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Analysis of a Commingled Skeletal Sample from Acacia Park
Memorial Cemetery

Rachel M. Winter

An Honors Thesis

Submitted for partial fulfillment of the requirements

For graduation with honors in the Anthropology Department

From Hamline University

Spring 2016

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ABSTRACT

A commingled sample of human skeletal remains from Acacia Park Cemetery in Mendota Heights, Minnesota was analyzed to address the commingled context, reconstruct the demographic profile, and make interpretations regarding health status and activity patterns. Prior to increasing European settlement during the 1800s in Minnesota, the site was known as “Oheyawahi” by the Dakota who used this site for burials and important ceremonies. In the 1920s a Masonic group in Minnesota purchased land at this site and founded Acacia Park Memorial Cemetery. Throughout the use of the cemetery, previous burials were disturbed and some of these remains were subsequently moved to a sheltered vault on the property. As a result of correspondence between the State Archaeologist Office, Minnesota Indian Affairs Council, and Acacia Park Cemetery, the contents of that vault were transported to the Hamline University Osteology Laboratory in 2004. This research project is the first to holistically analyze each individual of this skeletal sample. To address the commingled context, metric and visual analysis generated inventory data which was used to estimate how many individuals are present. Through the initial assessment, the minimum number of individuals was determined to be 25 and the most likely number of individuals was statistically estimated to be 26. After segregating each individual in the sample, a variety of techniques considered to be standards in the field of human osteology were applied to estimate each individual’s biological profile: their age at death, sex, stature, and ancestry. Further analyses of each individual of this sample provided insight into their health status during life and activity patterns. Collectively, all of this data about each individual has been used to reconstruct the demographic profile for this sample and contribute knowledge to what is known about life in the Twin Cities region of Minnesota during the 1800s and prior.

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CHAPTER 1: INTRODUCTION

Acacia Park Memorial Cemetery is located in Mendota Heights, Minnesota across the Minnesota River from Historic Fort Snelling. Another name for this site is *Oheyawahi*, which is Dakota for “the place much visited.”¹ Prior to European settlement in this area during the early 19th century, local Dakota used Oheyawahi for important ceremonies, such as the health-giving Wakan ceremony,² and burials. Other names created and used for this site by European settlers include Pilot Knob Hill and La Butte des Morts, French for “the knoll of the dead.” Historical documents and anecdotes indicate that this site was used for burials by both American Indian and European individuals throughout the 19th and 20th centuries.

In 1925 a local Masonic group in Minnesota purchased land at Pilot Knob Hill and after three years of construction and landscaping opened Acacia Park Memorial Cemetery in 1928. The purpose of this cemetery was to have a place for Masons and their family members to be buried. All of the grave markers used at Acacia Park Cemetery from 1928 and later are relatively uniform flat bronze markers because of the Masonic belief that all humans are equal in death, thus there are no elaborate displays of wealth depicted by large, ornate burial markers. During the 1970’s the cemetery became open to the general public for use.

There is a long standing history of mortuary practices at this site with some accounts suggesting it has been used for burial for thousands of years.³ Throughout the use of the cemetery, previous burials were disturbed and subsequently either moved to a sheltered vault on the property or pushed to the side of the new grave. In 1962, twenty teenagers broke into this

¹ The Pilot Knob Preservation Association. 2004. *The Oheyawahi/Pilot Knob Burial Register*.

² *Ibid*, 1.

³ Pilot Knob Preservation Act, 2004, 11.

vault stealing some of the remains and vandalizing the cemetery.⁴ After an investigation by the Mendota Heights Police Department most of the remains were given back to Acacia Park Cemetery. Three skulls were never returned and are presumably still missing.

In 2003, State Archaeologist Mark Dudzik contacted Dale Bachmeier, the general manager of Acacia Park Cemetery, to inquire as to the status of the vault of human remains which had been mentioned in a 1962 West St. Paul Booster newspaper article. Acacia Park Cemetery did indeed still have the collection of human remains and they were subsequently transferred to the Minnesota Office of the State Archaeologist later that year.⁵ The skeletal sample was then sent to Dr. Leslie Eisenberg in Madison, Wisconsin for analysis to determine if American Indian individuals were represented in the sample which she concluded there were. Hamline University's Osteology Laboratory is the repository for human skeletal remains for both the Office of the State Archaeologist and the Minnesota Indian Affairs Council. Under Minnesota St. 307.08 if American Indian remains are disturbed then the Minnesota Indian Affairs Council(MIAC) is responsible for their disposition. After it was

Figure 1. Picture of Acacia Park Cemetery skeletal sample



Image found in file at Hamline University's Osteology Laboratory associated with Acacia Park Cemetery sample depicting what is believed to be the vault that contained this skeletal sample.

⁴ "Juveniles Gang Up in Cemetery, Steal Skulls." July 13, 1962. *West St. Paul Riverview Booster News*.

⁵ Dudzik, Mark. 2003. *Transfer of Human Remains to OSA*. St. Paul, Minnesota: Office of the State Archaeologist.

determined that American Indian individuals were represented in this skeletal sample, Mr. Jim Jones, the Cultural Resource Director for MIAC, transferred the skeletal sample to Hamline University in 2004 for a complete analysis. (Figure 1)

The nature of this human skeletal sample is termed *commingled* in biological anthropology due to the presence of multiple individuals in the same burial context. A simple way to determine if there are multiple individuals represented in a context is to assess if any skeletal elements are duplicated or inconsistent with each other. When looking at **Figure 1** it is readily apparent that numerous individuals are present due to the observation of multiple skulls.

There are a handful of folders in Hamline University's Osteology Laboratory containing information about the history and use of the site these remains are from and data of preliminary analyses previously done. To date there has been no documentation found regarding the history of this skeletal sample aside from how it got to Hamline University. There is no information about which bones came from where in the cemetery, when each bone was removed from the earth and put into the vault, or which bones were found together. At some point in time someone, presumably affiliated with Hamline University in some capacity, individualized the remains and assigned nearly all of the bones an accession number. No records exist detailing what methodologies were utilized to determine what bones belonged to which individual. This research project is the first to holistically and collectively analyze the Acacia Park Cemetery sample and provide documentation for how individuals have been (and may have previously) been sorted.

The primary objective of this honors project has been to address the commingled context and reconstruct the demographic profile for this skeletal sample from Acacia Park Memorial

Cemetery. Conducting this research also provided the researcher with the opportunity to gain insight into the challenges of working with commingled, fragmentary, archaeological skeletal remains and experience the process of a larger-scale research project. The following questions were used to guide the research and achieve the goals of this project:

1. How many individuals are represented?
2. What is the biological profile (age-at-death, sex, ancestry, and stature) for each individual?
 - a. What is the demographic profile for this skeletal sample?
3. What interpretations about health status and activity patterns can be made from assessing pathologies in human skeletal remains?

CHAPTER 2: LITERATURE REVIEW

I: Commingled Contexts

1. Minimum Number of Individuals (MNI)

Analyzing a skeletal sample can be difficult when that sample is commingled. In biological anthropology, commingled is defined as “bone assemblages containing remains of multiple individuals, often incomplete and fragmentary.”⁶ The most common first step when working with a commingled set of human remains is to sort and inventory the entire sample by skeletal element (i.e. femur, rib, etc.) and which side of the body each element is from. This is done as a technique to assist with determining the minimum number of individuals or MNI represented in a sample. The publication, *Standards for Data Collection from Human Skeletal Remains*,⁷ presents a methodology for coding a commingled or incomplete sample of human skeletal remains. This technique involves grouping all like elements (i.e. all femora or humeri) together and upon completing inventory, the most represented element indicates the minimum number of individuals (MNI) represented in the sample. Commingled skeletal samples are frequently encountered in mass graves and mass disaster situations.

The accuracy of MNI estimates can be improved by applying additional methodologies for sorting commingled remains. One technique that can help lead to a more reliable estimate of

⁶ White, Tim D., Michael T. Black, and Pieter A. Folkens. 2012. *Human Osteology*, edited by Liz Brown and Kristi Anderson, 1-662. Burlington, Massachusetts, USA: Advanced Press.

⁷ Buikstra, Jane E. and Douglas H. Ubelaker, eds. 1994. *Standards for Data Collection from Human Skeletal Remains*, edited by Hester A. Davis. Vol. 1. Fayetteville, Arkansas: Arkansas Archaeological Society.

the true population size is using osteometrics to sort the long bones.⁸ Metric assessment (length and girth) of long bones in conjunction with morphological analyses are useful when determining if skeletal elements are a pair. Measurements should be taken of the length of complete long bones and girth at various identifiable positions on the bones. The morphoscopic analysis consists of comparing left and right skeletal elements for similarities in robusticity, musculoskeletal stress markers, epiphyseal shape, general bilateral symmetry, and taphonomic variables, such as soil staining and level of preservation. When subadults are represented in the sample, various sites of epiphyseal union should be assessed to assist in differentiating each individual.^{9,10} The presence of inconsistent sites of epiphyseal union suggests the presence of more than one individual.

