ABSTRACT

MCLAWHORN, JESSICA HAYES. The Impact of Brachydactyly on the Neighboring Digits in the Hands and Feet. (Under the direction of Dr. D. Troy Case).

Brachydactyly is a general term used to identify fingers or toes that are shorter than normal. The term "brachydactyly" comes from the Greek words "brachys" for short and "daktylos" for digit. Brachydactyly is usually caused by an autosomal dominant allele of the homeobox D13 genes but can occasionally be due to trauma. This study aimed to provide useful information for researchers working with skeletal collections or osteological data in bioarchaeological, forensic, and clinical contexts. The three forms of brachydactyly investigated in this study will be referenced as - shortening of the 5th intermediate phalanx (BD-H-IP5), shortening of the 4th metatarsal (BD-F-MT4), and shortening of the 1st distal phalanx (BD-H-DP1).

The purpose of this thesis is to provide three things: 1) an analysis of the impact of brachydactyly on the neighboring bones of the hands and feet, if any, 2) an analysis of whether biological sex, as the literature review in the next chapter will discuss, has an impact on length variation in an individual, and 3) information on bone length ranges and ratio ratios within these bones that can then help future researchers to identify abnormal length variation in the digital bones of the hands or feet when conducting skeletal analysis.

The data used in this thesis research are metric data on hand and foot bone lengths gathered by D. Troy Case. The skeletons used are from the Robert J. Terry Anatomical Skeletal Collection, and the sample for this thesis comprises 342 individuals, 171 males and 171 females. Within the total sample, the initial analysis indicated that seven individuals have BD-H-IP5, three have BD-F-MT4, and seven have BD-H-DP1.

Statistical analyses included Shapiro-Wilk normality tests, ANOVA analysis, Mann-Whitney non-parametric tests, and direct comparison of Z-scores to better understand the relationship, if any, that existed between the bones with brachydactyly and neighboring bones of the hands and feet, and to determine whether brachydactyly and biological sex had an impact on those bones.

Results of this study suggest that all three types of brachydactyly show some evidence of impacts from brachydactyly on neighboring bones. Individuals with BD-H-IP5 show evidence of effects on IP4 and PP5, with weaker evidence of an effect on IP2. Individuals with BD-F-MT4 show evidence for effects on MT5 and PP4, and one example of brachydactyly affecting both MT4 and MT3. Individuals with BD-H-DP1 show evidence of both PP1 and DP3 being impacted by brachydactyly.

Results from the analysis of bone ratios by sex showed that, while bone lengths are universally different between the sexes, some ratios are significantly different while others are not. Most ratios for BD-H-IP5 differed between the sexes for the intermediate phalanges, but those involving IP2 tended not to differ, suggesting that IP2 is relatively longer in females. This may help explain the well-known male/female differences in the ratio of digits 2 to 4 (called 2D:4D). About half of the ratios involving the metatarsals for BD-F-MT4 showed no difference, with the other half showing differences between the sexes. The ratios for BD-H-DP1 of DP3 to DP1 likewise did not differ by sex, but the other ratios did differ, necessitating that all analyses be done separately by sex.

The bone measurement ranges for the non-brachydactylous sample can be used to understand an individual skeleton and whether they may have brachydactyly, which can be seen through direct metric comparison. The bone ratio ranges for the non-brachydactylous sample can

be used to understand the normal relationships between the neighboring digits of an individual skeleton and can also be used to scan for digits showing possible brachydactyly using the provided ratio benchmarks. Limitations and future research are discussed.

The Impact of Brachydactyly on Neighboring Digits in the Hands and Feet

by
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DEDICATION

In loving memory of my mother, to show her that while she may not physically be here anymore, I am still achieving the goals and passions that she so strongly supported during her life.

BIOGRAPHY

Growing up, Jessica McLawhorn was the proud daughter of a single mother, Edie McLawhorn, to whom this thesis is dedicated. Her mother instilled in her the drive and motivation to pursue her dreams and passions. As a child, this included dancing, specifically Irish dancing, and Jessica went on to win several trophies at dance competitions. As she got older, however, her attention turned toward the medical field, first to veterinarian medicine. However, upon realizing that euthanasia is a part of the job, she could not pursue that path any further. It was then that human medicine came into perspective, but the idea of patients dying still was a reality. Then, her sixth-grade teacher, Mr. Frazier, told her, “Well, why don’t you just work with the dead”? Not even realizing this was an option as an 11-year-old, this question opened the door to the path she would spend her life traveling.

Since the conversation in sixth grade, Jessica McLawhorn knew she wanted to work with the dead through forensics. Using identification methods, she realized she could help give other people’s loved ones find the closure they would need. She began to collect anatomy books and study forensic science. Through her undergraduate degree, she found that forensic anthropology embodied what she wanted to achieve. She also discovered a passion for subadult osteology and learned that there were few methods available for biological anthropologists to identify children. She has decided to pursue a Ph.D. in forensic anthropology, further studying and advancing the field of subadult osteological identification methods and eventually getting board-certified by the American Board of Forensic Anthropology (ABFA). With this future degree and certification, she hopes to work as a medicolegal death investigator, getting the certification for that work at a Medical Examiner’s office while also doing forensic anthropology casework.

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I want to extend thanks to my advisor Dr. Troy Case. When my original idea for this thesis fell through at the last moment, he stepped up to help me sort through new ideas until I found one I could be passionate about researching. He allowed me to use his already collected data, which helped me avoid traveling costs I would have needed otherwise. Throughout this process, he has been there for me, willing and able to answer any questions about this research project and my personal life. He ensured I kept to a schedule of completing this thesis, but he always told me not to push myself and to turn the computer off at night to give myself time to decompress from the day. Studying and learning from him these past two years has been an honor and privilege. I knew from our first meeting that we would work well together, which has proven even more true than I initially believed.

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To briefly list others who have helped me in my life and educational endeavors, I want to thank Ms. Lillian Berry, Mrs. Ann Cherry, Ms. Dell Enecks, Melissa Peaden, Amanda Cole, Shante Wilcox, Jordan Misha, Wesley Parrish, Sarah Wells, Savannah Moore, Ms. Gloria Taylor, and Mrs. Lisa Hoerner-Hanson. I want to thank my mentor and friend, Dr. Cheryl Johnston, who always offered me advice and help when needed. I also want to thank my other mentors outside of NCSU who helped me with the application process, including Dr. Nicholas Passalacqua, Dr. Katie Zejdlik, Dr. John Williams, and Dr. Philip Coyle.

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Chapter 1: Introduction

This thesis will focus on a developmental condition called brachydactyly that is more often studied by clinicians or geneticists rather than anthropologists. However, the perspective taken in this thesis is anthropological, and this study is designed to address aspects of brachydactyly that would likely be of greatest interest to biological anthropologists. Biological anthropology, also called physical anthropology, is the subfield of anthropology that studies the biological and behavioral aspects of humans. The research conducted here will explore whether the presence of brachydactyly or significant shortening of (usually) a single digital bone of the hands or feet may nevertheless subtly impact the neighboring digital bones of the hands and feet. It will also explore the boundaries between “normal” length and “abnormal” length in specific bones of the hands and feet as a means of helping to identify brachydactyly metrically. The hope is that this research will be used and expanded upon by biological anthropologists, clinicians, or geneticists.

Brachydactyly is a general term used to identify fingers or toes that are shorter than normal (Temtamy and McKusick 1978). The term "brachydactyly" comes from the Greek words "brachys" for short and "daktylos" for digit (Temtamy and McKusick 1978, 187). Brachydactyly can be an isolated malformation in the hands and feet, which is the most common expression (Temtamy and McKusick 1978, 187), or it can be part of a complex malformation syndrome. Brachydactyly is usually caused by an autosomal dominant allele of the homeobox D13 genes (Temtamy and McKusick 1978), but in other cases can be due to trauma (Poznanski 1984). Therefore, the presence of this trait in specific bones of the hands or feet, without evidence of trauma, suggests an inherited genetic trait that can be used within bioarchaeological, forensic, or clinical contexts.

The typical terminology used to describe brachydactyly is clinical, dividing brachydactyly into types that are labeled with letters (e.g., Type A, Type B, etc.). One must know the definition of the types to recognize the bone, or type of bone, that is affected. To improve accessibility for biological anthropologists, the medical terminology introduced and developed by Bell (1951) has been altered to reflect the specific bone (intermediate phalanx (IP), distal phalanx (DP), metatarsal (MT)) where brachydactyly (BD) is seen in the hand (H) or foot (F), instead of using the "types" that Bell (1951) established. The three forms of brachydactyly investigated in this study will be referenced as - shortening of the 5th intermediate phalanx (BD-H-IP5), shortening of the 1st distal phalanx (BD-H-DP1), and shortening of the 4th metatarsal (BD-F-MT4). This thesis will describe the types Bell (1951) presented in the literature review chapter and will not change the language that previous researchers have used when discussing past scholarship. However, in discussing the work presented and analyzed in this thesis, the designations noted above for each of the three types of brachydactyly will be used in all other chapters for easy accessibility and understanding by non-clinical researchers.

This study aims to provide useful information for researchers working with skeletal collections or osteological data in bioarchaeological, forensic, and clinical contexts. The purpose of this thesis is to provide three things: 1) an analysis of the impact of brachydactyly on the neighboring bones of the hands and feet, if any, 2) an analysis of whether biological sex, as the literature review in the next chapter will discuss, has an impact on relative lengths in an individual, and 3) information on the non-brachydactylous ranges of length variation within these bones that can then help future researchers to identify abnormal lengths in the digital bones of the hands or feet when conducting skeletal analysis.

The data used in this thesis research are metric data on hand and foot bone lengths gathered by my advisor, Dr. D. Troy Case, using the Robert J. Terry Anatomical Skeletal Collection (Terry Collection) housed at the National Museum of Natural History (Smithsonian Institution). I, Jessica McLawhorn, analyzed the data at North Carolina State University (NCSU) for my Master's Thesis. The data are derived from individuals racially categorized as white, so no ancestral variation in brachydactyly is being investigated in this project. However, males and females will be compared for sex differences that may exist in the expression of brachydactyly.

It is important to acknowledge that multiple sexes and genders exist and that the term "race" is problematic for biological and cultural reasons that can misrepresent an individual's lived reality. However, for this study, this thesis research will be using what the Terry Collection has documented for the individuals via their death certificates, putting personal beliefs and biases aside.

Chapter 2: Literature Review

This chapter will review what researchers have compiled, researched, and currently know about brachydactyly. Awareness of this knowledge can be beneficial for biological anthropologists to apply during the skeletal analysis of an individual. The chapter has been divided into subsections as follows: a brief overview of terminology, morphology, genetics and inheritance, Type A3: BD-H-IP5, Type D: BD-H-DP1, Type E1: BD-F-MT4, lived experiences, application to skeletons, and the Terry Collection.

Brachydactyly results from premature fusion of an epiphysis (Temtamy & McKusick 1978). Premature fusion can come from trauma to the epiphysis or occasionally from other causes like frostbite (Poznanski 1984). Still, for the types of brachydactyly addressed here, the probability of isolated trauma to only these specific bones (intermediate fifth phalanx, first distal phalanx, fourth metatarsal) is low (Temtamy & McKusick 1978). In most cases, evidence of trauma should persist. Therefore, the brachydactyly of these specific bones is much more likely to be due to genetic or developmental influences (Temtamy & McKusick 1978, Bell 1951).

Brachydactyly can be an isolated malformation in the hands and feet, which is the most common expression (Temtamy & McKusick 1978, 187), or it can be part of a complex malformation syndrome. The seven types Bell (1951) described are Type A, Type A2, Type A3, Type B, Type C, Type D, and Type E, which I will describe in detail later in this background section. Brachydactyly is commonly discussed in the medical literature but seldom discussed by biological anthropologists. Our understanding of brachydactyly has changed and evolved. This chapter will summarize previous research on brachydactyly while focusing on translating it for an anthropological audience.

Biesecker et al. (2009) published an article as part of a series of six papers defining the human body's morphology, focusing specifically on hand and foot morphologies. These papers aimed to standardize terms and reach an agreement about their definitions. Their general definition of brachydactyly of the hand recognizes brachydactyly when "the middle finger is more than 2 SD below the mean for newborns 27-41 weeks EGA, or below the 3rd centile for children from birth to 16 years of age, and the five digits retain their normal length proportions relative to each" (Biesecker et al. 2009, 99). An alternative observational indicator was stated to be "fingers that appear disproportionately short compared to the hand" (Biesecker et al. 2009, 99). This definition attempts to provide a statistical means of defining brachydactyly by using standard deviations, but by its very definition, will leave approximately 3% of the population diagnosed with brachydactyly, whether there is a significant difference between those at 1.9 SD below the mean or those at 2.1 SD below the mean. Furthermore, the statistically-based indicator focuses on the brachydactyly of all fingers at once rather than the more common situation in which brachydactyly affects a single bone.

It is hoped that a closer look at length proportionality in the digits, as will be done in this thesis, will help to define brachydactyly better statistically and help to explain why the comparative bones selected for this study have been chosen. It may later help with the interpretation of results.

Morphology

It is essential to understand the morphology of the hands and feet in humans (Figure 1) to understand brachydactyly.

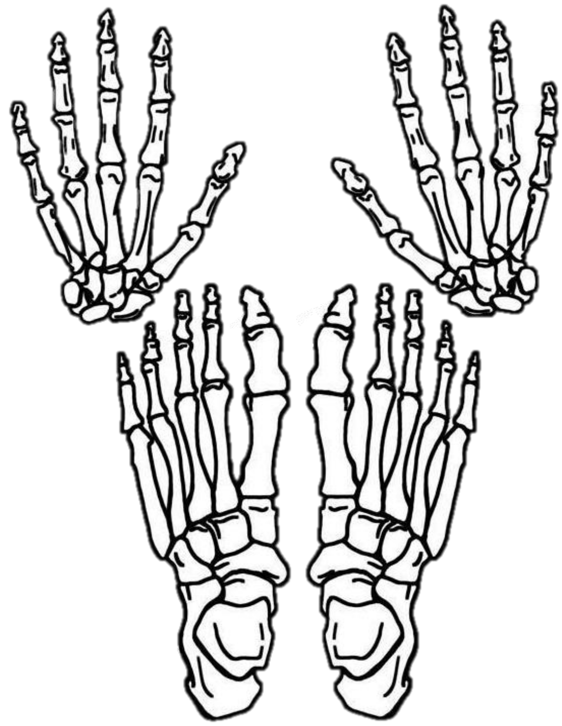
Figure 1. Skeletal model of human hands (top row) and feet (bottom row).

