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The potential of the angle of the first rib, head to tubercle, in sexing adult individuals in forensic contexts

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THE POTENTIAL OF THE ANGLE OF THE FIRST RIB, HEAD TO TUBERCLE, IN SEXING ADULT INDIVIDUALS IN FORENSIC CONTEXTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Accurately assessing the sex of an adult human skeleton is fundamental in forming the biological profile used in forensic anthropology (Patil and Mody, 2005). The first rib was chosen due to its distinct shape, compact size and increased sustainability to the taphonomic processes encountered in forensic and bioarchaeological situations. The first rib has been examined in previous studies; however, these studies have focused mainly on the sternal end of the rib. This study looks at the angle created between the tubercle and head and its potential use as an indication of the sex of an individual.

This angle, created by the tubercle and head, is present when the rib is viewed in its non-anatomical orientation, or with the head pointing upward. When a rib is sided in anatomical position, the head will point downward and the subclavian grooves will be located on the superior surface.

This study was conducted using 137 males and 149 females, including black and white individuals, from the William M. Bass and Hamann-Todd Skeletal Collections. The left and right first ribs of 286 individuals were measured using sliding calipers; all measurements were recorded in millimeters. The four measurements included: total exterior length (ASHL), interior length from sternal end to head (PSMH), height of the head off of a surface and length from the tubercle to the head. The angle was determined by calculating the inverse sine.

The calculated angles were then compared using logistic regression analysis, to determine the odds that a given angle was male. Of the 572 measured samples, 555 were calculated; 266 angles were male and 289 female. Logistic regression showed that angle alone is 60.2 percent concordant, while angle and total length combine to yield a 70.5 percent concordance. The data suggest that the angle can be used to predict the sex of an individual.

This research concludes that the angle of the first rib is able to determine the sex of an individual. These data could be combined with previously studied age methods to assess both age and sex of an unknown individual. Few skeletal elements are able to both sex and age individuals.

CHAPTER 1

INTRODUCTION

In forensic anthropology, determination of sex is among the most important aspects required in building the biological profile (Patil and Mody, 2005). A limited number of sexing methods are available in forensic contexts, and, given its compact size, the first rib offers a wealth of potential for sex estimation. The first rib is not only easily distinguishable from other ribs, it is also more likely to survive taphonomic processes than its longer, thinner counterparts (Kurki, 2005; Semine and Damon, 1975).

Previous research that has been conducted on the first rib as a sex determinant has focused on the sternal end (İşcan et al., 1984; İşcan, 1985; Koçak et al., 2003). Other research has shown that the determination of age, based on changes in the costal cartilage of the rib, is influenced by the sex of the individual (DiGangi et al., 2009; Kunos et al., 1999; Navani et al., 1970; Semine and Damon, 1975). Therefore, a possibility exists that the angle of attachment of the first rib to the vertebra may be impacted by the sex of the person and that angle may serve as an indicator of sex in a forensic context. This current research seeks to test whether or not a difference between the sexes is measurable in the angle of the head of the first rib relative to the tubercle.

CHAPTER 2

ANATOMY OF THE FIRST RIB

The first rib is the most curved, flattest, and usually the shortest of the ribs. It is located at the top most region of the rib cage and attaches to the first thoracic vertebra at its posterior aspect and to the sternum at its anterior aspect. Five distinct landmarks are found on the first rib: head, tubercle, sternal end, and two subclavian grooves –the anterior groove for the subclavian vein and the groove for the subclavian artery and inferior trunk of the brachial plexus (Figure 1). When siding a first rib, the rib's head will point downward when the rib is oriented in the proper anatomical position and the subclavian grooves will be on the superior surface (Bass, 1995). When the first rib is sided incorrectly, an angle is visible between the head and the tubercle at the inferior portion of the neck. The current research focuses on that angle and its potential as a sex indicator.

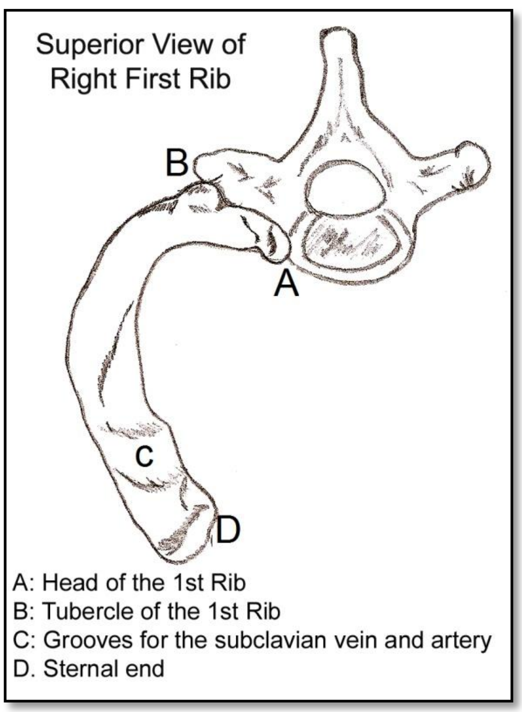

Figure 1: Diagram of First Rib

The articulation of the first rib to only the body of the first thoracic vertebra is unique to humans as the only extant hominoid with this articulation (Ohman, 1986). All other ribs have a bivertebral articulation, each articulating not only to the vertebral body with which it is associated but also to the inferior portion of the vertebra that precedes it. Fossil evidence suggests that this univertebral articulation is present as far back as 3.2 million years ago, as seen in AL-288-1, Lucy, who also presented with a univertebral first rib (Ohman, 1986). This univertebral first rib articulation and its uniqueness to the human lineage suggests that it is specialized to our upright posture, thoracic shape, and unique shoulder girdle (Figure 2).

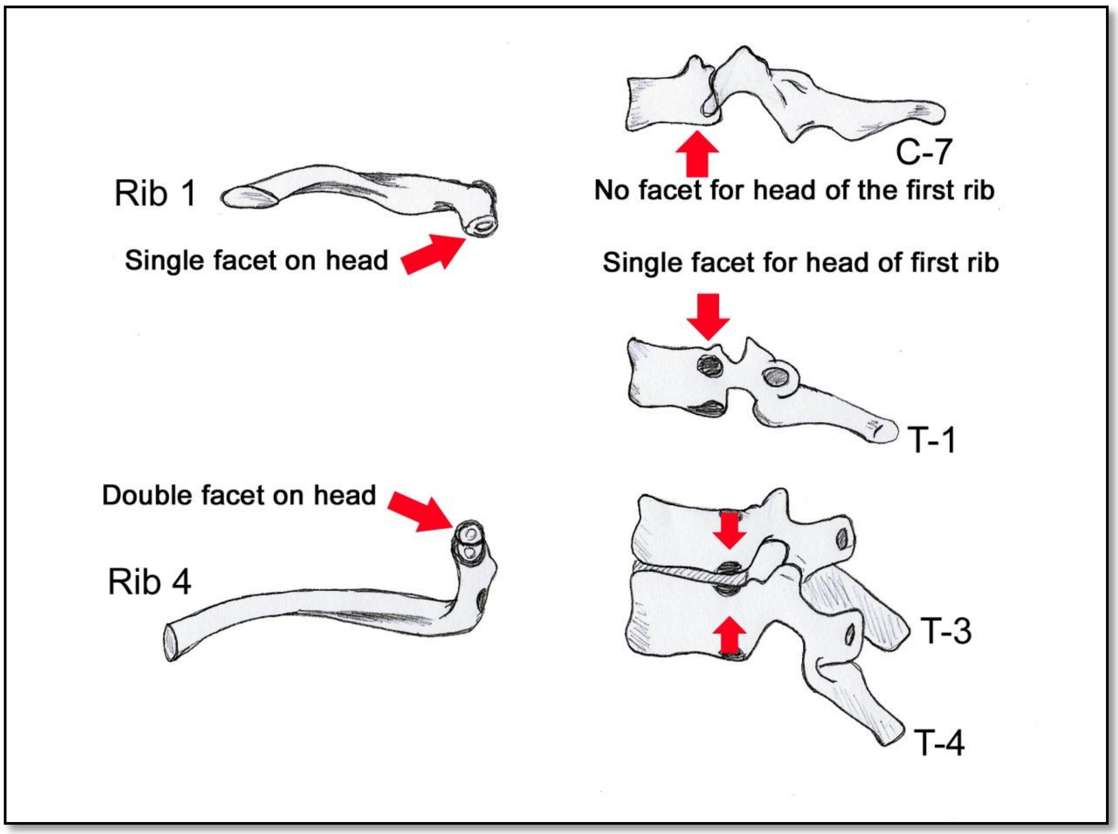

Figure 2: Articulation Diagram for First Ribs in Comparison to Subsequent Ribs

The shoulder complex includes the clavicle, scapula, and humerus, as well as the sternoclavicular and the acromioclavicular joints. The sternoclavicular (SC) joint is the only point of attachment between the shoulder complex and the axial skeleton. The SC joint is a synovial joint; the medial clavicle articulates with the sternum and with the cartilage of the first rib (Peat, 1986). The costoclavicular ligament connects the inferior-medial border of the clavicle to the first rib, anchoring the clavicle and limiting clavicular elevation (Bearn, 1967; Peat, 1986).

CHAPTER 3

LITERATURE REVIEW

The estimation of sex is vital to the completion of the biological profile that is required in medico-legal investigations. Most commonly, sex is determined from the cranium and pelvis. The goal of this study is to determine whether the angle of the first rib, the head relative to the tubercle, is a useful determinant of sex in an individual. The first rib was selected for its small stout size and resistance to the normal taphonomic processes that may render larger bones such as the pelvis and cranium too fragmented to use for determination of sex. While research has been conducted on sexing individuals using other ribs, prior to this study, no one had examined the possibility of using the head end of the first rib (DiGangi et al, 2009; İşcan et al., 1984; İşcan, 1985; İşcan and Loth, 1986; Kunos et al., 1999; Kurki, 2005; Ramadan et al., 2010). Because other skeletal elements have shown to be sexually dimorphic in characteristics other than size, there is a possibility the angle of the first rib may reflect some degree of sexual dimorphism.

Sexual dimorphism has been found in numerous skeletal elements including, but not limited to: the cranium, mandible, sternum, first rib, fourth rib, humerus, pelvis, and femur (Giles and Elliot, 1963; Giles, 1964; İşcan and Loth, 1986; İşcan et al., 1998; King et al., 1998). Also, the successful sexing of individual skeletal remains based on morphology has been proven to be reliable (Phenice, 1969).

Giles and Elliot (1963) examined the skulls of 408 individuals, both black and white ranging in age from 21 to 75 years of age. They took nine cranial measurements from each individual. After measurements were taken, they computed the data in a discriminant function. When this discriminant function is used, it yields an accuracy of 82-89%, in sex determination, for black and white specimens. Giles performed a similar study in 1964 to determine sex by a discriminant function of the mandible. The results of his study allow for the sex of an individual using a mandible to be accurately determined in 85% of cases (Giles, 1964).

Ramadan et al. (2010) established that while the sternum of males tends to be larger as defined by “Hyrtl’s Law,” the most accurate way to establish the dimorphism in sternal measurements is by using the overall sternal area, rather than individual sternal measurements. In a study performed by Navani et al. (1970), x-rays of patients were taken to determine the potential for sexing individuals using costal cartilage calcification at the sternal end. Their research showed that females were more likely to display central calcification, while, in males, calcification occurred on the margins.

Koçak et al. (2003) examined the fourth ribs of 78 females and 173 males to determine if osteometric measurements of the sternal end could indicate sex. They determined the measurements were more accurate for females than males. Multiple studies performed by İşcan (1985, 1991), İşcan et al. (1984, 1986, 1998) and Koçak et al. (2003) noted that the fourth rib is useful in sexing individuals using discriminant function analysis and known age of individuals.

İşcan et al. (1998) did a comparative analysis of Chinese, Japanese, and Thai individuals to determine sexual dimorphism in the humerus. The study focused on the application of a standardized analysis versus a population specific analysis. Ultimately they concluded that accuracy was increased if each population was assessed using population specific calculations. That study showed that sexual dimorphism is present, but calculations using general metric assessments can mask this dimorphism if the calculations are not specific to that population. For example, using a standardized measurement placed the Chinese with the largest measurements in the least dimorphic category. With cross validation, İşcan et al. were able to sex the Chinese individuals accurately 87% of the time in contrast to the Thais which were accurately sexed in 97% of cases.

Phenice (1969) determined that the pubic bone was a valuable skeletal element in the sexing process. To date, Phenice's technique is still considered one of the most accurate sexing methods in use because of the reliable sex differences associated with that region of the hip bone in the sub-pubic concavity, width of the ischio-pubic ramus, and presence or absence of a ventral arc.