2. Most Likely Number of Individuals (MLNI)

Estimates of population size using techniques to determine the MNI have a tendency to underestimate the true population size. This has led to discussions about using additional techniques to estimate the most likely number of individuals (MLNI).¹¹ The technique proposed

⁸ Byrd, John E. 2008. "Models and Methods for Osteometric Sorting." In *Recovery, Analysis, and Identification of Commingled Human Remains*, edited by Bradley J. Adams and John E. Byrd, 199-220. Totowa, New Jersey, USA: Humana Press.

⁹ Schaefer, Maureen. 2008. "Patterns of Epiphyseal Union and their use in the Detection and Sorting of Commingled Remains." In *Recovery, Analysis, and Identification of Commingled Human Remains*, edited by Bradley J. Adams and John E. Byrd, 123-144. Totowa, New Jersey, USA: Humana Press.

¹⁰ Schaefer, Maureen and Sue Black. 2007. "Epiphyseal Union Sequencing: Aiding in the Recognition and Sorting of Commingled Remains." *Journal of Forensic Sciences* 52 (2): 277-285.

¹¹ Adams, Bradley J. and Lyle W. Konigsberg. 2008. "How Many People? Determining the Number of Individuals Represented by Commingled Human Remains." In *Recovery, Analysis, and Identification of Commingled Human Remains*, edited by Bradley J. Adams and John E. Byrd, 241-255. Totowa, New Jersey, USA: Humana Press.

by Adams and Konigsberg (2008), involves pair matching using one, two, three, or four skeletal elements. For this technique, the analyst looks at two paired bones (i.e. a left and a right femur) and determines if those two bones likely pair together, representing one individual. The data generated from assessing pair matches can then be analyzed using hypergeometric probability functions to estimate the MLNI and support that estimate with a confidence interval.

II: Biological Profile

Estimating the biological profile of human skeletal remains is a key component of work done in both forensic and archaeological contexts. The biological profile of an individual consists of their biological sex, age-at-death, stature, and ancestry. There are many challenges when estimating the biological profile due to the influence of one's environment, genetics, and lifestyle on their osseous tissues. In regards to the skeletal sample from Acacia Park Memorial Cemetery, estimating ancestry for each individual carries a lot of weight when determining the disposition for each set of human remains. Under MN.St. 307.08, the Minnesota Office of the State Archaeologist is responsible for all human skeletal remains that are not of American Indian ancestry and the Minnesota Indian Affairs Council is responsible for human remains that are of American Indian ancestry.

1. Stature

It can be challenging to accurately estimate the stature of an individual from their skeletal remains given the variation in height, body composition, and proportion of skeletal elements seen in various populations. Currently, many techniques used to estimate the living stature of an

individual from skeletal remains rely upon measurements taken from the long bones and the application of appropriate regression models for that sample.¹²

Auerbach and Ruff¹³ developed a technique for estimating stature of individuals indigenous to North America. For their study they started with a total of 2,621 adult skeletons from 149 archaeological sites in North America and spanning a variety of time periods. There were 967 individuals from 75 archaeological sites in this larger sample that had enough skeletal elements represented (as per the protocols of Raxter et al. 2006)¹⁴ for estimating stature. Maximum long bone lengths were taken from complete tibiae and femora because of their direct contribution to living stature and their more common preservation over upper limb bones in archaeological contexts. Due to differences in body proportions geographically, they developed regression formulae that are sex-specific and specific for indigenous populations in three different regional geographic areas that were based on the original eleven.

2. Sex

The process of estimating biological sex from skeletal remains is one which is well documented utilizing numerous aspects of the human skeleton. Generally speaking, the skeletons of males and females differ from each other in both size and shape as the human species is sexually dimorphic. One of the many challenges that come with estimating the biological sex of

¹² Moore, Megan and Ann Ross. 2013. "Stature Estimation." In *Research Methods in Human Skeletal Biology*, edited by Elizabeth DiGangi and Megan Moore, 151-180. Waltham, Massachusetts: Academic Press.

¹³ Auerbach, Benjamin M. and Christopher B. Ruff. 2010. "Stature Estimation Formulae for Indigenous North American Populations." *American Journal of Physical Anthropology* 141: 190-207.

¹⁴ Raxter, Michelle H., Benjamin M. Auerbach, and Christopher B. Ruff. 2006. "Revision of the Fully Technique for Estimating Statures." *American Journal of Physical Anthropology* 130: 374-384.

an individual is that the sex suggested osteologically may not accurately reflect the gender with which an individual socially identified. Subadults present a particular challenge for estimating sex. During puberty the human body is undergoing many changes that affect the morphology of the skeleton. If an individual has not yet undergone puberty, it is not possible to apply analytical techniques that can accurately assist in estimating an individual's biological sex.

Many of the well-documented and reliable techniques for estimating sex are presented in *Standards for Data Collection from Human Skeletal Remains*.¹⁵ Techniques involving visual observations of the pelvis, particularly the pubic bones,^{16,17} are generally regarded as the most reliable for estimating sex. After the pubic bones, there is debate about whether post-cranial elements or the skull is the second most reliable area of the human skeleton for estimating sex. As mentioned, the pubic bone has been demonstrated to be a highly reliable area of the skeleton for use as an indicator of sex.^{18,19} Morphoscopic and metric techniques utilizing other aspects of the skeleton in estimating sex have been developed with variable reliability.²⁰

T.W. Phenice²¹ developed a technique for estimating sex using macroscopic traits of the pubis bone. Those traits are the ventral arc, subpubic concavity, and the medial aspect of the ischio-pubis ramus which collectively are referred to as the "Phenice traits". To test his theory that sex could be reliably estimated using these three traits, 275 adult individuals of known

¹⁵ Buikstra and Ubelaker, 1994, Standards, 16.

¹⁶ Ibid, 289.

¹⁷ Bass, William. 2005. "Sex Estimation." In *Human Osteology A Laboratory and Field Manual*. 5th ed., 81-82. Springfield, Missouri: Missouri Archaeological Society.

¹⁸ Spradley, Katherine and Richard Jantz. 2011. "Sex Estimation in Forensic Anthropology: Skull Versus Postcranial Elements." *Journal of Forensic Sciences* 56 (2): 289-296.

¹⁹ Phenice, T. W. 1969. "A Newly Developed Visual Method of Sexing the Os Pubis." *American Journal of Physical Anthropology* 30: 297-302.

²⁰ White et al., 2012, Human Osteology, 408-419.

²¹ Phenice, 1969, Newly Developed Visual Method of Sexing the Os Pubis.

ancestry and sex from the Terry Skeletal Collection were used. The results of testing this technique accurately estimated the sex for 96% of the individuals in the study, indicating the high reliability of this technique when all three Phenice traits are present. The medial aspect of the ischio-pubic ramus was determined to be the most ambiguous of the three when estimating sex with the use of one or both of the other traits (ventral arc and subpubic concavity) producing accurate results at least 96% of the time.

Brenda Williams and Tracy Rogers²² demonstrated the accuracy and precision of estimating sex from traits of the cranium. For this study, 50 adult skulls (25 males, 25 females, and encompassing a wide age range) from individuals of known sex and age-at-death from the William M. Bass Donated Skeletal Collection were used. Rodgers randomly selected crania from their sample and Williams evaluated 17 morphological characteristics of the skull and four from the mandible for sex estimation. This process was then repeated to determine the level of intraobserver error when utilizing this technique. Of the 21 traits used in this study, 6 were found to meet acceptable levels of intraobserver error ($\leq 10\%$) and accuracy ($\geq 80\%$). Those 6 morphological traits are: mastoid process, supraorbital ridge, size and architecture, zygomatic extension, nasal aperture, and the gonial angle of the mandible. In this study, when all 6 of those traits were used, sex was accurately estimated 94% of the time.

Given the known reliability of the pelvis and the skull,^{23,24} many of the techniques most commonly used rely on those areas of the skeleton.²⁵ When possible, multiple areas of the

²² Williams, Brenda A. and Tracy L. Rogers. 2006. "Evaluating the Accuracy and Precision of Cranial Morphological Traits for Sex Determination." *Journal of Forensic Sciences* 51 (4): 729-735.

²³ Acsadi, Gy and Janos Nemeskeri. 1970. *History of Human Life Span and Mortality*. Budapest: Akademiai Kiado.

skeleton should be observed for sex estimation, this is particularly useful in a commingled sample when trying to ascertain which skeletal elements belong to each individual.

3. Age

Age estimation from skeletal remains can be divided into two different approaches, aging techniques for adults and techniques for juveniles/subadults. Estimating the age of juveniles typically generates more narrow age ranges than age ranges for adults because the development of the human skeleton is believed to be under strong genetic control while the degeneration of the skeleton is much more susceptible to environmental influence (i.e. lifestyle, nutrition).^{26,27} It is worth noting that age estimation techniques estimate the biological age of a person which may not be consistent with their chronological age.

The Suchey-Brooks²⁸ method refined age estimation techniques that rely upon morphological changes of the pubic symphysis. Their study sample consisted of 1,225 modern individuals of known age-at-death from the Office of the Chief Medical Examiner in Los Angeles. Demographically, the sample contained 739 males and 273 females, ranging from 14 to

²⁴ Moore, Megan. 2013. "Sex Estimation and Assessment." In *Research Methods in Human Skeletal Biology*, edited by Elizabeth DiGangi and Megan Moore, 91-116. Waltham, Massachusetts.: Advance Publication.

