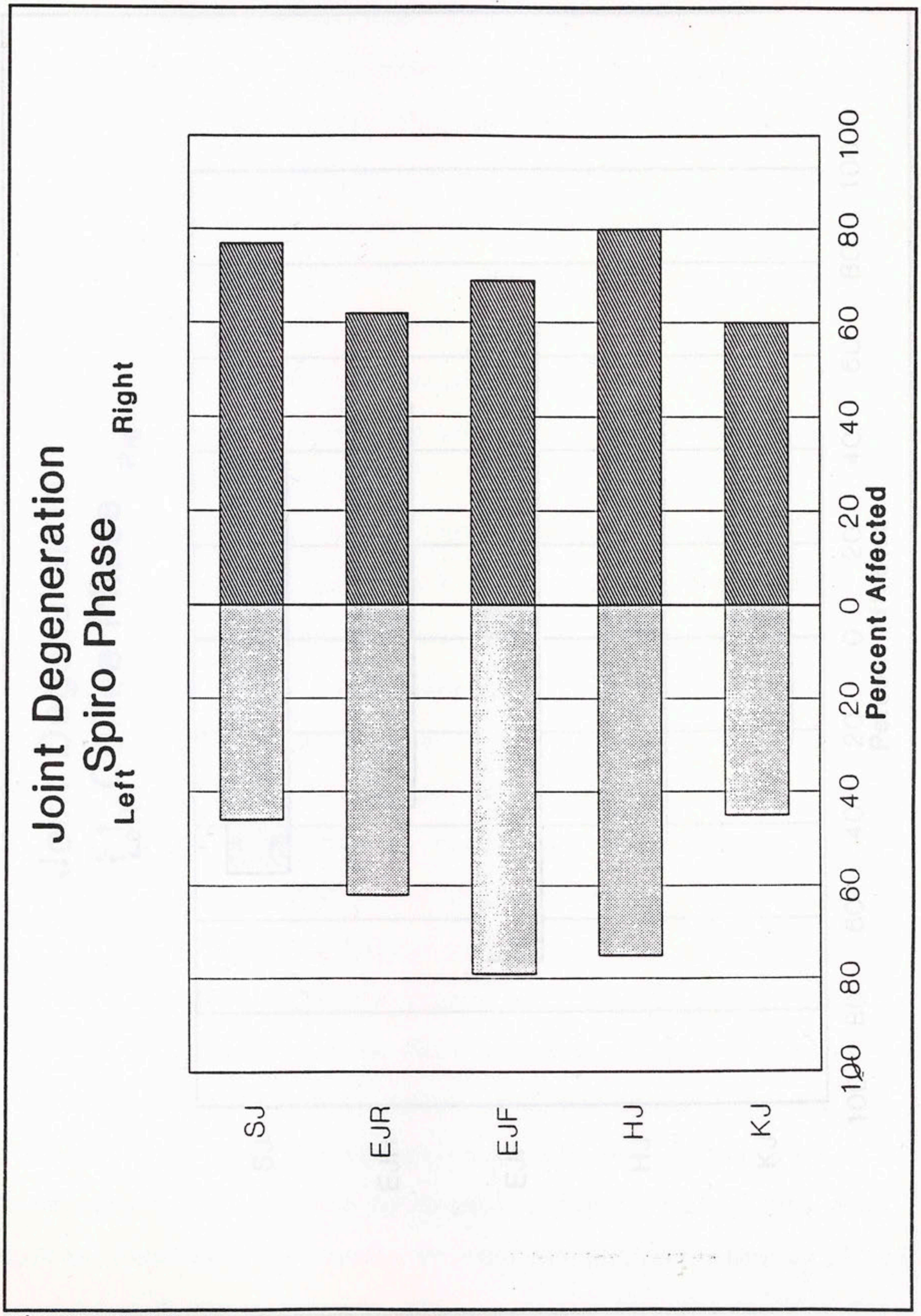

Joint Degeneration by Phase
Percent Affected
100
80
60
40
20
0
SJ
EJR
EJF
HJ
KJ
Left
SJ
EJR
EJF
HJ
KJ
Right
Spiro
Ft. Coffee

Figure 5.15



Joint Degeneration
Spiro Phase
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected


Figure 5.16

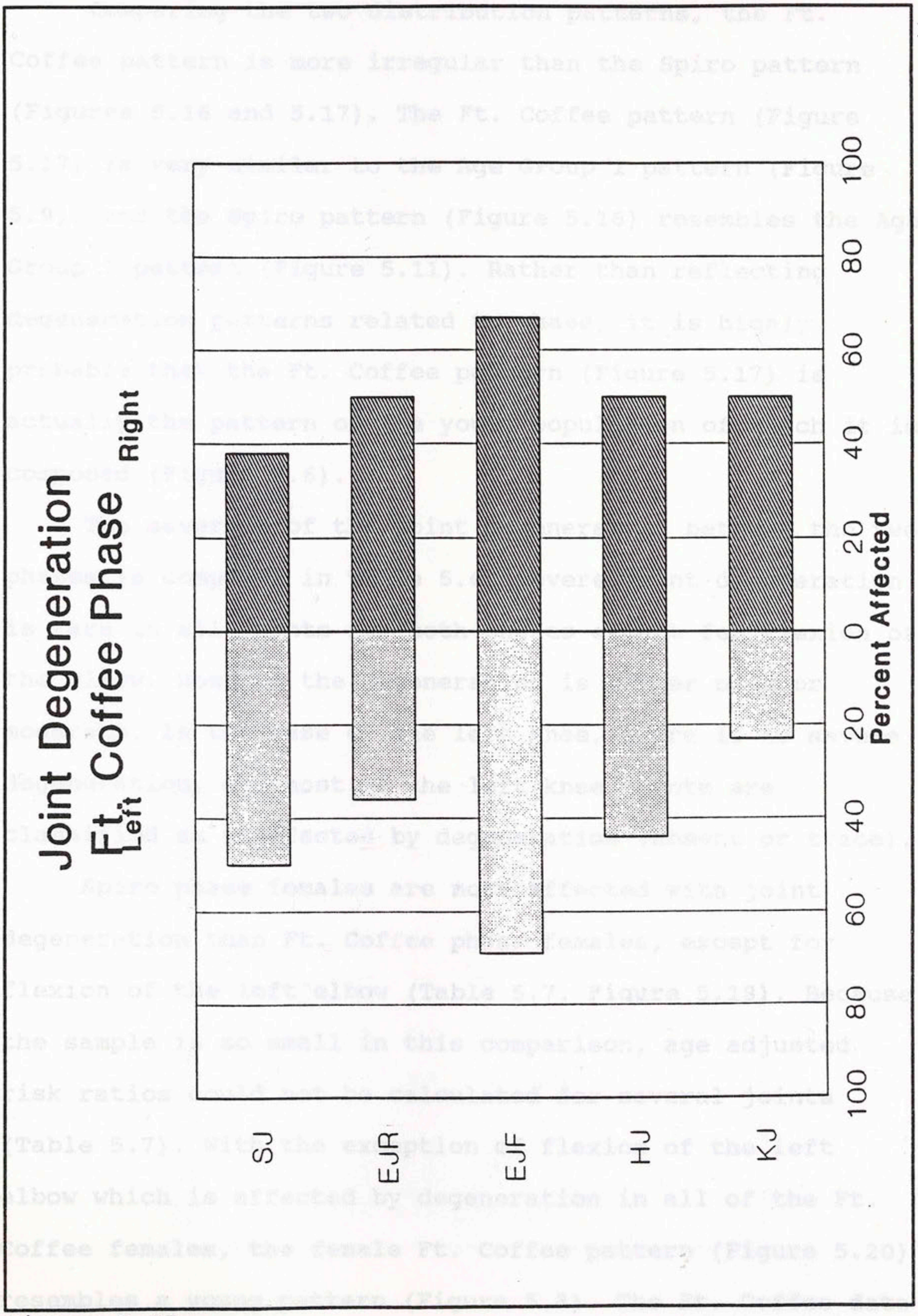

Joint Degeneration
Ft. Coffee Phase
Left
Right
SJ
EJR
EJF
HJ
KJ
100 80 60 40 20 0 20 40 60 80 100
Percent Affected

Figure 5.17

Comparing the two distribution patterns, the Ft. Coffee pattern is more irregular than the Spiro pattern (Figures 5.16 and 5.17). The Ft. Coffee pattern (Figure 5.17) is very similar to the Age Group 1 pattern (Figure 5.9), and the Spiro pattern (Figure 5.16) resembles the Age Group 3 pattern (Figure 5.11). Rather than reflecting degeneration patterns related to phase, it is highly probable that the Ft. Coffee pattern (Figure 5.17) is actually the pattern of the young population of which it is composed (Figure 5.6).

The severity of the joint degeneration between the two phases is compared in Table 5.6. Severe joint degeneration is rare in all joints for both phases except for flexion of the elbow. Most of the degeneration is either mild or moderate. In the case of the left knee, there is no severe degeneration, and most of the left knee joints are classified as unaffected by degeneration (absent or trace).

Spiro phase females are more affected with joint degeneration than Ft. Coffee phase females, except for flexion of the left elbow (Table 5.7, Figure 5.18). Because the sample is so small in this comparison, age adjusted risk ratios could not be calculated for several joints (Table 5.7). With the exception of flexion of the left elbow which is affected by degeneration in all of the Ft. Coffee females, the female Ft. Coffee pattern (Figure 5.20) resembles a young pattern (Figure 5.8). The Ft. Coffee data

Table 5.6: Severity of Joint Degeneration by Phase

| SJ | Absent % (n) | Trace % (n) | Mild % (n) | Moderate % (n) | Severe % (n) | p | Absent % (n) | Trace % (n) | Mild % (n) | Moderate % (n) | Severe % (n) | p |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spiro | 23 (3) | 30 (4) | 46 (6) | 0 (0) | 0 (0) | 0.98 | 8 (1) | 15 (2) | 46 (6) | 23 (3) | 8 (1) | 0.03* |
| Ft. Coffee | 33 (4) | 16 (2) | 41 (5) | 8 (1) | 0 (0) | | 46 (6) | 15 (2) | 31 (4) | 0 (0) | 8 (1) | |
| **EJR** | | | | | | | | | | | | |
| Spiro | 8 (1) | 31 (4) | 23 (3) | 38 (5) | 0 (0) | 0.04* | 23 (3) | 15 (2) | 23 (3) | 15 (2) | 23 (3) | 0.33 |
| Ft. Coffee | 57 (8) | 7 (1) | 21 (3) | 7 (1) | 7 (1) | | 36 (5) | 14 (2) | 21 (3) | 29 (4) | 0 (0) | |
| **EJF** | | | | | | | | | | | | |
| Spiro | 14 (2) | 7 (1) | 28 (4) | 36 (5) | 14 (2) | 0.69 | 13 (2) | 19 (3) | 31 (5) | 0 (0) | 38 (6) | 0.92 |
| Ft. Coffee | 15 (2) | 15 (2) | 23 (3) | 39 (5) | 8 (1) | | 20 (3) | 13 (2) | 13 (2) | 27 (4) | 27 (4) | |
| **NJ** | | | | | | | | | | | | |
| Spiro | 0 (0) | 25 (3) | 50 (6) | 25 (3) | 0 (0) | 0.12 | 13 (2) | 7 (1) | 40 (6) | 33 (5) | 7 (1) | 0.11 |
| Ft. Coffee | 31 (5) | 25 (4) | 25 (4) | 13 (2) | 6 (1) | | 38 (6) | 13 (2) | 25 (4) | 25 (4) | 0 (0) | |
| **KJ** | | | | | | | | | | | | |
| Spiro | 18 (2) | 36 (4) | 27 (3) | 18 (2) | 0 (0) | 0.19 | 10 (1) | 30 (3) | 30 (3) | 30 (3) | 0 (0) | 0.41 |
| Ft. Coffee | 46 (6) | 31 (4) | 8 (1) | 15 (2) | 0 (0) | | 33 (4) | 17 (2) | 33 (4) | 8 (1) | 8 (1) | |

Table 5.7: Joint Degeneration by Phase (Females)

| | LEFT | | | | | RIGHT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJ | EJR | EJF | HJ | KJ | SJ | EJR | EJF | HJ | KJ |
| | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) |
| Spiro | 75 (3) | 50 (2) | 60 (3) | 100 (4) | 50 (1) | 60 (3) | 60 (3) | 83 (5) | 80 (4) | 67 (2) |
| Ft. Coffee | 40 (2) | 33 (2) | 100 (5) | 29 (2) | 17 (1) | 20 (1) | 33 (2) | 50 (3) | 43 (3) | 60 (3) |
| RR | 1.86 | 1.52 | 0.60 | 3.45 | 2.94 | 3.00 | 1.82 | 1.66 | 1.86 | 1.12 |
| p | 0.52 | 1.00 | 0.44 | 0.06* | 0.46 | 0.52 | 0.57 | 0.55 | 0.29 | 1.00 |
| Adjusted for Age: | | | | | | | | | | |
| $RR_{mh}$ | n.d. | n.d. | n.d. | 3.50 | 0.00 | 0.00 | 3.00 | 2.00 | 2.33 | 0.00 |
| p | n.d. | n.d. | n.d. | 0.20 | 0.68 | 0.66 | 0.25 | 0.39 | 0.32 | 0.32 |