Bruzek (2002) conducted a comprehensive study that combined several of the commonly used pelvic traits to create a method for visual determination of sex using points from the entire os coxae rather than a localized portion. The five main characteristics he examined were: preauricular surface, greater sciatic notch, form of the composite arch, morphology of the inferior pelvis (pubic area), and ischiopubic proportions (ratio of pubic length to ischial length). These five characteristics comprise the sacroiliac complex and the ischiopubic complex, two morphologically distinct areas that had previously been examined separately. Using the combination of the five characteristics, Bruzek was able to accurately determine sex in 93-98% of all cases.

The combination of multiple aspects that are used in sexing individuals is ideal in presenting a more accurate determination of sex. This is seen not only in Bruzek's study but also in the study performed by Đurić et al. (2005). Đurić et al. found that by using a combination of seven non-metric pelvic traits, as well as several cranial traits, including mandibular thickness, the sex of individuals can be determined with at least 95% accuracy.

The femur has also been studied for its sexually dimorphic properties. King et al. (1998) studied the sexual dimorphism of Thai femora. They recorded six of the common osteometric measurements of the femur including: maximum length, maximum diameter of the head, bicondylar breadth, midshaft anterior-posterior diameter, midshaft transverse diameter and midshaft circumference. The study of 70 males and 34 females determined that maximum head diameter and bicondylar breadth are the most significant indicators of sex. Using a stepwise function, they correctly identified the sex of an individual with 94.2% accuracy.

While the first rib has been examined for its overall usefulness in physical anthropology, most, if not all of that research has focused on the sternal end, especially as an aging technique. The majority of the research examined the costal cartilage and its versatility in aging and sexing individuals. The previous research with the most relevant data to assist in this research study, including measurement information about internal length from head to sternal end, was the aging method established by Kunos et al. (1999). Specimens were measured and examined to determine age-related changes. The Kunos study focused on the head, tubercle, and sternal end of the first rib as aging variables over time and was performed on individuals from the Hamann-Todd Collection. However, Kurki (2005) determined that the method developed by Kunos et al. over-ages individuals younger than 60 and under-ages those over age 60, thus representing the young as older and the old as younger in their sample. While the 1999 study by Kunos et al. was useful in determining aspects of the first rib that change through time, the reliability of aging methods is still questionable in the first rib.

Still, other studies have looked at age assessment using the first rib. McCormick (1980) used x-ray data obtained from 210 cadavers to examine the mineralization of the costal cartilage. He determined that costal cartilage mineralization was not found before age 15 and was rarely marked in individuals under age 50. A similar study by Kampen et al. (1995) also examined the age related mineralization of the first rib at the sternal end. The study noted that the mineralization was due to age not degeneration; however, the exact stratification of age was unclear. Additionally, the use of x-ray technology in fresh bone and soft tissue makes these methods difficult to translate to forensic usability.

If the current research shows that the angle of the first rib is able to reliably determine sex of an individual, it could be combined with the aforementioned aging methods of the first rib to assess both age and sex. Since few skeletal elements can both age and sex an individual, this research could have great potential for forensic applications. Expanding the list of aging methods to include smaller elements that are more likely to survive long postmortem intervals would be beneficial in a forensic context during which scavenging might disperse the larger bones used in sexing. "The first rib is less fragile than other skeletal elements, such as the pubic symphysis, and is, therefore, more likely to survive in archaeological and forensic contexts" (Kurki, 2005: 343-344).

CHAPTER 4

MATERIALS AND METHODS

For this research, two large collections were examined, the William M. Bass Donated Skeletal Collection at the University of Tennessee, Knoxville, and the Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History.

The William M. Bass collection was started in 1981 by Dr. William Bass. The collection currently houses over 870 individuals, some from forensic contexts, with known sex identification. The age range of individuals in this collection varies from fetal to 101 years. The individuals used were chosen at random, with the sex of the individual being recorded at the same time the measurements were recorded. All choices were made randomly so that age would not be a biased factor in the sample. As this is a donated and forensic collection, individuals with trauma to the thoracic region, including autopsy trauma to both ribs, were removed from the list of potential samples so as to not impact the angle measurements.

The Hamann-Todd Human Osteological Collection at the Cleveland Museum of Natural History is a historic collection of individuals collected between 1912 and 1938. The collection contains over 3,000 skeletons, making it the largest documented modern collection in the world. As this collection has such a large number of both males and females, a sample of more than 100 individuals will still maintain the 50/50 male: female ratio as well as 50/50 black: white ratio – which is not as easily maintained in the William M. Bass Collection. This sample was used to collect more data on blacks than whites in comparison to the William M. Bass collection, as the Hamann-Todd collection has a much larger number of black individuals.

The proposed sample size was 100 individuals from each collection, a total of 200 specimens. All individuals are age 18 and above, as this was a study of the angle in the adult first rib. Both the left and right first ribs of individuals of known sex, age, and ancestry were measured. At least 100 individuals per collection were recorded. Left and right ribs for each individual were examined, if present, to determine the significance of the angle differences in individuals. The samples from each collection met a minimum of 50 males and 50 females. Ancestry was also considered in measurement, and the males and females were divided into whites and blacks with 25 black males, 25 white males, 25 black females and 25 white females – this was the goal in measurement, but was not met in the Bass collection. Due to the limited number of females, both black and white, as well as black males in the Bass collection, some individuals were only recorded unilaterally if there was damage to one of the two ribs.

Table 1: Summary of Individuals from Each Collection

Collection	White Males	White Females	Black Males	Black Females
William M. Bass	44	56	30	8
Hamann-Todd	30	31	33	54
Total	74	87	63	62

In this sample, the average age at death was 49 years old for males, and 50 years old for females. The sex of each individual was recorded at the time measurements were taken. Knowing the sex should not have biased the sample as sex did not affect angle calculation. Once measurements were recorded, the angle of each specimen was calculated using its given identification number, ie: UTK-WM1L (University of Tennessee Knoxville-White Male #1 Left Rib) and CMNH-WM1L (Cleveland Museum of Natural History – White Male # 1 Left Rib).

Figure 3 demonstrates the measurements that were taken. Each rib was measured, in millimeters, to determine the angle of the elevated head from a surface when laid flat on its superior aspect. In this non-anatomical position, the subclavian grooves are inferior and the head is elevated off of the surface. The length measurement used to determine the angle was measured, using sliding calipers, from head to tubercle. In non-anatomical position, the height of the head off a surface is measured from the head's most inferior point to the surface. The height of the highest point, along the inferior margin, of the head relative to that surface was the landmark used.

The point of measurement at the tubercle was the same for the height and length measurements. The point of measurement for the tubercle was more variable than the measurement point at the base of the head, for the tubercle the measurements were taken from the point where it made contact with the surface. In cases where the tubercle did not follow the measurement standards, where it did not make contact with the surface at the base of the angle, the rib was excluded from the sample.

The angle was determined using an inverse sine function, with the measured height over the length. This sine function was calculated in Excel using the function: =Degrees(Asin(Height/Length)). This formula calculates the angle of the head relative to the neck when assuming that the angle at which the head met the table was 90^{o} (Figure 3).

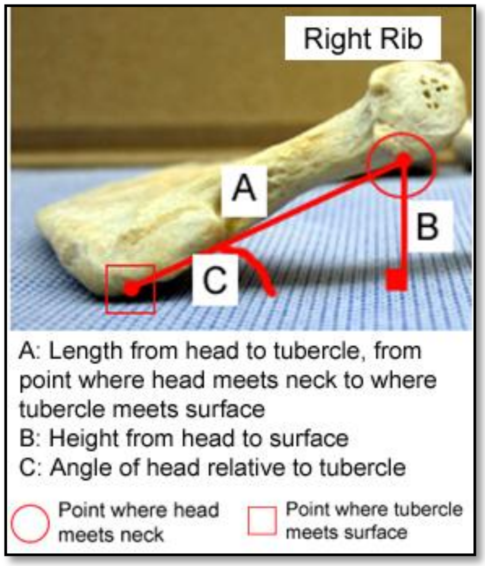

Figure 3: Measurements to Determine Angle

Two other measurements were taken as well: the total exterior length of the rib and the sternal end to head inner length (Figure 4). The total length was measured using a soft tape measure to record the distance from the posterior portion of the sternal end to the head, while the inner length was taken using sliding calipers. The exterior length was measured from the anterior sternal end to the lateral portion of the head (ASLH) . The inner head length was measured from the posterior portion of the sternal end to the medial portion of the head (PSMH).

These length measurements were taken to see if there was any correlation between them and the angle in sexing individuals. ASHL, total exterior length, and PSMH, interior length, were measured in all specimens that had their sternal end – this measurement was not taken for some individuals in which autopsy cuts removed the sternal end.

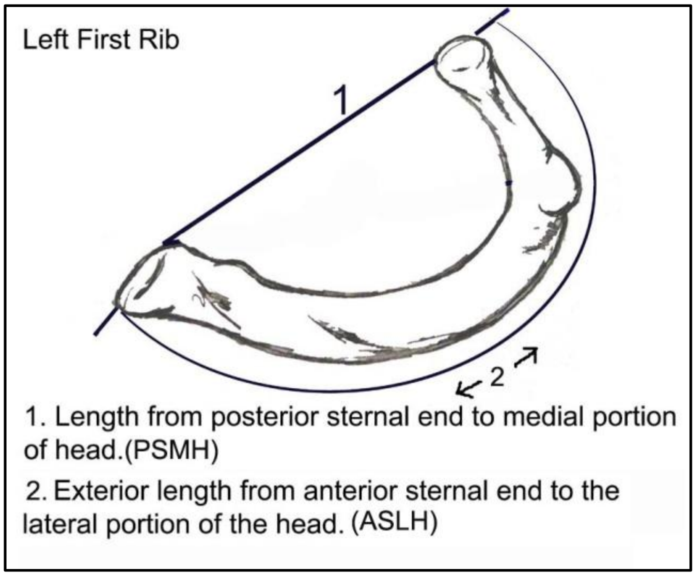

Figure 4: PSMH and ASLH Measurements of First Rib

In a preliminary study of 25 individuals from the LSU Forensic Anthropology and Computer Enhancement Services (FACES) collection, the ASLH did not appear to correlate with the angle using scatter plots and linear regressions. Given this initial conclusion, I hypothesized that there may be a possibility that it is the PSMH, which was not recorded in the preliminary study, that correlates with the angle. PSMH and ASLH, in addition to angle, might aid in the sex determination using the angle. Any ossified cartilage present at the sternal end was recorded and noted. If it interfered with the angle measurement, the rib was not included in data analysis. If the rib was calcified in such a way that it was fused to the manubrium, it was not included in the sample. Any additional cartilage was not included in the total length measurement.

Once all data were collected, angles were calculated in Excel and data were examined. The overall data consisted of 572 ribs, 17 of which were excluded for missing data, resulting in a total of 555 ribs – 266 male and 289 female. The calculated angles were graphed on a scatter plot to determine the type of analysis that would be required. A regression analysis was performed to calculate if any correlation existed between the angles for males and females. Given the sporadic distribution of points on the scatter plot of the data, a linear regression would not be useable. The data were log transformed to an approximate normal distribution. The logistic regression, unlike the linear regression, calculates the probability of a variable that has only two outcomes– in this case, that the angle either was or was not a particular sex.

A linear regression of the data was run in Excel to determine any correlation. When the regression displayed sporadic distribution, the data were then examined in a logistic regression in SAS. An F-test determined that the data were equal rather than unequal, after which a Student's t-test was run assuming equal variance. All statistical calculations were run in SAS versions 9.2 and 9.3.

CHAPTER 5

RESULTS

Before any regression calculations were performed, a Student's t-test was run on all data to determine the statistical significance of the angle to sex. Summary statistics were run for all variables including: height of the head off a surface, length from head to tubercle, angle, total length (ASHL) and length from head to sternal end (PSMH). The three tables of summary data compare all males to all females, black males to white males and black females to white females, these tables can be found in Appendix A. T-tests were also run for all variables including: height of the head off a surface, length from head to tubercle, angle, total length (ASHL) and length from head to sternal end (PSMH), these can be found in Appendix B.

Table 2 shows a brief statistical summary of angle of the 572 data points, from 286 individuals, including the average angle measurement of 26.418 degrees for males and 22.508 degrees for females.