The bones of the hand and foot are represented by five rays, usually four bones per digit. The metacarpals are the longest bones in the hands, with the second metacarpal generally the longest and the first metacarpal the shortest (Case & Ross 2007). The proximal and intermediate third phalanges of the hand generally have a greater maximum length than the other bones in the same row (Varas & Thompson 2010, Case & Heilman 2006), while the first distal phalanx of the hand has the greatest maximum length in the distal row (Case & Heilman 2006). See Table 1. The metatarsals are the longest bones of the foot, with the second metatarsal generally the longest and the first metatarsal the shortest (Case & Ross 2007). The first proximal phalanx of the foot has a greater maximum length than the other proximal phalanges (Case & Ross 2007), while the first distal phalanx has the greatest maximum length in the distal row (Case & Ross 2007); See Table 2 for the longest to shortest bones per ray of the feet. After an exhaustive review of the literature, length measurements for the intermediate and most distal phalanges of the feet could not be found, suggesting that further research is needed on this topic.

Table 1. The longest to shortest maximum lengths per bone of the hands.

	Hands			
Metric Trait	Metacarpal	Proximal Phalanx	Intermediate Phalanx	Distal Phalanx
Longest	2	3	3	1
	3	4	4	3
	4	2	2	4
	5	5	5	2
Shortest	1	1		5
Reference:	Case & Ross (2007)	Case & Heilman (2006)	Case & Heilman (2006)	Case & Heilman (2006)

Table 2. The longest to shortest maximum lengths per bone of the feet.

	Feet			
Metric Trait	Metatarsal	Proximal Phalanx	Intermediate Phalanx	Distal Phalanx
Longest	2	1		1
	3	2		
	5	3		
	4	4		
Shortest	1	5		
Reference:	Case & Ross (2007)	Case & Ross (2007)		Case & Ross (2007)

A major goal of this study is to better understand the impact of brachydactyly on length variation in the neighboring bones of the hands and feet, such as the other intermediate phalanges in the case of IP5 brachydactyly, or perhaps the other bones of the same ray, such as PP5. Hewitt (1963) made a significant discovery while studying radiographs from children that the length of the fifth intermediate phalanx, which is one of the more common sites for brachydactyly, shows poor correlation with other digital bones of the hand and therefore displays the least well-integrated growth pattern with the rest of the hand. This may be because the fifth intermediate phalanx is hyper-responsive to some general growth factor (Hewitt 1963), making it more likely to have malformations (Hewitt 1963), as later expanded upon in the genetics and inheritance section based on a study by Muenke & Schell (1995) and a study by Kraus & Choi (1958). The reaction of the fifth intermediate phalanx to the general growth factor that Hewitt (1963) postulates for the entire hand is much larger as a percentage of total size than in any other bone of the hand. Lewenz & Whiteley (1902) conducted a study showing hand ray and row relationships using a small sample of 50 cadaver bones. It was found that hand ray correlations were smaller than those identified in the Hewitt (1963) study, but that is likely because Lewenz & Whitely were studying adults rather than children, and many factors, such as activity, may influence relative bone lengths. The Lewenz & Whiteley (1902) study did confirm two observations from the Hewitt (1963) study, the first being a greater correlation in bone lengths among bones from the same row rather than those from the same ray and the second being greater correlations between adjacent than non-adjacent bones, whether in the same ray or the same row, which they called a "rule of neighborhood".

Roche & Hermann (1969) sought to analyze the relationships between the rates of total, epiphyseal, and diaphyseal elongation of the short bones of the hand (metacarpals and phalanges) using radiographs. To accomplish this, Roche & Hermann (1969) calculated the ratios for each bone (Table 1 in Roche & Hermann 1969), the averages of bone lengths (Table 2 in Roche & Hermann 1969), and by rows and rays (Table 3 in Roche & Hermann 1969), as well as by the neighborhood effect (Table 4 in Roche & Hermann 1969). As a note, the total length of each bone was diaphysis + cartilage + ossified epiphysis since this was a radiographic study. Measurements of total length taken and used in this present study were done on ossified skeletal adults, so cartilage was not a factor. Roche & Hermann (1969) state that both Lewenz & Whiteley (1902) and Hewitt (1963) reported neighborhood and marginal effects (i.e., correlation differences between the central digits and those on the margins of the hand) in rows and rays. Roche & Hermann’s (1969) study showed that the rows had neighborhood effects and a minor tendency to marginal effects, but neither were demonstrated among the bones of the individual rays. Given these similarities in development for bones of the same row and for immediate neighbors, it is possible that individuals with brachydactyly might show effects in the neighboring bones of the hands and feet, and specifically those bones from the same row.

Another factor affecting hand and foot morphology is length variation due to sexual dimorphism and population differences. Kimura (1973), using a Japanese sample of 60 individuals (30 males and 30 females) from the same family, found the order of increasing variability in the rays (Table 3) and rows (Table 4) of the hands were sex-dependent.

Table 3. Kimura (1973) order of variability in the hands by ray.

Order of Variability in the Rays of the Hands

Rays in the Hands	Males	Females	Combined
Highest	5	5	5
	2	1	1
	1	4	2
	3	2	4
Lowest	4	3	3

Table 4. Kimura (1973) order of variability in the hands by row.

Order of Variability in the Rows of the Hands

Rows in the Hands	Males	Females	Combined
Highest	Distal Phalanx	Intermediate phalanx	Distal Phalanx
	Intermediate phalanx	Distal Phalanx	Intermediate phalanx
	Proximal Phalanx	Proximal Phalanx	Proximal Phalanx
Lowest	Metacarpal	Metacarpal	Metacarpal

Expanding from Kimura (1973), Harris et al. (1992) studied changes in bone lengths in the hand by studying radiographs of the same individuals about 34 years apart. Surprisingly, they found that the lengths did change somewhat over the course of adult life, and these changes were somewhat differently patterned by sex. Such information is relevant to this study because all individuals examined were adults, and most were older adults. Harris et al. (1992) found that the differences in length are more row-specific than ray-specific, and the distal and middle phalanges are most strongly affected, which given the subject of this thesis, is important to take note of regarding brachydactyly of IP5 and DP1. These findings are supported by McFadden & Bracht (2009), who found that human metacarpals do not show the same pattern of sexual dimorphism that occur in human finger-length ratios, while Harris et al. (1992) found the distal and middle phalanges to be more sexually dimorphic in white Americans and Lewis (2001) found in a Welsh sample that the middle and proximal phalanges were more sexually dimorphic.

Furthermore, the length ratios of metacarpals and metatarsals, as investigated by McFadden & Bracht (2009), show that there are sexual differences between European-Americans and African Americans, exhibiting evidence that sexual dimorphism, as it presents in the finger digits of the hand, are dependent upon population. The changes in the proximal phalanges average approximately zero between the sexes, with proximal phalanx four becoming shorter with age in both sexes (Harris et al. 1992). However, the metacarpals demonstrate highly significant length reductions along the whole bone row and in both sexes (Harris et al. 1992). Harris et al. (1992) also found size reduction is slightly higher in males than in females. The percent of sexual dimorphism between both sexes was 11.7% in early adulthood and 12.2% in late middle age, with sexual dimorphism increasing with age in 14 of the 19 diaphyseal hand bones (Harris et al. 1992). This difference is due to males changing more than females in adulthood (Harris et al. 1992). It is important to note that the sample used by Harris et al. (1992) is comprised of individuals who were children in the 1920s who had above-average health histories and socioeconomic settings. The population used in this thesis is from around this same timeframe. Still, the individuals have poorer health histories and socioeconomic settings (Hunt & Albanese 2005), which will be expanded upon in the last section of this chapter.

Sex differences have also been reported in overall digit length and digit length ratio (e.g., 2D:4D, which refers to the relative length of the 2nd to 4th digits (Park 1977, Manning & Fink

2018)). However, the ontogeny of these sex differences is not well understood. Manning & Fink (2018) found that the sex differences for 2D:4D are independent of age and sex-related changes in the digit's lengths. However, Hönekopp and Watson (2010) extended the work by Williams et al. (2007) and Bell (1951) by analyzing sex differences in length ratios of the second and fourth digits (2D:4D). While not related to brachydactyly, they found that there is sexual dimorphism in the relative lengths of at least some of the digital bones of the hands (specifically, the 2nd and 4th digits). It shows that this dimorphism is even evident in prenatal humans. With one of the goals of this thesis being to understand how brachydactyly can be used in forensic or bioarchaeological context, it should be noted that Voracek (2009) found that through the comparison of five studies using 2D:4D through logistic regression and receiver operating characteristic analysis, that the degree of separation between the two sexes, while present, is too small for this approach to be useful within a forensic context since the degree of dimorphism would need to be enough to correctly distinguish the sexes at least 80% of the time, as needed with sex estimation methods.

Asymmetry within the human skeleton is a morphological feature where one side of the body can be larger than the other. This concept is used for different purposes within the biological sciences. An example of this can be seen within both forensic and bioarchaeological contexts. Since most humans favor the right arm, the bones of the left arm are typically shorter and more gracile. Therefore, the left side is preferred to the right side when conducting sex estimation on unknown individuals (Case & Ross 2007). Within the context of this thesis, only directional asymmetry will be discussed. Auerbach & Ruff (2006) point out that general patterns of directional asymmetry can be found across a wide selection of modern human populations. All asymmetry in the human skeleton is more pronounced in the upper limb, with a decreased prevalence in the lower limb, specifically around the knee, with evidence showing an overall preference for the right side (Auerbach & Ruff 2006). This preference can either result from individual preference or cultural factors (Auerbach & Ruff 2006) due to what is often referred to as handedness. Kumar et al. (2021) found that right and left asymmetry in the phalangeal bone lengths of the hands is impacted by hand preference, sex, and age, the same factors that affect the upper-limb bone lengths as discussed by Auerbach & Ruff (2006). This explains why the data of this thesis will be dealt with separately by the side, where applicable for brachydactyly, instead of using both sides if only one side is affected. While directional asymmetry is more well known in the arms rather than the hands and feet, the data used in this thesis may be able to demonstrate these effects regarding brachydactyly.

Genetics and Inheritance

A vital component of this thesis is the growth and development of humans as it relates to digit length. Abnormalities in genetics and/or developmental traumas can cause brachydactyly in humans as they grow. However, given the literature surveyed, there was insufficient supporting evidence for developmental trauma as a potential cause for brachydactyly. Different researchers' theories and approaches to growth and development through a genetic lens work to explain the causes of brachydactyly and how this approach is foundational to all other clinical research into brachydactyly.

Mendelian Theory describes a biological inheritance pattern that follows the laws of segregation and independent assortment. The two alleles of a gene inherited from either parent separate into gametes at an equal frequency, and only one is inherited by each offspring. Drinkwater (1912) briefly discusses Mendelian Theory and how it relates to the family with the brachydactyly they were analyzing. They discuss how there is allele segregation so that brachydactyly in the family is either fully transmitted or never transmitted. Only the abnormal family members transmit this abnormality, and the gametes separate into the offspring with a theoretical possibility of 50% of the offspring being abnormal (dominant) or normal (recessive).

Understanding Mendelian Theory helps in the genetic understanding of bone development and the importance of timing and sequence in human growth and development. Muenke & Schell (1995) found that fibroblast-growth-factor-receptor mutations within humans play crucial roles in the signal transduction and development of the human skeletal system. Fibroblast-growth-factors regulate cell proliferation, differentiation, and migration in numerous tissues through complex signaling pathways. These mutations can have multiple genetic indicators. For example, Robledo et al. (2002) found that the Dlx homeobox genes are the mammalian homologs of the Drosophila Distal-less (Dll) gene. The Dll expresses itself in the distal portion of the developing limbs. It is critical to developing distal structures, including hands and feet, where brachydactyly, a genetic malformation, is seen.

All forms of brachydactyly have been identified as an autosomal dominant trait of the homeobox D13 genes (Temtamy & McKusick, 1978). Disruption of the developmental process of these genes can create congenital defects, such as brachydactyly. Kraus & Choi (1958), in a sample of 118 fetuses, examined whether the growth of a human fetal skeleton is under the control of a singular growth regulatory field or whether other growth fields are involved. Kraus & Choi (1958) concluded that there were four principal components responsible for the changing metric relationship for the bones of the hands, arms, and legs during growth that are regulated by a general growth mechanism under genetic control. The first component is characterized by a general growth factor with dynamics overseen by the genetic composition of an individual (Kraus & Choi 1958). The influence of the first component lessens slightly near the periphery of the skeleton, where the other components, which are specific to certain areas, come into focus (Kraus & Choi 1958). This would include the hands and feet. The second principal component was found to be primarily involved with the distal phalanges, the third component with the middle phalanges, and the fourth component with the proximal phalanges (Kraus & Choi 1958).

Kraus & Choi's (1958) theory that these influences are distinctly determined genetically obtains some backing from the existence of hereditary abnormalities affecting the lengths of certain phalanges. Muenke & Schell (1995) discuss how fibroblast-growth-factor-receptor-related skeletal disorders include dwarfism, which has connections to brachydactyly, as Temtamy & McKusick (1978) explained. These authors discuss syndromes associated with brachydactyly. The information presented in the article by Muenke & Schell (1995) shows significant evidence for how disruptions and mutations of this fibroblast-growth-factor-receptor affect the timing of skeletal development. Suppose that fibroblast-growth-factor-receptors work in conjunction with homeobox D13 genes, as Robledo et al. (2002) discussed. Add to that Kraus & Choi's (1958) discovery that different genes are responsible for different growth factors. Then it is possible that a single mutant gene (Muenke & Schell 1995) might lead to effects in a single row of bones under the control of that gene. If we further include Hewitt's (1963) discovery that the fifth intermediate phalanx displays the least well-integrated growth pattern with the rest of the hand, then this could explain the premature fusion of brachydactylous bones, such as IP5, in the hands and feet.

Along with understanding the genetics behind bone development, it is crucial to understand how this understanding directly translates into theories about brachydactyly. With previous connections made, Bell (1951) is crucial in understanding the theories surrounding brachydactyly. Bell (1951) analyzed 124 pedigrees containing 1336 individuals who had brachydactyly and found that anatomically, the pedigrees could be organized into five main groups with two subgroups, albeit with a slight overlap between the type classifications. Bell organized brachydactyly into Type A, Type A2, Type A3, Type B, Type C, Type D, and Type E. My thesis focuses only on the most common types - Types A3, D, and E, as described by Bell and further examined by Temtamy & McKusick (1978).