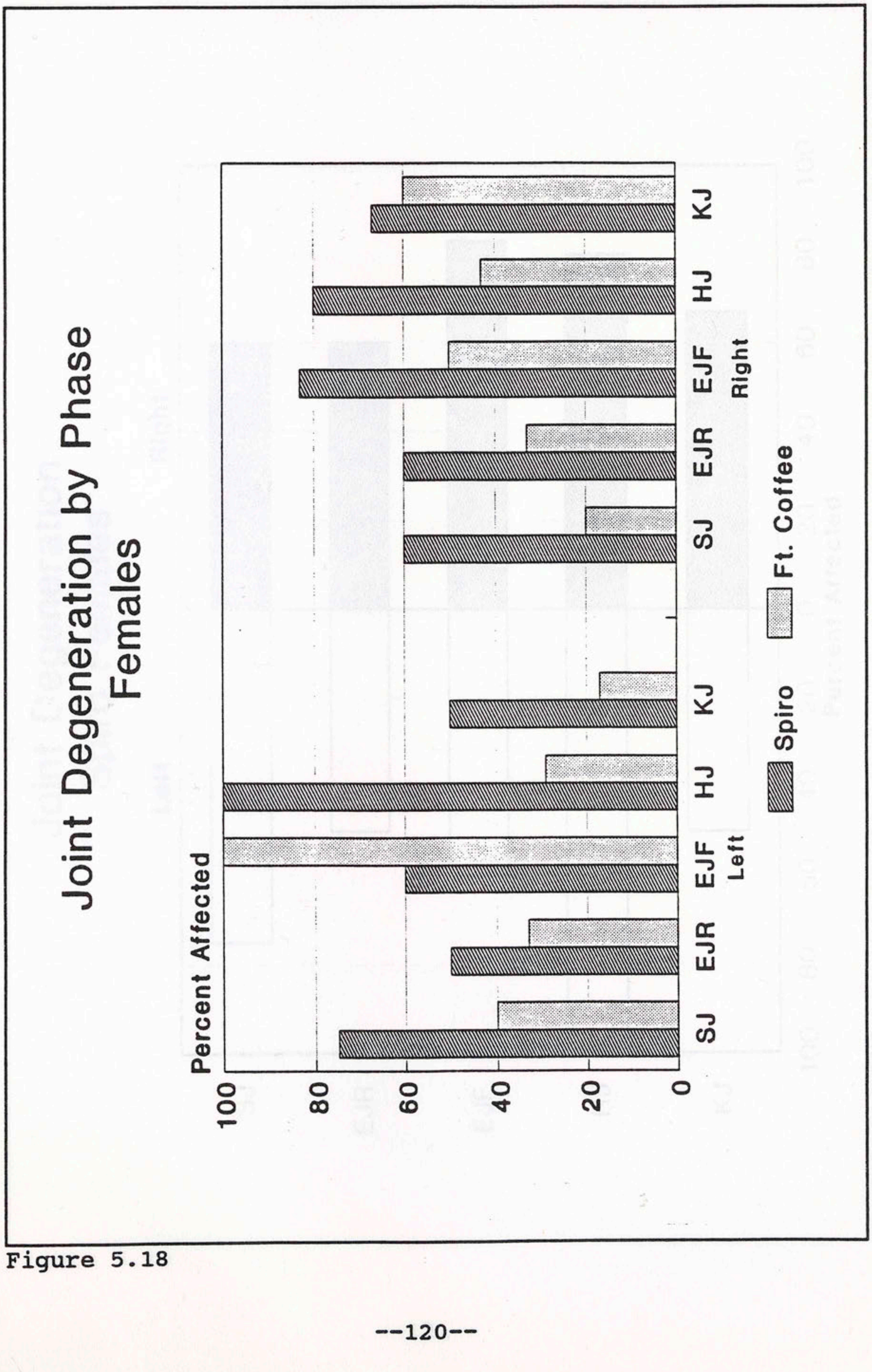

Joint Degeneration by Phase
Females
Percent Affected
100
80
60
40
20
0
SJ
EJR
EJF
HJ
KJ
Left
SJ
EJR
EJF
HJ
KJ
Right
Spiro
Ft. Coffee