Table 2: Statistical Summary for Angle

Sex	Observations	Mean	Maximum	Minimum	Std. Dev	Std. Error
Female	298	22.5	51.5	2.3	9.6	0.56
Male	274	26.4	52.3	6.8	9.7	0.59

Both a pooled and unpooled T-test of the relationship between rib angle and sex yielded a T-value of -4.77 (Table 3). The associated p-value for the data was calculated at <0.0001 with a 0.05 alpha. The null hypothesis can be rejected, meaning that the angle of the first rib is significantly associated with the sex of an individual.

Table 3: Results of T-Test for Angle

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	553	-4.77	<.0001

Once statistical significance was established, data were calculated using a logistic regression to determine the probability that an angle was either male or female. In logistic regression, the data are binary, meaning they must lie between one and zero. Females were assigned the number one while males were zero. The logistic regression calculates the odds that a variable either is or is not close to the binary 1, in this case the odds that the variable either is or is not male.

The logistic regression gives the odds, for each angle, that the angle is or is not male. It yielded angle measurement ranges for sex estimation: 22.02 degrees and below is more likely female and larger than 31.45 degrees is more likely male. Measurements between 22.03 degrees and 31.44 degrees are not able to be classified as male or female with as much certainty because this is the point at which the odds drop below 55% to successfully determine angle. The cutoff of 55% was chosen because the lower limit is close to 50%, selecting a range above 55% allows probabilities to be significant. When the angle alone is observed, the odds are calculated to accurately sex a rib with a concordance of 60.2% (Appendix D). Concordance percentage calculates that for any pair, males and females, the odds of accurately sexing a male are higher than for the odds of the angle for the female 60.2% of the time. When the angle is observed in conjunction with total length, ASLH, the concordance increases to 70.5%, a 10% increase – meaning that angle and total length combined are a more statistically significant measure of sex than angle alone (Appendix E).

Since angle was significantly correlated to sex, all points of measured data were used in the regression. Again, removing data points with missing values, in most cases the sternal end, the data that were regressed decreased from 572 to 527 individual measurements. The results of significance per "parameter" or measurement are shown below (Table 4).

Table 4: Analysis of Maximum Likelihood Estimates for All Measurements

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept*	1	-9.0053	1.3105	47.2200	<.0001
Angle	1	0.0720	0.0120	35.8931	<.0001
TotalLength(ASHL)	1	0.0456	0.00928	24.1530	<.0001
SternalHead(PSMH)	1	0.0419	0.0187	5.0207	0.0250
Age	1	-0.0192	0.00620	9.5308	0.0020
Ancestry	1	-0.4508	0.2127	4.4941	0.0340

*****Intercept is a calculated variable, not a measurement

Table 4 reflects that angle and total length, ASHL, were the most significant measurements, with an alpha of 0.05. The PSMH, age and ancestry were not as statistically significant as were angle and ASHL. When PSMH, age and ancestry were combined with angle and ASHL the concordance increased by 1%; this was not considered significant enough to continue use in further logistic analysis. The p-values for PSMH, age, and ancestry were 0.0250, 0.0020 and 0.0340 respectively, which while significant did not change the concordance enough to be included. Angle and total length are more significant as well as present on the bone, without needing to know the age or ancestry prior to calculation. A contributing factor in excluding ancestry, age and sternal PSMH, was the ability to use angle and total length without having to know information that cannot be found using just the first rib – thus limiting the information available if just the first rib is present.

Using angle alone, with the 60.2% concordance, a formula was generated to find the probability of any angle using the intercepts from the logistic regression (Table 5). The coefficients for the formula are taken from the estimates for intercept and angle to get the formula: Log(odds)= -1.1073 + 0.0419 x angle. This formula is the log of the odds formula that is calculated in the logistic regression. The -1.1073 and 0.0419 are the estimates calculated from the logistic regression run on the data for 555 ribs. To find the probability that the angle is male, the original formula is used to find the odds, then the probability: odds=e^log(odds) and then P=1/1+odds.

Table 5: Analysis of Maximum Likelihood Estimates for Angle

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-1.1073	0.2390	21.4677	<.0001
Angle	1	0.0419	0.00911	21.1728	<.0001

A formula was also generated for the use of both angle and ASLH, which together had a 70.5% concordance. The estimates obtained from the odds calculated for the logistic regression are slightly different than those used for angle alone, and the addition of total length changes the formula slightly (Table 6). The new coefficients for the intercept and angle become -8.0905 and 0.0506, respectively, with a new coefficient for total length, 0.0513 being added. The formula for both angle and total length is: Log(odds) = -8.0905 +0.0506 x Angle + 0.0513 x TotalLength. All calculations to determine the probability that an angle is male are the same as they are for angle alone.

Table 6: Analysis of Maximum Likelihood Estimates for Angle and Total Length

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-8.0905	1.1745	47.4481	<.0001
Angle	1	0.0506	0.00997	25.7200	<.0001
TotalLength	1	0.0513	0.00846	36.8128	<.0001

CHAPTER 6

DISCUSSION AND CONCLUSION

The goal of this study was to determine whether or not the angle of the first rib could be used to determine the sex of an adult individual. Few studies have been conducted on the ribs, and none has focused on using the angle formed by the head and tubercles at the points where the rib attaches to the first thoracic vertebra. Many other skeletal elements have proven valuable in sexing individuals; yet, little focus has been placed on the ribs. The fourth rib is commonly used as an example of age determination (İşcan, 1991), but the fourth rib easily can be confused with the surrounding ribs if not all ribs are present. For this reason, the first rib has the potential to be valuable as both an aging and sexing method.

The data support that the angle of the first rib, head to tubercle, is indicative of sex of the individual. This study has shown with 60% probability that we can determine the sex of an individual using the angle of the first rib, head to tubercle. This 60% probability determination lies below 22.02 degrees for females and above 31.44 degrees for males. Adding the total length, ASHL, to the process of determining sex can increase the probability of correctly sexing individual unknown ribs to at least 70%. Using the data obtained from the logistic regression, several calculations for determination of sex were derived and can be used to identify the probability of an angle being male.

These derived probability calculations are very useful in terms of not needing a data set to which to compare an unknown rib’s angle. All that is needed to determine the sex of an individual using the first rib is the angle of the rib in question and the formulae. The calculations that allow for the sex probability of any angle could have great implications by adding valuable information to the field of forensics, in which a biological profile is necessary for identification.

If the entire rib is present, a greater accuracy can be obtained using the combined angle and total length of the first rib, a more statistically significant prediction of sex than angle alone. If the sternal end is damaged, then the calculation for angle alone can be used to predict the sex of the individual.

With this knowledge, perhaps more research will be performed on the first rib – to allow for more accurate and thorough sex and age estimates. Further research would help to add more information to the first rib data bank in addition to the benefits of increasing ancestry diversity. It appears that the first rib has the potential to be an important bone when the methods of aging and sexing individuals are combined. Combining the current research with the aging methods determined by McCormick (1980) and Kunos et al. (1999) could prove to be beneficial in forming the biological profile.

The impact of stature and overall body size on the angle of the first rib should be studied to note whether idiosyncratic variation in larger or smaller individuals impacts angle. If so, this could help to explain the wide range of angles which do not offer statistically significant indications of male or female. Comparing stature to the angle would allow the researchers to know if the angle was indeed indicative of sex or if it is directly correlated to stature, with the range of error falling around shorter males and taller females.

Research could also be done to determine whether the same angle, formed in the articulation points of the vertebrae, produces similar results. The ability to use the vertebral articulation points to identify sex would be useful.

There is also the potential for research to be done looking at angle and secular change. This was not a factor studied in this research due to limited number of black individuals in the

William M. Bass collection. A secular study of the first rib would have to focus on the angles of white individuals, as the black collections are limited in regards to a modern sample.

This study shows that the percentage of identifying sex is 70% accurate using multiple measurements. This information is useful to the establishment of the overall biological profile. Research focused on elements that are more likely to survive taphonomic processes could prove valuable to the field of forensic anthropology. Use of smaller elements to estimate sex for individuals would lower the dependence on larger elements, such as the crania and pelvis. Further research that adds to the information the first rib can provide will only continue to improve the field's ability to identify the sex of an individual.

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APPENDIX A

STATISTICAL SUMMARIES OF DATA

FOR FEMALES AND MALES:

GENDER	N Obs	Variable	Mean	Minimum	Maximum	Range	Std Error	Variance
Female	298	Height	8.8	1.0	19.0	18.0	0.23	14.82
		Length	23.3	13.0	33.0	20.0	0.21	12.89
		Angle	22.5	2.3	51.5	49.2	0.56	92.08
		TotalLength	128.2	95.0	161.0	66.0	0.69	133.30
		SternalHead	54.9	38.0	75.0	37.0	0.33	31.37
Male	274	Height	11.2	2.0	22.0	20.0	0.26	17.66
		Length	25.4	14.0	40.0	26.0	0.24	14.97
		Angle	26.4	6.8	52.3	45.6	0.59	93.98
		TotalLength	134.5	105.0	169.0	64.0	0.71	128.16
		SternalHead	57.1	41.0	72.0	31.0	0.36	32.79

FOR BLACK MALES AND WHITE MALES:

ANCESTRY	N Obs	Variable	Mean	Minimum	Maximum	Range	Std Error	Variance
Black Males	126	Height	9.3	2.0	21.0	19.0	0.35	14.81
		Length	24.3	14.0	40.0	26.0	0.37	16.60
		Angle	22.6	6.8	49.5	42.7	0.79	74.45
		TotalLength	136.4	105.0	169.0	64.0	1.17	155.81
		SternalHead	56.7	41.0	72.0	31.0	0.57	37.07
White Males	148	Height	12.7	3.0	22.0	19.0	0.32	14.95
		Length	26.2	19.0	35.0	16.0	0.29	12.08
		Angle	29.5	7.2	52.3	45.1	0.78	88.87
		TotalLength	133.1	110. 0	155.0	45.0	0.86	101.67
		SternalHead	57.5	44.0	71.0	27.0	0.46	29.22

FOR BLACK FEMALES AND WHITE FEMALES:

ANCESTRY	N Obs	Variable	Mean	Minimum	Maximum	Range	Std Error	Variance
Black Females	124	Height	7.0	1.0	18.0	17.0	0.33	12.83
		Length	22.4	15.0	29.0	14.0	0.28	9.03
		Angle	18.4	2.3	51.5	49.2	0.85	83.02
		TotalLength	127.7	101.0	161.0	60.0	1.07	132.86
		SternalHead	53.8	41.0	75.0	34.0	0.54	33.94
White Females	174	Height	10.0	2.0	19.0	17.0	0.27	12.55
		Length	23.9	13.0	33.0	20.0	0.29	14.65
		Angle	25.2	6.2	50.6	44.4	0.68	79.88
		TotalLength	128.5	95.0	157.0	62.0	0.90	134.17
		SternalHead	55.7	38.0	70.0	32.0	0.41	28.33

APPENDIX B

T-TESTS FOR ALL MEASUREMENTS BY SEX AND ANCESTRY

ANGLE:

	Method	Variances	DF	t Value	Pr > |t|
All Males/Females	Pooled	Equal	553	-4.77	<.0001
Black Males/White Males	Pooled	Equal	264	-6.19	<.0001
Black Females/White Females	Pooled	Equal	287	-6.31	<.0001

HEIGHT OF HEAD OFF SURFACE:

	Method	Variances	DF	t Value	Pr > |t|
All Males/Females	Pooled	Equal	553	-6.90	<.0001
Black Males/White Males	Pooled	Equal	264	-7.09	<.0001
Black Females/White Females	Pooled	Equal	287	-7.08	<.0001

LENGTH FROM HEAD TO TUBERCLE:

	Method	Variances	DF	t Value	Pr > |t|
All Males/Females	Pooled	Equal	553	-6.50	<.0001
Black Males/White Males	Pooled	Equal	264	-4.12	<.0001
Black Females/White Females	Satterthwaite	Unequal	279.87	-3.70	0.0003

TOTAL EXTERIOR LENGTH (ASHL):

	Method	Variances	DF	t Value	Pr > |t|
All Males/Females	Pooled	Equal	534	-6.41	<.0001
Black Males/White Males	Satterthwaite	Unequal	213.57	2.29	0.0232
Black Females/White Females	Pooled	Equal	282	-0.54	0.5863

INTERIOR LENGTH (PSMH):

	Method	Variances	DF	t Value	Pr > |t|
All Males/Females	Pooled	Equal	536	-4.49	<.0001
Black Males/White Males	Pooled	Equal	252	-1.08	0.2822
Black Females/White Females	Pooled	Equal	282	-2.78	0.0058