²⁵ Sutherland, L. M. and J. M. Suchey. 1991. "Use of the Ventral Arc in Pubic Sex Determination." *Journal of Forensic Sciences* 36: 501-511.

²⁶ Uhl, Natalie. 2013. "Age-at-Death Estimation." In *Research Methods in Human Skeletal Biology*, edited by Elizabeth DiGangi and Megan Moore, 63-90. Waltham, Massachusetts: Advanced Publication.

²⁷ Buikstra and Ubelaker, 1994, Standards, 21-39.

²⁸ Brooks, S. and J. M. Suchey. 1990. "Skeletal Age Determination Based on the Os Pubis: A Comparison of the Acsadi-Nemcskri and Suchey-Brooks Methods." *Human Evolution* 5 (3): 227-238.

99 years old. For analysis, individuals are classified into one of six phases²⁹, each phase corresponding with typical morphology for a specific age range. They propose that their method for estimating age translates well when working with archaeological and ancient remains for producing reliable age ranges for individuals.

The auricular surface of the ilium tends to be preserved more frequently in archaeological populations than the pubic symphysis because it is more durable. Buckberry and Chamberlain³⁰ refined an age estimation technique observing changes in the auricular surface with age. They found no significant difference between males and females and when using their description for different morphological changes they were able to generate more narrow age range estimates than many other techniques. The scoring system they proposed was tested on a sample of 180 individuals of known age-at-death from Christ Church, Spitalfields, London and found a 60% correlation between their scoring system and known age of individuals and insignificant levels of intraobserver error.

In regards to adult remains, morphoscopic analyses of the pubic symphysis, auricular surfaces, and fourth sternal rib³¹ end are regarded as some of the most reliable indicators used in age estimation. The degenerative changes observed in each of these regions of the skeleton have been well studied and scrutinized to develop techniques that perform well on adult skeletal remains.³² Additionally, cranial suture closure is often assessed despite producing notably large

²⁹ Males and females age differently and thus there are different age ranges associated with each phase for males and females and casts of male and female pubis bones have also been made to assist with the application of this technique.

³⁰ Buckberry, J. L. and A. T. Chamberlain. 2002. "Age Estimation from the Auricular Surface of the Ilium: A Revised Method." *American Journal of Physical Anthropology* 119: 231-239.

³¹ Iscan, Yasar M., Susan R. Loth, and Ronald K. Wright. 1984. "Age Estimation from the Rib by Phase Analysis: White Males." *Journal of Forensic Sciences* 29 (4): 1094-1104.

³² White, 2012, *Human Osteology*, 397-404.

age ranges and being highly variable between populations due to genetic and cultural influences.^{33,34}

The development of juvenile skeletons tends to occur at relatively predictable intervals with less influence from environmental factors than is observed in the degenerative processes of adult skeletons,³⁵ this allows researchers to establish more narrow age estimates while still generating sufficiently accurate results. Extensive research and efforts have been put into developing techniques which utilize timing of epiphyseal union, long bone length, and development and eruption of the dentition for estimating the age of juvenile remains.

Jointly, Maureen Schaefer, Sue Black, and Louise Scheuer published *Juvenile Osteology a Laboratory and Field Manual*³⁶ in 2009. This book is designed to be a manual for individuals that already have a background in human osteology and presents summary data for estimating age from epiphyseal union. Maureen Schaefer refined previous techniques using data collected from the deceased following the fall of Srebrenica³⁷. The only previous techniques combined with Maureen Schaefer's data for this book relied upon skeletal samples of known age at death. This book provides a holistic presentation of epiphyseal union in the human skeleton.

³³ Buikstra and Ubelaker, 1994, Standards, 32-38.

³⁴ Meindl, Richard S. and C. Owen Lovejoy. 1985. "Ectocranial Suture Closure: A Revised Method for the Determination of Skeletal Age at Death Based on the Lateral-Anterior Sutures." *American Journal of Physical Anthropology* 68: 57-66.

³⁵ Uhl, 2013, Research Methods, 64-65

³⁶ Schaefer, Maureen, Sue Black, and Louise Scheuer. 2009. *Juvenile Osteology a Laboratory and Field Manual*. San Diego, California; Burlington, Massachusetts; London, United Kingdom: Academic Press.

³⁷ Ibid.

For assessing epiphyseal union of the anterior iliac crest and medial clavicle in populations residing in the United States, Patricia Webb and Judy Suchey³⁸ developed age ranges using a sample of known age-at-death and sex, with ancestry being estimated by a visual analysis at autopsy. Their research sample consisted of 605 males and 254 females autopsied between 1977 and 1979 by the Department of the Chief Medical Examiner-Coroner, Los Angeles. Individuals in the sample were between the ages of 11 and 40 years old and based on visual observations at autopsy 50% of individuals appeared to be white, 27% American black, 2% of Asian origins, and 20% of Latin-American origins. Collectively their data showed that epiphyseal timing is generally similar for males and females and they were able to establish more reliable age estimates for different stages of union than had previously been developed.³⁹

Douglas Ubelaker⁴⁰ compiled data collected by numerous other biological anthropologists over the years to present an accurate method for estimating age from American Indian subadult skeletal remains. The most accurate age estimates for subadults rely upon evaluation dental development and eruption. Based on what current data is available, this technique is best applied to prehistoric American Indian skeletal samples.

4. Ancestry

In early anthropology, there were two general philosophies developed around the turn of the 20th century about how to explain human races (variation). One perspective was that of Ales

³⁸ Webb, Patricia A. and Judy Suchey. 1985. "Epiphyseal Union of the Anterior Iliac Crest and Medial Clavicle in a Modern Multiracial Sample of American Males and Females." *American Journal of Physical Anthropology* 68: 457-466.

³⁹ The previous technique developed for estimating age from epiphyseal union at the anterior iliac crest and medial clavicle (McKern and Stewart, 1957) was developed from a sample of primarily of American white males between the ages of 17 and 30 years old.

⁴⁰ Ubelaker, Douglas H. 1978. "Estimation of Age at Death." In *Human Skeletal Remains Excavation, Analysis, Interpretation*. 2nd ed., 45-67. Washington, D.C.: Taraxcum.

Hrdlicka and Earnest Hooton that proposed observed variation in human beings is the result of separate, distinct races evolving independently of each other. The other perspective was that of Franz Boas who theorized that all humans were of the same race and that variation could be explained by environmental and cultural differences.⁴¹ Generally speaking, anthropology is aligned with the recognition of human variation as having a strong genetic basis that is the result of evolutionary forces in addition to environmental pressures. Efforts on behalf of anthropologists to estimate genetic affiliation or ancestry from human remains typically relies on a combination of metric and nonmetric techniques⁴². Metric techniques typically rely on measurements from the cranium and postcranial skeletal elements, a statistical software called FORDISC is often used in modern, forensic cases⁴³ to assist with estimating ancestry. The FORDISC software compares metric data from an individual whose biological profile is unknown to metric data that has been collected from individuals of known biological profiles. The software program then uses discriminate function analysis to estimate the sex and ancestry of the unknown individual to the available reference samples.

Cranial macromorphoscopic traits have traditionally been used in forensic anthropology and are believed to be highly reliable when estimating ancestry.⁴⁴ Joseph Hefner attempted to quantify this approach and test its validity utilizing a sample of both contemporary and ancient remains. His results indicated that cranial macromorphoscopies are not as reliable as historically

⁴¹ DiGangi, Elizabeth and Joseph T. Hefner. 2013. "Ancestry Estimation." In *Research Methods in Human Skeletal Biology*, edited by Elizabeth DiGangi and Megan Moore, 117-150. Waltham, MA: Academic Press.

⁴² Ibid, 130.

⁴³ Jantz, Richard and Stephan Ousley. 2013. "Introduction to Fordisc 3." In *Forensic Anthropology an Introduction*, edited by Maria Teresa Tersigni-Tarrant and Natalie Shirley, 253-269. Boca Raton, FL: CRC Press.

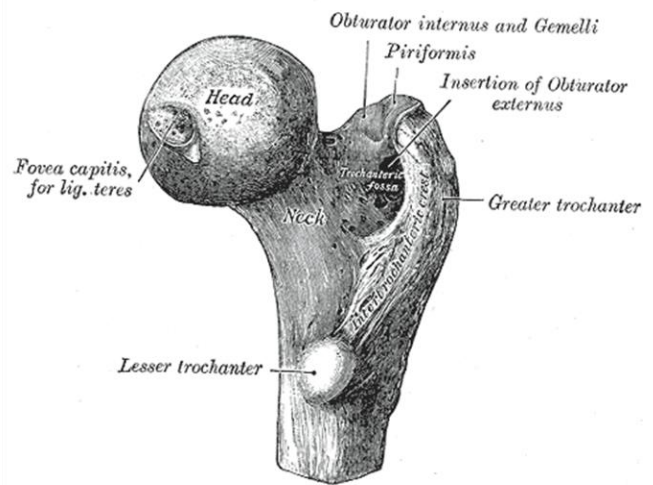
⁴⁴ Hefner, Joseph T. 2009. "Cranial Nonmetric Variation and Estimating Ancestry." *Journal of Forensic Sciences* 54 (5): 985-995.

believed to be.⁴⁵ Work by Joseph Hefner suggests that cranial macromorphoscopies may be reliable and accurate for modern populations when a decision tree that has been founded in logistic regression models is used.⁴⁶ However there is not currently a technique developed that shows that cranial macromorphoscopies can be reliably applied to ancient and historic skeletons.