Figure 5.18

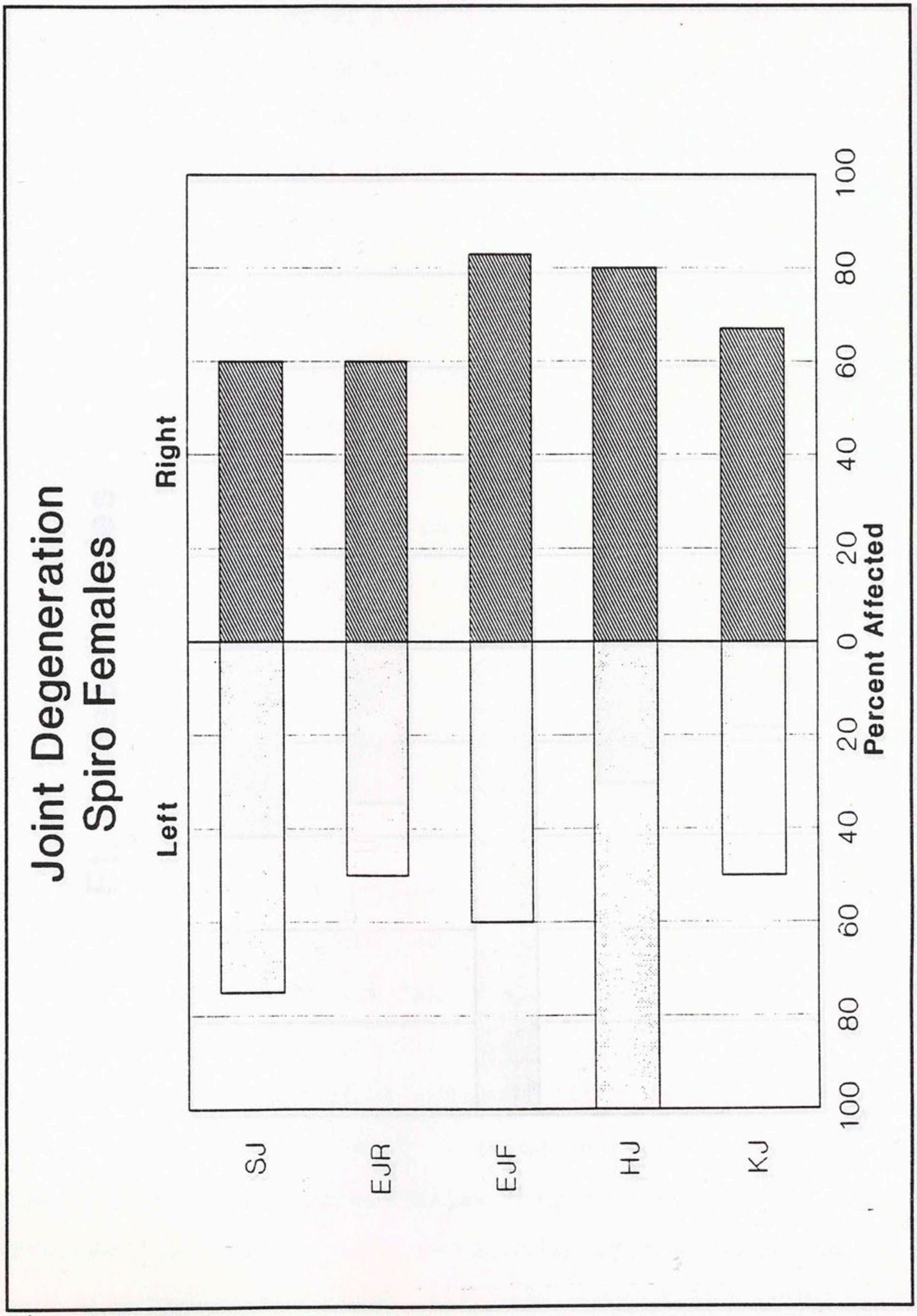
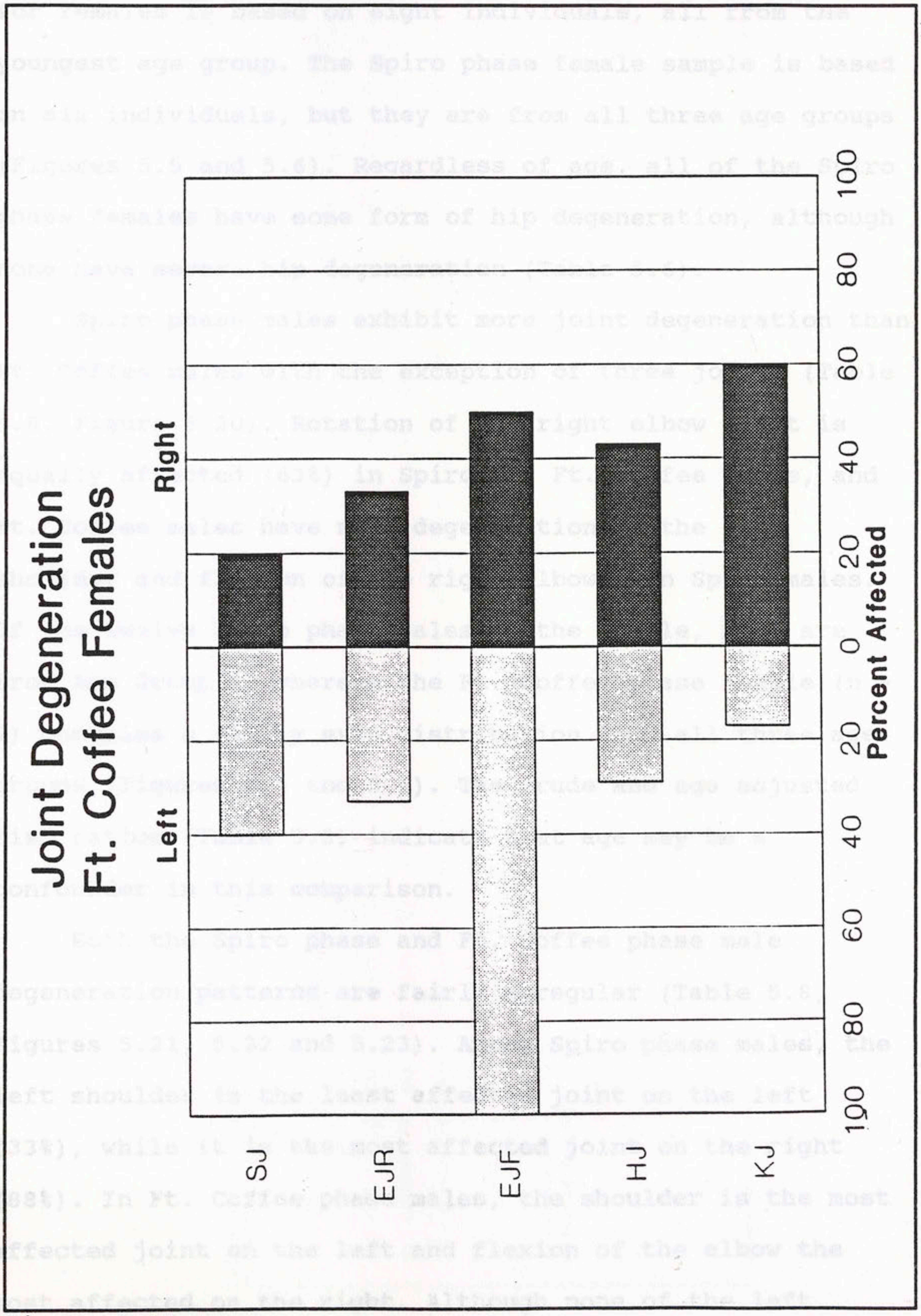

Joint Degeneration
Spiro Females
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected

Figure 5.19


Joint Degeneration
Ft. Coffee Females
Left
Right
SJ
EJR
EJF
HJ
KJ
100 80 60 40 20 0 20 40 60 80 100
Percent Affected
Figure 5.20