APPENDIX C

RAW DATA

*all measurements in millimeters

Project Name	Collection ID	Age	Height	Length	Angle	Total Length	Sternal-Head Length
UTK-WM1L	1-82	55	22	28	51.7868	149	63
UTK-WM1R	1-82	55	19	26	46.9509	147	60
UTK-WM2L	8-87	25	7	24	16.9578	125	50
UTK-WM2R	8-87	25	4	24	9.5941	-	-
UTK-WM3L	24-02	52	16	28	34.8499	142	63
UTK-WM3R	24-02	52	19	24	52.3415	141	66
UTK-WM4L	13-03	48	9	24	22.0243	142	61
UTK-WM4R	13-03	48	11	23	28.5719	137	62
UTK-WM5L	14-03	50	15	22	42.9859	144	66
UTK-WM5R	14-03	50	13	27	28.7822	135	71
UTK-WM6L	19-03	55	13	27	28.7822	155	62
UTK-WM6R	19-03	55	11	26	25.0290	153	62
UTK-WM7L	26-03	49	12	21	34.8499	143	56
UTK-WM7R	26-03	49	10	26	22.6199	132	57
UTK-WM8L	27-03	46	13	24	32.7972	143	61
UTK-WM8R	27-03	46	15	29	31.1474	140	60
UTK-WM9L	37-03	43	14	25	34.0558	127	56
UTK-WM9R	37-03	43	11	25	26.1039	129	50
UTK-WM10L	36-03	71	18	27	41.8103	131	61
UTK-WM10R	36-03	71	15	29	31.1474	130	57
UTK-WM11L	23-01	80	15	26	35.2344	119	56
UTK-WM11R	23-01	80	21	30	44.4270	119	55
UTK-WM12L	01-02	96	15	23	40.7057	113	50
UTK-WM12R	01-02	96	9	25	21.1002	125	54
UTK-WM13L	02-02	46	12	25	28.6854	128	51
UTK-WM13R	02-02	46	11	22	30.0000	123	52
UTK-WM14L	34-02	58	13	23	34.4174	128	57
UTK-WM14R	34-02	58	18	29	38.3665	123	55
UTK-WM15L	33-02	39	16	26	37.9799	135	50
UTK-WM15R	33-02	39	13	24	32.7972	142	51
UTK-WM16L	03-03	52	13	24	32.7972	126	55
UTK-WM16R	03-03	52	11	26	25.0290	134	57
UTK-WM17L	04-03	70	20	27	47.7946	130	60

UTK-WM17R	04-03	70	19	27	44.7249	131	61
UTK-WM18L	05-03	62	14	25	34.0558	123	63
UTK-WM18R	05-03	62	14	25	34.0558	124	60
UTK-WM19L	07-86	67	12	29	24.4433	130	48
UTK-WM19R	07-86	67	13	21	38.2466	125	49
UTK-WM20L	01-87	39	10	30	19.4712	145	63
UTK-WM20R	01-87	39	13	31	24.7939	150	65
UTK-WM21L	20-90	29	9	24	22.0243	135	51
UTK-WM21R	20-90	29	8	32	14.4775	138	51
UTK-WM22L	21-90	69	10	24	24.6243	120	60
UTK-WM22R	21-90	69	14	23	37.4952	117	58
UTK-WM23L	22-90	78	21	34	38.1445	150	65
UTK-WM23R	22-90	78	21	32	41.0145	144	57
UTK-WM24L	17-91	26	8	22	21.3237	138	62
UTK-WM24R	17-91	26	9	29	18.0800	140	61
UTK-WM25L	14-93	32	13	27	28.7822	124	55
UTK-WM25R	14-93	32	17	27	39.0228	126	58
UTK-WM26L	02-96	87	18	29	38.3665	145	53
UTK-WM26R	02-96	87	15	29	31.1474	145	57
UTK-WM27L	24-01	60	12	23	31.4490	-	-
UTK-WM27R	24-01	60	12	23	31.4490	-	-
UTK-WM28L	19-92	27	9	26	20.2522	-	-
UTK-WM28R	19-92	27	6	25	13.8865	-	-
UTK-WM29L	21-06	46	17	27	39.0228	121	65
UTK-WM29R	21-06	46	17	27	39.0228	122	65
UTK-WM30L	12-08	89	19	29	40.9327	136	50
UTK-WM30R	12-08	89	15	25	36.8699	130	52
UTK-WM31L	38-03	65	-	-	-	-	-
UTK-WM31R	38-03	65	10	25	23.5782	129	60
UTK-WM32L	50-03	62	15	28	32.3924	139	53
UTK-WM32R	50-03	62	15	29	31.1474	140	51
UTK-WM33L	49-03	86	11	25	26.1039	154	57
UTK-WM33R	49-03	86	12	25	28.6854	141	58
UTK-WM34L	55-03	67	-	-	-	-	-
UTK-WM34R	55-03	67	16	28	34.8499	135	58
UTK-WM35L	54-03	54	15	28	32.3924	140	61
UTK-WM35R	54-03	54	16	26	37.9799	134	63
UTK-WM36L	02-04	68	14	22	39.5212	125	53

UTK-WM36R	02-04	68	17	24	45.0995	127	56
UTK-WM37L	09-04	46	14	25	34.0558	137	55
UTK-WM37R	09-04	46	14	19	47.4631	138	57
UTK-WM38L	08-04	57	15	22	42.9859	125	60
UTK-WM38R	08-04	57	14	24	35.6853	131	58
UTK-WM39L	29-04	34	8	29	16.0134	153	64
UTK-WM39R	29-04	34	11	30	21.5102	149	64
UTK-WM40L	44-04	39	17	25	42.8436	140	53
UTK-WM40R	44-04	39	18	29	38.3665	142	55
UTK-WM41L	59-04	48	10	20	30.0000	121	53
UTK-WM41R	59-04	48	8	22	21.3237	119	48
UTK-WM42L	01-05	44	14	27	31.2329	122	59
UTK-WM42R	01-05	44	10	22	27.0357	125	63
UTK-WM43L	34-03	77	15	23	40.7057	121	58
UTK-WM43R	34-03	77	10	28	20.9248	121	60
UTK-WM44L	04-05	72	14	22	39.5212	123	54
UTK-WM44R	04-05	72	15	22	42.9859	122	51
UTK-BM1L	6-87	69	15	23	40.7057	142	71
UTK-BM1R	6-87	69	14	26	32.5790	144	71
UTK-BM2L	9-89	43	9	28	18.7493	169	68
UTK-BM2R	9-89	43	9	27	19.4712	161	61
UTK-BM3L	18-90	27	6	18	19.4712	135	53
UTK-BM3R	18-90	27	9	22	24.1477	-	-
UTK-BM4L	15-91	51	7	24	16.9578	138	52
UTK-BM4R	15-91	51	7	22	18.5530	-	-
UTK-BM5L	1-92	55	10	22	27.0357	139	64
UTK-BM5R	1-92	55	9	22	24.1477	139	65
UTK-BM6L	21-92	25	10	23	25.7715	132	48
UTK-BM6R	21-92	25	10	21	28.4369	119	47
UTK-BM7L	15-93	84	13	27	28.7822	146	62
UTK-BM7R	15-93	84	19	25	49.4642	147	62
UTK-BM8L	5-94	46	13	25	31.3323	139	61
UTK-BM8R	5-94	46	12	21	34.8499	-	-
UTK-BM9L	8-99	43	13	27	28.7822	141	49
UTK-BM9R	8-99	43	12	27	26.3878	145	54
UTK-BM10L	06-02	77	12	23	31.4490	151	61
UTK-BM10R	06-02	77	15	29	31.1474	145	56
UTK-BM11L	12-05	56	10	23	25.7715	139	57

UTK-BM11R	12-05	56	6	24	14.4775	140	63
UTK-BM12L	48-04	46	12	27	26.3878	141	57
UTK-BM12R	48-04	46	10	20	30.0000	140	61
UTK-BM13L	40-04	49	9	24	22.0243	134	65
UTK-BM13R	40-04	49	10	23	25.7715	132	67
UTK-BM14L	53-05	43	10	21	28.4369	133	56
UTK-BM14R	53-05	43	8	19	24.9011	127	54
UTK-BM15L	41-06	71	11	24	27.2796	128	58
UTK-BM15R	41-06	71	6	20	17.4576	134	59
UTK-BM16L	98-06	47	17	29	35.8883	130	57
UTK-BM16R	98-06	47	10	26	22.6199	140	61
UTK-BM17L	54-06	43	6	25	13.8865	151	57
UTK-BM17R	54-06	43	13	27	28.7822	150	65
UTK-BM18L	75-06	47	21	29	46.3972	152	59
UTK-BM18R	75-06	47	17	25	42.8436	162	62
UTK-BM19L	19-07	53	21	32	41.0145	126	61
UTK-BM19R	19-07	53	19	28	42.7321	122	62
UTK-BM20L	74-07	55	14	26	32.5790	132	56
UTK-BM20R	74-07	55	16	26	37.9799	133	54
UTK-BM21L	81-07	49	15	25	36.8699	130	49
UTK-BM21R	81-07	49	13	24	32.7972	136	48
UTK-BM22L	100-07	59	6	21	16.6015	148	57
UTK-BM22R	100-07	59	9	22	24.1477	150	57
UTK-BM23L	31-93	68	11	26	25.0290	123	59
UTK-BM23R	31-93	68	8	19	24.9011	124	61
UTK-BM24L	17-00	35	7	25	16.2602	120	51
UTK-BM24R	17-00	35	6	25	13.8865	118	50
UTK-BM25L	30-01	64	13	31	24.7939	145	65
UTK-BM25R	30-01	64	11	29	22.2910	142	67
UTK-BM26L	35-93	61	12	27	26.3878	-	-
UTK-BM26R	35-93	61	-	-	-	-	-
UTK-BM27L	15-90	54	9	21	25.3769	-	-
UTK-BM27R	15-90	54	8	23	20.3544	-	-
UTK-BM28L	23-03	68	16	26	37.9799	139	53
UTK-BM28R	23-03	68	-	-	-	-	-
UTK-BM29L	25-04	40	10	31	18.8191	160	48
UTK-BM29R	25-04	40	10	32	18.2100	-	-
UTK-BM30L	23-06	70	5	23	12.5559	155	72

UTK-BM30R	23-06	70	5	22	13.1366	153	69
CMNH-WM1L	HTH-1125	40	11	30	21.51018827	144	51
CMNH-WM1R	HTH-1125	40	11	33	19.47122063	142	54
CMNH-WM2L	HTH-687	30	15	35	25.37693353	126	63
CMNH-WM2R	HTH-687	30	16	30	32.23095264	127	65
CMNH-WM3L	HTH-688	24	16	32	30	133	54
CMNH-WM3R	HTH-688	24	14	32	25.94447977	130	54
CMNH-WM4L	HTH-689	45	11	29	22.29097037	122	52
CMNH-WM4R	HTH-689	45	10	30	19.47122063	130	55
CMNH-WM5L	HTH-691	65	9	32	16.33482278	142	58
CMNH-WM5R	HTH-691	65	9	32	16.33482278	142	62
CMNH-WM6L	HTH-694	23	9	27	19.47122063	116	49
CMNH-WM6R	HTH-694	23	6	20	17.45760312	115	51
CMNH-WM7L	HTH-707	32	9	27	19.47122063	131	53
CMNH-WM7R	HTH-707	32	8	29	16.01339442	146	55
CMNH-WM8L	HTH-708	32	11	29	22.29097037	140	51
CMNH-WM8R	HTH-708	32	6	29	11.94054396	138	55
CMNH-WM9L	HTH-712	29	6	28	12.37362512	135	50
CMNH-WM9R	HTH-712	29	8	23	20.3544064	142	50
CMNH-WM10L	HTH-714	35	17	33	31.00758301	132	59
CMNH-WM10R	HTH-714	35	17	32	32.08995126	139	55
CMNH-WM11L	HTH-1645	50	18	31	35.49593265	126	66
CMNH-WM11R	HTH-1645	50	14	27	31.23292902	126	65
CMNH-WM12L	HTH-1662	40	8	21	22.39268781	135	59
CMNH-WM12R	HTH-1662	40	10	24	24.62431835	135	60
CMNH-WM13L	HTH-1663	75	11	24	27.27961274	147	61
CMNH-WM13R	HTH-1663	75	16	25	39.7918195	148	69
CMNH-WM14L	HTH-1664	67	8	30	15.46600995	133	64
CMNH-WM14R	HTH-1664	67	10	26	22.61986495	138	69
CMNH-WM15L	HTH-1681	54	14	30	27.81813928	119	64
CMNH-WM15R	HTH-1681	54	18	28	40.00520088	124	62
CMNH-WM16L	HTH-1683	81	18	27	41.8103149	145	56
CMNH-WM16R	HTH-1683	81	13	26	30	150	56
CMNH-WM17L	HTH-1685	62	8	21	22.39268781	135	67
CMNH-WM17R	HTH-1685	62	6	22	15.82662013	-	-
CMNH-WM18L	HTH-1686	40	10	26	22.61986495	151	67
CMNH-WM18R	HTH-1686	40	12	26	27.48642625	152	66
CMNH-WM19L	HTH-1726	57	12	29	24.44333543	128	55