Type A is a digital anomaly confined to the middle phalanx of fingers and toes and contains two subgroups, Type A2 and Type A3. Type A and all subsequent subgroups include the Drinkwater type (Drinkwater, 1912), where the affected middle phalanx may or may not be fused with the distal phalanx. Type A3 includes cases where only the middle phalanx of the 5th digit is obviously affected, with most examples showing shortening on the radial side of the phalanx, leading to radial deflexion, creating a curved little finger known as clinodactyly. It is difficult to note if Type A3 anomaly is or is not associated with anomalies in the toes. Williams et al. (2007) expand on this question by addressing how Type A3 is an autosomal dominant trait in some populations and an incompletely dominant trait in others with less penetrance. This means that brachydactyly is not always expressed, even when the dominant alleles associated with the malformation are present. Since the ossification centers in the fifth intermediate phalanx are the last to form and are particularly vulnerable to the general growth factor (Hewitt 1963), they may also have a prolonged period of vulnerability to biological variation and change. Japanese individuals and some Native American groups from North America exhibit a higher prevalence of Type A3 than other groups, and Type A3 appears to have no sex bias in prevalence. Biological anthropologists should pay particular attention to Type A3, given that it is the most common hand anomaly and is heritable. It could, for example, be used for kinship analysis in forensic and bioarchaeological contexts.

Type D includes cases where the distal phalanx of the thumb is short in otherwise normal hands causing the thumb to extend possibly only as far as the metacarpophalangeal joint of the index finger, with the bone being short and broad, and the big toes also possibly sharing this anomaly (Bell 1951; Temtamy & McKusick 1978). It is possible that some of the shortening is due to a possible impact on the first proximal phalanx as well, which will be further investigated in this thesis study.

Type E includes cases where one or more of the metatarsals or metacarpals are shortened. In most cases, only a single metacarpal or metatarsal is clearly affected (Bell 1951; Temtamy & McKusick 1978). In the feet, the 4th metatarsal is most commonly affected. A key trait is a lack of symmetry between the sides in many cases and a lack of apparent shortening of corresponding bones between the hands and feet (Bell 1951; Temtamy & McKusick 1978).

Despite variation among populations (as noted for Type A3 above), no research studying brachydactyly has observed sex-based differences. Bell's (1951) sample included 1220 examples of brachydactyly for which sex was known and found no significant difference in the presence of the anomaly between the two sexes. Williams et al. (2007) found no sex differences in their sample.

Finally, Bell's (1951) different types of brachydactyly exhibit variation associated with other syndromes that affect other parts of the body than the skeleton (Temtamy & McKusick 1978). Type A3 is often associated with Down’s syndrome and can be found in relation to poly-X syndromes such as XXXY, XXXXY, and XXXXX syndromes. Other syndromes that include brachydactyly of the fifth intermediate phalanx (sometimes called brachymesophalangy V) as a feature include Russell-Silver dwarfism, Cornelia de Lange syndrome, Prader-Willi syndrome, Coffin-Siris syndrome, Orofaciodigital syndromes I and II, OPD syndrome, TAR syndrome, and Bloom Syndrome (Temtamy & McKusick 1978).

Type D brachydactyly is associated with Heart-Hand syndrome II, Robinow syndrome, and Rubinstein-Taybi syndrome (Temtamy & McKusick 1978). Rubinstein-Taybi syndrome exhibits broad thumbs and toes, facial abnormalities, intellectual disability, and brachytelephalangy (Temtamy & McKusick 1978). Type E brachydactyly is connected to Turner Syndrome, which involves a missing X chromosome (XO) and is associated with gonadal dysgenesis. The importance of the X chromosome might suggest the possibility of sexual dimorphism in the condition. This type is also seen in Albright Hereditary Osteodystrophy, Nevoid Basal Cell Carcinoma syndrome, Cryptodontic Brachymetacarpalla, Ruvalcaba syndrome, and Blemond syndrome I. As noted above, Muenke and Schell (1995) discussed how fibroblast-growth-factor-receptor-related skeletal disorders include dwarfism, which also has connections to brachydactyly, as explained by Temtamy & McKusick (1978).

Ray (1968) discussed the shortening of the fourth metatarsal in humans in a reasonably large sample comprised of different family pedigrees of individuals with brachydactyly. Among 130 cases, the anomaly was present in 76 individuals unilaterally and 54 individuals bilaterally, with the largest pedigree including 12 affected members and the longest having affected members over five generations (Ray 1968:108). The author, after analyzing 61 pedigrees of short fourth metatarsals in India, said there is good reason to believe the inheritance of sex incidence in some pedigrees and for inheritance of laterality (Ray 1968, 107), meaning that genes may be impacting whether the condition is expressed unilaterally or bilaterally, and perhaps on which side. In an earlier article, Steggerda (1942) also studied the inheritance of shortened fourth metatarsals. However, the pedigree that was analyzed was small, and it was one family over three generations, so the type of inheritance could not be determined. Still, it provided enough evidence to show that 4th metatarsal brachydactyly is inherited and that it affected two of the three generations, skipping one generation (Steggerda 1942, 233-234). The reappearance of the condition after missing a generation suggested either incomplete dominance or recessive inheritance (Steggerda 1942, 233-234).

Superti-Furga et al. (2007) revised the Nosology of Constitutional Disorders of Bone to incorporate newly recognized skeletal disorders and to reflect new molecular and pathogenic concepts to assist with diagnosis and to direct research in skeletal biology and genetic disorders. By reviewing Table 1 of this publication, it is clear that in all of the classes of brachydactyly analyzed, there is evidence for an inherited autosomal dominant trait in most cases. This means that a single nonsex (autosomal) chromosome that is abnormal from one parent is enough to pass the disorder to the child (dominant inheritance). It should also be noted that while Superti-Furga et al. (2007) found that Type A3 is autosomal dominant, Williams et al. (2007) found in their sample population of 1,357 Jirel children that this mode of inheritance was not supported. So, some questions still remain about modes of inheritance even for the most common form of brachydactyly in humans, and may suggest the actions of multiple genes, with some being more important than others and therefore behaving more like an autosomal dominant in some pedigrees but not others

It is also important to note that Bell (1951) found that within the 1220 examples of brachydactyly examined where sex was known, there was no significant difference in the presence of the anomaly overall between the two sexes (Bell 1951, 10), but that when the individual types are examined, differences in the sexes can be seen (Bell 1951). Sex has a known influence on human growth and development, and sexual dimorphism can be seen in the sizes of the digits of the hands and feet (Case & Ross 2007). Given this information, the influence of sex on the possible presence of brachydactyly will be further analyzed in this current research thesis.

However, for the sake of my research project, I will only focus on three of the more common classes of brachydactyly discussed by Bell (1951). As noted previously, I will use my own names for these different forms of brachydactyly (indicated in parentheses), making it more obvious which specific bones are impacted; Type A3 (BD-H-IP5), Type D (BD-H-DP1) and Type E (BD-F-MT4). “BD” indicates brachydactyly, “H” or “F” indicates whether it is in the hands or feet, and the last code describes the specific bone involved: intermediate phalanx five (IP5), distal phalanx one (DP1) and metatarsal four (MT4).

Type A3: BD-H-IP5

Type A3, or BD-H-IP5 for this thesis (Figure 2), is a type of brachydactyly that involves shortening of the 5th intermediate phalanx in the hand; see Figure 2. Several terms are synonymous with Type A3, such as crooked little fingers, clinodactyly, clinomicrodactyly, and brachymesophalangy V (Temtamy & McKusick 1978, 200).

Figure 2. Terry 1153, bilateral brachydactyly of the intermediate fifth phalanx. Right hand pictured—photo courtesy of Dr. Case.

Williams et al. (2007) published the first large-scale quantitative genetic analysis of Type A3, showing that this is the most common of all hand anomalies and is often seen as part of a group of traits that characterize most brachydactyly and many developmental disorders. Since the ossification centers in the fifth intermediate phalanx are the last to form and are vulnerable to common growth factors, they may also have a prolonged period of vulnerability to biological variation and change (Williams et al. 2007:610). Japanese individuals and some Native American groups from North America exhibit a higher prevalence of Type A3 than other groups (Williams et al. 2007:614). Unlike Type D, Type A3 appears to have no sex bias in prevalence (Williams et al. 2007:618). Bell (1951) found that within males and females, a higher number of affected individuals in the pedigree received the trait from their fathers who were either affected themselves or a carrier. Biological anthropologists should pay particular attention to BD-H-IP5, given that it is the most common hand anomaly and is highly heritable (Williams et al. 2007).

Type E1: BD-F-MT4

Type E1, or BD-F-MT4 (Figure 3), is a type of brachydactyly representing the shortening of the 4th metatarsal. Several terms are synonymous with Type E, such as brachymetapody (for the hands or feet) and brachymetatarsy for the feet alone (Temtamy & McKusick 1978, 218).

Figure 3. Radiographic image of a 15-year-old female with Type E1 brachydactyly. Both feet pictured have brachydactyly of MT4—photo from Ivan (2013).

Pereda et al. (2013) report that, although commonly observed as part of a syndrome, 4th metatarsal brachydactyly can be an isolated entity. When reported as a singular entity, it is due to four heterozygous mutations in the homeobox D13 gene with two missenses mutations and two nonsenses mutations (Pereda et al. 2013, 2). In two of these four cases, there is an overlap between Brachydactyly E1 and Brachydactyly D (Pereda et al. 2013, 2). When reported as part of a syndrome, it can correlate with multihormonal resistance, generally to the parathyroid and thyroid hormones (Pereda et al. 2013, 1). Regarding inheritance of the trait, Bell (1951) found that within males and females, there was no discernable difference of affected individuals in the pedigree who received the trait from their mothers or fathers who were either affected themselves or a carrier.

Type D: BD-H-DP1

Type D, or BD-H-DP1 (Figure 4), is a form of brachydactyly characterized by the shortening of the 1st distal phalanx in the hand. Several terms are synonymous with Type D, such as brachytelephalangy and brachymegalodactylism (Temtamy & McKusick 1978, 215).

Figure 4. Terry 839, bilateral brachydactyly of the first distal phalanx. Both hands are pictured—photo courtesy of Dr. Case.

The shortening of the 1st distal phalanx results from the early closure of its epiphysis (Temtamy & McKusick 1978, 217). This trait is inherited as an autosomal dominant trait with reduced penetrance (Temtamy & McKusick 1978, 217), meaning that Type D is a dominantly inherited trait. Still, fewer individuals are affected than expected, given its prevalence in the parent population. Bell (1951) found that within males and females, a higher number of affected individuals in the pedigree received the trait from their mothers who were either affected themselves or a carrier. Type D brachydactyly has been studied in numerous populations, and its frequency depends on population and sex. This frequency is particularly high among Arabs in Israel and among the Japanese (Temtamy & McKusick 1978, 217). It is significantly higher in a random sample of Jews than in a random sample of US whites and is very low in US blacks (Temtamy & McKusick 1978, 217). It is more prevalent in females than males among the Japanese and US samples, with no sex differences seen in Israeli Arabs or Jews (Temtamy & McKusick 1978, 217). Thus, BD-H-DP1 can be expected to show population variability in its frequency and may have some tendency to be more common in females than in males, in agreement with statements made by Bell (1951).

Lived Experiences

The skeleton is the foundation and support for the rest of the body. Given this fact, if there are skeletal anomalies, it is possible that they might impact the lived experience of an individual. According to the literature, however, difficulty with gripping and walking only arises from extreme cases of brachydactyly. Because of this, most surgical procedures to correct brachydactyly are not for functional reasons but for cosmetic ones (Temtamy & McKusick 1978, Vickers 1987).

As previously discussed, Type A3 brachydactyly includes cases where only the middle phalanx of the 5th digit is affected, with most examples showing shortening on the radial side of the phalanx, leading to radial deflexion creating a curved little finger known as clinodactyly (Bell 1951, 1). While some affected individuals simply live with the malformation, an osteotomy is a simple operative technique to help correct it (Vickers 1987). This involves a resection of the mid-zone of the continuous epiphysis and the underlying physis in a child, where a replacement by a fat graft (physiolysis) is simpler and allows further growth in the phalanx, decreases the angular deformity, and improves the articular surfaces (Vickers 1987). This procedure is shown to have exceptional functional and cosmetic results for the affected individuals (Vickers 1987).

Application to Skeletons

As a genetic malformation, brachydactyly can be observed in forensic and bioarchaeological contexts and investigations. The previously discussed knowledge can be applied to these two fields during analysis to help biological anthropologists understand the skeleton being analyzed.

The metacarpal sign has been used to identify brachydactyly from radiographic images and requires a fully articulated hand radiograph to view this pattern. It has been researched by Park (1977), who found that those with Turner's Syndrome had increased angulation of the proximal metacarpal row that decreased with age. In contrast, those who did not have Turner's Syndrome had a metacarpal angle that increased with age.

Cybulski (1988) studied brachydactyly in a prehistoric population from Prince Rupert Harbour in British Columbia. They found through comparison of modern frequencies to the prehistoric data that brachydactyly in Prince Rupert Harbour was unusually high, showing evidence for this trait being inherited rather than sporadic (Cybulski 1988, 370). Ray (1968, cited by Cybulski, 1988) found BD-F-MT4 to behave as an irregular autosomal dominant trait with penetrance between 23% and 40%. Although Cybulski's (1988) data is prehistoric, since they looked at numerous sites in the area, they could suggest the possibility of blood-relationships among at least some of the remains within the Prince Rupert Harbour village sites and, potentially, between sites (Cybulski 1988, 372). This suggests the possibility of migration between locations and the potential of defects such as brachydactyly in conducting skeletal kinship analysis.

Kinship is a component of bioarchaeological research regarding brachydactyly that can provide information to anthropologists about an individual in relation to a community. Case et al. (2016) conducted kinship analysis through developmental anomalies of the feet of skeletal samples, one of which was brachydactyly, within archaeological sites in Denmark and England. It was found that among the traits analyzed, brachydactyly was a good candidate to be a potential indicator for skeletal kinship, although it did not help to identify genetic relatives in their particular study (Case et al. 2016). The trait was seen as a good candidate for kinship analysis because, among the traits considered, brachydactyly mostly shows no evidence of age or sex bias (Case et al. 2016). It also occurs in less than 5% of European individuals and much less than that for some of the types, so if several individuals share the trait in a cemetery, it may indicate a familial relationship (Case et al. 2016). Considering how this defect can be used in a bioarchaeological context, it is possible to see how this could also be applied in a forensic context. Brachydactyly is an inherited trait, so, if possible, victim identities could be linked to an unknown skeleton. Analyzing a family for brachydactyly could help narrow the scope of possible identities for an unknown individual in a forensic context who exhibits the trait.