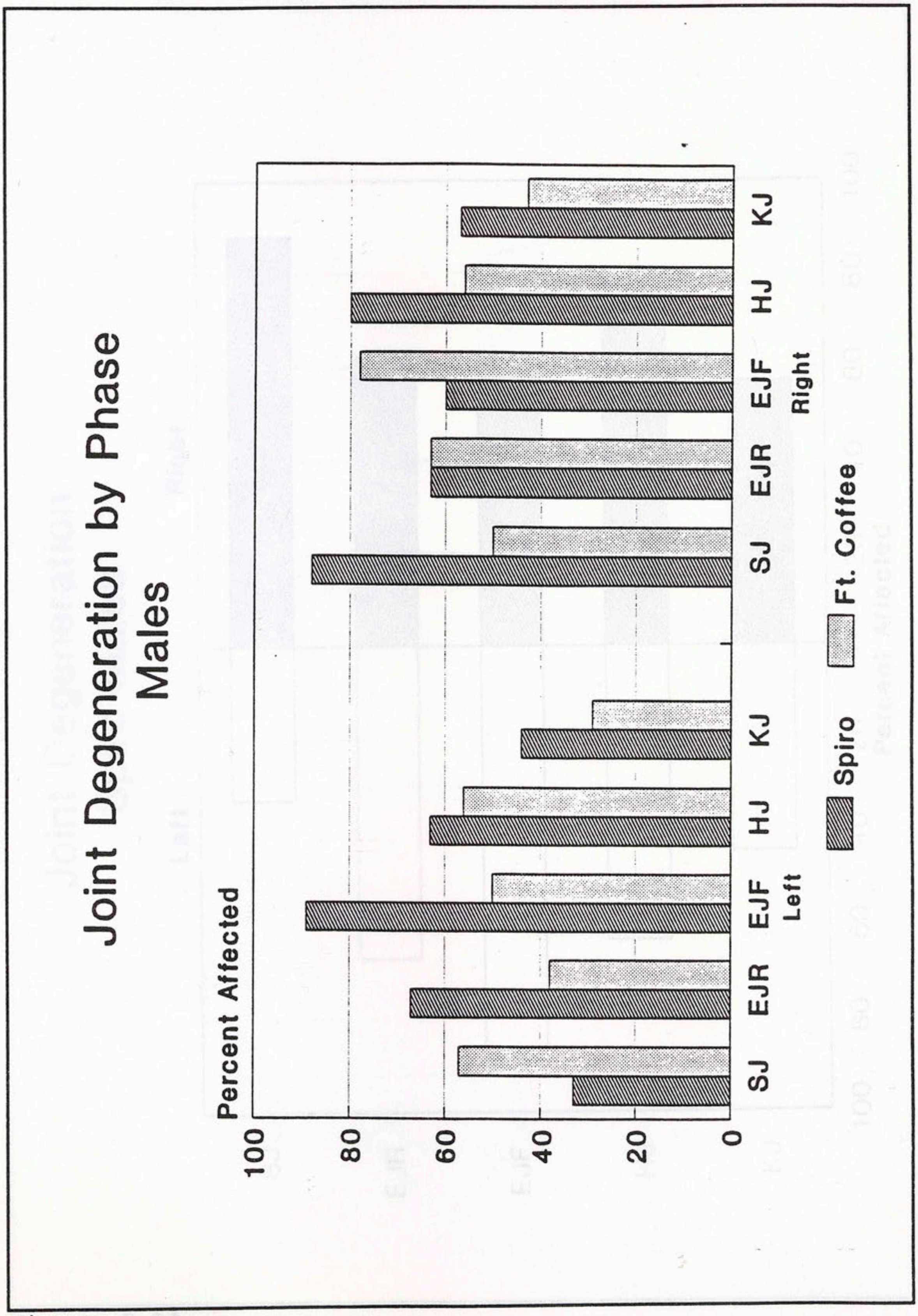
for females is based on eight individuals, all from the youngest age group. The Spiro phase female sample is based on six individuals, but they are from all three age groups (Figures 5.5 and 5.6). Regardless of age, all of the Spiro phase females have some form of hip degeneration, although none have severe hip degeneration (Table 5.6).

Spiro phase males exhibit more joint degeneration than Ft. Coffee males with the exception of three joints (Table 5.8, Figure 5.20). Rotation of the right elbow joint is equally affected (63%) in Spiro and Ft. Coffee males, and Ft. Coffee males have more degeneration in the left shoulder and flexion of the right elbow than Spiro males. Of the twelve Spiro phase males in the sample, none are from Age Group 1, whereas the Ft. Coffee phase sample (n = 9) contains a fairly even distribution from all three age groups (Figures 5.5 and 5.6). The crude and age adjusted risk ratios (Table 5.8) indicate that age may be a confounder in this comparison.

Both the Spiro phase and Ft. Coffee phase male degeneration patterns are fairly irregular (Table 5.8, Figures 5.21, 5.22 and 5.23). Among Spiro phase males, the left shoulder is the least affected joint on the left (33%), while it is the most affected joint on the right (88%). In Ft. Coffee phase males, the shoulder is the most affected joint on the left and flexion of the elbow the most affected on the right. Although none of the left

Table 5.8: Joint Degeneration by Phase (Males)

| | LEFT | | | | | RIGHT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SJ<br>% (n) | EJR<br>% (n) | EJF<br>% (n) | HJ<br>% (n) | KJ<br>% (n) | SJ<br>% (n) | EJR<br>% (n) | EJF<br>% (n) | HJ<br>% (n) | KJ<br>% (n) |
| Spiro | 33 (1) | 67 (6) | 89 (8) | 63 (5) | 44 (4) | 88 (7) | 63 (5) | 60 (6) | 80 (8) | 57 (4) |
| Ft. Coffee | 57 (4) | 38 (3) | 50 (4) | 56 (5) | 29 (2) | 50 (4) | 63 (5) | 78 (7) | 56 (5) | 43 (3) |
| RR | 0.58 | 1.76 | 1.78 | 1.13 | 1.52 | 1.76 | 1.00 | 0.77 | 1.43 | 1.33 |
| p | 0.62 | 0.35 | 0.13 | 1.00 | 0.63 | 0.28 | 1.00 | 0.63 | 0.35 | 1.00 |
| Adjusted for Age: | | | | | | | | | | |
| $RR_{mh}$ | 0.69 | 1.25 | 1.54 | 0.92 | 1.14 | n.d. | 0.92 | 0.75 | 0.80 | 1.27 |
| p | 0.47 | 0.65 | 0.19 | 0.86 | 0.88 | 0.11 | 0.86 | 0.42 | 0.66 | 0.63 |