CMNH-WM19R	HTH-1726	57	9	19	28.27371363	128	54
CMNH-WM20L	HTH-1728	70	12	24	30	131	54
CMNH-WM20R	HTH-1728	70	18	29	38.36651426	146	59
CMNH-WM21L	HTH-1732	84	14	26	32.57897039	133	55
CMNH-WM21R	HTH-1732	84	10	19	31.75686386	115	49
CMNH-WM22L	HTH-1745	63	18	35	30.94972308	122	44
CMNH-WM22R	HTH-1745	63	12	24	30	121	45
CMNH-WM23L	HTH-1764	55	3	24	7.180755781	137	58
CMNH-WM23R	HTH-1764	55	9	24	22.02431284	137	58
CMNH-WM24L	HTH-1769	24	5	21	13.774147	114	50
CMNH-WM24R	HTH-1769	24	8	21	22.39268781	110	54
CMNH-WM25L	HTH-1770	59	10	25	23.57817848	141	63
CMNH-WM25R	HTH-1770	59	12	28	25.37693353	140	64
CMNH-WM26L	HTH-1809	45	10	28	20.92483243	134	62
CMNH-WM26R	HTH-1809	45	12	25	28.68540201	131	55
CMNH-WM27L	HTH-2217	21	11	30	21.51018827	125	61
CMNH-WM27R	HTH-2217	21	6	20	17.45760312	124	60
CMNH-WM28L	HTH-2243	57	15	29	31.14738992	125	57
CMNH-WM28R	HTH-2243	57	15	25	36.86989765	0	0
CMNH-WM29L	HTH-2287	54	12	29	24.44333543	129	57
CMNH-WM29R	HTH-2287	54	9	31	16.87726944	125	62
CMNH-WM30L	HTH-2305	39	15	23	40.70570683	130	55
CMNH-WM30R	HTH-2305	39	18	23	51.50004959	130	54
CMNH-BBM1L	HTH-25	40	9	29	18.08001262	124	41
CMNH-BM1R	HTH-25	40	3	21	8.213210702	123	44
CMNH-BM2L	HTH-27	48	13	21	38.24661988	-	57
CMNH-BM2R	HTH-27	48	11	25	26.10388114	-	56
CMNH-BM3L	HTH-74	35	9	19	28.27371363	133	57
CMNH-BM3R	HTH-74	35	4	23	10.01541017	135	62
CMNH-BM4L	HTH-93	30	3	15	11.53695903	-	-
CMNH-BM4R	HTH-93	30	4	17	13.60896063	144	55
CMNH-BM5L	HTH-97	50	7	23	17.71893187	142	61
CMNH-BM5R	HTH-97	50	6	25	13.88654036	149	61
CMNH-BM6L	HTH-225	38	8	21	22.39268781	105	45
CMNH-BM6R	HTH-225	38	7	26	15.61849828	105	47
CMNH-BM7L	HTH-290	33	7	25	16.26020471	146	60
CMNH-BM7R	HTH-290	33	5	20	14.47751219	151	59
CMNH-BM8L	HTH-291	20	10	25	23.57817848	133	47

CMNH-BM8R	HTH-291	20	7	22	18.55300454	131	48
CMNH-BM9L	HTH-327	35	3	19	9.084720287	149	58
CMNH-BM9R	HTH-327	35	5	19	15.25752329	139	56
CMNH-BM10L	HTH-343	30	3	14	12.37362512	138	59
CMNH-BM10R	HTH-343	30	2	17	6.756327031	135	63
CMNH-BM11L	HTH-366	22	6	19	18.40848017	121	60
CMNH-BM11R	HTH-366	22	4	17	13.60896063	129	62
CMNH-BM12L	HTH-400	56	11	28	23.1323964	109	54
CMNH-BM12R	HTH-400	56	15	27	33.7489886	109	50
CMNH-BM13L	HTH-402	29	7	20	20.48731511	147	51
CMNH-BM13R	HTH-402	29	4	20	11.53695903	152	55
CMNH-BM14L	HTH-441	49	7	24	16.9577633	125	54
CMNH-BM14R	HTH-441	49	5	28	10.28656061	124	53
CMNH-BM15L	HTH-448	31	7	21	19.47122063	112	52
CMNH-BM15R	HTH-448	31	7	21	19.47122063	116	49
CMNH-BM16L	HTH-486	32	11	27	24.04207591	134	56
CMNH-BM16R	HTH-486	32	11	26	25.02899949	140	59
CMNH-BM17L	HTH-502	28	7	20	20.48731511	121	59
CMNH-BM17R	HTH-502	28	6	21	16.6015496	127	57
CMNH-BM18L	HTH-506	35	9	20	26.74368395	142	55
CMNH-BM18R	HTH-506	35	8	25	18.66292488	139	60
CMNH-BM19L	HTH-523	24	7	40	10.07865811	151	66
CMNH-BM19R	HTH-523	24	5	30	9.594068227	152	59
CMNH-BM20L	HTH-524	34	9	29	18.08001262	131	57
CMNH-BM20R	HTH-524	34	8	26	17.92021314	129	57
CMNH-BM21L	HTH-525	22	10	29	20.17127135	142	49
CMNH-BM21R	HTH-525	22	6	27	12.83958841	139	51
CMNH-BM22L	HTH-528	50	11	30	21.51018827	132	59
CMNH-BM22R	HTH-528	50	9	29	18.08001262	125	60
CMNH-BM23L	HTH-563	19	8	20	23.57817848	129	51
CMNH-BM23R	HTH-563	19	4	21	10.98057543	127	48
CMNH-BM24L	HTH-568	29	-	-	-	135	57
CMNH-BM24R	HTH-568	29	-	-	-	137	58
CMNH-BM25L	HTH-692	53	-	-	-	155	56
CMNH-BM25R	HTH-692	53	-	-	-	149	55
CMNH-BM26L	HTH-695	18	8	23	20.3544064	129	52
CMNH-BM26R	HTH-695	18	6	24	14.47751219	134	52
CMNH-BM27L	HTH-709	33	7	24	16.9577633	160	47

CMNH-BM27R	HTH-709	33	9	23	23.03568411	164	48
CMNH-BM28L	HTH-735	40	8	22	21.32368626	134	52
CMNH-BM28R	HTH-735	40	9	24	22.02431284	135	52
CMNH-BM29L	HTH-736	40	15	30	30	138	53
CMNH-BM29R	HTH-736	40	14	29	28.86572742	134	53
CMNH-BM30L	HTH-738	25	10	28	20.92483243	123	56
CMNH-BM30R	HTH-738	25	6	27	12.83958841	126	57
CMNH-BM31L	HTH-2026	61	12	33	21.32368626	132	52
CMNH-BM31R	HTH-2026	61	9	29	18.08001262	126	57
CMNH-BM32L	HTH-2079	51	8	25	18.66292488	130	62
CMNH-BM32R	HTH-2079	51	9	26	20.25224674	128	60
CMNH-BM33L	HTH-2080	61	11	20	33.36701297	134	61
CMNH-BM33R	HTH-2080	61	7	29	13.96796267	-	-
UTK-WF1L	1-86a	39	11	20	33.36701297	115	53
UTK-WF1R	1-86a	39	13	21	38.24661988	115	54
UTK-WF2L	1-83	79	16	27	36.34120309	152	59
UTK-WF2R	1-83	79	16	26	37.97987244	155	63
UTK-WF3L	5-87	53	8	18	26.38779996	128	55
UTK-WF3R	5-87	53	6	19	18.40848017	128	57
UTK-WF4L	1-88	71	14	25	34.05579774	125	55
UTK-WF4R	1-88	71	15	20	48.59037789	111	55
UTK-WF5L	23-88	59	8	24	19.47122063	150	67
UTK-WF5R	23-88	59	8	24	19.47122063	151	60
UTK-WF6L	11-90	68	11	28	23.1323964	144	56
UTK-WF6R	11-90	68	13	20	40.54160187	135	60
UTK-WF7L	27-91	38	9	20	26.74368395	115	54
UTK-WF7R	27-91	38	9	18	30	119	58
UTK-WF8L	9-00	43	6	25	13.88654036	135	59
UTK-WF8R	9-00	43	10	20	30	138	57
UTK-WF9L	13-02	69	14	26	32.57897039	155	68
UTK-WF9R	13-02	69	12	21	34.84990458	157	65
UTK-WF10L	12-02	49	6	24	14.47751219	141	54
UTK-WF10R	12-02	49	11	29	22.29097037	140	54
UTK-WF11L	23-02	62	14	23	37.49524976	127	56
UTK-WF11R	23-02	62	12	19	39.16671072	133	55
UTK-WF12L	37-02	52	9	27	19.47122063	135	52
UTK-WF12R	37-02	52	9	24	22.02431284	138	57
UTK-WF13L	11-03	47	10	21	28.43689015	115	51

UTK-WF13R	11-03	47	10	16	38.68218745	116	52
UTK-WF14L	17-03	58	11	25	26.10388114	95	38
UTK-WF14R	17-03	58	10	23	25.77146174	110	45
UTK-WF15L	18-03	47	9	23	23.03568411	121	48
UTK-WF15R	18-03	47	10	23	25.77146174	115	49
UTK-WF16L	21-93	82	12	26	27.48642625	119	53
UTK-WF16R	21-93	82	9	21	25.37693353	112	54
UTK-WF17L	26-93	62	12	24	30	120	55
UTK-WF17R	26-93	62	10	25	23.57817848	113	54
UTK-WF18L	18-94	83	16	26	37.97987244	124	51
UTK-WF18R	18-94	83	9	22	24.14773992	124	49
UTK-WF19L	07-95	71	10	23	25.77146174	140	59
UTK-WF19R	07-95	71	12	24	30	134	59
UTK-WF20L	07-92	64	19	27	44.72491315	116	59
UTK-WF20R	07-92	64	16	26	37.97987244	115	54
UTK-WF21L	10-98	69	8	21	22.39268781	134	65
UTK-WF21R	10-98	69	8	27	17.23528526	133	65
UTK-WF22L	56-04	76	14	29	28.86572742	134	66
UTK-WF22R	56-04	76	13	29	26.63311875	132	67
UTK-WF23L	57-04	81	13	25	31.3322515	130	56
UTK-WF23R	57-04	81	15	27	33.7489886	124	59
UTK-WF24L	31-05	51	-	-	-	-	-
UTK-WF24R	31-05	51	10	25	23.57817848	132	57
UTK-WF25L	30-05	69	17	32	32.08995126	115	50
UTK-WF25R	30-05	69	17	27	39.02280257	113	53
UTK-WF26L	27-05	59	10	21	28.43689015	122	51
UTK-WF26R	27-05	59	12	25	28.68540201	116	50
UTK-WF27L	25-05	51	14	24	35.68533471	116	57
UTK-WF27R	25-05	51	15	24	38.68218745	120	56
UTK-WF28L	61-05	55	8	25	18.66292488	134	48
UTK-WF28R	61-05	55	10	25	23.57817848	136	48
UTK-WF29L	88-05	84	10	26	22.61986495	130	58
UTK-WF29R	88-05	84	11	27	24.04207591	130	59
UTK-WF30L	92-05	47	9	22	24.14773992	138	67
UTK-WF30R	92-05	47	12	29	24.44333543	141	61
UTK-WF31L	15-06	59	10	22	27.03569179	136	52
UTK-WF31R	15-06	59	10	25	23.57817848	138	53
UTK-WF32L	17-06	50	11	24	27.27961274	125	57