The Terry Collection

My research will focus on an early-mid 20th-century population, specifically, the Terry Collection curated at the Smithsonian Institution's National Museum of Natural History. The collection was assembled between 1917 and 1966, and individuals who were included before World War II generally came from the lowest socioeconomic strata in Missouri at the time of their deaths. A majority of the cadavers that Dr. Robert Terry obtained for this collection came from specific segments of the populations in St. Louis, Missouri (Hunt & Albanese 2005:416). Many of the individuals are people who died during the Great Depression and whose bodies were unclaimed at the time of their deaths. However, they may not have spent their childhood impoverished (Hunt & Albanese 2005, 416). Many were also institutionalized, and some may have been in institutions because of congenital syndromes (e.g., Down’s syndrome) that may increase the probability of brachydactyly in the sample. Socioeconomic status (Stinson 1985, Perkins et al. 2016) and environmental factors (Stinson 1985, Perkins et al. 2016) have a known impact on the development of bones (Stinson 1985, Perkins et al. 2016), particularly bone lengths.

The demographics of this collection are as follows. There are 1,728 skeletons, with specific ages known for 1,608 skeletons, 508 black males and 355 black females, 436 white males, and 303 white females, 5 Asian males and 1 with no racial data, with recorded ages ranging from 14 to 102 years for the age at death (Hunt & Albanese 2005:414).

This study will focus on the data available from individuals in the collection whose race is labeled as white. Hunt & Albanese (2005) make a point to address the race concept, stating how racial profiling of specimens, both during the time the collection was being established and by researchers today, is problematic. They state that the racial categories were designated during the time of collecting between 1917 – 1966. They reflect the concept of race for that time and are focused on social ideals and less accurately based on any biological/genetic reality. Hunt & Albanese (2005) also note that the lack of younger and older adult male individuals born in the 20th century may be a significant source of bias. However, the magnitude of bias will vary depending on the research question. Age is not likely to be an important source of bias for this study because brachydactyly would be present in most individuals by age 16 when the digital epiphyses should be fused and would persist for life.

The Terry Collection sample's representativeness has been debated because these skeletons were collected in the early 20th century. Therefore, they may no longer represent a modern population sample in the United States, particularly for forensic identification. However, attempts to demonstrate this danger were inconclusive (Hunt & Albanese 2005:416). Because the current study will focus on bone proportions rather than aspects of general size, this issue should not significantly impact the study's outcome.

The Terry Collection is still significantly helpful in understanding human skeletal biology, secular change, and variation. Brachydactyly is one of the traits that can be observed in this collection. The greatest asset of the Terry Collection is the completeness and preservation of the skeletons, the consistent format and accuracy in the data associated with the collection, and for the purposes of this particular study, the fact that bones from both sides were labeled in different colors to eliminate errors in siding the phalanges. These advantages make this a particularly appropriate collection for my research.

Chapter 3: Materials and Methods

This chapter will review the materials and methods used in this thesis to investigate three questions directly or tangentially related to brachydactyly: 1) whether brachydactyly has an impact on the neighboring bones of the hand and feet, 2) the impact of sex on length variation in the certain digital bones pertinent to Question 1, and 3) to define non-brachydactylous ranges of length variation in those digital bones in individuals with no evidence of brachydactyly, as a means for helping to define length ratios that might be indicative of brachydactyly metrically. This chapter has been divided into three subsections to assist in presenting this information. It includes information regarding the sample population, brachydactyly type and the neighboring bones to be examined, and my approach to statistical analysis.

Sample Population

Brachydactyly and interdigit length relationships of the neighboring bones in the hands and feet were evaluated using skeletons from the Terry Anatomical Collection. The skeletons in this collection are primarily made up of individuals who died in institutions or impoverished conditions (Hunt and Albanese 2005). These data were previously collected by D. Troy Case and used in his Ph.D. dissertation (Case 2003). When collecting the sample, he focused on individuals labeled as white, including males and females. Since the collection is organized sequentially by skeletal number, he started with the first skeleton, focusing initially on individuals under sixty years of age and excluding individuals with poor bone quality or significant missing elements. To maintain a numeric balance between males and females in the sample, he later increased the age limit for females, such that the eldest females in the sample were 72 years old, and the eldest males were 60 years old at the time of death. This approach resulted in a sample of over 342 skeletons.

Measurements for the length of the metacarpals and phalanges in each ray were taken for each individual's left and right hand using a mini-osteometric board. Case (2003) used an early version of this device developed by PaleoTech Concepts that could be attached to calipers. See Figure 3.1 in Case (2003:68). Measurements for the metatarsals and pedal phalanges were taken only from each individual's right foot. Poorly preserved or damaged bones were not used in the original sample. Individuals with bone lipping that might impact measurements were noted in the sample and were excluded from the data used in this thesis.

The sample for this thesis comprised 342 individuals; 171 males and 171 females. Seven individuals in the total sample were diagnosed by Dr. Case by means of visual inspection to have BD-H-IP5, three individuals in the total sample were diagnosed as having BD-F-MT4, and seven individuals in the total sample were diagnosed as having BD-H-DP1. Within the data set were individuals with missing measurements for certain bones. Individuals were not initially removed from the overall data set when measurements were missing, but rather, only once individuals were segregated into separate groups to investigate each of the three specific types of brachydactyly. At that point, individuals missing one or more of the relevant bones for that type of brachydactyly were removed. This was done to maximize the data available for each specific region of the hands or feet.

Sex has a known influence on human growth and development. Therefore, it was necessary to divide my sample into male and female groups to understand the effects of brachydactyly best and determine sex relevance, as well as to describe length relationships within male and female hands to determine whether the patterns differ. If those patterns differ, then analyses must proceed separately by sex. Consequently, the sample was separated for each analysis based on the type of brachydactyly being investigated, the sex of the skeletons, and the presence of all the correct bones for a particular analysis.

Brachydactyly Type and the Neighboring Bones

There were three types of brachydactyly investigated in this thesis. These three types were chosen because they were the three types visually identified by Dr. Case when he was analyzing the collection. The three types include brachydactyly of intermediate phalanx five (BD-H-IP5), brachydactyly of metatarsal four (BD-F-MT4), and brachydactyly of distal phalanx one (BD-H-DP1). Roche & Hermann's (1969) study showed that the relative bone length in the hands was impacted by which row the bones belonged to, and that there was a tendency for marginal effects as well at the medial and lateral sides of the hand, but that such effects e were not demonstrated in the rays. Harris et al. (1992) also found that changes in hand bone lengths that occur after adulthood are more row-specific than ray-specific. Therefore, the neighboring bones for each brachydactyly type were selected as described below, with selection preference given to neighboring bones in the same row rather than the same ray, except for the largest bone immediately adjacent to the brachydactylous one in the same ray. An analysis with both sexes combined was conducted first. Then a separate analysis was done that treated the sexes separately to determine whether sex influenced the identified bone proportions. The bones analyzed for BD-H-IP5, BD-F-MT4, and BD-H-DP1 are featured in Figure 5.

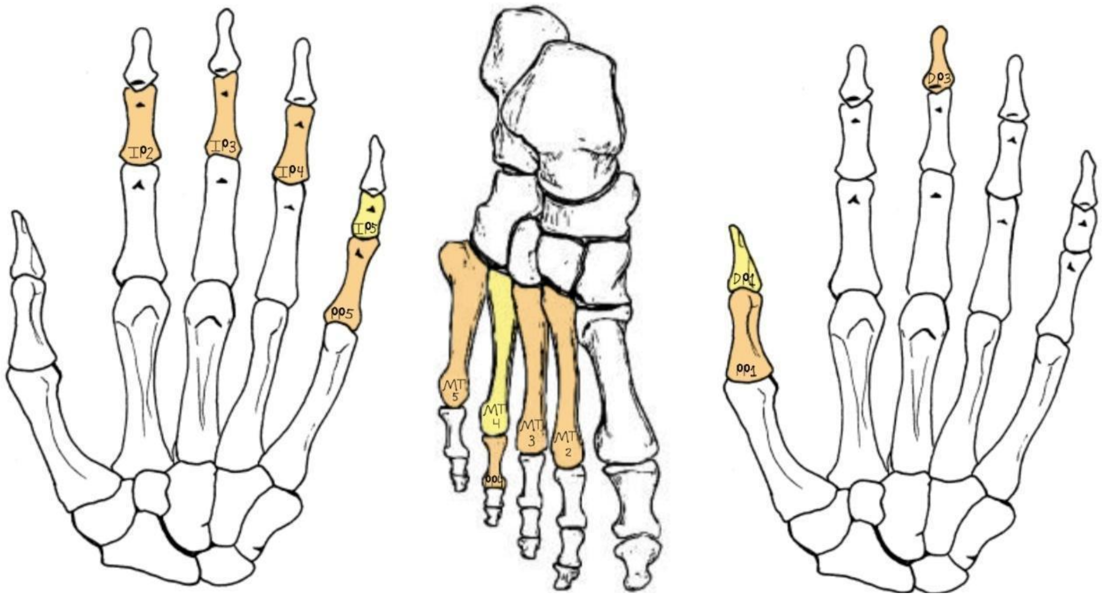

Figure 5. From left to right, BD-H-IP5, BD-F-MT4, and BD-H-DP1. The yellow highlighted bone is the type of brachydactyly being analyzed, and the orange highlighted bones are the neighboring digits in the analysis. For BD-H-IP5 and BD-H-DP1, the left hand is featured, but both sides were analyzed. For BD-F-MT4, only the right foot had measurements available, so it was the side analyzed.

To assess whether bones adjacent to a brachydactylous bone are affected, it was necessary to identify “control” bones for each brachydactyly type. The “control” bones should be from the same bone row so that they are under the same influence from row-related growth factors as the other bones of the row, from the central part of the row to avoid marginal factors, and far enough from the brachydactylous bone to avoid direct neighbor effects from whatever factor is causing the brachydactyly. They are also bones not commonly reported as being brachydactylous. These control bones should reflect non-brachydactylous length for an individual and serve as a benchmark so that the relative length relationships between neighboring bones can be compared and understood. For BD-H-DP1, the first and third distal phalanx are the easiest to identify. Due to this, and the high amount of variation in the distal phalanges, as outlined by Kimura (1973), and unreliability when siding, the only other distal phalanx used as a neighboring bone within this analysis was the third distal phalanx. The controls selected for each type of brachydactyly are as follows; for BD-H-IP5 it will be the intermediate third left and right phalanges; for BD-F-MT4 it will be metatarsal two; for BD-H-DP1, it will be the distal third left and right phalanges. The reason that RMT3 was not chosen as the control for MT4 brachydactyly, following the pattern from the hands of the third ray being the control, is because MT3 is immediately adjacent to MT4 and because for one of the brachydactylous individuals, there was brachydactyly of both MT3 and MT4, which is an uncommon occurrence. Therefore, the second ray was chosen. These control bones are intended to represent the “normal" size for the bones of the relevant phalangeal row, to which bones in both non-brachydactylous and brachydactylous hands and feet can be compared. The samples used to investigate BD-H-IP5, BD-F-MT4, and BD-H-DP1 can be seen in Table 5. The sample sizes exclude individuals with missing data for the relevant bones of each investigation and individuals with problematic lipping. It should be specified that these are the numbers of individuals in the two samples before outliers were removed (see below). In the sample of individuals with identified brachydactyly, the breakdown of sexes can be seen in Table 5. Still, due to the small number of individuals with visually identified brachydactyly, sexual differences were still viewed overall but the sexes were not intentionally separated as was done with the non-brachydactylous sample.

Table 5. These three tables show the final samples used per type of brachydactyly.

BD-H-IP5			
	Normal	Brachydactyly	N
Females	142	4	146
Males	141	3	144
Total	283	7	290

BD-F-MT4			
	Normal	Brachydactyly	N
Females	144	1	145
Males	153	2	155
Total	297	3	300

BD-H-DP1			
	Normal	Brachydactyly	N
Females	128	4	132
Males	135	3	138
Total	263	7	270

Statistical Analysis

Statistical analysis was performed using IBM SPSS Software, Version 28.0.1.0 (142). Descriptive statistics were calculated separately by sex for each bone identified for the types of brachydactyly being analyzed. Boxplots were used to identify potential outliers in the non-brachydactylous sample. These were removed if they were significant outliers, as the goal is to define what relatively normal ratios of bone lengths look like for specific areas of the hand or foot. Z-scores were also calculated for each bone in the non-brachydactylous data set, and individuals with Z-scores greater than three standard deviations from the mean were also removed, as such outliers more likely represent measurement error, recording error, or individuals with unrecognized developmental issues rather than a typical individual in the population. Outliers can have an outsized effect on the mean or standard deviation of a sample, and as the goal is to define something close to "normal," these were removed whether they were on the shorter or longer end of the distribution. Once the data were cleaned, the total sample for each type can be seen in Tables 6-8. It is important to note that one individual with BD-H-DP1 had bone lipping. Due to this, the individual was used to talk about how the DP1 lengths compare to non-brachydactylous individuals, but was not used to discuss the ratio of DP1 to DP3 because DP3 is probably longer than it should be due to the presence of lipping.

Table 6. The percentage of bones for BD-H-IP5 that were removed and identified as brachydactylous and as outliers, compared with non-brachydactylous bones for the final samples used in the analysis.

	BD-H-IP5						
		Present		Missing		Total	
	Sample Type	N	%	N	%	N	%
LPP5	Normal	285	96.6%	10	3.4%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
LIP2	Normal	282	95.6%	13	4.4%	295	100%
	Brachydactyly	6	85.7%	1	14.3%	7	100%
	Outliers	23	100%	0	0%	23	100%
LIP3	Normal	281	95.3%	14	4.7%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	22	95.7%	1	4.3%	23	100%
LIP4	Normal	279	94.6%	16	5.4%	295	100%
	Brachydactyly	7	100%	7	100%	7	100%
	Outliers	22	95.7%	1	4.3%	23	100%
LIP5	Normal	278	94.2%	17	5.8%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
RPP5	Normal	290	98.3%	5	1.7%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
RIP2	Normal	290	98.3%	5	1.7%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
RIP3	Normal	290	98.3%	5	1.7%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
RIP4	Normal	289	98.0%	6	2.0%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%
RIP5	Normal	287	97.3%	8	2.7%	295	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	23	100%	0	0%	23	100%

Table 7. The percentage of bones for BD-F-MT4 that were removed and identified as brachydactylous and as outliers, compared with non-brachydactylous bones for the final samples used in the analysis.