Joint Degeneration by Phase
Males
Percent Affected
100
80
60
40
20
0
SJ
EJR
EJF
HJ
KJ
Left
SJ
EJR
EJF
HJ
KJ
Right
Spiro
Ft. Coffee


Figure 5.21

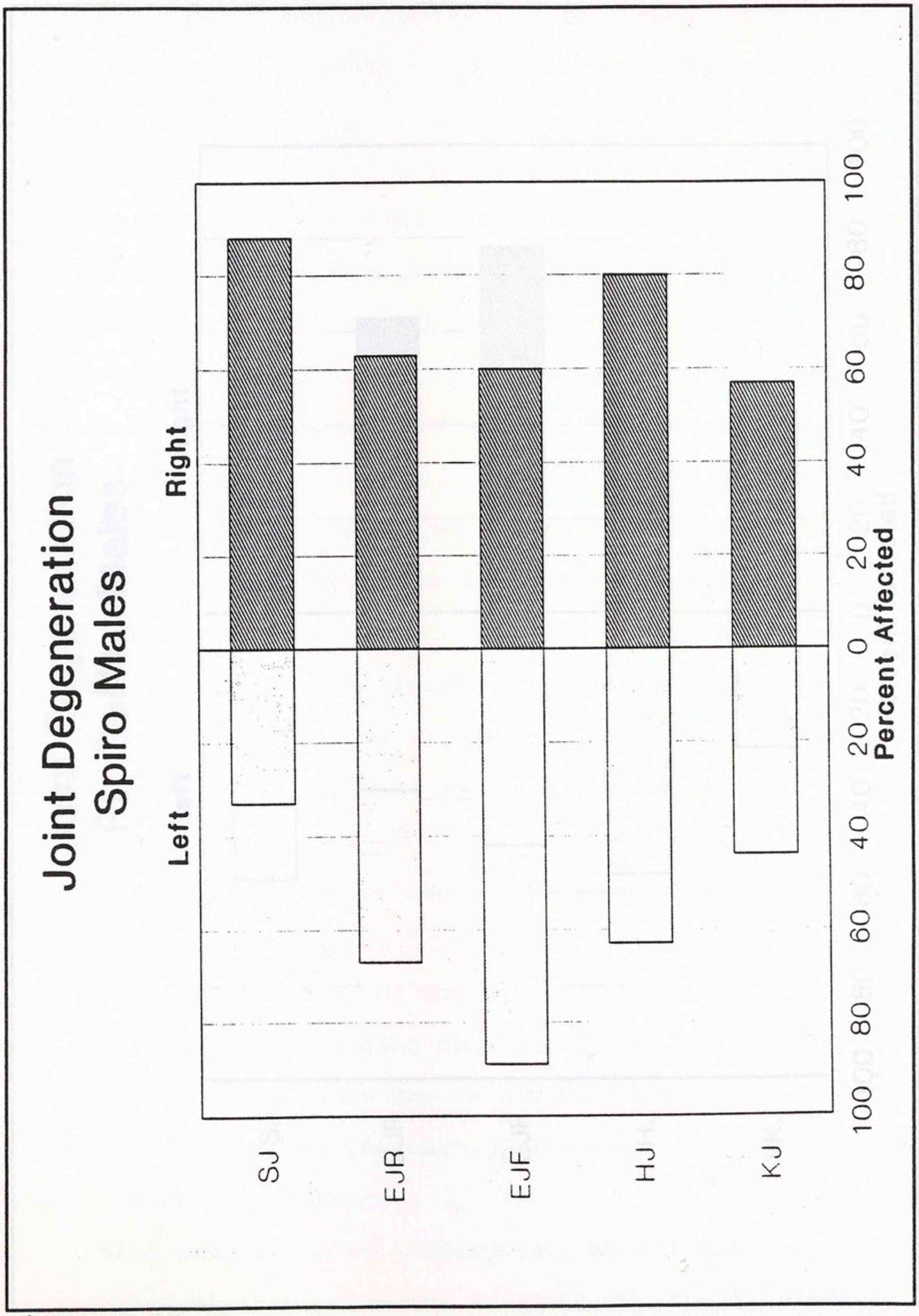
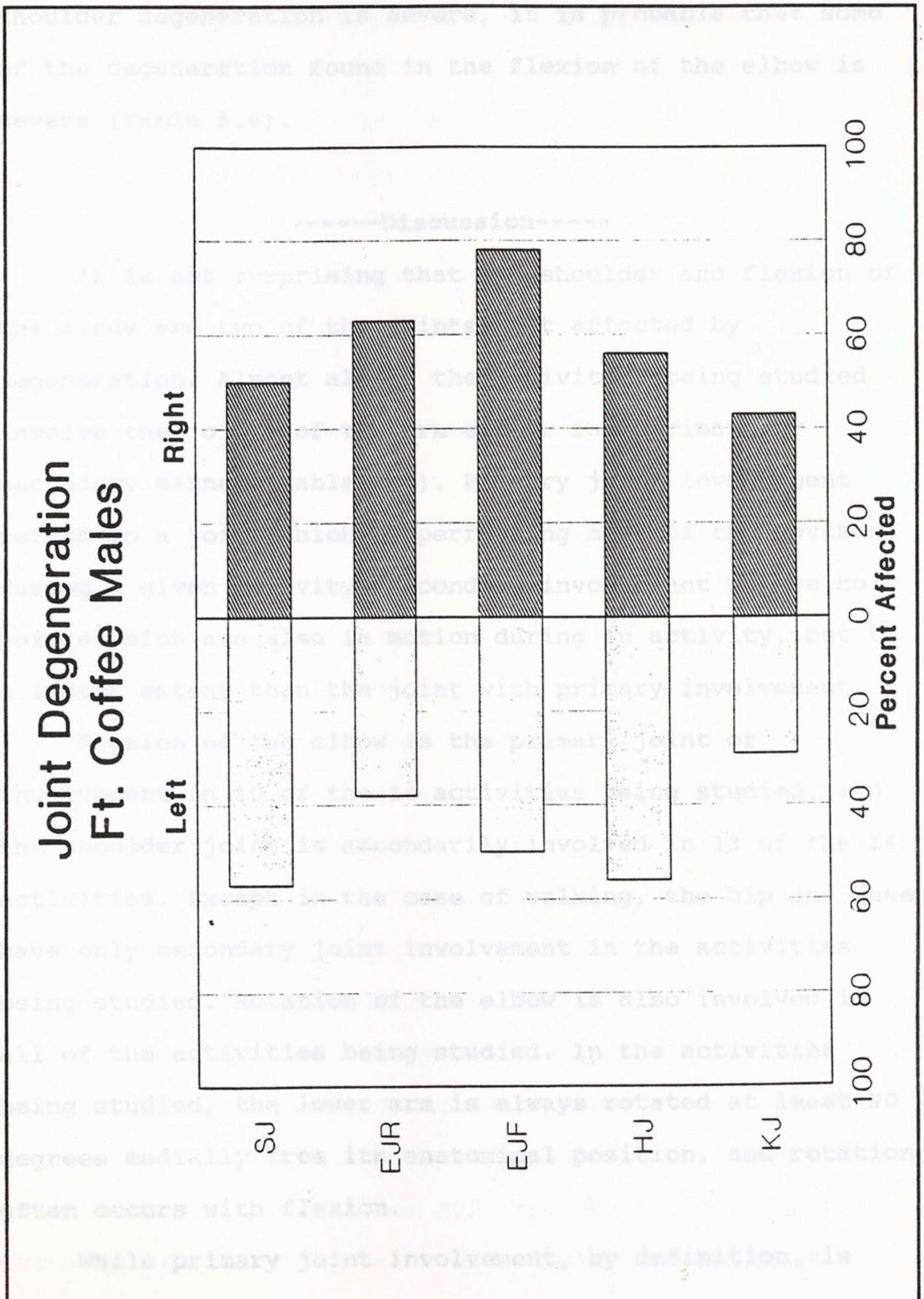