UTK-WF32R	17-06	50	12	32	22.02431284	140	60
UTK-WF33L	25-06	44	8	28	16.6015496	156	67
UTK-WF33R	25-06	44	6	32	10.80692287	155	66
UTK-WF34L	32-06	39	10	27	21.73846079	128	51
UTK-WF34R	32-06	39	13	27	28.78220468	123	54
UTK-WF35L	39-06	85	15	22	42.98588608	122	58
UTK-WF35R	39-06	85	9	21	25.37693353	130	57
UTK-WF36L	40-06	51	17	29	35.88829755	134	59
UTK-WF36R	40-06	51	16	31	31.07295097	137	63
UTK-WF37L	41-07	37	6	16	22.02431284	112	53
UTK-WF37R	41-07	37	4	17	13.60896063	118	58
UTK-WF38L	82-07	31	7	21	19.47122063	115	57
UTK-WF38R	82-07	31	8	22	21.32368626	120	53
UTK-WF39L	13-08	75	11	24	27.27961274	134	57
UTK-WF39R	13-08	75	8	22	21.32368626	140	59
UTK-WF40L	32-07	78	13	23	34.41738871	-	-
UTK-WF40R	32-07	78	14	21	41.8103149	-	-
UTK-WF41L	30-07	64	9	20	26.74368395	130	53
UTK-WF41R	30-07	64	8	27	17.23528526	125	51
UTK-WF42L	31-07	67	9	18	30	140	55
UTK-WF42R	31-07	67	9	25	21.10019602	133	53
UTK-WF43L	51-07	44	16	29	33.48537662	149	60
UTK-WF43R	51-07	44	10	30	19.47122063	143	63
UTK-WF44L	52-07	68	5	20	14.47751219	123	55
UTK-WF44R	52-07	68	11	21	31.58813551	120	54
UTK-WF45L	89-06	50	14	23	37.49524976	115	54
UTK-WF45R	89-06	50	15	23	40.70570683	126	57
UTK-WF46L	39-03	52	11	22	30	-	-
UTK-WF46R	39-03	52	7	19	35.37654015	-	-
UTK-WF47L	43-03	73	9	28	14.47751219	127	64
UTK-WF47R	43-03	73	9	27	19.47122063	127	66
UTK-WF48L	53-03	60	14	28	18.74934085	134	59
UTK-WF48R	53-03	60	13	29	28.86572742	135	55
UTK-WF49L	63-03	58	17	22	36.22154662	134	52
UTK-WF49R	63-03	58	12	22	50.59943125	134	55
UTK-WF50L	12-04	60	13	28	25.37693353	141	61
UTK-WF50R	12-04	60	15	27	28.78220468	138	62
UTK-WF51L	11-04	54	16	25	36.86989765	119	56

UTK-WF51R	11-04	54	16	26	37.97987244	116	56
UTK-WF52L	11-05	76	14	25	39.7918195	141	60
UTK-WF52R	11-05	76	14	28	30	148	61
UTK-WF53L	02-05	76	12	24	30	123	47
UTK-WF53R	02-05	76	12	24	30	122	47
UTK-WF54L	13-05	74	6	22	15.82662013	130	57
UTK-WF54R	13-05	74	6	22	15.82662013	127	50
UTK-WF55L	57-04	81	14	26	32.57897039	137	56
UTK-WF55R	57-04	81	14	28	30	138	58
UTK-WF56L	19-04	60	7	13	32.57897039	131	54
UTK-WF56R	19-04	60	8	17	28.07248694	121	53
UTK-BF1L	2-86	39	11	21	31.58813551	143	53
UTK-BF1R	2-86	39	18	23	51.50004959	132	52
UTK-BF2L	6-89	40	10	20	30	115	50
UTK-BF2R	6-89	40	12	24	30	120	53
UTK-BF3L	1-96	66	4	20	11.53695903	136	58
UTK-BF3R	1-96	66	3	21	8.213210702	134	60
UTK-BF4L	05-01	59	16	26	37.97987244	125	60
UTK-BF4R	05-01	59	-	-	-	-	-
UTK-BF5L	18-05	99	-	-	-	125	58
UTK-BF5R	18-05	99	7	21	19.47122063	132	59
UTK-BF6L	36-06	73	17	29	35.88829755	138	60
UTK-BF6R	36-06	73	12	20	36.86989765	-	-
UTK-BF7L	78-07	24	6	21	16.6015496	118	49
UTK-BF7R	78-07	24	6	20	17.45760312	120	46
UTK-BF8L	62-06	54	7	22	18.55300454	120	60
UTK-BF8R	62-06	54	10	22	27.03569179	122	56
CMNH-WF1L	HTH-1747	34	5	22	13.13655879	128	55
CMNH-WF1R	HTH-1747	34	4	23	10.01541017	123	58
CMNH-WF2L	HTH-1750	75	11	22	30	115	53
CMNH-WF2R	HTH-1750	75	9	20	26.74368395	117	53
CMNH-WF3L	HTH-1771	54	5	19	15.25752329	138	63
CMNH-WF3R	HTH-1771	54	9	22	24.14773992	130	58
CMNH-WF4L	HTH-1811	73	6	19	18.40848017	-	-
CMNH-WF4R	HTH-1811	73	10	25	23.57817848	121	57
CMNH-WF5L	HTH-1825	56	15	24	38.68218745	113	65
CMNH-WF5R	HTH-1825	56	11	18	37.66988696	111	62
CMNH-WF6L	HTH-1900	27	6	24	14.47751219	114	45

CMNH-WF6R	HTH-1900	27	7	24	16.9577633	113	48
CMNH-WF7L	HTH-1976	47	7	21	19.47122063	126	48
CMNH-WF7R	HTH-1976	47	4	23	10.01541017	131	49
CMNH-WF8L	HTH-2025	49	2	16	7.180755781	128	58
CMNH-WF8R	HTH-2025	49	5	20	14.47751219	120	57
CMNH-WF9L	HTH-2082	42	14	31	26.84721333	150	57
CMNH-WF9R	HTH-2082	42	12	28	25.37693353	146	56
CMNH-WF10L	HTH-2125	36	9	25	21.10019602	129	53
CMNH-WF10R	HTH-2125	36	7	27	15.02611376	-	-
CMNH-WF11L	HTH-2244	41	5	29	9.928191842	138	57
CMNH-WF11R	HTH-2244	41	7	27	15.02611376	132	61
CMNH-WF12L	HTH-2282	62	9	19	28.27371363	133	59
CMNH-WF12R	HTH-2282	62	11	24	27.27961274	137	57
CMNH-WF13L	HTH-755	45	12	33	21.32368626	155	53
CMNH-WF13R	HTH-755	45	14	33	25.10272076	156	59
CMNH-WF14L	HTH-774	38	10	30	19.47122063	123	44
CMNH-WF14R	HTH-774	38	5	32	8.989299345	120	49
CMNH-WF15L	HTH-781	23	6	24	14.47751219	125	51
CMNH-WF15R	HTH-781	23	3	27	6.379370208	130	50
CMNH-WF16L	HTH-886	32	10	24	24.62431835	122	57
CMNH-WF16R	HTH-886	32	13	25	31.3322515	120	56
CMNH-WF17L	HTH-893	51	7	16	25.94447977	118	53
CMNH-WF17R	HTH-893	51	12	25	28.68540201	115	54
CMNH-WF18L	HTH-929	31	9	21	25.37693353	125	51
CMNH-WF18R	HTH-929	31	5	21	13.774147	123	53
CMNH-WF19L	HTH-1059	28	10	28	20.92483243	132	53
CMNH-WF19R	HTH-1059	28	11	28	23.1323964	131	51
CMNH-WF20L	HTH-1119	35	10	24	24.62431835	131	52
CMNH-WF20R	HTH-1119	35	7	24	16.9577633	131	57
CMNH-WF21L	HTH-1157	25	8	25	18.66292488	119	49
CMNH-WF21R	HTH-1157	25	9	25	21.10019602	117	52
CMNH-WF22L	HTH-1162	28	8	29	16.01339442	120	50
CMNH-WF22R	HTH-1162	28	8	29	16.01339442	125	49
CMNH-WF23L	HTH-1219	82	4	19	12.15319747	129	59
CMNH-WF23R	HTH-1219	82	5	21	13.774147	130	55
CMNH-WF24L	HTH-1279	39	11	21	31.58813551	138	63
CMNH-WF24R	HTH-1279	39	6	19	18.40848017	136	70
CMNH-WF25L	HTH-1302	47	5	21	13.774147	134	57

CMNH-WF25R	HTH-1302	47	9	25	21.10019602	130	60
CMNH-WF26L	HTH-2857	31	3	22	7.837479763	125	57
CMNH-WF26R	HTH-2857	31	7	24	16.9577633	129	58
CMNH-WF27L	HTH-2920	42	5	23	12.5558578	141	59
CMNH-WF27R	HTH-2920	42	5	17	17.10463518	145	58
CMNH-WF28L	HTH-2939	25	3	25	6.892102579	119	53
CMNH-WF28R	HTH-2939	25	3	28	6.150639828	120	57
CMNH-WF29L	HTH-3032	89	6	17	20.66731649	105	43
CMNH-WF29R	HTH-3032	89	11	20	33.36701297	110	46
CMNH-WF30L	HTH-3118	54	12	23	31.44898139	115	51
CMNH-WF30R	HTH-3118	54	10	23	25.77146174	119	55
CMNH-WF31L	HTH-3164	61	10	20	30	127	50
CMNH-WF31R	HTH-3164	61	11	27	24.04207591	126	55
CMNH-BF1L	HTH-128	35	6	20	17.4576	128	59
CMNH-BF1R	HTH-128	35	6	19	18.4085	124	64
CMNH-BF2L	HTH-152	70	-	-	-	-	-
CMNH-BF2R	HTH-152	70	7	20	20.4873	122	59
CMNH-BF3L	HTH-226	29	12	26	27.4864	112	47
CMNH-BF3R	HTH-226	29	10	24	24.6243	119	51
CMNH-BF4L	HTH-439	35	3	23	7.4947	123	59
CMNH-BF4R	HTH-439	35	9	27	19.4712	132	58
CMNH-BF5L	HTH-442	40	6	23	15.1217	121	52
CMNH-BF5R	HTH-442	40	2	17	6.7563	-	-
CMNH-BF6L	HTH-461	30	8	24	19.4712	127	53
CMNH-BF6R	HTH-461	30	6	23	15.1217	127	50
CMNH-BF7L	HTH-530	45	12	25	28.6854	116	53
CMNH-BF7R	HTH-530	45	10	24	24.6243	109	52
CMNH-BF8L	HTH-545	25	-	-	-	145	55
CMNH-BF8R	HTH-545	25	-	-	-	145	54
CMNH-BF9L	HTH-589	30	4	19	12.1532	144	54
CMNH-BF9R	HTH-589	30	2	27	4.2480	139	51
CMNH-BF10L	HTH-612	36	10	21	28.4369	125	44
CMNH-BF10R	HTH-612	36	9	22	24.1477	122	48
CMNH-BF11L	HTH-668	37	7	22	18.5530	143	56
CMNH-BF11R	HTH-668	37	2	20	5.7392	151	57
CMNH-BF12L	HTH-673	38	7	21	19.4712	133	46
CMNH-BF12R	HTH-673	38	8	22	21.3237	124	47
CMNH-BF13L	HTH-773	60	3	19	9.0847	111	49

CMNH-BF13R	HTH-773	60	3	21	8.2132	112	54
CMNH-BF14L	HTH-839	60	4	23	10.0154	134	55
CMNH-BF14R	HTH-839	60	5	23	12.5559	136	59
CMNH-BF15L	HTH-928	69	9	26	20.2522	133	58
CMNH-BF15R	HTH-928	69	4	21	10.9806	0	0
CMNH-BF16L	HTH-933	28	12	23	31.4490	134	56
CMNH-BF16R	HTH-933	28	9	25	21.1002	140	56
CMNH-BF17L	HTH-954	24	3	19	9.0847	120	53
CMNH-BF17R	HTH-954	24	3	21	8.2132	119	53
CMNH-BF18L	HTH-1012	18	3	17	10.1642	121	59
CMNH-BF18R	HTH-1012	18	3	22	7.8375	120	56
CMNH-BF19L	HTH-1040	20	8	22	21.3237	113	48
CMNH-BF19R	HTH-1040	20	6	20	17.4576	115	52
CMNH-BF20L	HTH-1122	70	14	24	35.6853	122	53
CMNH-BF20R	HTH-1122	70	11	22	30.0000	133	54
CMNH-BF21L	HTH-1124	40	4	15	15.4660	128	43
CMNH-BF21R	HTH-1124	40	7	21	19.4712	125	43
CMNH-BF22L	HTH-1161	24	1	21	2.7294	121	49
CMNH-BF22R	HTH-1161	24	1	25	2.2924	123	51
CMNH-BF23L	HTH-1208	23	7	24	16.9578	116	57
CMNH-BF23R	HTH-1208	23	-	-	-	113	58
CMNH-BF24L	HTH-1243	24	5	17	17.1046	133	64
CMNH-BF24R	HTH-1243	24	6	27	12.8396	135	62
CMNH-BF25L	HTH-1301	87	3	22	7.8375	133	55
CMNH-BF25R	HTH-1301	87	3	27	6.3794	131	54
CMNH-BF26L	HTH-1328	19	3	23	7.4947	138	45
CMNH-BF26R	HTH-1328	19	7	24	16.9578	129	51
CMNH-BF27L	HTH-1345	39	8	20	23.5782	138	47
CMNH-BF27R	HTH-1345	39	6	19	18.4085	139	48
CMNH-BF28L	HTH-1367	72	5	25	11.5370	161	75
CMNH-BF28R	HTH-1367	72	10	28	20.9248	155	67
CMNH-BF29L	HTH-1427	28	4	20	11.5370	143	62
CMNH-BF29R	HTH-1427	28	4	24	9.5941	145	60
CMNH-BF30L	HTH-1515	26	5	19	15.2575	143	51
CMNH-BF30R	HTH-1515	26	5	26	11.0875	131	56
CMNH-BF31L	HTH-1516	37	5	16	18.2100	127	57
CMNH-BF31R	HTH-1516	37	5	16	18.2100	120	56
CMNH-BF32L	HTH-1536	29	9	20	26.7437	136	50