BD-F-MT4							
		Present		Missing		Total	
	Sample Type	N	%	N	%	N	%
RMT2	Normal	284	97.3%	8	2.7%	292	100%
	Brachydactyly	3	100%	0	0%	3	100%
	Outliers	18	100%	0	0%	18	100%
RMT3	Normal	285	97.6%	7	2.4%	292	100%
	Brachydactyly	3	100%	0	0%	3	100%
	Outliers	18	100%	0	0%	18	100%
RMT4	Normal	283	96.9%	9	3.1%	292	100%
	Brachydactyly	3	100%	0	0%	3	100%
	Outliers	18	100%	0	0%	18	100%
RMT5	Normal	288	98.6%	4	1.4%	292	100%
	Brachydactyly	3	100%	0	0%	3	100%
	Outliers	18	100%	0	0%	18	100%
RPedPP4	Normal	289	99%	3	1.0%	292	100%
	Brachydactyly	3	100%	0	0%	3	100%
	Outliers	18	100%	0	0%	18	100%

Table 8. The percentage of bones for BD-H-DP1 that were removed and identified as brachydactylous and as outliers, compared with non-brachydactylous bones for the final samples used in the analysis.

BD-H-DP1							
		Present		Missing		Total	
	Sample Type	N	%	N	%	N	%
LPP1	Normal	286	96.6%	10	3.4%	296	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	13	100%	0	0%	13	100%
LDP1	Normal	287	97%	9	3%	296	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	13	100%	0	0%	13	100%
LDP3	Normal	258	87.2%	38	12.8%	296	100%
	Brachydactyly	4	57.1%	3	42.9%	7	100%
	Outliers	13	100%	0	0%	13	100%
RPP1	Normal	293	99%	3	1%	296	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	13	100%	0	0%	13	100%
LDP1	Normal	292	98.6%	4	1.4%	296	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	13	100%	0	0%	13	100%
LDP3	Normal	276	93.2%	20	6.8%	296	100%
	Brachydactyly	7	100%	0	0%	7	100%
	Outliers	13	100%	0	0%	13	100%

Once the outliers were removed, the non-brachydactylous distributions were analyzed separately by sex. A Shapiro-Wilk normality test was carried out for each bone in each sample.

Ratios of bone length between the bone that is normally susceptible to brachydactyly and the control bone were calculated, along with similar ratios between neighboring bones and the control, to ascertain a typical ratio and range of variation that might be expected in the non-brachydactylous population.

Next, the same ratios were calculated for the digits with brachydactyly to determine how much the brachydactylous bones differ from the non-brachydactylous range. This showed me what sort of cutoff point(s) would identify each individual with brachydactyly while excluding any (or the vast majority, at least) of the non-brachydactylous individuals. The closest neighbors of these brachydactylous bones were also compared to the controls to determine whether they seemed to be at all affected by whatever factor had led to brachydactyly in the more obviously affected bone.

Standard deviation values for the brachydactylous bones were calculated based on the non-brachydactylous distribution to determine how far the visually identified brachydactylous bones were below the population mean to aid in further investigating the impact of brachydactyly on neighboring bones. Three, four, or five standard deviations below the mean might indicate brachydactyly within the sample. Individuals previously removed as outliers were included in the descriptive statistics to understand how they related to the non-brachydactylous and brachydactylous samples; however, they were included in the brachydactyly case studies. The two samples (non-brachydactylous and brachydactylous) were analyzed by sex through ANOVA to see the impacts of sexual dimorphism on the sample population.

Mann-Whitney non-parametric tests were used to understand the relationship, if any, that existed between the neighboring bones of the hands and feet and whether brachydactyly did impact those bones. The Mann-Whitney non-parametric test uses two categorical, independent groups, which in the case of this thesis, would be the brachydactylous and non-brachydactylous samples. This test is a more conservative statistical test where normal distribution and equal variance are not assumed. This test was done first for females before analyzing the males. The Mann-Whitney non-parametric test was done to analyze the bone lengths and the directly neighboring bone ratios. Due to the "rule of neighborhood" discussed in the previous chapter (Lewenz & Whitely 1902, Hewitt 1963), there is a higher probability for these ratios to be impacted when brachydactyly is present, so that is why only those ratios for this section of the analysis, were used.

Lastly, the individuals with brachydactyly were analyzed separately as case studies by type of brachydactyly to look for a consistent pattern of lower-than-expected z-scores compared to the control bone as a means of analyzing more subtle shortening effects. The outliers were included in these case studies to investigate whether they fall into the brachydactylous ranges, with the potential of showing that it is possible to identify brachydactyly metrically where it may have been missed during the morphological analysis. For the pattern recognition, the Z-scores were calculated using the formula:

$$Z - score = \frac{(\ brachydactyly\ x) - (\ normal\ \mu)}{(normal\ \sigma)} \text{ and } Z - score = \frac{(\ outlier\ x) - (\ normal\ \mu)}{(normal\ \sigma)}$$

This was done separately by the affected side, both because some individuals were only affected unilaterally and because of size variation that can result from directional asymmetry. As noted previously, the neighboring bones for each brachydactyly type were selected as described below, with the selection preference given to neighboring bones in the same row rather than the same ray. The case studies aim to discern whether the neighboring bones consistently show lower Z-scores than the other bones. If so, that would be a sign of a minor effect from brachydactyly on the neighboring bones, even if it is not enough to be discernible through simple visual inspection or small-sample statistical analysis. However, the standard deviations would need to be consistently lower for the neighboring bones for this analysis to show an effect. Otherwise, it can be concluded there is no real effect; at this point, the ratios developed for this sample (both from the non-brachydactylous and brachydactylous samples) could be applied to other cases where brachydactyly is suspected. Within the BD-F-MT4 case study sample of three individuals, one individual, the only female, had to be removed from analysis due to the brachydactyly being morphologically seen in the left foot, while measurements were only available for the right foot.

Chapter 4: Results

This chapter will compile the results obtained in this thesis based on the analyses done to ascertain whether there is an impact on the neighboring bones of the hand and feet due to brachydactyly. This chapter has been divided into subsections to assist in presenting the information. It includes information regarding the sample population descriptives, tests of normality, bone measurement ranges, bone ratio ranges, ANOVA analysis, Mann-Whitney analysis, and the brachydactyly case studies.

Sample Population Descriptives

Once the data were cleaned for outliers, descriptive statistical summaries were calculated using the non-brachydactylous sample's bone measurements, then compared with the samples of brachydactylous individuals and the outlier individuals. Due to missing measurements, the count of skeletons for each bone measurement is listed in Tables 9-11. Males and females were separated to ascertain whether sexual dimorphism was present in the measurements used to examine the three types of brachydactyly. Within the descriptives for BD-F-MT4, the sample size is comprised of three individuals, with one individual, the only female, having to be removed from analysis due to the brachydactyly being morphologically seen in the left foot; however, only right foot measurements were provided for this study.

As expected, based on the literature reviewed, the means amongst the non-brachydactylous, brachydactylous, and outlier individuals show a general pattern of sexual dimorphism, with females having consistently smaller mean bone lengths than males. As anticipated, the mean lengths for the brachydactylous bones (IP5, DP1, and MT4) are also smaller than the mean lengths of the non-brachydactylous sample.

Table 9. The descriptive summaries for BD-H-IP5. The mean is in mm.

Descriptives for BD-H-IP5							
		Female			Male		
Bone	Sample Type	N	Mean	SD	N	Mean	SD
LPP5	Normal	148	31.4333	1.77468	137	34.4032	1.71063
	Brachydactyly	4	28.2225	1.88068	3	33.3200	0.68608
	Outliers	8	30.2638	5.99323	15	34.3400	3.43012
LIP2	Normal	145	22.8131	1.63436	137	25.2374	1.71873
	Brachydactyly	4	20.9850	1.29487	2	23.4850	0.00707
	Outliers	8	22.7150	3.60270	15	25.4993	3.38418
LIP3	Normal	145	27.7494	1.90801	136	30.8843	1.89236
	Brachydactyly	4	25.8400	1.37344	3	31.1233	2.15282
	Outliers	8	27.2163	4.28800	14	29.9821	4.25562
LIP4	Normal	146	26.2758	1.81778	133	29.6674	1.88112
	Brachydactyly	4	23.3275	1.99937	3	29.3567	2.63608
	Outliers	8	25.9875	4.01467	14	29.5943	4.38253
LIP5	Normal	143	18.4783	1.72911	135	21.1112	1.69687
	Brachydactyly	4	14.2375	2.78498	3	17.4200	0.46508
	Outliers	8	17.7238	2.68844	15	22.5893	4.56314
RPP5	Normal	148	31.7846	1.78730	142	34.6890	1.77332
	Brachydactyly	4	28.8025	1.66596	3	33.4067	0.64841
	Outliers	8	31.5388	4.45308	15	34.4107	3.42371
RIP2	Normal	149	22.9266	1.59470	141	25.3825	1.80204
	Brachydactyly	4	21.2325	1.11015	3	24.1100	1.43885
	Outliers	8	21.8625	3.98549	15	25.6487	3.44431
RIP3	Normal	149	27.7756	1.85156	141	30.8403	1.80824
	Brachydactyly	4	26.1925	1.78752	3	30.8267	2.04554
	Outliers	8	26.6100	4.91481	15	29.5773	3.99681
RIP4	Normal	148	26.2961	1.86523	141	29.4057	1.86224
	Brachydactyly	4	23.3925	1.80679	3	29.1433	2.76097
	Outliers	8	25.7700	4.23455	15	29.3913	3.94581
RIP5	Normal	145	18.4401	1.63889	142	20.8379	1.59563
	Brachydactyly	4	14.6075	1.35367	3	17.2000	0.33779
	Outliers	8	18.5175	3.55656	15	23.1440	4.61275

Table 10. The descriptive summaries for BD-F-MT4. The mean is in mm. ** indicates the one female who was removed.

Descriptives for BD-F-MT4								
		Female			Male			
Bone	Sample Type	N	Mean	SD	N	Mean	SD	
RMT2	Normal	141	71.5348	4.19996	143	76.7643	3.56425	
	Brachydactyly	**	**	**	2	70.4950	5.02753	
	Outliers	4	70.5075	13.50289	14	77.5243	9.29696	
RMT3	Normal	141	66.8980	4.21354	144	71.7114	3.43573	
	Brachydactyly	**	**	**	2	60.3950	11.39149	
	Outliers	4	67.6900	12.31304	14	72.1257	9.64318	
RMT4	Normal	140	65.6565	4.11527	143	70.7105	3.55039	
	Brachydactyly	**	**	**	2	53.3850	3.20319	
	Outliers	4	66.6750	10.95267	14	70.5757	9.17676	
RMT5	Normal	141	67.1706	3.87534	147	72.8776	4.14986	
	Brachydactyly	**	**	**	2	64.0900	0.83439	
	Outliers	4	67.5500	9.86215	14	71.4807	9.04706	
RPedPP4	Normal	143	23.9619	1.70745	146	26.5371	1.40007	
	Brachydactyly	**	**	**	2	24.3600	2.89914	
	Outliers	4	23.7525	5.53884	14	26.3036	3.98232	

Table 11. The descriptive summaries for BD-H-DP1. The mean is in mm.

Descriptives for BD-H-DP1							
		Female			Male		
Bone	Sample Type	N	Mean	SD	N	Mean	SD
LPP1	Normal	143	29.8022	1.86226	143	32.8860	1.91946
	Brachydactyly	3	27.7133	4.66460	3	32.0333	2.84001
	Outliers	6	29.4567	2.95390	7	31.3543	5.31271
LDP1	Normal	144	21.4665	1.53037	143	24.3207	1.47476
	Brachydactyly	3	19.4233	2.55259	3	19.9000	2.35217
	Outliers	6	22.0950	3.26711	7	22.0271	3.76064
LDP3	Normal	126	17.2306	1.17462	132	19.6480	1.31211
	Brachydactyly	2	15.4850	1.83141	1	21.3400	
	Outliers	6	16.8783	3.90952	7	19.3414	2.15050
RPP1	Normal	146	29.5642	1.90472	147	32.6208	1.92788
	Brachydactyly	3	26.6833	3.76505	3	31.6500	3.15240
	Outliers	6	29.2967	2.93106	7	31.0286	5.28416
RDP1	Normal	145	21.4724	1.40890	147	24.2154	1.40091
	Brachydactyly	3	15.7733	2.27159	3	20.5200	4.03668
	Outliers	6	20.3600	4.54655	7	20.9143	3.53878
RDP3	Normal	132	17.3364	1.21180	144	19.6953	1.28753
	Brachydactyly	3	16.1667	2.28018	3	19.5500	1.99697
	Outliers	6	16.5433	3.69483	7	19.4671	2.38854

For BD-H-IP5 among females, the average brachydactylous (IP5) bone measurement is much smaller, 23% on the left and 28% on the right, when compared to the non-brachydactylous mean. The average brachydactylous control (IP3) bone measurement is much closer, 7% on the left and 6% on the right when compared to the mean. Among males, the average brachydactylous (IP5) bone measurement is not as small as among females, 17% on both sides, when compared to the mean. The average brachydactylous control (IP3) bone measurement is much closer than among females, at <1% on both sides, when compared to the mean, and with the left side brachydactylous mean being slightly larger than the non-brachydactylous mean, suggesting that the three individuals who make up the sample, on average, have slightly larger hands than the population average.

For BD-F-MT4, among females, the percentages for average brachydactylous (MT4) and control (MT2) bone measurements, when compared to the mean, were unable to be calculated due to a lack of brachydactyly data. Among males, the average brachydactylous (MT4) bone measurement is much smaller, 25% on the right side, when compared to the mean. The average brachydactylous control (MT2) bone measurement is not as small, 8% on the right side when compared to the non-brachydactylous mean.

For BD-H-DP1, among females, the average brachydactylous (DP1) bone measurement is much smaller on the right (27%) compared to 10% on the left when compared to the non-brachydactylous mean. The average brachydactylous control (DP3) bone measurement is much closer, 10% shorter on the left and 7% on the right, when compared to the non-brachydactylous mean. This means that the average percentage of the difference between the means for the two samples on the left side is the same. Among males, the average brachydactylous (DP1) bone measurement is much smaller, relatively, than for females, 18% smaller on the left and 15% on the right, when compared to the non-brachydactylous mean. The average brachydactylous control (DP3) bone measurement is much closer to the mean than among females, differing by <1% on both sides when compared to the mean, and with the left side brachydactylous mean being larger than the non-brachydactylous mean.