It has been demonstrated that the shape of the proximal end of the femoral shaft is under strong genetic influence as opposed to being heavily influenced by biomechanical or environmental forces.⁴⁷ Visual assessment of this area, the subtrochanteric region of the femur (see Fig. 2), has long been used as a technique for determining if a set of remains is of American

Indian ancestry or not.⁴⁸ A cross-section of the subtrochanteric region tends to exhibit greater flattening in the antero-posterior plane and lateral flaring (see Fig. 3) in American Indian femora than in American White or Black femora.⁴⁹ In an effort to increase the precision and replicability of

Figure 2. Picture of the proximal femur.



The subtrochanteric regions lies just inferior (below) of the lesser trochanter.

⁴⁵ Ibid.

⁴⁶ Hefner, Joseph T. and Stephan D. Ousley. 2014. "Statistical Classification Methods for Estimation Ancestry using Morphoscopic Traits." *Journal of Forensic Sciences* 59 (4): 883-890.

⁴⁷ Lovejoy, Owen, Richard Meindl, James Ohman, Kingsbury Heiple, and Tim White. 2002. "The Maka Femur and its Bearing on the Antiquity of Human Walking: Applying Contemporary Concepts of Morphogenesis to the Human Fossil Record." *American Journal of Physical Anthropology* 119: 97-133.

⁴⁸ Gilbert, Randi and George W. Gill. 1990. "A Metric Technique for Identifying American Indian Femora." *Skeletal Attribution of Race: Methods for Forensic Anthropology* (4): 97-99.

⁴⁹ Ibid.

this technique, Gilbert and Gill⁵⁰ proposed a metric technique utilizing measurements of the antero-posterior diameter and medio-lateral diameter of the subtrochanteric region. To quantify this hypothesis, they measured the femora of 102 Blacks and 59 Whites from the Terry Collection and 113 American Indian femora from the prehistoric collection at the Smithsonian Institution. They measured the antero-posterior diameter and medio-lateral diameter of the subtrochanteric region of each femur. The measurements were then plotted on an x-y graph with symbols to differentiate by sex and ancestry. From this graph they determined a sectioning point which placed 100% of Whites and Blacks on the right side of the sectioning line and 61% of the American Indian individuals on the left side of the line. The general observation is that American Indian individuals have a more shape flattened (an oval cross-section) and non-Indians a rounded shape (a circular cross-section) in the subtrochanteric region.

Wescott and Srikanta⁵¹ tested the validity of the technique

Figure 3. Illustration of Differences in American Indian and American White/Black Femora



The femur on the left shows the typical morphology of an individual of American White or Black ancestry and the femur on the right shows the typical morphology of an individual of American Indian ancestry. Note the presence of lateral flaring on the American Indian individual and absence of the American White/Black individual.

⁵⁰ Ibid.

⁵¹ Wescott, D. and D. Srikanta. 2008. "Testing Assumptions of the Gilbert and Gill Method for Assessing Ancestry using the Femur Subtrochanteric Shape." *Journal of Comparative Human Biology* (59): 347-363.

developed by Gilbert and Gill to assess how well the subtrochanteric region of the femur can assist with estimating ancestry. The sample for testing the validity of this technique consisted of:

31 individuals of African ancestry from the American Museum of Natural History

320 individuals of American Black ancestry and 668 American White ancestry from the Terry Collection, Forensic Data Base, and historic archaeological sites

41 individuals of Hispanic ancestry from the Forensic Data Base

147 individuals of Australian ancestry from the George Murray Black collection

179 individuals of Polynesian ancestry from the Hawaii—Snow collection

1695 individuals of American Indian ancestry from the University of Tennessee and Smithsonian Institution's postcranial database

The final results their analysis relevant to this study classified 76% of Native Americans correctly and 78% of American White individuals correctly, reaffirming the reasonable reliability of the subtrochanteric region of the femur in estimating ancestry.

III. Pathological Conditions

1. Musculoskeletal Stress Markers

Musculoskeletal stress markers are considered a category of pathological conditions that may present themselves in osseous materials because they are the result of repeated microtrauma. They are caused by the unique relationship of muscle to bone. The more frequently a muscle is

used the greater the stress that is put on the periosteum of where that muscle attaches to bone.

This concept is explained by Hawkey and Merbs(1995)⁵²:

“...the term musculoskeletal stress markers (MSM) [refers] specifically to a distinct skeletal mark that occurs where a muscle, tendon or ligament inserts onto the periosteum and into the underlying bony cortex. In general, the periosteum is well vascularized, and the capillaries that supply the periosteum increases when the muscle/tendon/ligament-bone junctions are regularly subject to minor stress. Osteon remodeling is stimulated by this increased blood flow, and develops where there is greatest muscular activity. Hypertrophy of bone, in the form of robust muscle attachment, is the direct result of this increased stress, and continual stress of a muscle in daily, repetitive tasks creates a well-preserved skeletal record of an individual’s habitual activity patterns.”⁵³

These more developed and rugged muscle attachment sites on the bones can be readily observed and evaluated macroscopically.⁵⁴ General knowledge within the field of biological anthropology is that the extent of the development of musculoskeletal markers at various muscle attachment sites can be indicative of activity patterns that individuals commonly and frequently engaged in during life.⁵⁵

Assessing the presence and robusticity of musculoskeletal stress markers have the potential to provide insight into activity patterns of an individual, a gender, or collectively of a population, making the method one of interest in both archaeological and forensic contexts.

⁵² Hawkey, Diane E. and Charles F. Merbs. 1995. "Activity-Induced Musculoskeletal Stress Markers (MSM) and Subsistence Strategy Changes among Ancient Hudson Bay Eskimos." *International Journal of Osteoarchaeology* 5: 324-338.

⁵³ Ibid, 324.

⁵⁴ Kroman, Anne and Steven Symes. 2013. "Investigation of Skeletal Trauma." In *Research Methods in Human Skeletal Biology*, edited by Elizabeth DiGangi and Megan Moore, 219-239. Waltham, Massachusetts: Academic Press.

⁵⁵ Kennedy, Kenneth A. R. 1989. "Skeletal Markers of Occupational Stress." In *Reconstruction of Life from the Skeleton*, edited by Yasar M. Iscan and Kenneth A. R. Kennedy, 129-160. New York: Wiley-Liss Inc.

Nevertheless, caution needs to be exercised to avoid overstating conclusions that can be made from these analyses.^{56,57,58} The presence of fractures, osteoarthritis, or other anomalies observed in an individual can bias the results generated from analyzing musculoskeletal stress markers. There is a pressing need for verification and validation of the theories about musculoskeletal markers being accurate means for interpreting activity patterns in order for them to gain broader acceptance and usage in the biological anthropology community.⁵⁹

Hawkey⁶⁰ developed a standardized method for scoring musculoskeletal markers of the upper extremities by observing gross morphological changes.⁶¹ This methodology was developed using two ancient populations, the Thule Eskimo of northwestern Hudson Bay⁶² and the Gran Quivira Pueblo from New Mexico. The methodology created utilizes numerical ranking and visual references to assist those applying the technique with scoring and help establish standards for evaluating musculoskeletal markers. For the current analysis, twenty muscle attachment sites, two common muscle origin sites, and three clavicular ligament sites are scored. Individuals that exhibited healed fractures or severe degenerative joint disease⁶³ were excluded from the analysis to avoid results that falsely illustrated the amount of stress placed on a musculoskeletal marker

⁵⁶ Jurmain, Robert. 1999. "Osteoarthritis: Anthropological Interpretations." Chap. 5, In *Stories from the Skeleton Behavioral Reconstruction in Human Osteology*, 141-184. Amsterdam, Netherlands: Gordon and Breach Science Publishers.

⁵⁷ White, 2012, *Human Osteology*, 457.

⁵⁸ Ortner, Donald J. 2003. *Identification of Pathological Conditions in Human Skeletal Remains*. Vol. 2. San Diego, California: Academic Press.

⁵⁹ Jurmain, 1999, *Stories from the Skeleton*, 159-163.

⁶⁰ Hawkey, 1988, *Use of Upper Extremity Enthesopathies*.

⁶¹ Hawkey, Diane E. 1988. "Use of Upper Extremity Enthesopathies to Indicate Habitual Activity Patterns." Master of Arts, Arizona State University. *At some point in the past decade, there was a shift in the field from referring to these markers as "ethnesopathies" to the term currently encountered in the literature of "musculoskeletal markers of stress" or "musculoskeletal stress markers"*

⁶² The technique developed by Hawkey 1988 was applied and combined with ethnographic data in Hawkey and Merbs, 1995.

⁶³ Current literature also refers to this gross morphological change as osteoarthritis.

due to activity patterns alone since either of these pathologies may bias the results. Finally, data was collected from the right skeletal element due to the high prevalence of right-side dominance in human populations.