Joint Degeneration
Spiro Males
Left
Right
SJ
EJR
EJF
HJ
KJ
100 80 60 40 20 0 20 40 60 80 100
Percent Affected

Figure 5.22


Joint Degeneration
Ft. Coffee Males
Left
Right
SJ
EJR
EJF
HJ
KJ
100
80
60
40
20
0
20
40
60
80
100
Percent Affected
Figure 5.23

shoulder degeneration is severe, it is probable that some of the degeneration found in the flexion of the elbow is severe (Table 5.6).

**-----Discussion-----**

It is not surprising that the shoulder and flexion of the elbow are two of the joints most affected by degeneration. Almost all of the activities being studied involve the joints of the arm either in a primary or secondary manner (Table 3.2). Primary joint involvement refers to a joint which is performing most of the movement during a given activity. Secondary involvement refers to joints which are also in motion during an activity, but to a lessor extent than the joint with primary involvement.

Flexion of the elbow is the primary joint of involvement in 10 of the 14 activities being studied, and the shoulder joint is secondarily involved in 13 of the 14 activities. Except in the case of walking, the hip and knee have only secondary joint involvement in the activities being studied. Rotation of the elbow is also involved in all of the activities being studied. In the activities being studied, the lower arm is always rotated at least 90 degrees medially from its anatomical position, and rotation often occurs with flexion.

While primary joint involvement, by definition, is more stressful than secondary involvement, the type of joint stress must also be considered. As discussed in Chapter Two, there is a difference between joints which are stressed by repetitive motions, and joints which are stressed by extending them beyond their normal range of motion. Activities such as clearing, hoeing, corn processing, tool-making, and deer fleshing are examples of repetitive movement activities. In these activities, joint movement, while continuous and repetitive, is still within the joint's normal range of motion.

Hide working is also an example of this type of joint stress. Hide working differs from some of these other activities in that the repetitive movement is occurring much more quickly than it is in activities such as tool-making. It must also be kept in mind that different activities will require more force than other activities (hoeing vs. walking), and that the force exerted by individuals will vary.

Shooting (i.e., bow and arrow) is the only activity in this study which definitely extends a joint beyond its normal range of motion. The shoulder of the arm which is used to pull back the bowstring will be hyper-extended until the bow is released. Collecting may extend joints beyond their normal range depending on how the collecting is being performed. The hip and knee joints may also be involved in activities which extend them beyond their normal range of movement. For example, while performing specific activities, individuals may be sitting with their knees bent and lower legs folded beneath them. This position has the potential to keep the knee flexed beyond its normal range for considerable periods of time.

During walking, the hip and knee are the joints of primary involvement. Walking will place a repetitive stress on these joints, but does not necessarily extend them beyond their normal range of motion. The knee, in particular, is well-adapted for this type of stress.

Overall, the data do not support any of the specific research hypotheses because chance could not be ruled out for any of the observed distribution patterns. Regardless, some interesting patterns do emerge.

Hypotheses IA and IB examined the patterns of joint degeneration between males and females. Hypothesis IA predicted a different pattern of joint degeneration between the two groups. Two different patterns are clearly observable as illustrated in Figures 5.11, 5.12, and 5.13. Males are more affected by joint degeneration than females, and this fact is interesting given that most of the activities under consideration are being performed by women (Table 3.2).

These higher levels of male joint degeneration may be the result of male activities which were not considered in this study. They may indicate that males from the study population participated more in the activities than was indicated in the ethnographic accounts. Or they may be an artifact of the sample distribution in that the female sample is skewed towards younger individuals, and the male sample is skewed towards older individuals (Figure 5.4).

Hypothesis IB is a two-part hypothesis related to the assumption of a changing subsistence strategy. The first part expects a change in the pattern of female degeneration between the two phases, and the second part expects the male pattern to remain the same for both phases. In fact, both the male and female patterns change (Figures 5.18, 5.19, 5.21, 5.22). The difference between the two male patterns is not significantly different, and thus this pattern could be said to remain the same (Table 5.8). However, because the female pattern is also not statistically significant, this hypothesis cannot be supported (Table 5.7).

Hypothesis IIA anticipated an increase in the number of Ft. Coffee phase joints affected with degeneration over the number of Spiro phase joints. In fact, just the opposite occurred (Table 5.5, Figure 5.14). In nine of the ten joints studied, Spiro phase individuals had more degeneration than Ft. Coffee phase individuals. Hypothesis IIB anticipated more severe joint degeneration in the Ft. Coffee phase population than in the Spiro phase population. However, the data do not indicate this expectation to be the case (Table 5.6).

Hypotheses IIA and IIB were developed to test the assumption that a change in subsistence strategy would also effect a change in the pattern of joint degeneration. It was assumed that more horticulture was being performed during the Ft. Coffee phase, and that horticultural activities were more stressful than foraging activities. There are several explanations for why these assumptions were not supported by the data.