CMNH-BF32R	HTH-1536	29	11	19	35.3765	143	54
CMNH-BF33L	HTH-1539	26	13	27	28.7822	130	61
CMNH-BF33R	HTH-1539	26	11	24	27.2796	125	59
CMNH-BF34L	HTH-1558	24	8	22	21.3237	116	58
CMNH-BF34R	HTH-1558	24	6	19	18.4085	123	58
CMNH-BF35L	HTH-1600	28	4	27	8.5196	154	55
CMNH-BF35R	HTH-1600	28	-	-	-	130	55
CMNH-BF36L	HTH-1622	27	10	22	27.0357	123	46
CMNH-BF36R	HTH-1622	27	6	27	12.8396	120	45
CMNH-BF37L	HTH-1705	85	-	-	-	-	-
CMNH-BF37R	HTH-1705	85	9	21	25.3769	126	53
CMNH-BF38L	HTH-1709	25	6	24	14.4775	126	46
CMNH-BF38R	HTH-1709	25	9	26	20.2522	123	44
CMNH-BF39L	HTH-1744	49	1	24	2.3880	137	52
CMNH-BF39R	HTH-1744	49	2	25	4.5886	130	53
CMNH-BF40L	HTH-1748	44	10	20	30.0000	128	50
CMNH-BF40R	HTH-1748	44	7	27	15.0261	126	51
CMNH-BF41L	HTH-1749	42	9	21	25.3769	132	41
CMNH-BF41R	HTH-1749	42	7	26	15.6185	136	45
CMNH-BF42L	HTH-1785	32	6	22	15.8266	113	58
CMNH-BF42R	HTH-1785	32	5	20	14.4775	117	57
CMNH-BF43L	HTH-1856	45	2	21	5.4650	140	54
CMNH-BF43R	HTH-1856	45	1	24	2.3880	152	52
CMNH-BF44L	HTH-1871	36	12	26	27.4864	125	57
CMNH-BF44R	HTH-1871	36	9	22	24.1477	146	57
CMNH-BF45L	HTH-1899	30	7	25	16.2602	-	-
CMNH-BF45R	HTH-1899	30	7	21	19.4712	142	51
CMNH-BF46L	HTH-1924	38	9	29	18.0800	115	49
CMNH-BF46R	HTH-1924	38	7	27	15.0261	116	49
CMNH-BF47L	HTH-1949	19	6	20	17.4576	130	44
CMNH-BF47R	HTH-1949	19	4	22	10.4757	135	45
CMNH-BF48L	HTH-1978	23	5	24	12.0247	101	50
CMNH-BF48R	HTH-1978	23	5	25	11.5370	109	47
CMNH-BF49L	HTH-2039	65	7	25	16.2602	111	54
CMNH-BF49R	HTH-2039	65	6	19	18.4085	112	52
CMNH-BF50L	HTH-2099	45	16	26	37.9799	121	55
CMNH-BF50R	HTH-2099	45	14	27	31.2329	114	50
CMNH-BF51L	HTH-2127	51	4	19	12.1532	102	55

CMNH-BF51R	HTH-2127	51	5	18	16.1276	106	54
CMNH-BF52L	HTH-2147	65	10	24	24.6243	134	63
CMNH-BF52R	HTH-2147	65	11	24	27.2796	126	59
CMNH-BF53L	HTH-2329	75	5	23	12.5559	127	69
CMNH-BF53R	HTH-2329	75	7	24	16.9578	123	65
CMNH-BF54L	HTH-2404	60	9	20	26.7437	127	52
CMNH-BF54R	HTH-2404	60	8	17	28.0725	137	57

APPENDIX D

CALCULATED PROBABILITIES FOR ANGLE

*Listing of one kept value for each value of angle

Obs	Angle	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
1	.	.	.	.
2	2.2924	0.26675	0.19129	0.35878
3	2.388	0.26754	0.19215	0.35934
4	2.7294	0.27035	0.19526	0.36135
5	4.248	0.2831	0.20953	0.3704
6	4.5886	0.28601	0.21282	0.37245
7	5.465	0.29357	0.22146	0.37777
8	5.7392	0.29596	0.22421	0.37945
9	6.1506	0.29957	0.22837	0.38198
10	6.3794	0.30159	0.23071	0.38339
11	6.7563	0.30493	0.23459	0.38572
12	6.8921	0.30613	0.236	0.38657
13	7.1808	0.30871	0.23901	0.38836
14	7.4947	0.31153	0.24231	0.39033
15	7.8375	0.31462	0.24595	0.39249
16	8.2132	0.31803	0.24997	0.39486
17	8.5196	0.32082	0.25328	0.39681
18	8.9893	0.32513	0.25839	0.39981
19	9.0847	0.32601	0.25944	0.40042
20	9.5941	0.33072	0.26506	0.40371
21	9.9282	0.33383	0.26878	0.40588
22	10.0154	0.33464	0.26976	0.40644
23	10.0787	0.33523	0.27046	0.40686
24	10.1643	0.33603	0.27143	0.40741
25	10.2866	0.33718	0.2728	0.40822
26	10.4757	0.33895	0.27493	0.40946
27	10.8069	0.34207	0.27869	0.41164
28	10.9806	0.34371	0.28067	0.41279
29	11.0875	0.34472	0.28189	0.4135
30	11.537	0.34899	0.28705	0.4165
31	11.9405	0.35285	0.29172	0.41921
32	12.0247	0.35366	0.29269	0.41978
33	12.1532	0.35489	0.29419	0.42065
34	12.3736	0.35701	0.29676	0.42215
35	12.5559	0.35876	0.29889	0.42339

Obs	Angle	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
36	12.8396	0.36151	0.30222	0.42533
37	13.1366	0.36438	0.30572	0.42738
38	13.609	0.36899	0.31131	0.43067
39	13.7742	0.3706	0.31327	0.43182
40	13.8865	0.3717	0.31461	0.43261
41	13.968	0.3725	0.31558	0.43319
42	14.4775	0.37751	0.32166	0.4368
43	15.0261	0.38293	0.32824	0.44075
44	15.1217	0.38387	0.32939	0.44144
45	15.2575	0.38522	0.33102	0.44243
46	15.466	0.3873	0.33353	0.44395
47	15.6185	0.38881	0.33537	0.44507
48	15.8266	0.39089	0.33788	0.44661
49	16.0134	0.39276	0.34013	0.44799
50	16.1276	0.3939	0.34151	0.44884
51	16.2602	0.39523	0.34311	0.44984
52	16.3348	0.39598	0.34402	0.4504
53	16.6016	0.39865	0.34724	0.45241
54	16.8773	0.40143	0.35057	0.45451
55	16.9578	0.40224	0.35154	0.45512
56	17.1046	0.40372	0.35331	0.45625
57	17.2353	0.40504	0.35489	0.45726
58	17.4576	0.40729	0.35757	0.45898
59	17.7189	0.40994	0.36072	0.46103
60	17.9202	0.41198	0.36315	0.46262
61	18.08	0.41361	0.36507	0.46389
62	18.21	0.41493	0.36663	0.46492
63	18.4085	0.41695	0.36901	0.46652
64	18.553	0.41843	0.37074	0.46768
65	18.6629	0.41955	0.37206	0.46858
66	18.7493	0.42043	0.37309	0.46928
67	18.8191	0.42114	0.37393	0.46985
68	19.4712	0.42783	0.38168	0.47526
69	20.1713	0.43503	0.38993	0.48122
70	20.2523	0.43586	0.39088	0.48192
71	20.3544	0.43692	0.39208	0.48281
72	20.4873	0.43829	0.39362	0.48397
73	20.6673	0.44015	0.39572	0.48556
74	20.9248	0.44281	0.3987	0.48784

Obs	**Angle**	**PROB (Odds)**	**Lower Confidence Limit**	**Upper Confidence Limit**
75	21.1002	0.44462	0.40072	0.48942
76	21.3237	0.44694	0.40328	0.49144
77	21.5102	0.44887	0.4054	0.49314
78	21.7385	0.45124	0.40799	0.49524
79	22.0243	0.45421	0.41121	0.49791
80	22.291	0.45699	0.41419	0.50043
81	22.3927	0.45805	0.41532	0.5014
82	22.6199	0.46041	0.41783	0.50358
83	23.0357	0.46475	0.42238	0.50763
84	23.1324	0.46576	0.42343	0.50858
85	23.5782	0.47041	0.42822	0.51303
86	24.0421	0.47526	0.43312	0.51775
87	24.1477	0.47636	0.43423	0.51884
88	24.4433	0.47946	0.4373	0.52191
89	24.6243	0.48135	0.43916	0.52382
90	24.7939	0.48313	0.44089	0.52561
91	24.9011	0.48425	0.44197	0.52675
92	25.029	0.48559	0.44327	0.52812
93	25.1027	0.48636	0.44401	0.52891
94	25.3769	0.48924	0.44675	0.53188
95	25.7715	0.49337	0.45063	0.53621
96	25.9445	0.49518	0.45232	0.53812
97	26.1039	0.49686	0.45386	0.5399
98	26.3878	0.49983	0.45657	0.54309
99	26.6331	0.5024	0.4589	0.54588
100	26.7437	0.50356	0.45993	0.54714
101	26.8472	0.50465	0.4609	0.54832
102	27.0357	0.50662	0.46265	0.55049
103	27.2796	0.50918	0.4649	0.55332
104	27.4864	0.51135	0.46679	0.55573
105	27.8181	0.51482	0.46978	0.55963
106	28.0725	0.51749	0.47204	0.56265
107	28.2737	0.51959	0.47382	0.56504
108	28.4369	0.5213	0.47525	0.567
109	28.5719	0.52271	0.47642	0.56862
110	28.6854	0.5239	0.47741	0.56999
111	28.7822	0.52491	0.47824	0.57116
112	28.8657	0.52579	0.47896	0.57217
113	30	0.53763	0.48849	0.58605

Obs	Angle	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
114	30.9497	0.54752	0.49617	0.59787
115	31.0076	0.54812	0.49663	0.59859
116	31.073	0.5488	0.49715	0.59941
117	31.1474	0.54957	0.49774	0.60034
118	31.2329	0.55046	0.49842	0.60142
119	31.3323	0.55149	0.4992	0.60266
120	31.449	0.5527	0.50011	0.60413
121	31.5881	0.55414	0.5012	0.60588
122	31.7569	0.55589	0.50251	0.608
123	32.09	0.55933	0.50509	0.6122
124	32.231	0.56079	0.50617	0.61398
125	32.3924	0.56246	0.5074	0.61602
126	32.579	0.56438	0.50882	0.61837
127	32.7972	0.56663	0.51047	0.62113
128	33.367	0.57249	0.51473	0.62834
129	33.4854	0.5737	0.5156	0.62984
130	33.749	0.5764	0.51755	0.63317
131	34.0558	0.57954	0.51979	0.63705
132	34.4174	0.58323	0.52242	0.64161
133	34.8499	0.58764	0.52554	0.64706
134	35.2344	0.59154	0.52828	0.6519
135	35.3765	0.59298	0.52929	0.65368
136	35.4959	0.59418	0.53014	0.65518
137	35.6853	0.5961	0.53147	0.65755
138	35.8883	0.59815	0.5329	0.66009
139	36.2216	0.6015	0.53523	0.66425
140	36.3412	0.6027	0.53607	0.66574
141	36.8699	0.608	0.53973	0.67229
142	37.4953	0.61423	0.54402	0.68
143	37.6699	0.61597	0.54521	0.68214
144	37.9799	0.61904	0.54731	0.68592
145	38.1445	0.62066	0.54842	0.68792
146	38.2466	0.62167	0.54911	0.68916
147	38.3665	0.62285	0.54992	0.69062
148	38.6822	0.62596	0.55204	0.69443
149	39.0228	0.6293	0.55431	0.69853
150	39.1667	0.6307	0.55527	0.70025
151	39.5212	0.63416	0.55762	0.70447
152	39.7918	0.63679	0.55941	0.70768