2. Dental Pathologies

Common dental pathologies evaluated in bioarchaeological skeletal samples include evidence of caries and dental attrition. Dental caries is an infectious disease caused by acid-producing bacteria that grow in plaque that can accumulate on teeth. As the infection progresses, it breaks down tooth enamel and then the underlying dentin. In more severe cases of caries, it can destroy the crown and/or root and even leak into the blood stream through the pulp chamber.^{64,65} Caries have been observed at greater frequencies (number of carious lesions per mouth) in populations practicing agriculture than in hunter-gatherer populations, this trend is believed to be the result of greater carbohydrate intake among agriculturalists.⁶⁶

Dental attrition is the degree of wear observed on the occlusal (chewing) surface of the teeth and can be the result of natural mastication. Severe attrition is more commonly observed in historic and ancient populations than in contemporary populations and has been used in archaeological skeletal samples as an indicator of age.^{67,68}

⁶⁴ Ortner, 2003, *Pathological Conditions*, 590.

⁶⁵ Pindborg, J. J. 1970. *Pathology of the Dental Hard Tissues*. Philadelphia: Saunders.

⁶⁶ Aufderheide and Rodriguez-Martin, 1998, *Human Paleopathology*, 404.

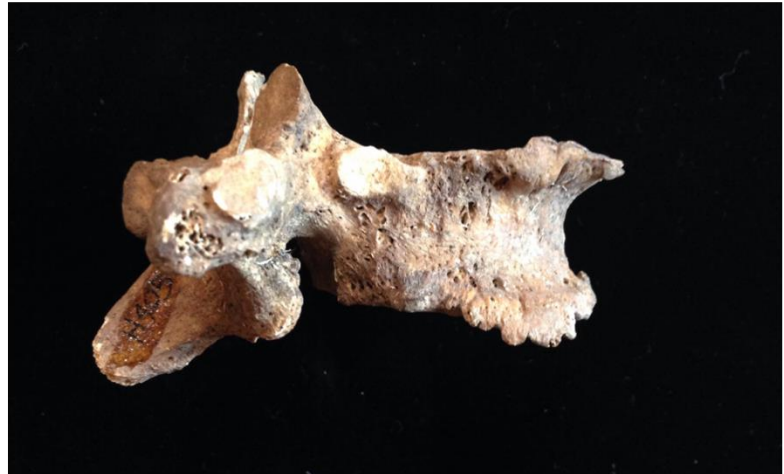
⁶⁷ Ortner, 2003, *Pathological Conditions*, 604.

⁶⁸ Pindborg, 1970, *Pathology Dental Hard Tissues*, 296.

3. Osteoarthritis

Osteoarthritis is a chronic, pathological condition resulting from the breakdown of cartilage at joints leading to bone on bone contact at these locations which may result in corresponding

Figure 4. Example of a vertebra with osteophytes on the superior and inferior surfaces of the body.



lesions on affected bone.^{69,70} Morphologically, some of these lesions include the development of osteophytes (*see Fig. 4*), eburnation, and calcification of cartilage at the affected site of cartilage loss. More severe presentations of osteoarthritis are most commonly found in older individuals however lifestyle and genetic predisposition may also play a role in the development of osteoarthritis.⁷¹ It is believed that the stressors of everyday life play the largest role in the development of osteoarthritis and that the distribution and severity likely varies between populations and different roles within a population.⁷²

4. Nutritional Deficiencies

A variety of dietary components, in excess or deficiency, can present themselves as pathologies in the human skeleton. Prolonged vitamin C deficiency manifesting as scurvy and vitamin D deficiency in children causing rickets are a couple of examples of how evidence of

⁶⁹ Ortner, 2003, *Pathological Conditions*, 546-547.

⁷⁰ Aufderheide and Rodriguez-Martin, 1998, *Human Paleopathology*, 93-96.

⁷¹ Solomon, Linda. 2001. "Clinical Features of Osteoarthritis." In *Kelley's Textbook of Rheumatology*, edited by Shaun Ruddy, Edward D. Harris, Clement B. Sledge and William N. Kelley. 6th ed. Philadelphia: W.B. Saunders.

⁷² Ortner, Donald J., 1968. "Description and Classification of Degenerative Bone Changes in the Distal Joint Surfaces of the Humerus." *American Journal of Physical Anthropology* 28 (2): 139-155.

nutritional deficiencies can be observed in the human skeleton. Porotic hyperostosis or porosity of osseous tissues, is another example of a deficiency that has the potential to be observed in the skeleton. This deficiency is most commonly caused by some type of anemia, most frequently this anemia is an iron deficiency.^{73,74} Other etiologies include scurvy, parasites, inflammation, genetic conditions, and vitamin deficiency. When the pathology is observed on the superior orbital surface of juveniles, the pathology is classified as cribra orbitalia. Frequencies of pathologies associated with nutritional deficiencies in human skeletal samples may enable inferences about environmental or demographic circumstances a population was facing.⁷⁵ Such interpretations should avoid overstating conclusions as the original living population may not be accurately reflected in the archaeological skeletal sample.⁷⁶

⁷³ Ortner, 2003, *Pathological Conditions*, 370.

⁷⁴ DiGangi and Moore, 2010, 185.

⁷⁵ Angel, J.L. 1966. "Porotic Hyperostosis, Anemias, Malaras, and Marshes in the Prehistoric Eastern Mediterranean." *Science* 153 (3737): 760--763.

⁷⁶ Ortner, 2003, *Pathological Conditions*, 56.

CHAPTER 3: MATERIALS AND METHODS

I. Acacia Park Cemetery Skeletal Sample

1. History of the Site

The individuals in this skeletal sample are all from previously disturbed burials at Acacia Park Memorial Cemetery. Working with human skeletal remains is an understandably sensitive subject that demands biological anthropologists to exhibit the utmost respect for the work they are doing at all times. Adhering to ethical practices in osteology is essential to ensure that the humanity and living component of working with dead is never forgotten. The recognition that human skeletons were once living people and that they likely have descendants alive today should forever remain at the forefront of one's mind when they are working with the deceased.

Prior to European arrival in the Minnesota area during the 1800's, Acacia Park Memorial Cemetery was called Oheyawahi by the Dakota which translates to "the place much visited". This sacred site's original use was for burials and the health-giving Wakan Ceremony.^{77,78,79} It is noted in an ongoing burial register of the usage of Oheyawahi that early European accounts of Dakota burial practices may be conceived of as culturally insensitive but contribute to our knowledge regarding usage of this site.⁸⁰

Several historical accounts describe Dakota burial practices in the early 1800's. Typical mortuary practice included dressing the deceased in their best clothing and placing them high on a scaffold or in a tree where they would remain for days or months before their remains were

⁷⁷ The Pilot Knob Preservation Association. 2004. *The Oheyawahi/Pilot Knob Burial Register*.

⁷⁸ White, Bruce and Alan Woolworth. 2004. "Oheyawahi/Pilot Knob: A Hill of State & National Significance in Dakota County." *Dakota County Historical Society* 45 (2): 1-18.

⁷⁹ "Historic Pilot Knob Will be Dedicated Next Sunday as Minnesota Acacia Memorial Park Cemetery." October 1, 1928. *The Saint Paul Pioneer Press*.

⁸⁰ Pilot Knob Preservation Association, 2004, Burial Register, 2.

gathered and buried in graves 2-3 feet deep.⁸¹ Graves were then marked with stones or wood which often would go unnoticed by the Europeans who were accustomed to seeing large tombstones demarcating graves.⁸²

European settlement in this area was conceived during the Lieutenant Zebulon Pike's expedition of 1805 to explore the northern territories acquired through the Louisiana Purchase.⁸³ The results of Lieutenant Pike's voyage was a questionable treaty signed by himself and leaders of one of the seven bands –the Seven Fires or *Oceti Sakowin* of the Dakota nation.^{84,85} This treaty promised the Dakota \$2,000 or the equivalent in material goods prior to taking possession of the land, neither of which ever were given to the Dakota.⁸⁶

Throughout the 19th century, Dakota in the area continued to use the site for burials and with a growing European presence in the area, there are some indicators that European burials occurred at this site as well.^{87,88} It is at some point in this time period of the early 19th century that Europeans associate the name Pilot Knob Hill with what to the Dakota is Oheyawahi.

In 1925 a Masonic group in the state of Minnesota purchases Pilot Knob Hill/Oheyawahi for use as a cemetery for Masonic members. Landscaping of the site took three years during which “many graves of the Indians were found and the bones carefully transferred to other parts

⁸¹ Pilot Knob Preservation Association, 2004, Burial Register, 1.

⁸² Ibid, 1.

⁸³ Coleman, Nick. 2005. "A Name of Fame, but an Anniversary of Shame." *Star Tribune*. *Lieutenant Zebulon Pike's expedition was the northern counterpart to Lewis and Clark*.

⁸⁴ Ibid.

⁸⁵ Pike, Zebulon, Le Petit Corbeau, and Way Aga Enogee. 1805. *Treaty with the Sioux Nation of Indians - 1805*. Conference Between the United States of America and the Sioux Nation of Indians.

⁸⁶ Coleman, 2005.

⁸⁷ White and Woolworth, 2004.

⁸⁸ Coleman, 2005.

of the park and there reburied.”⁸⁹ The cemetery was formally opened as Acacia Memorial Park Cemetery in October of 1928. Throughout the use of the cemetery, human remains from previous burials would be found and there is one record of those bones being set aside in the grave with the new individual still being placed in it and another record from 1942 mentioning “bones and relics recovered on the ground some years ago have been reverently set aside to be buried at some future date with fitting ceremonials.”⁹⁰ At some undocumented point in time, Acacia Park Cemetery staff began to use a vault in a shed on their property to store human remains (see Fig. 1) that were disturbed when interring new individuals into their graves.