The outliers seen within these descriptive statistics require further explanation. If one individual was seen as an outlier in a boxplot for only one of the bones analyzed per type, they were removed. In most cases, the same individual was seen as an outlier for multiple bones. These individual outliers have been pulled into Tables 12-14 to show the high-end and low-end outliers from the boxplots and the outliers removed based on the z-scores for BD-H-IP5. There are 23 outliers for BD-H-IP5, 18 outliers for BD-F-MT4, and 13 outliers for BD-H-DP1.

Table 12. Outliers for BD-H-IP5 identified by boxplots and Z-scores. ** indicates no outlier individuals.

Outliers for BD-H-IP5										
	Boxplots								Z-score	
	Low				High				High	
	Female		Male		Female		Male		Female	
Bone	N	CaseNum	N	CaseNum	N	CaseNum	N	CaseNum	N	CaseNum
LPP5	2	251, 235	1	20	3	9, 314, 315	2	64, 199	0	**
LIP2	0	**	2	20, 130	0	**	2	177, 199	0	**
LIP3	0	**	2	20, 221	1	315	1	199	0	**
LIP4	0	**	3	66, 20, 130	0	**	1	199	0	**
LIP5	0	**	1	20	0	**	3	199, 220, 135	1	103
RPP5	1	235	1	20	3	9, 315, 314	2	199, 64	0	**
RIP2	2	295, 263	1	20	2	315, 314	1	61	0	**
RIP3	1	90	1	20	0	**	1	199	0	**
RIP4	0	**	2	20, 130	0	**	1	199	0	**
RIP5	0	**	1	20	0	**	5	199, 84, 62, 123, 77	0	**

Table 13. Outliers for BD-F-MT4 identified by boxplots. ** indicates no outlier individuals.

Outliers for BD-F-MT4								
	Boxplots							
	Low				High			
	Female		Male		Female		Male	
Bone	N	CaseNum	N	CaseNum	N	CaseNum	N	CaseNum
RMT2	1	295	2	132, 20	1	246	3	64, 100, 177
RMT3	0	**	3	132, 82, 186	1	246	3	208, 100, 177
RMT4	0	**	3	186, 132, 20	0	**	4	64, 208, 100, 177
RMT5	1	235	1	20	0	**	0	**
RPedPP4	2	295, 235	4	130, 189, 82, 166	1	315	4	43, 67, 199, 177

Table 14. Outliers for BD-H-DP1 identified by boxplots. ** indicates no outlier individuals.

Outliers for BD-H-DP1								
	Boxplots							
	Low				High			
	Female		Male		Female		Male	
Bone	N	CaseNum	N	CaseNum	N	CaseNum	N	CaseNum
LPP1	0	**	2	7, 20	0	**	0	**
LDP1	0	**	3	7, 153, 209	1	314	0	**
LDP3	1	310	0	**	1	314	0	**
RPP1	0	**	2	20, 7	0	**	1	45
RDP1	2	90, 306	5	7, 77, 209, 20, 62	2	69, 314	0	**
RDP3	1	272	2	20, 209	1	314	0	**

Test of Normality

The next part of the analysis was the normality testing for the chosen bones used to examine the three types of brachydactyly in the larger sample intended to represent a typical population of non-brachydactylous individuals. The Shapiro-Wilk Test was used to test for normality, and a p-value of 0.05 was used as the alpha. An alpha of less than 0.05 suggests a non-normal distribution for a variable. Normally distributed data are required to create bone measurement ranges for the non-brachydactylous sample and to understand the ratio relationships between the neighboring bones in the hands and feet. Non-normal distribution in the case of measurements can be a sign of some problems with the data or errors that occurred during data collection. The data were normally distributed after the outliers were identified and removed as discussed in the Materials and Methods section.

For BD-H-IP5, the initial non-brachydactylous sample before outliers were removed was not normally distributed for LPP5 females, LIP4 males, and LIP5 and RIP5 males. For BD-F-MT4, the initial sample before outliers were removed was not normally distributed for RMT3 males. RMT2 males and RPedPP4 (Pedal PP4) males were normally distributed but close to the 0.05 p-value alpha. This suggests that the control (MT2) and the neighboring digits (MT3 and PedPP4) may be somewhat susceptible to the subtle effects of the tendency of MT4 toward brachydactyly. For BD-H-DP1, most of the initial non-brachydactylous sample before outliers were removed was not normally distributed, with it only being normally distributed for LDP1 females, LDP3 males, RPP1 males, and RDP1 males. It was also normally distributed for RDP1 females, but it was close to the 0.05 p-value alpha.

Bone Measurement Ranges

The results of the analyses to create bone measurement ranges for the two samples by sex can be seen in Tables 15-17.

Table 15. The bone measurement ranges for BD-H-IP5. The minimum and maximum are in mm.

Bone Measurement Range					
		Female		Male	
Bone	Sample Type	Minimum	Maximum	Minimum	Maximum
LPP5	Normal	27.57	36.91	30.36	39.08
	Brachydactyly	26.68	30.52	32.81	34.10
LIP2	Normal	19.42	27.70	21.50	29.03
	Brachydactyly	19.20	22.13	23.48	23.49
LIP3	Normal	23.77	34.25	26.06	35.30
	Brachydactyly	24.51	27.38	29.26	33.48
LIP4	Normal	21.54	32.75	25.15	33.55
	Brachydactyly	21.55	25.47	27.05	32.23
LIP5	Normal	13.70	24.41	16.92	25.99
	Brachydactyly	10.25	16.39	16.95	17.88
RPP5	Normal	27.07	37.44	30.43	39.30
	Brachydactyly	27.07	30.87	32.80	34.09
RIP2	Normal	19.02	27.42	21.54	30.67
	Brachydactyly	19.71	22.13	23.22	25.77
RIP3	Normal	23.78	31.94	26.03	34.73
	Brachydactyly	24.83	28.61	29.11	33.09
RIP4	Normal	21.58	31.23	25.38	33.17
	Brachydactyly	21.74	25.14	26.97	32.25
RIP5	Normal	13.61	23.54	16.66	24.63
	Brachydactyly	13.05	16.02	16.89	17.56

Table 16. The bone measurement ranges for BD-F-MT4. The minimum and maximum are in mm.

Bone Measurement Range					
		Female		Male	
Bone	Sample Type	Minimum	Maximum	Minimum	Maximum
RMT2	Normal	61.08	81.58	67.20	87.17
	Brachydactyly	**	**	66.94	74.05
RMT3	Normal	57.65	78.23	65.00	80.32
	Brachydactyly	**	**	52.34	68.45
RMT4	Normal	56.24	74.61	62.18	78.98
	Brachydactyly	**	**	51.12	55.65
RMT5	Normal	57.60	76.18	64.75	84.48
	Brachydactyly	**	**	63.50	64.68
RPedPP4	Normal	19.76	28.10	22.61	30.17
	Brachydactyly	**	**	22.31	26.41

Table 17. The bone measurement ranges for BD-H-DP1. The minimum and maximum are in mm.

Bone Measurement Range					
		Female		Male	
Bone	Sample Type	Minimum	Maximum	Minimum	Maximum
LPP1	Normal	24.86	35.37	28.11	38.37
	Brachydactyly	22.44	31.30	30.01	35.28
LDP1	Normal	18.04	27.53	20.98	27.83
	Brachydactyly	17.89	22.37	17.21	21.57
LDP3	Normal	14.56	19.74	16.76	23.20
	Brachydactyly	14.19	16.78	21.34	21.34
RPP1	Normal	24.07	35.17	27.61	38.34
	Brachydactyly	22.93	30.46	29.81	35.29
RDP1	Normal	18.23	26.28	20.67	27.59
	Brachydactyly	13.90	18.30	17.48	25.10
RDP3	Normal	14.64	20.26	17.10	23.00
	Brachydactyly	13.75	18.28	17.72	21.68

Bone Ratio Ranges

To investigate whether brachydactyly impacts the neighboring bones of the hands and feet, ratios were calculated between the control and other applicable digits for each bone most commonly susceptible to brachydactyly. As previously discussed in the last chapter, the control bones for each type of brachydactyly are as follows; for BD-H-IP5, it will be the proximal and intermediate second left and right phalanges; for BD-F-MT4, it will be metatarsal two; for BD-H-DP1, it will be the distal third left and right phalanges.

The ratios calculated for both sexes can be seen in Tables 18-20. A complete list of every ratio by type of brachydactyly analyzed will be available in Appendix A, Parts I-III. It is also important to note that the length ratios reported here between the bones may vary from measurements taken with calipers. The measurements of the bones used in this thesis were taken using a mini-osteometric board so that the ratios might differ somewhat from those produced in other studies if the proximal and distal measurement points differ due to the instrument used. When analyzing the ratio ranges, if a ratio at the minimum or maximum of the range was more than 0.05 from the closest value, it was removed to get more consistent ranges within the non-brachydactylous sample population. A difference of 0.05 is only seen at the extremes of these ranges and could result from measurement error in such a large dataset.

Table 18. The bone ratio ranges for BD-H-IP5. Ratios are based on measurements in mm.

		Bone Ratio Range					
		Female			Male		
Bone	Sample Type	Minimum	Mean	Maximum	Minimum	Mean	Maximum
LIP3/LIP2	Normal	1.12	1.22	1.33	1.10	1.22	1.36
	Brachydactyly	1.17	1.23	1.30	1.25	1.28	1.30
LIP3/LIP4	Normal	0.95	1.06	1.12	0.98	1.04	1.13
	Brachydactyly	1.04	1.11	1.15	1.04	1.06	1.08
LIP3/LIP5	Normal	1.33	1.51	1.80	1.23	1.47	1.68
	Brachydactyly	1.67	1.90	2.43	1.68	1.79	1.87
LIP3/LPP5	Normal	0.78	0.88	0.96	0.80	0.90	0.96
	Brachydactyly	0.90	0.92	0.93	0.89	0.93	0.98
LIP5/LIP2	Normal	0.70	0.81	0.93	0.70	0.84	0.93
	Brachydactyly	0.53	0.67	0.74	0.72	0.73	0.74
LIP5/LIP4	Normal	0.60	0.70	0.81	0.63	0.71	0.83
	Brachydactyly	0.48	0.61	0.67	0.55	0.59	0.64
LIP5/LPP5	Normal	0.48	0.59	0.66	0.52	0.61	0.73
	Brachydactyly	0.38	0.50	0.55	0.51	0.52	0.53
RIP3/RIP2	Normal	1.07	1.21	1.33	1.14	1.22	1.37
	Brachydactyly	1.18	1.23	1.29	1.25	1.28	1.30
RIP3/RIP4	Normal	0.97	1.06	1.17	0.99	1.05	1.19
	Brachydactyly	1.07	1.12	1.14	1.03	1.06	1.08
RIP3/RIP5	Normal	1.32	1.51	1.76	1.33	1.50	1.70
	Brachydactyly	1.72	1.80	1.90	1.70	1.80	1.88
RIP3/RPP5	Normal	0.77	0.88	0.96	0.79	0.89	0.98
	Brachydactyly	0.89	0.91	0.93	0.87	0.92	0.97
RIP5/RIP2	Normal	0.67	0.81	0.93	0.67	0.82	0.93
	Brachydactyly	0.66	0.69	0.72	0.68	0.71	0.73
RIP5/RIP4	Normal	0.61	0.70	0.81	0.63	0.71	0.79
	Brachydactyly	0.60	0.62	0.64	0.54	0.59	0.64
RIP5/RPP5	Normal	0.48	0.58	0.64	0.51	0.60	0.67
	Brachydactyly	0.48	0.51	0.53	0.51	0.52	0.52

Table 19. The bone ratio ranges for BD-F-MT4. Ratios are based on measurements in mm.

Bone Ratio Range							
		Female			Male		
Bone	Sample Type	Minimum	Mean	Maximum	Minimum	Mean	Maximum
RMT2/RMT3	Normal	1.01	1.07	1.15	1.03	1.07	1.13
	Brachydactyly	**	**	**	1.08	1.18	1.28
RMT2/RMT4	Normal	1.03	1.09	1.22	1.02	1.09	1.20
	Brachydactyly	**	**	**	1.31	1.32	1.33
RMT2/RMT5	Normal	0.98	1.07	1.16	0.94	1.05	1.19
	Brachydactyly	**	**	**	1.05	1.09	1.14
RMT2/RPedPP4	Normal	2.68	2.99	3.39	2.58	2.91	3.24
	Brachydactyly	**	**	**	2.80	2.90	3.00
RMT4/RMT3	Normal	0.90	0.98	1.04	0.90	0.98	1.06
	Brachydactyly	**	**	**	0.81	0.90	0.98
RMT4/RMT5	Normal	0.87	0.98	1.05	0.86	0.97	1.08
	Brachydactyly	**	**	**	0.81	0.83	0.86
RMT4/RPedPP4	Normal	2.43	2.75	3.06	2.39	2.67	2.93
	Brachydactyly	**	**	**	2.11	2.20	2.29

Table 20. The bone ratio ranges for BD-H-DP1. Ratios are based on measurements in mm.

Bone Ratio Range							
		Female			Male		
Bone	Sample Type	Minimum	Mean	Maximum	Minimum	Mean	Maximum
LDP3/LPP1	Normal	0.49	0.58	0.71	0.52	0.60	0.70
	Brachydactyly	0.48	0.51	0.54	0.60	0.60	0.60
LDP3/LDP1	Normal	0.71	0.81	0.97	0.69	0.81	0.91
	Brachydactyly	0.75	0.77	0.79	1.02	1.02	1.02
LDP1/LPP1	Normal	0.61	0.72	0.85	0.63	0.74	0.86
	Brachydactyly	0.61	0.71	0.80	0.57	0.62	0.70
RDP3/RPP1	Normal	0.49	0.59	0.70	0.49	0.60	0.69
	Brachydactyly	0.52	0.61	0.72	0.59	0.62	0.65
RDP3/RDP1	Normal	0.72	0.81	0.93	0.67	0.82	0.95
	Brachydactyly	0.99	1.03	1.09	0.86	0.96	1.01
RDP1/RPP1	Normal	0.58	0.73	0.85	0.62	0.74	0.85
	Brachydactyly	0.52	0.59	0.66	0.59	0.65	0.71

While there was some overlap and similarities between the non-brachydactylous sample and the brachydactylous samples in terms of the bone measurement ranges, once the ratios of those measurements were taken between the control and other applicable digits for each type, as well as the brachydactylous bone in question, the ratio ranges show a relatively clear difference, for each type, between the two samples. The mean for both samples and sexes for all three types of brachydactyly shows that the mean tends to fall in the middle of the ranges, suggesting a normally distributed range for each bone length and bone ratio that lacks skew.