First, the assumption could be wrong in that there is no connection between subsistence activities and degeneration patterns. Second, the assumption could be wrong in that more horticulture was being performed during the Spiro phase rather than during the Ft. Coffee phase; or that horticultural related activities are not as stressful as foraging related activities. Third, even though subsistence strategies may have changed, the specific activities being performed were very similar, and thus the pattern of degeneration would not change. Fourth, the assumption that subsistence strategies changed between the two phases is wrong, and, as a result, the sample should not have been treated as two separate populations. Fifth, other statistical factors could have biased the results.

Enough research has been done (see discussions in Chapter Two) to safely say that there is definitely some type of connection between subsistence activities and joint degeneration. In the case of this particular study, it was probably premature to separate the sample into two groups based on Rohrbaugh's phase distinctions.

Although Rohrbaugh's analysis (1982) does document a change in artifact distributions and thus provides diagnostic phase criteria, this change in artifact distributions does not necessarily represent a change in subsistence activity. Even if a change did occur, it was probably not extreme enough to adequately affect a change in degeneration patterns. Moreover, the changes in degeneration patterns observed between the two phases are probably the result of the skewness and small size of the sample (Figures 5.5 and 5.6).

When treated as one population as in the age comparisons (Table 5.3, Figures 5.8, 5.9, 5.10 and 5.11), the data tend to be much more significant. There are clear differences between age groups (Table 5.3, Figure 5.8), and the age group patterns, as discussed above, follow the anticipated trends regarding time and degeneration.

Based on the observed patterns, three conclusions can be reached. First, the observed degeneration patterns cannot be linked to specific activities. Second, the high levels of degeneration in the arm joints over the leg joints is consistent with the large number of activities which involve the arms. Finally, activities associated with the upper limb may be more stressful than those associated with the lower limb.

# CHAPTER SIX

## CONCLUSIONS

The conclusions listed at the end of Chapter 5 can be nothing more than tentative. The small sample size and its skewed distribution make it statistically impossible to generalize from the sample to a larger population. Observations about the research project itself, now that the investigation has been completed, can be made.

There is an inherent difficulty in this type of anthropological analysis. It is one thing to already know activity patterns prior to observing degeneration, and quite another to observe degeneration patterns without knowing for certain the activities which may have caused such patterns. The first scenario has primarily been that of the clinical worker assessing osteoarthritis within a living population. The latter scenario characterizes the task of the physical anthropologist.

Even though the objectives of both the clinician and the anthropologist may be the same (to correlate joint disease with activity-related stress), because of the different research populations being used for study, anthropologists cannot directly duplicate the methodologies and techniques of the clinical researcher.

While this fact is clear, it must also be remembered that the comparisons and results of the anthropologist can not be as accurate as those of the clinician. Few anthropologists will enjoy the luxury, as did Merbs, of knowing precisely which activities were being performed by the population and exactly how they were being performed.

Within archaeological studies of degenerative joint disease, there has been an implicit assumption that a population's subsistence strategy can be measured through the sum of the activities being performed. But, activities do not equal subsistence strategy. People perform many of the same activities regardless of their different subsistence strategies. While some activities are unique to specific subsistence strategies, (i.e., plowing in agriculture), there are usually a variety of ways these activities may be performed, or even similar activities in other subsistence strategies (i.e., digging for tubers when foraging).

The assumption that a change in subsistence strategy may cause a change in the joint degeneration patterns may not necessarily be the case. The reverse of this assumption may also not be valid. Given the methodological constraints of an archaeological population, it may not be possible to identify specific activities using the joint degeneration patterns (Wilson 1993). At this time, research should probably focus on using activities to understand joint degeneration patterns.

Although this research project used a more Merbs-like methodology, based on the knowledge learned from this study, future research should probably use a more standardized scale as Pickering did. In discussing the general utility of his methodology, Merbs (1992) confirmed that his technique was subjective. He recognized that the application of a category (mild, moderate, severe) to a joint surface was population-specific, based on what seemed to be most severe for that population. However, the integrity of the study would not be violated, he believed, as long as clear definitions of each severity level were stated. Regardless, Merbs' methodology is not readily amenable to cross-study comparisons.

Finally, a better anatomical and biomechanical understanding of joint anatomy would have aided this particular study, and would enhance future degenerative joint disease studies of skeletal populations. It also needs to be clarified as to what exactly constitutes joint stress. The biomechanical requirements of specific activities must be assessed before one assumes an activity to be "stressful" on the joints. The type of biological response an activity will generate must be known in order to determine how "stressful" the activity is.

Issues of frequency, duration, and the range of joint motion required by the activity should also be considered. It is possible that activities which researchers have thought to be inherently stressful, are not. Cockburn et al. (1979) recognized that hunting probably does not cause joint disease, and that foraging is probably more "laborious" (in terms of joint stress) than has been assumed. Yet anthropologists have continued to form research hypotheses contrary to these early observations. Perhaps it is time for anthropologists to revise their assumptions.

# APPENDIX

Site #:______ Burial #:______ Period:______ Gender:____ Age:______ Side:

| | Lipping | Pitting | Eburnation | Max. Score |
|---|---|---|---|---|
| **SHOULDER JOINT** | | | | |
| 1. Humerus, head | | | | |
| 2. Glenoid Fossa | | | | |
| 3. Clavicular Facet | | | | |
| 4. Acromial facet (clavicle) | | | | |
| **ELBOW JOINT** | | | | |
| (Rotation) | | | | |
| 5. Capitulum | | | | |
| 6. Radius, head | | | | |
| 7. Radius, margin | | | | |
| 8. Radial notch (Ulna) | | | | |
| (Flex/Exten) | | | | |
| 9. Trochlea | | | | |
| | | | | |
| 11. Coronoid fossa | | | | |
| 12. Radial fossa | | | | |
| 13. Olecranon fossa | | | | |
| 14. Olecranon process | | | | |
| **HIP JOINT** | | | | |
| 15. Acetabular fossa | | | | |
| 16. Lunate surface | | | | |
| 17. Femur, head | | | | |
| 18. Fovea capitis (femur) | | | | |
| **KNEE JOINT** | | | | |
| 19. Femur, medial condyle | | | | |
| 20. Femur, lateral condyle | | | | |
| 21. Tibia, medial condyle | | | | |
| 22. Tibia, lateral condyle | | | | |
| 23. Patella, medial | | | | |
| 24. Patella, lateral | | | | |

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| NAME AND ADDRESS | DATE |
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