The next mention of this vault or any storage of disturbed human remains is in 1962 with a West St. Paul Riverview Booster newspaper article describing twenty teenagers from the St. Paul area breaking into the vault and stealing human remains.⁹¹ The newspaper article reports that seven skulls were stolen from the vault, the windows to the shed were broken multiple times, and that the Mendota Heights Police Department was only able to recover three of the skulls to return to Acacia Park Memorial Cemetery.

On March 20, 2003, Mark Dudzik, the State Archaeologist for Minnesota, contacted the general manager of Acacia Park Memorial Cemetery, Dale Bachmeier indicating that the Office of the State Archaeologist (OSA) had received the skeletal remains mentioned in the 1962 newspaper article.⁹² The skeletal remains were then sent to Dr. Leslie Eisenberg in Madison, Wisconsin to be assessed for ancestry, she determined that American Indian remains were represented in the skeletal sample. With the identification of American Indian ancestry, the

⁸⁹ Historic Pilot Knob, 1928.

⁹⁰ Pilot Knob Preservation Association, 2004, 8.

⁹¹ "Juveniles Gang Up in Cemetery, Steal Skulls." July 13, 1962. *West St. Paul Riverview Booster News*.

⁹² Dudzik, 2003.

remains were then transferred from OSA to Jim Jones, the Cultural Resource Director of the Minnesota Indian Affairs Council (MIAC) and then brought to Hamline University's Osteology Laboratory on September 30, 2004.

II. Research Methods

1. Minimum Number of Individuals (MNI) and Most Likely Number of Individuals (MLNI)

The first step in analyzing the Acacia Park Cemetery sample was to address the commingled context by determining the minimum number of individuals (MNI) represented and individualizing each set of remains to the extent possible. Nearly all of the bones in the sample had been given accession numbers prior to the commencement of this research project. To date there has been no paperwork or documents found describing how individuals were associated and subsequently given accession numbers. For initial inventory of the skeletal sample, visual recording forms (pictures of skeletons that could be colored to show what bones are present/missing) were completed for each accession number to provide a basic knowledge of what skeletal elements are represented in this sample.

The next step to address the commingled context of this sample was to inventory the entire sample noting completeness of bones, preservation, and from which side of the skeleton bones had originated. The techniques applied for sorting and segregating individuals was a hybrid of inventory,⁹³ pair matching, metrics,⁹⁴ and assessing adjoining bones.⁹⁵ Application of all of these techniques involved creating a document coding the inventory of the entire sample,

⁹³ Buikstra and Ubelaker, 1994, Standards, 9.

⁹⁴ Byrd, 2008, Models and Methods.

⁹⁵ Adams and Konigsberg, 2008, How Many People.

supplemental notes about possible paired or adjoining bones, and recording metric analyses that had potential to assist in segregating remains.

The MNI was then determined by counting repeated skeletal elements and noting when two skeletal elements could not be from the same individual (i.e. a fused, osteoarthritic radius and a fetal mandible). After assessing whether bones previously paired together did have the possibility of belonging to the same individual, the resulting numbers for left, right, and paired bones were entered into the Excel spreadsheet provided by Adams and Konigsberg (2008) to calculate the MLNI.

2. Biological Profile

After sorting individuals from each other to the extent possible, various techniques discussed in the literature review for estimating a biological profile were applied to each individual. The biological profile consists of the age at death, biological sex, ancestry, and stature of an individual. First will be a discussion of the methodology applied to the adult remains followed by a discussion of methods applied to the juvenile remains.

2a. Sex Estimation

The first component of the biological profile determined for adults was their biological sex. The primary techniques used for estimating sex included morphoscopic analyses of the innominates and cranium, both regions of the skeleton which are considered to have high reliability when estimating sex of an individual.^{96,97,98,99,100} All observations that were made to assist with estimating sex have been recorded on data forms.

⁹⁶ Buikstra and Ubelkater, 1994, Standards, 15-20.

2b. Age Estimation

Due to the application of several age estimation techniques being dependent upon an individual's sex,^{101,102,103} it was critical to have first estimated the biological sex for each set of remains. All of the techniques used to estimate age for adults relied upon morphoscopic analyses. The change in morphology of several surfaces was assessed; those surfaces included the pubic symphysis,¹⁰⁴ the fourth sternal rib end,¹⁰⁵ and the auricular surface.¹⁰⁶ Despite producing large age ranges, cranial suture closure¹⁰⁷ was also recorded and assessed for adults with complete skulls because of the importance of collecting all data available.

2c. Ancestry Estimation

Ancestry is arguably the component of the biological profile that carries the most weight because it determines what state agency is legally responsible for the disposition of each individual. The Gilbert and Gill¹⁰⁸ method and refinement of the technique by Wescott and Srikanta¹⁰⁹ were the principal techniques used for determining the ancestry of each individual because of their high reliability. Although cranial macromorphoscopies are not currently

⁹⁷ Phenice, 1969, A Newly Developed Method.

⁹⁸ Sutherland and Suchey, 1991, Ventral Arc.

⁹⁹ White, 2012, Human Osteology.

¹⁰⁰ Williams and Rodgers, 2006, Evaluating the Accuracy.

¹⁰¹ Brooks and Suchey, 1990, Pubic Symphysis Morphology.

¹⁰² Webb and Suchey, 1985, Medial Clavicle and Anterior Iliac Crest.

¹⁰³ Iscan, Yasar M., Susan R. Loth, and Ronald K. Wright. 1984. "Age Estimation from the Rib by Phase Analysis: White Males." *Journal of Forensic Sciences* 29 (4): 1094-1104.

¹⁰⁴ Brooks and Suchey, 1990, Pubic Symphysis Morphology.

¹⁰⁵ Iscan, Loth, and Wright, 1984, Age Estimation from the Rib.

¹⁰⁶ Lovejoy et al., 1985, Chronological Metamorphosis of the Auricular Surface.

¹⁰⁷ Meindl and Lovejoy, 1985, Ectocranial Suture Closure.

¹⁰⁸ Gilbert and Gill, 1990, A Metric Technique for Identifying American Indian Femora.

¹⁰⁹ Wescott and Srikanta, 2008, Testing the Assumptions of the Gilbert and Gill Method.

considered to be highly reliable when applied to historic and ancient populations,¹¹⁰ the data was still collected given the possibility that it may be further developed and validated in the future.

2d. Stature Estimation

Stature of an individual is known to have a strong genetic and temporal component and therefore methods for estimating the stature of individuals in this sample had to be specific to their population. The stature for individuals that were estimated to be of American Indian, probable American Indian, and indeterminate ancestry was calculated using formulae developed specifically for indigenous populations of the Great Plains¹¹¹ which is geographically consistent with the Acacia Park Cemetery site. While the stature of individuals estimated to be of European or non-American Indian ancestry was estimated using the software program FORDISC.¹¹² In the FORDISC software program, the metrics obtained from the Acacia Park Cemetery sample were run against data in the software program taken from the Terry Anatomical Collection because of this collection's shared temporal and ancestral background as individuals of European ancestry that would be present in the Acacia Park Cemetery sample.

3. Juvenile Human Skeletal Remains

It is often challenging to reliably estimate the sex of juvenile or subadult remains and cannot be accurately done if the individual has not yet undergone puberty. The primary goal with the juvenile remains present is to estimate a range for their age at death. Juvenile remains of the Acacia Park Cemetery sample were either too fragmented or damaged to reliably assess the

¹¹⁰ Hefner, 2009, Cranial Nonmetric Variation.

¹¹¹ Auerbach, Benjamin M. and Christopher B. Ruff. 2010. "Stature Estimation Formulae for Indigenous North American Populations." *American Journal of Physical Anthropology* 141: 190-207.

¹¹² Jantz and Ousley, 2013, Introduction to FORDISC 3.

proximal femur for ancestry¹¹³ or to estimate stature. To assess subadult age, dental eruption¹¹⁴ was assessed in conjunction with analyses of epiphyseal union.¹¹⁵ One individual was estimated to be between two and four years old which met the parameters for applying a sex estimation technique developed for juveniles under the age of five years old.¹¹⁶

4. Pathological Conditions

Several pathological conditions were analyzed for each set of remains; those that were assessed include dental pathologies, osteoarthritis, and evidence of nutritional deficiencies. Observations of pathologies were recorded according to *Standards for Data Collection*.¹¹⁷ The identification and recognition of pathological conditions was greatly aided by literature on the presentation of pathologies in human skeletal material.^{118,119}

5. Musculoskeletal Stress Markers

The final methodology applied to the analysis of this sample of human remains was assessing the robusticity of musculoskeletal stress markers. A standardized approach utilizing a coding system and visual observations had previously been developed¹²⁰ however to record

¹¹³ Lovejoy et al., 2002, The Maka Femur. *It has been demonstrated that the shape of the proximal femur is established early in life, suggesting the potential for assessing the region as an indicator of ancestry in subadult remains.*

¹¹⁴ Ubelaker, Douglas H. 1978. "Estimation of Age at Death." In *Human Skeletal Remains Excavation, Analysis, Interpretation*. 2nd ed., 45-67. Washington, D.C.: Taraxcum.