For BD-H-IP5, among females, the LIP3/LIP5 ratio shows overlap with the non-brachydactylous sample only between the range of 1.67-1.80, and there is no overlap from 1.81 - 2.43. Even less overlap is seen on the right side, where the only overlapping ratio is 1.72-1.76, and there is no overlap between 1.77 and 1.90. Thus, any ratio above 1.80 has a high probability of indicating brachydactyly of IP5 in females, regardless of side. Among males, the LIP3/LIP5 ratio does not overlap with the non-brachydactylous sample ending at 1.68, where the brachydactylous range starts. This same pattern of no overlap is seen on the right side with the non-brachydactylous sample for the RIP3/RIP5 ratio ending at 1.70, which is where the brachydactylous sample starts the ratio range. Since 1.68 on the left side overlaps with 1.70 on the right side, a ratio above 1.70 overall has a high probability of indicating brachydactyly of IP5 in males.

For BD-F-MT4 among females, the RMT2/RMT4 ratio was only available for the non-brachydactylous sample, so any ratio above 1.22 has a high probability of indicating brachydactyly of MT4 in females. Among males, the RMT2/RMT4 ratio has no overlap between the two samples. Even though the non-brachydactylous sample ends at 1.20 and the brachydactylous sample ratio starts at a minimum of 1.31, it would be safer to use the latter as a designation point, since the in-between range of 1.20-1.31 could be outliers. So, if any ratio above 1.31 is found, there is a high probability of indicating brachydactyly of MT4 in males

For BD-H-DP1, among females, the LDP3/LDP1 ratio shows a complete overlap with the non-brachydactylous sample having a range of 0.71-0.97 and the brachydactylous sample having a range of 0.75-0.79. The RDP3/RDP1 ratio shows no overlap between the two samples, with the non-brachydactylous sample having a maximum of 0.93 and the brachydactylous sample having a minimum of 0.99. Given the ratio ranges of the left side, using the right-side ratio range as a designation point would be safer. Since the right maximum of 0.93 overlaps with the left side maximum of 0.97, any ratio above 0.99 has a high probability of indicating brachydactyly of DP1 in females. Among males, the RDP3/RDP1 ratio shows no overlap between the two samples. It should also be noted that LDP3/LDP1 only had an N of 1, and the right-side ratio does show overlap. The non-brachydactylous sample has a maximum of 0.95, with the brachydactylous sample having a minimum of 0.86, showing an overlap between the two samples. Due to this overlap and given the N of 1 on the left side, the maximum of 0.95 on the non-brachydactylous sample's right side should be with the maximum of the brachydactylous sample's left side, creating a range of 0.95-1.01. So, any ratio above 0.95 has a high probability of indicating brachydactyly of DP1 in males.

The ratio benchmarks described above are in Table 21 for quick reference.

Table 21. Ratio benchmarks that indicate any ratio at or above the value have a high probability of indicating brachydactyly.

Ratio Benchmarks for BD-H-IP5		
Ratios	Females	Males
IP3/IP5	1.80 +	1.70 +

Ratio Benchmarks for BD-F-MT4		
Ratios	Females	Males
MT2/MT4	1.22 +	1.31 +

Ratio Benchmarks for BD-H-DP1		
Ratios	Females	Males
DP3/DP1	0.99 +	0.95 +

By having a clearer difference, which will be further discussed in the next chapter, biological anthropologists should be able to use these ratios to understand the relationship of IP5, MT4, and DP1 to the neighboring bones and estimate whether the presence of brachydactyly of the hands and feet has a direct impact on the neighboring bones.

The ratios for the brachydactyly individuals are substantially larger than the ranges for the non-brachydactylous individuals for all three types of brachydactyly analyzed. The ratios were substantially higher since the brachydactylous bones were noticeably shorter in length than the non-brachydactylous ones. This is also emphasized by taking the directional asymmetry of the malformation into the analysis by only applying the brachydactylous bone of the appropriate side and sex when applicable.

ANOVA Analysis

To further understand the impact of sexual dimorphism on length variation between the sexes, ANOVA analysis was conducted. For each type of brachydactyly analyzed, the applicable bone measurements and ratios, as the dependent variable, were compared with sex as the independent variable to gauge variation, and a p-value of 0.05 was used as the alpha. The null hypothesis was that there is no impact on length variation and/or bone interrelationships caused by sexual differences, and the alternate hypothesis is that there is an impact on length variation and/or bone interrelationships caused by sexual differences. This analysis can be seen in Tables 22-24. This ANOVA analysis was done for both the non-brachydactylous and brachydactylous samples.

Table 22. The ANOVA analysis for BD-H-IP5 compared with sex to gauge variation.

ANOVA Analysis of Sexual Dimorphism									
Sexual Dimorphic Impacts on Bone Length					Sexual Dimorphic Impacts on Bone Ratios				
Bone	Sample Type	df	F	Significance	Bone	Sample Type	df	F	Significance
LPP5	Normal	283	206.268	**<0.001**	LIP3/LIP2	Normal	276	1.246	0.265
	Brachydactyly	5	19.280	**0.007**		Brachydactyly	4	1.037	0.366
LIP2	Normal	280	147.417	**<0.001**	LIP3/LIP4	Normal	273	20.049	**<.001**
	Brachydactyly	4	6.627	0.062		Brachydactyly	5	2.705	0.161
LIP3	Normal	279	190.964	**<0.001**	LIP3/LIP5	Normal	271	15.951	**<.001**
	Brachydactyly	5	16.027	**0.010**		Brachydactyly	5	0.131	0.733
LIP4	Normal	277	234.369	**<0.001**	LIP3/LPP5	Normal	276	9.521	**0.002**
	Brachydactyly	5	12.035	**0.018**		Brachydactyly	5	0.539	0.496
LIP5	Normal	276	163.944	**<0.001**	LIP5/LIP2	Normal	272	16.158	**<.001**
	Brachydactyly	5	3.663	0.114		Brachydactyly	4	0.641	0.468
RPP5	Normal	288	192.842	**<0.001**	LIP5/LIP4	Normal	270	6.462	**0.012**
	Brachydactyly	5	19.821	**0.007**		Brachydactyly	5	0.041	0.847
RIP2	Normal	288	151.424	**<0.001**	LIP5/LPP5	Normal	275	35.779	**<.001**
	Brachydactyly	5	9.055	**0.030**		Brachydactyly	5	0.189	0.682
RIP3	Normal	288	203.043	**<0.001**	RIP3/RIP2	Normal	286	0.278	0.598
	Brachydactyly	5	10.253	**0.024**		Brachydactyly	5	1.715	0.247
RIP4	Normal	287	201.004	**<0.001**	RIP3/RIP4	Normal	285	4.588	**0.033**
	Brachydactyly	5	11.321	**0.020**		Brachydactyly	5	6.081	0.057
RIP5	Normal	285	157.633	**<0.001**	RIP3/RIP5	Normal	283	8.721	**0.003**
	Brachydactyly	5	10.062	**0.025**		Brachydactyly	5	0.008	0.934
					RIP3/RPP5	Normal	284	9.550	**0.002**
						Brachydactyly	5	0.273	0.623
					RIP5/RIP2	Normal	284	7.962	**0.005**
						Brachydactyly	5	1.434	0.285
					RIP5/RIP4	Normal	284	3.187	0.075
						Brachydactyly	5	1.607	0.261
					RIP5/RPP5	Normal	284	25.293	**<.001**
						Brachydactyly	5	0.53	0.499

Table 23. The ANOVA analysis for BD-F-MT4 compared with sex to gauge variation.

ANOVA Analysis of Sexual Dimorphism									
Sexual Dimorphic Impacts on Bone Length					Sexual Dimorphic Impacts on Bone Ratios				
Bone	Sample Type	df	F	Significance	Bone	Sample Type	df	F	Significance
RMT2	Normal	282	128.119	**<0.001**	RMT2/RMT3	Normal	280	0.260	0.610
	Brachydactyly	1	2.054	0.388		Brachydactyly	1	1.365	0.451
RMT3	Normal	283	111.922	**<0.001**	RMT2/RMT4	Normal	280	1.836	0.177
	Brachydactyly	1	0.031	0.888		Brachydactyly	1	200.936	**0.045**
RMT4	Normal	281	122.528	**<0.001**	RMT2/RMT5	Normal	280	6.575	**0.011**
	Brachydactyly	1	1.488	0.437		Brachydactyly	1	0.059	0.848
RMT5	Normal	286	145.199	**<0.001**	RMT2/RPedPP4	Normal	280	24.974	**<.001**
	Brachydactyly	1	47.056	0.092		Brachydactyly	1	0.911	0.515
RPedPP4	Normal	287	196.933	**<0.001**	RMT4/RMT3	Normal	280	0.839	0.360
	Brachydactyly	1	0.271	0.694		Brachydactyly	1	0.046	0.866
					RMT4/RMT5	Normal	280	3.120	0.078
						Brachydactyly	1	15.118	0.160
					RMT4/RPedPP4	Normal	279	18.679	**<.001**
						Brachydactyly	1	5.823	0.250

Table 24. The ANOVA analysis for BD-H-DP1 compared with sex to gauge variation.

ANOVA Analysis of Sexual Dimorphism									
Sexual Dimorphic Impacts on Bone Length					Sexual Dimorphic Impacts on Bone Ratios				
Bone	Sample Type	df	F	Significance	Bone	Sample Type	df	F	Significance
LPP1	Normal	284	190.140	**<0.001**	LDP3/LPP1	Normal	253	14.910	**<0.001**
	Brachydactyly	4	1.877	0.243		Brachydactyly	1	4.256	0.287
LDP1	Normal	285	258.766	**<0.001**	LDP3/LDP1	Normal	254	0.292	0.589
	Brachydactyly	4	0.057	0.824		Brachydactyly	1	44.363	0.095
LDP3	Normal	256	242.329	**<0.001**	LDP1/LPP1	Normal	282	15.290	**<.001**
	Brachydactyly	1	6.814	0.233		Brachydactyly	4	1.590	0.276
RPP1	Normal	291	186.342	**<0.001**	RDP3/RPP1	Normal	273	12.233	**<.001**
	Brachydactyly	4	3.069	0.155		Brachydactyly	4	0.012	0.920
RDP1	Normal	290	278.281	**<0.001**	RDP3/RDP1	Normal	273	0.730	0.394
	Brachydactyly	4	3.150	0.151		Brachydactyly	4	1.088	0.356
RDP3	Normal	274	244.521	**<0.001**	RDP1/RPP1	Normal	288	11.266	**<.001**
	Brachydactyly	4	3.738	0.125		Brachydactyly	4	0.876	0.402

For BD-H-IP5, the results show that sex has an unsurprising, highly statistically significant impact on all bone lengths in the non-brachydactylous sample for both sides, but surprisingly, for the ratios LIP3/LIP4, LIP3/LIP5, LIP5/LIP2, LIP5/LPP5, and RIP5/RPP5 as well. The fact that four ratios are affected on the left but only one on the right suggests the possibility that sex has more impact on bone ratios on the left side compared to the right. Among the bone ratios, it is interesting that the IP3/IP2 ratio, for both sides, is not significantly different between the sexes, but all the others are significantly different except for RIP5/RIP4, which is quite close to being significant at a 0.05 alpha value. This suggests that either female IP2s are longer relative to the other IPs, or that male IP2s are shorter, or perhaps a combination of both.

For BD-F-MT4, results show that sex has a highly statistically significant impact on all bone lengths for the non-brachydactylous sample for both sides and on the ratios RMT2/RPedPP4 and RMT4/ RPedPP4, with RMT2/RMT5 being statistically significant and RMT2/RMT4 being close to the 0.05 p-value alpha. This also suggests some differences in relative bone lengths between the sexes in the metatarsals and pedal phalanx 4.

BD-H-DP1 shows that sex has a highly statistically significant impact on all bone lengths for the non-brachydactylous sample on both sides and for the ratios LDP3/LPP1, LDP1/LPP1, RDP3/RPP1, and RDP1/RPP1. In this case, the common denominator is proximal phalanx 1, suggesting that males and females differ in the length of this bone relative to other bones of the hand.

Mann-Whitney Non-Parametric Tests

The results of the Mann-Whitney test comparing bone lengths and the bone ratios of the immediately neighboring or adjacent bones in the brachydactylous and non-brachydactylous samples can be seen in Tables 25-27. It is once again important to note the problems with using statistical tests when the samples being compared to the population means are very small. Still, this analysis provides a statistical means of showing some impacts in neighboring bones in individuals with brachydactyly if we assume that individuals can be impacted by brachydactyly regardless of the overall body (and hand or foot) size. The designated alpha is 0.05, with asymptotic significance used. The null hypothesis was that there is no impact caused from brachydactyly on the neighboring bones of the hands or feet, and the alternate hypothesis is that there is a brachydactylous impact on the neighboring bones of the hands and feet.

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Table 25. Mann-Whitney non-parametric test for BD-H-IP5.

Mann-Whitney for BD-H-IP5								
	Bone Lengths							
	Female				Male			
Bone	N	U-value	Z	Significance	N	U-value	Z	Significance
LPP5	152	56.000	-2.762	**0.006**	140	114.000	-1.317	0.188
LIP2	149	109.000	-2.126	**0.034**	139	46.000	-1.610	0.107
LIP3	149	118.500	-2.014	**0.044**	139	217.000	0.188	0.851
LIP4	150	77.000	-2.508	**0.012**	136	172.000	0.684	0.705
LIP5	147	25.000	-3.107	**0.002**	138	7.000	-2.854	**0.004**
RPP5	152	62.500	-2.688	**0.007**	145	109.000	-1.445	0.149
RIP2	153	112.000	-2.127	**0.033**	144	120.000	-1.28	0.201
RIP3	153	160.500	-1.572	0.116	144	207.000	-0.063	0.950
RIP4	152	71.000	-2.590	**0.010**	144	182.000	-0.413	0.680
RIP5	149	15.000	-3.230	**0.001**	145	6.000	-2.875	**0.004**
	Bone Ratios							
	Female				Male			
Bone	N	U-value	Z	Significance	N	U-value	Z	Significance
LIP5/LIP4	146	48.000	-2.829	**0.005**	133	3.000	-2.909	**0.004**
LIP5/LPP5	146	31.000	-3.033	**0.002**	138	3.000	-2.913	**0.004**
RIP5/RIP4	149	17.000	-3.206	**0.001**	144	2.000	-2.930	**0.003**
RIP5/RPP5	148	19.000	-3.181	**0.001**	145	6.000	-2.875	**0.004**

Table 26. Mann-Whitney non-parametric test for BD-F-MT4.