Obs	**Angle**	**PROB (Odds)**	**Lower Confidence Limit**	**Upper Confidence Limit**
153	40.0052	0.63885	0.56081	0.71019
154	40.5416	0.64403	0.56433	0.71647
155	40.7057	0.6456	0.5654	0.71838
156	40.9327	0.64778	0.56688	0.72101
157	41.0145	0.64856	0.56741	0.72195
158	41.8103	0.65613	0.57255	0.73105
159	42.7321	0.6648	0.57844	0.74137
160	42.8436	0.66584	0.57915	0.74261
161	42.9859	0.66717	0.58006	0.74418
162	44.427	0.68045	0.58913	0.75975
163	44.7249	0.68316	0.59098	0.76289
164	45.0995	0.68655	0.59331	0.76681
165	46.3972	0.69814	0.60131	0.78005
166	46.9509	0.70301	0.60469	0.78555
167	47.4631	0.70748	0.60781	0.79055
168	47.7946	0.71034	0.60981	0.79374
169	48.5904	0.71716	0.6146	0.80126
170	49.4642	0.72454	0.61982	0.80928
171	50.5994	0.73394	0.62654	0.81935
172	51.5001	0.74125	0.63181	0.82706
173	51.7868	0.74355	0.63348	0.82945
174	52.3415	0.74796	0.6367	0.83402

APPENDIX E

CALCULATED PROBABILITIES FOR ANGLE AND TOTAL LENGTH

*Listing of one kept value for each value of angle

Obs	Angle	Total Length	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
1	.	.	.	.	.
2	2.2924	123	0.15939	0.10238	0.23966
3	2.388	137	0.28099	0.19682	0.38396
4	2.7294	121	0.14889	0.09466	0.22642
5	4.248	139	0.32239	0.23481	0.4245
6	4.5886	130	0.23372	0.16504	0.32002
7	5.465	140	0.34752	0.25897	0.44805
8	5.7392	151	0.4871	0.36772	0.60797
9	6.1506	120	0.16499	0.11035	0.23939
10	6.3794	130	0.25033	0.18256	0.33302
11	6.7563	135	0.30551	0.22959	0.3937
12	6.8921	119	0.1631	0.10931	0.23633
13	7.1808	137	0.33245	0.25315	0.42254
14	7.4947	123	0.19787	0.1395	0.27293
15	7.8375	125	0.21761	0.15707	0.29336
16	8.2132	123	0.20371	0.14537	0.27784
17	8.5196	154	0.56045	0.43882	0.67522
18	8.9893	120	0.18573	0.13026	0.25782
19	9.0847	149	0.50375	0.39765	0.60951
20	9.5941	.	.	.	.
21	9.9282	138	0.37594	0.29937	0.45926
22	10.0154	135	0.34156	0.27056	0.42046
23	10.0787	151	0.54188	0.43249	0.64737
24	10.1643	121	0.20307	0.14667	0.27419
25	10.2866	124	0.23022	0.17156	0.30163
26	10.4757	135	0.34682	0.27664	0.42435
27	10.8069	155	0.60109	0.48278	0.70866
28	10.9806	127	0.26541	0.20497	0.33614
29	11.0875	131	0.30845	0.24456	0.38063
30	11.537	.	.	.	.
31	11.9405	138	0.40011	0.32771	0.47715
32	12.0247	101	0.09117	0.05136	0.15676
33	12.1532	129	0.29816	0.23763	0.36669
34	12.3736	135	0.36888	0.30241	0.44073

Obs	Angle	Total Length	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
35	12.5559	155	0.6221	0.50843	0.72377
36	12.8396	139	0.42355	0.35119	0.49935
37	13.1366	153	0.60473	0.49755	0.70271
38	13.609	144	0.49682	0.41466	0.57916
39	13.7742	114	0.17598	0.12298	0.24543
40	13.8865	.	.	.	.
41	13.968	.	.	.	.
42	14.4775	138	0.43127	0.36452	0.50062
43	15.0261	.	.	.	.
44	15.1217	121	0.24667	0.19142	0.31173
45	15.2575	139	0.45366	0.38673	0.52231
46	15.466	133	0.38149	0.32384	0.44268
47	15.6185	105	0.12872	0.08038	0.1998
48	15.8266	.	.	.	.
49	16.0134	153	0.63894	0.53859	0.72847
50	16.1276	106	0.13761	0.08778	0.20925
51	16.2602	120	0.24784	0.1929	0.31238
52	16.3348	142	0.50564	0.43435	0.5767
53	16.6016	148	0.58515	0.49882	0.66654
54	16.8773	125	0.30526	0.25184	0.36449
55	16.9578	125	0.30613	0.25279	0.36521
56	17.1046	145	0.55365	0.47626	0.62853
57	17.2353	133	0.40282	0.34879	0.45931
58	17.4576	134	0.41795	0.36345	0.47454
59	17.7189	142	0.52312	0.45452	0.59087
60	17.9202	129	0.36254	0.31129	0.41712
61	18.08	140	0.50205	0.43878	0.56526
62	18.21	.	.	.	.
63	18.4085	121	0.27885	0.22487	0.3401
64	18.553	.	.	.	.
65	18.6629	139	0.49659	0.4365	0.55679
66	18.7493	169	0.82203	0.70787	0.89801
67	18.8191	160	0.74496	0.63765	0.829
68	19.4712	145	0.58301	0.50958	0.65293
69	20.1713	142	0.55394	0.48917	0.61694
70	20.2523	.	.	.	.
71	20.3544	.	.	.	.
72	20.4873	147	0.61991	0.54264	0.69155
73	20.6673	105	0.16017	0.10478	0.2371

Obs	Angle	Total Length	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
74	20.9248	121	0.30515	0.25182	0.36428
75	21.1002	125	0.35235	0.30286	0.40522
76	21.3237	138	0.51741	0.46302	0.57138
77	21.5102	149	0.65556	0.57454	0.72844
78	21.7385	128	0.39592	0.3492	0.44462
79	22.0243	142	0.57697	0.51408	0.63747
80	22.291	142	0.58026	0.51755	0.64048
81	22.3927	135	0.49245	0.44398	0.54106
82	22.6199	132	0.45694	0.41129	0.50333
83	23.0357	164	0.81615	0.71543	0.88685
84	23.1324	109	0.20966	0.14886	0.28691
85	23.5782	129	0.43091	0.38563	0.47738
86	24.0421	134	0.50048	0.45374	0.54721
87	24.1477	.	.	.	.
88	24.4433	130	0.45437	0.40938	0.50011
89	24.6243	120	0.33469	0.27925	0.39511
90	24.7939	150	0.70287	0.62266	0.77226
91	24.9011	127	0.42218	0.37537	0.47042
92	25.029	153	0.7363	0.65075	0.80711
93	25.1027	156	0.76576	0.67587	0.83674
94	25.3769	.	.	.	.
95	25.7715	132	0.49669	0.45077	0.54267
96	25.9445	130	0.47325	0.42748	0.51947
97	26.1039	129	0.46248	0.41627	0.50934
98	26.3878	145	0.66486	0.59574	0.72757
99	26.6331	132	0.50759	0.46081	0.55423
100	26.7437	142	0.63393	0.57127	0.69236
101	26.8472	150	0.72409	0.64498	0.79128
102	27.0357	125	0.42348	0.37269	0.47595
103	27.2796	128	0.46451	0.41637	0.51332
104	27.4864	152	0.75023	0.66818	0.81753
105	27.8181	119	0.35967	0.29924	0.42491
106	28.0725	121	0.38668	0.32876	0.44799
107	28.2737	128	0.47704	0.42731	0.52723
108	28.4369	119	0.36691	0.30546	0.43302
109	28.5719	137	0.59508	0.54001	0.64786
110	28.6854	128	0.48224	0.43173	0.5331
111	28.7822	135	0.57273	0.52004	0.62383
112	28.8657	134	0.56117	0.50938	0.61167

Obs	Angle	Total Length	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
113	30	123	0.43508	0.37643	0.49561
114	30.9497	122	0.43427	0.37202	0.49868
115	31.0076	132	0.56258	0.50715	0.61649
116	31.073	137	0.62516	0.56531	0.68142
117	31.1474	140	0.66133	0.59714	0.7201
118	31.2329	122	0.4378	0.37484	0.50283
119	31.3323	139	0.65187	0.5888	0.71003
120	31.449	.	.	.	.
121	31.5881	120	0.41708	0.35036	0.48698
122	31.7569	115	0.35829	0.2845	0.43946
123	32.09	139	0.66052	0.59597	0.7196
124	32.231	127	0.51424	0.45424	0.57382
125	32.3924	139	0.66394	0.59879	0.7234
126	32.579	144	0.72049	0.64856	0.78264
127	32.7972	143	0.71231	0.64137	0.77416
128	33.367	134	0.61624	0.5534	0.67543
129	33.4854	149	0.77719	0.69925	0.83956
130	33.749	109	0.31219	0.22829	0.41052
131	34.0558	127	0.53725	0.47162	0.60161
132	34.4174	128	0.5545	0.48835	0.61878
133	34.8499	142	0.72296	0.65006	0.78567
134	35.2344	119	0.44976	0.37105	0.53107
135	35.3765	.	.	.	.
136	35.4959	126	0.5426	0.47139	0.61211
137	35.6853	131	0.60754	0.53827	0.67273
138	35.8883	130	0.59771	0.52756	0.66407
139	36.2216	134	0.64977	0.57872	0.71474
140	36.3412	152	0.82459	0.74488	0.8833
141	36.8699	130	0.60959	0.5362	0.67833
142	37.4953	117	0.45267	0.36373	0.54474
143	37.6699	111	0.38014	0.28452	0.48607
144	37.9799	135	0.68098	0.60484	0.74855
145	38.1445	150	0.82293	0.74335	0.88176
146	38.2466	125	0.5643	0.48253	0.64272
147	38.3665	123	0.54043	0.456	0.6226
148	38.6822	116	0.45483	0.36042	0.55261
149	39.0228	126	0.58643	0.50289	0.66527
150	39.1667	133	0.67166	0.59195	0.74257
151	39.5212	125	0.58008	0.49375	0.66178

Obs	Angle	Total Length	PROB (Odds)	Lower Confidence Limit	Upper Confidence Limit
152	39.7918	148	0.8201	0.73991	0.8796
153	40.0052	124	0.57353	0.48434	0.65819
154	40.5416	135	0.70845	0.62557	0.77946
155	40.7057	113	0.44208	0.33684	0.55279
156	40.9327	136	0.72292	0.6394	0.79334
157	41.0145	144	0.79797	0.7162	0.86076
158	41.8103	131	0.67848	0.58993	0.75583
159	42.7321	122	0.58215	0.48049	0.67727
160	42.8436	140	0.77918	0.69365	0.84613
161	42.9859	144	0.81357	0.72998	0.87569
162	44.427	119	0.56547	0.45326	0.67135
163	44.7249	131	0.70977	0.61305	0.79057
164	45.0995	127	0.66994	0.56712	0.75874
165	46.3972	152	0.8866	0.80902	0.93519
166	46.9509	147	0.86151	0.77856	0.91671
167	47.4631	138	0.80091	0.70711	0.87018
168	47.7946	130	0.73071	0.62498	0.81543
169	48.5904	111	0.51587	0.37654	0.65277
170	49.4642	147	0.87599	0.79297	0.92872
171	50.5994	134	0.79337	0.68921	0.86925
172	51.5001	130	0.76597	0.65258	0.8508
173	51.7868	149	0.898	0.81846	0.94503
174	52.3415	141	0.85726	0.76434	0.91749

VITA

Paige Whitney Elrod was born in November, 1987 in Fresno, California. She was graduated from the University of Washington in Seattle in August, 2009, with a Bachelor of Arts in anthropology. In August, 2010, Paige entered graduate school in the Geography and Anthropology Department at Louisiana State University. Paige presented a poster at the American Academy of Forensic Sciences annual meeting in 2012. She currently holds student memberships with the American Academy of Forensic Science and the American Association of Physical Anthropologists. Paige plans to begin a career in law enforcement with a focus on forensics.