¹¹⁵ Schaefer, Maureen, Sue Black, and Louise Scheuer. 2009. *Juvenile Osteology a Laboratory and Field Manual*. San Diego, California; Burlington, Massachusetts; London, United Kingdom: Academic Press

¹¹⁶ Schutkowski, Holger. 1993. "Sex Determination of Infant and Juvenile Skeletons: I. Morphognostic Features." *American Journal of Physical Anthropology* 90: 199-205.

¹¹⁷ Buikstra and Ubelaker, 1994, Standards.

¹¹⁸ Aufderheide, Arthur C. and Conrado Rodriguez-Martin. 1998. *Encyclopedia of Human Paleopathology*. Cambridge, United Kingdom: Cambridge University Press.

¹¹⁹ Ortner, 2003, Identification of Pathological Conditions.

¹²⁰ Hawkey, 1988, Use of Upper Extremity Enthesopathies.

observations a data form that worked with this method had to be created. Details about which insertion sites were utilized and which bone they are located on is show in **Table 1**.

Morphoscopic observations (descriptions of coding system used are in **Table 2**) of attachment sites on bones¹²¹ of the upper extremities was recorded for individuals from both the left and the right side of the individual, individuals with age estimations which classify them as “adolescents,”¹²² and individuals with evidence of fractures and osteoarthritis which are all deviations from the method developed by Hawkey.¹²³ Reasons for these deviations are discussed later in the thesis.

All data forms that were used in the analysis of the Acacia Park Cemetery sample can be found in Appendix 1.

¹²¹ McMinn, R. M. H. and R. T. Hutchings. 1985. *Color Atlas of Human Anatomy*. Weert, Netherlands: Year Book Medical Publishers, Inc.

¹²² Buikstra and Ubelaker, 1994, Standards, 9.

¹²³ Hawkey, 1988, Use of Upper Extremity Enthesopathies.

Table 1. Muscle and ligaments used for analysis and attachment sites

Muscle or ligament	Site
Subclavius	clavicle
Costoclavicular ligament	clavicle
Trapezoid ligament	clavicle
Conoid ligament	clavicle
Trapezius	scapula
Pectoralis minor	scapula
Subscapularis	humerus
Supraspinatus	humerus
Pectoralis major	humerus
Latissimus dorsi	humerus
Teres major	humerus
Deltoideus	humerus
Coracobrachialis	humerus
Extensors, common origin	humerus
Flexors, common origin	humerus
Infraspinatus	humerus
Teres minor	humerus
Brachialis	ulna
Triceps brachii	ulna
Anconeus	ulna
Biceps brachii	radius
Supinator	radius
Pronator quadratus	radius
Brachioradialis	radius
Pronator teres	radius

Table 1 is adapted from Hawkey (1988).

Table 2. Coding system used for assessing musculoskeletal markers

Numerical Score	Expression
0	No expression
1	Robusticity type 1 (Faint)
2	Robusticity type 2 (Moderate)
3	Robusticity type 3 (Strong)
4	Groove type 1 (Faint)
5	Groove type 2 (Moderate)
6	Groove type 3 (Strong)

Table 2 adapted from Hawkey (1988)

CHAPTER 4: RESULTS

After reviewing the long and intricate history of burials at Acacia Park Memorial Cemetery and recognizing that this skeletal sample consists entirely of disturbed graves, it is clear that approaches to analyzing this sample need to be holistic. The objectives of this honors project were to address the commingled context, reconstruct a demographic profile for the sample by estimating the biological profile for each individual, and to gain insight into lifestyle and activity patterns by assessing musculoskeletal markers and pathologies.

I: Minimum Number of Individuals (MNI) and Most Likely Number of Individuals (MLNI)

The commingled context of this sample was addressed by conducting an inventory of the sample, assessing possible pair matches, sequencing epiphyseal union, and recording metric observations. As a result of all of these methodologies, it was determined that the minimum number of individuals (MNI) for the Acacia Park Cemetery sample is 25 individuals. Modeling that data statistically using the technique developed by Adams and Konigsberg (2008)¹²⁴ estimated the most likely number of individuals (MLNI) to be 26. Results of the pair matching

Table 3. Most Likely Number of Individuals (MLNI)

	<i>Tibia</i>	<i>Os Coxa</i>	<i>Humer us</i>	<i>Femur</i>	<i>Overall</i>
L	14	10	13	18	55
R	20	13	16	18	67
P	10	5	8	12	35
MNI	24	18	21	24	24
MLNI	27	24	25	26	26

Data in table is from analysis of Acacia Park Cemetery sample, table is from Adams and Konigsberg (2008)

¹²⁴ Adams and Konigsberg, 2008, How Many People?

and subsequent calculations using Microsoft Excel are displayed in **Table 3**. The discrepancy in the MNI calculated in the table and the MNI determined through the osteological analysis is due to the table of paired bones not accounting for a juvenile that was represented only by cranial fragments.

II: Demographic Profile

With the commingled context addressed and individuals segregated to the extent possible, the biological profile (age at death, sex, stature, ancestry) for each individual was able to be estimated. It was difficult to ascertain sex and age for numerous individuals due to the highly fragmented and poorly preserved state of many of the remains.

Collectively the biological profiles provide the data necessary to reconstruct the demographic profile of the skeletal sample **Table 4**. None of the adult individuals in this skeletal sample presented morphologically as biological females however that is not to say that women were not present in the living populations that occupied this area. One suggestion that could explain the lack of females in this burial context comes from a 1928 Saint Paul Pioneer Press Article¹²⁵ that describes the history of this site as being used for burying the “leading braves of the warring tribes.” Historically, men occupy roles in combat and military positions; if historic burials at this site by the Dakota were reserved for fallen warriors it *may* explain the absence of females in this mortuary context.

¹²⁵ "Historic Pilot Knob Will be Dedicated Next Sunday as Minnesota Acacia Memorial Park Cemetery." October 1, 1928. *The Saint Paul Pioneer Press*.

Table 4. Demographic Distribution of Acacia Park Cemetery Sample

	Male	Probable Male	Female	Probable Female	Indeterminate	Total by age estimation
Fetal <birth						
Infant birth – 3 years				1	2	3
Children 3-12 years					2	2
Adolescents 12-20 years					4	4
Young Adults 20-35 years	1	1			2	4
Middle Adults 35-50 years	4	1			1	6
Old Adults +50 years						
Adults		1			5	6
Totals by sex estimation	5	3		1	16	Total for sample: 25

Age categories are those suggested by Standards for Data Collection, Buikstra and Ubelaker, 1994, 9.

The ancestral background of each individual carries a lot of weight when working with this sample because the ancestry of each individual determines the agency responsible for the disposition of that individual. Individuals of American Indian ancestry fall to the Minnesota Indian Affairs Council and those of European or non-American Indian ancestry to the Minnesota Office of the State Archaeologist. The ancestral breakdown for the Acacia Park Cemetery sample is presented in **Table 5**.

Table 5. Ancestral Breakdown of Acacia Park Cemetery Sample

Ancestry	Number of Individuals
Probable European	0
European	2
Probable American Indian	6
American Indian	5
Indeterminate	12

One of the particular challenges when estimating the ancestry for individuals of this skeletal sample was the frequency with which individuals exhibited some traits consistent with being of American Indian ancestry and some that are more consistent with being of American/White or Black ancestry. As previously discussed, there is a low level of accuracy when relying solely on cranial macromorphoscopics to estimate ancestry. However, the proximal femur has demonstrated a much higher level of accuracy for determining if an individual is or is not of American Indian ancestry.^{126,127}

Numerous individuals in this sample would present in the proximal femoral region as one ancestral group but then have morphoscopic traits that are consistent with the other ancestral group. This seeming discrepancy in ancestry is possibly the result of these individuals being of mixed ancestry. Throughout the nineteenth century, there are two genetically distinct populations, the Dakota and European settlers, occupying the same area of land. From the

¹²⁶ Gilbert and Gill, 1990, Metric Technique for Identifying American Indian Femora.

¹²⁷ Wescott and Srikanta, 2008, Testing Assumptions of the Gilbert and Gill Method.

perspective of population genetics, it is highly probable that some degree of genetic interaction was occurring between the two populations given their close proximity. This hypothesis could in part explain the presence of genetic traits typical for both populations being observed in individuals with some of this phenomenon being attributable to human variation within populations.

III: Pathological Conditions

Evidence of porotic hyperostosis was a pathological condition observed in more than a third of this sample (9 out of 25 or 36%) and the prevalence can be observed in **Table 6**. The relatively high incidence of this observation is of note due to the pathology being most typically observed in infants and younger children.¹²⁸ The presence of this pathology in adults may suggest that the population was undergoing nutritional, sociopolitical, or ecological stress.¹²⁹ Without more knowledge about the time period during which any of these individuals lived and died during, interpretations regarding the presence of this pathology are appropriately kept to hypothetical proposals that are feasible.

Table 6. Observations of porotic hyperostosis in the Acacia Park Cemetery sample

Age	Number of Individuals
Adults (>20 years)	6
Adolescents and Juveniles (<20 years)	3

¹²⁸ Aufderheide and Rodriguez- Martin, 1998, 349.

¹²⁹ Ibid, 186.

IV: Musculoskeletal Stress Markers

The final component of this analysis was evaluating the musculoskeletal stress markers of the upper extremities using a method developed by Hawkey (1988).¹³⁰ Her method proposed assessing 20 muscle insertion sites, three clavicular ligament attachment sites, and two common origin muscle sites. For the technique proposed by Hawkey (1988) individuals meeting any of the following criteria were excluded from analysis: under the age of 20, individuals whose age and sex could not be reliably estimated, poor preservation, evidence of healed fractures, or severe degenerative joint disease (osteoarthritis). Additionally in the technique applied, it was proposed to only assess musculoskeletal stress markers from the right side of the body due to the high prevalence of right handed dominance in human populations.

The recommended parameters proposed if applied would have greatly limited the amount of data that could be collected from the Acacia Park Cemetery sample. Half of the individuals in the current sample that were determined to be adults or over the age of twenty, could not be reliably estimated for sex and/or age.¹³¹ Additionally, numerous adults had evidence of osteoarthritis and were poorly preserved. For the purpose of recording all data available, the application of this technique to the Acacia Park Cemetery sample included the left side of the skeleton in data collection, adolescents (12-20 years old with all of them being on the older half of that range), individuals with evidence of osteoarthritis, and an individual with evidence of healed fractures.

¹³⁰ Hawkey, 1988, Use of Upper Extremity Enthesopathies.

¹³¹ Age in this context referring to the ability to place an individual in the categories of young, middle, or older adult.

There are 16 adults, over the age of 20 represented, in this sample if all of them were well preserved and all 25 sites could be observed, a total of 400 site observations and scores would be generated. The significant taphonomic alteration of the remains and fragmentary condition of this sample complicated the process of applying this technique, thus even with expanding the parameters as described there were only 129 attachment sites that could be observed. This is only 33% of the data that could have been collected from this skeletal sample about muscle attachment sites under ideal conditions. Due to the preservation of this sample, there were no individuals that could be evaluated for all 25 attachment sites and many of them had less than a dozen that could be assessed. **Table 7** depicts an overview of the scores assigned to the attachment sites of the right upper extremities analyzed from the Acacia Park Cemetery sample.

Table 7. Musculoskeletal marker scores of the right upper extremities from Acacia Park Cemetery sample

Muscle	0	1	1.5	2	2.5	3	4	5	6	Score
Subclavius	1	1								
Costoclavicular ligament						1	1			
Trapezoid ligament		1	1							
Conoid ligament				2						
Trapezius		2								
Pectoralis minor		2	2							
Subscapularis		2		2	2	1				
Supraspinatus		3	2							
Pectoralis major	1	6	3			1	1			
Latissimus dorsi	6	4	1							
Teres major	6	3	1	1						
Deltoides		1	4	7						
Coracobrachialis	7	1	2	2						
Extensors, common origin	2	4		1						
Flexors, common origin		5		2						
Infraspinatus	2	1	1							
Teres minor		4		2						
Brachialis					1	2				
Triceps brachii			1	1	1					
Anconeus		2		1						
Biceps brachii				2		1				
Supinator		2		1						
Pronator quadratus	3									
Brachioradialis		2		1						
Pronator teres		1		1						

The location of attachment sites was described in *Table 2* and the coding system used is presented in *Table 3* with additional descriptions provided in *Appendix 3*.

Table 7 demonstrates that generally speaking, there is not a lot of data that can be interpreted to make conclusions about activity patterns of the individuals represented in this sample. As previously discussed, considerable caution needs to be exercised when attempting to make interpretations about activity patterns of a population from musculoskeletal

markers.^{132,133,134} These recommendations coupled with the lack of expertise on behalf of the researcher working with the Acacia Park Cemetery sample leads to a concern that any conclusions or interpretations made from musculoskeletal markers would be overstatements that lack adequate support. Several individuals whose age and sex could be reliably estimated have the scores assigned to five major muscle attachment sites displayed in **Table 8**. Details about the scores and coding system that were used can be found in **Table 3** with the descriptions for each score contained in **Appendix 3**.

The five muscles depicted in **Table 8** are several of the major muscles that are frequently used in the upper body. A primary function of the pectoralis major muscle is enabling movement at the shoulder joint which is where the deltoideus muscle is located. The deltoideus muscle attaches on the humerus and is involved in raising the arm laterally and overhead pressing motions. The latissimus dorsi muscle is likewise involved in moving the arm in a variety of

Table 8. Musculoskeletal Stress Marker Scores for Several Individuals from the Acacia Park Cemetery Skeletal Sample

Individual	Sex	Age	Pectoralis major	Deltoideus	Latissimus dorsi	Biceps brachii	Triceps brachii
H405-1	Male	30-45 years old	3	2	1	3	2.5
H405-2	Male	37-55 years old	1.5, 4	1.5	1	2	2
H405-3	Male	25-37 years old	1	1	0	2	Not observable
H405-9	Male	32-39 years old	1.5	2	1.5	Not observable	Not observable

There are no females in the table because there were no individuals in the Acacia Park Cemetery skeletal sample that were reliably estimated to be female.

¹³² Jurmain, 1999, Osteoarthritis Anthropological Interpretations, 141-184.

¹³³ White, 2012, Human Osteology, 457.

¹³⁴ Ortner, 2003, Identification of Pathological Conditions, 561.

directions and planes, notably horizontal upwards movement of the arm. While biceps brachii and triceps brachii are primarily involved respectively in flexion and extension of the arm, hinging at the elbow.¹³⁵

¹³⁵ McMinn and Hutchings, 1985, Human Anatomy.

CHAPTER 5: SUMMARY AND DISCUSSION

I: Summary

Complete analysis of the Acacia Park Memorial Cemetery skeletal sample indicated that there are a minimum of 25 individuals (MNI) represented in this sample. A statistical calculation relying upon the results of pair matching femora, tibiae, humeri, and innominates estimated the most likely number of individuals (MLNI) represented in this sample is 26. There were no adults in the sample that could be reliably estimated to have been female or probable female. Over half of the sample, 14 individuals, were estimated to have been over the age of twenty which classifies them from an osteological perspective as being adults. There were four individuals that were estimated to be within the age ranges of 12-20 years old and five individuals estimated to have been under the age of 12 years of age. Ancestrally, there were two individuals that were estimated to have been of a European background, 11 that were estimated to have been or to likely have been of an American Indian ancestral background, and there were 12 individuals whose ancestral affiliation could not be reliably estimated. Porotic hyperostosis of the cranium was observed in nine of the individuals in this skeletal sample.

II: Directions for Future Research

Additional work assessing musculoskeletal markers of the lower extremities and combining upper and lower extremity observations with ethnographic data has the potential to lead to meaningful interpretations about activity patterns in the future. Ethnographic and ethnohistorical research about what activity patterns were regularly engaged in by Dakota and European settlers during the nineteenth century (as well as time periods extending before and after that century) would provide insight into whether a wide variety of activity patterns were

routine, what those movement patterns were and for what purpose, and if there were substantially different activity patterns when comparing the local Dakota and European settlers. It has also been noted in the literature that more refinement and verification of the underlying theories about musculoskeletal stress markers being correlated with certain movement patterns needs to be done for interpretations from musculoskeletal markers to gain greater acceptance and applicability.¹³⁶

Working with ethnographic data could also be of assistance in determining the most likely ancestral affiliation for individuals. Learning more about mortuary practices during the 19th century in Mendota area of Minnesota could provide insight into some of the taphonomic effects observed in the Acacia Park Cemetery sample. Some of the taphonomic patterns observed in this sample were copper staining, impressions of a plant that appear to possibly the root system of a fungi or mushroom, and gnaw marks from animals.

Further research into the history of Acacia Park Cemetery/Pilot Knob Hill/La Butte des Morts/Oheyawahi could contribute to our knowledge about who was using this site and for what purposes. There is likely more that can be learned about who was using this site, at what times, if the uses of this site changed and if so to what extent, how long have the Dakota been using this site for burials, and to what extent did Europeans use this site for burials prior to the opening of Acacia Park Cemetery. Having a richer understanding of the history of this site could have an impact on the analyses of this skeletal sample as well as contributing greater detail to our knowledge about the history of such a historical site in Minnesota.

The final and arguably most pressing area for future work with the Acacia Park Memorial Cemetery sample is working towards the repatriation of these individuals. It is important to

¹³⁶ Jurmain, 1999, Osteoarthritis Anthropological Interpretations, 141-184.

recognize that all of these individuals are being housed and cared for at the Hamline University Osteology Laboratory because at some point in time their graves were disturbed. In continuing to recognize and respect their humanity, it is important that they be returned to appropriate descendent communities. The additional work already discussed could be of great use in determining which state agency, the Minnesota Indian Affairs Council or the Office of State Archaeologist, is responsible for the disposition of each individual. In light of the proposal that some of these individuals may be of mixed ancestry, future research should look into how disposition of human remains has been decided in other cases of mixed ancestry. Another option that could be looked into in the future is the reburial of this entire skeletal sample at the site where they all originated, Acacia Park Memorial Cemetery.

All of the data forms and written documentation that supplements this thesis is located in the Hamline University Osteology Laboratory in St. Paul, Minnesota.

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APPENDIX I

Data Collection Forms