Mann-Whitney for BD-F-MT4				
	Bone Lengths			
	Male			
Bone	N	U-value	Z	Significance
RMT2	145	35.500	-1.822	0.068
RMT3	146	28.000	-1.953	0.051
RMT4	145	0.000	-2.424	**0.015**
RMT5	149	0.000	-2.425	**0.015**
RPedPP4	149	67.000	-1.312	0.190
	Bone Ratios			
	Male			
Bone	N	U-value	Z	Significance
RMT4/RMT3	144	49.000	-1.588	0.112
RMT4/RMT5	144	1.000	-2.407	**0.016**
RMT4/RPedPP4	143	0.000	-2.424	**0.015**

Table 27. Mann-Whitney non-parametric test for BD-H-DP1.

Mann-Whitney for BD-H-DP1								
	Bone Lengths							
	Female				Male			
Bone	N	U-value	Z	Significance	N	U-value	Z	Significance
LPP1	146	171.000	-0.600	0.548	146	162.500	-0.717	0.473
LDP1	147	108.000	-1.480	0.139	146	5.000	-2.890	**0.004**
LDP3	128	45.500	-1.547	0.122	133	120.000	1.407	0.160
RPP1	149	104.000	-1.554	0.120	150	158.500	-0.832	0.405
RDP1	148	1.000	-2.946	**0.003**	150	111.000	-1.47	0.142
RDP3	135	134.500	-0.948	0.343	147	191.000	-0.343	0.732
	Bone Ratios							
	Female				Male			
Bone	N	U-value	Z	Significance	N	U-value	Z	Significance
LDP1/LPP1	146	201.000	-0.186	0.852	144	29.000	-2.553	**0.011**
RDP1/RPP1	147	5.000	-2.891	**0.004**	149	33.000	-2.514	**0.012**

Statistical differences suggest that brachydactyly impacting the neighboring digits of the hands and feet can be seen with this non-parametric test for all three types to varying degrees. The results suggest that brachydactyly may impact immediately neighboring bone lengths, at least for BD-H-IP5 and BD-F-MT4. The bone ratios for all three types showed high statistical significance, which varies by side and sex for BD-H-DP1, indicating the relationship between these immediately neighboring and adjacent bones to the brachydactylous bone shows brachydactylous impact.

The neighboring impacts are seen for BD-H-IP5 on all of the bone lengths included in the analysis, except for RIP3, so this includes the immediate neighbors PP5 and IP4, and IP2, but only among females. The only significance observed for the bone lengths among males is on the brachydactylous bone. The ratios IP5/IP4 and IP5/PP5 on both sides for each sex show high statistical significance.

Neighboring impacts are seen for BD-F-MT4 in the form of MT4's immediate neighbor RMT5, with RMT3 nearly reaching statistical significance. The ratios RMT4/RMT5 and RMT4/RPedPP4 show high statistical significance, but not for RMT4/RMT3.

No statistically significant neighbor effects were identified using this approach for BD-H-DP1 for the bone lengths, with the only significance being observed on the brachydactylous bone. However, the ratios LDP1/LPP1 and RDP1/RPP1 showed statistical significance for brachydactylous impacts on the adjacent bone for both sides in males and on the right side in females.

Brachydactyly Case Studies

Lastly, the final part of the data analysis was to analyze the brachydactylous sample by means of case studies by examining Z-scores for the closest neighbors of the brachydactylous bone in comparison to the control bone to determine whether there is a relatively consistent pattern of smaller relative size for the immediate neighbors of a brachydactylous bone compared to the more distant neighbors and the control bone. Only individuals identified as outliers for the specific brachydactylous bone being analyzed (IP5, MT4, DP1), which were previously identified through boxplots, were included in the analysis of these brachydactyly case studies. The outliers included come from the identified case numbers in Tables 12-14. The Z-scores for this analysis were calculated using the formula:

$$Z - score = \frac{(\,brachydactyly\ x) - (\,normal\ \mu)}{(normal\ \sigma)} \text{ and } Z - score = \frac{(\,outlier\ x) - (\,normal\ \mu)}{(normal\ \sigma)}$$

This analysis was limited to the affected side since no significant variation in Z-scores would be expected in the unaffected hand or foot of an individual with unilateral brachydactyly. This smaller case study examines whether the neighboring bones show lower Z-scores than the other bones. If so, that would signify a minor effect from brachydactyly on the neighboring bones. However, the Z-score values would need to be consistently lower among individuals with brachydactyly for the neighboring bone analysis to mean anything. Otherwise, it could be concluded there is no real effect, at which point the ranges developed for this sample could be applied to other cases where brachydactyly is suspected. In practice, if a researcher's Z-score is within the ranges provided below or lower, it could indicate possible brachydactyly.

The case studies can be seen in Tables 28-30. Measurements of the brachydactylous sample are provided at the top of the tables, followed by the mean and standard deviation for females and males within the non-brachydactylous population. The BD-F-MT4 analysis is limited to males because only males were affected in the right foot.

Table 28. Case study of BD-H-IP5. ** indicates that side of the individual had no brachydactyly observed.

Case Study of BD-H-IP5

Measurements of Brachydactylous Bones

						Control		BD Bone			Control		BD Bone
SkelNum	CaseNum	BD	Sex	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Terry 202	40	YES	M	34.10		33.48	32.23	17.88	34.09	25.77	33.09	32.25	17.56
Terry 261	58	YES	M	33.05	23.49	30.63	28.79	16.95	32.80	23.22	30.28	28.21	16.89
Terry 813	184	YES	M	32.81	23.48	29.26	27.05	17.43	33.33	23.34	29.11	26.97	17.15
Terry 1153	225	YES	F	26.69	19.20	24.87	21.55	10.25	27.07	19.71	24.85	21.74	13.05
Terry 1186	227	YES	F	26.68	20.90	24.51	21.70	14.43	27.93	21.11	24.83	21.93	13.95
Terry 92R	307	YES	F	30.52	22.13	27.38	24.59	16.39	30.87	22.13	28.61	25.14	16.02
Terry 1058	319	YES	F	**	**	**	**	**	29.34	21.98	26.48	24.76	15.41

Measurements of Lower IP5 Outlier Individual

						Control		BD Bone			Control		BD Bone
SkelNum	CaseNum	BD	Sex	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Terry 111R	20	Outlier	M	27.98	19.26	24.03	22.56	16.10	28.05	19.27	24.11	22.81	15.98

Female for Normal Sample

	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Mean	31.4333	22.8131	27.7494	26.2758	18.4783	31.7846	22.9266	27.7756	26.2961	18.4401
SD	1.77468	1.63436	1.90801	1.81778	1.72911	1.78730	1.59470	1.85156	1.86523	1.63889

Male for Normal Sample

	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Mean	34.4032	25.2374	30.8843	29.6674	21.1112	34.6890	25.3825	30.8403	29.4057	20.8379
SD	1.71063	1.71873	1.89236	1.88112	1.69687	1.77332	1.80204	1.80824	1.86224	1.59563

Z-scores for BD-H-IP5

						Control		BD Bone			Control		BD Bone
SkelNum	CaseNum	BD	Sex	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Terry 202	40	YES	M	-0.18		1.37	1.36	-1.90	-0.34	0.22	1.24	1.53	-2.05
Terry 261	58	YES	M	-0.79	-1.02	-0.13	-0.47	-2.45	-1.07	-1.20	-0.31	-0.64	-2.47
Terry 813	184	YES	M	-0.93	**-6.39**	-0.86	-1.39	-2.17	-0.77	-1.13	-0.96	-1.31	-2.31
Terry 1153	225	YES	F	**-2.67**	-2.21	-1.51	**-2.60**	-4.76	**-2.64**	-2.02	-1.58	-2.44	-3.29
Terry 1186	227	YES	F	**-2.68**	-1.17	-1.70	**-2.52**	-2.34	-2.16	-1.14	-1.59	-2.34	-2.74
Terry 92R	307	YES	F	-0.51	-0.42	-0.19	-0.93	-1.21	-0.51	-0.50	0.45	-0.62	-1.48
Terry 1058	319	YES	F	**	**	**	**	**	-1.37	-0.59	-0.70	-0.82	-1.85

Z-scores for Lower IP5 Outlier Individual

						Control		BD Bone			Control		BD Bone
SkelNum	CaseNum	BD	Sex	LPP5	LIP2	LIP3	LIP4	LIP5	RPP5	RIP2	RIP3	RIP4	RIP5
Terry 111R	20	Outlier	M	**-3.75**	**-3.48**	**-3.62**	**-3.78**	-2.95	**-3.74**	**-3.39**	**-3.72**	**-3.54**	-3.04

Table 29. Case study of BD-F-MT4. ** indicates that side of the individual had no brachydactyly observed.

Case Study of BD-F-MT4

Measurements of Brachydactylous Bones

				Control		BD Bone		
SkelNum	CaseNum	BD	Sex	RMT2	RMT3	RMT4	RMT5	RPedPP4
Terry 230	49	YES	M	74.05	68.45	55.65	64.68	26.41
Terry 867	193	YES	M	66.94	52.34	51.12	63.50	22.31
Terry 1270R	232	YES	F	**	**	**	**	**

Measurements of Lower MT4 Outlier Individuals

				Control		BD Bone		
SkelNum	CaseNum	BD	Sex	RMT2	RMT3	RMT4	RMT5	RPedPP4
Terry 111R	20	Outlier	M	65.44	61.99	60.62	59.24	22.81
Terry 564	132	Outlier	M	65.83	60.72	60.60	62.07	23.14
Terry 828	186	Outlier	M	69.08	61.87	59.02	63.57	23.38

Male for Normal Sample

	RMT2	RMT3	RMT4	RMT5	RPedPP4
Mean	76.7643	71.7114	70.7105	72.8776	26.5371
SD	3.56425	3.43573	3.55039	4.14986	1.40007

Z-scores for BD-F-MT4

				Control		BD Bone		
SkelNum	CaseNum	BD	Sex	RMT2	RMT3	RMT4	RMT5	RPedPP4
Terry 230	49	YES	M	-0.76	-0.95	-4.24	-1.98	-0.09
Terry 867	193	YES	M	**-2.76**	**-5.64**	-5.52	-2.26	**-3.02**
Terry 1270R	232	YES	F	**	**	**	**	**

Z-scores for Lower MT4 Outlier Individuals

				Control		BD Bone		
SkelNum	CaseNum	BD	Sex	RMT2	RMT3	RMT4	RMT5	RPedPP4
Terry 111R	20	Outlier	M	**-3.18**	**-2.83**	-2.84	**-3.29**	**-2.66**
Terry 564	132	Outlier	M	**-3.07**	**-3.20**	-2.85	**-2.60**	-2.43
Terry 828	186	Outlier	M	-2.16	**-2.86**	-3.29	-2.24	-2.25

Table 30. Case study of BD-H-DP1. ** indicates that side of the individual had no brachydactyly or outliers observed. *L* indicates the individual removed for bone lipping.

Case Study of BD-H-DP1

Measurements of Brachydactylous Bones

					BD Bone	Control		BD Bone	Control
SkelNum	CaseNum	BD	Sex	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Terry 709	161	YES	M	30.81	21.57		29.81	18.98	19.25
Terry 778	178	YES	M	35.28	20.92	21.34	35.29	25.10	21.68
Terry 839	187	YES	M	30.01	17.21		29.85	17.48	17.72
Terry 80RR	18	YES	F	31.30	22.37	16.78	30.46	18.30	18.28
Terry 164R	33	YES	F	*L*	*L*	*L*	*L*	*L*	*L*
Terry 1617	263	YES	F	29.40	17.89	14.19	26.66	13.90	13.75
Terry 899R	295	YES	F	22.44	18.01		22.93	15.12	16.47

Measurements of Lower DP1 Outlier Individuals

					BD Bone	Control		BD Bone	Control
SkelNum	CaseNum	BD	Sex	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Terry 34R	7	Outlier	M	24.66	18.23	20.13	24.98	17.75	20.40
Terry 111R	20	Outlier	M	24.65	19.80	16.10	24.15	19.46	16.04
Terry 273	62	Outlier	M	32.16	24.47	20.12	32.05	20.44	20.27
Terry 315	77	Outlier	M	33.29	26.48	21.55	33.40	18.53	22.08
Terry 672	153	Outlier	M	35.95	18.76	20.10	34.97	24.70	20.37
Terry 918	209	Outlier	M	30.16	19.61	16.49	29.04	18.52	16.14
Terry 373	90	Outlier	F	27.49	21.02	16.50	27.21	15.95	16.65
Terry 1629	306	Outlier	F	27.63	21.37	16.75	27.05	16.39	16.59

Female for Normal Sample

	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Mean	31.4333	22.8131	27.7494	26.2758	18.4783	31.7846
SD	1.77468	1.63436	1.90801	1.81778	1.72911	1.78730

Male for Normal Sample

	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Mean	34.4032	25.2374	30.8843	29.6674	21.1112	34.6890
SD	1.71063	1.71873	1.89236	1.88112	1.69687	1.77332

Z-scores for BD-H-DP1

					BD Bone	Control		BD Bone	Control
SkelNum	CaseNum	BD	Sex	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Terry 709	161	YES	M	**	**		0.08	-1.26	**-8.71**
Terry 778	178	YES	M	0.51	-2.51	**-5.04**	**	**	**
Terry 839	187	YES	M	**-2.57**	-4.67		0.10	-2.14	**-9.57**
Terry 80RR	18	YES	F	**	**	**	2.30	-0.10	**-7.56**
Terry 164R	33	YES	F	*L*	*L*	*L*	*L*	*L*	*L*
Terry 1617	263	YES	F	**	**	**	0.21	-2.65	**-10.09**
Terry 899R	295	YES	F	**	**		-1.84	-1.94	**-8.57**

Z-scores for Lower DP1 Outlier Individuals

					BD Bone	Control		BD Bone	Control
SkelNum	CaseNum	BD	Sex	LPP1	LDP1	LDP3	RPP1	RDP1	RDP3
Terry 34R	7	Outlier	M	**-5.70**	-4.08	**-5.68**	-2.49	-1.98	**-8.06**
Terry 111R	20	Outlier	M	**	**	**	**-2.93**	-0.97	**-10.52**
Terry 273	62	Outlier	M	**	**	**	1.27	-0.40	**-8.13**
Terry 315	77	Outlier	M	**	**	**	1.98	-1.52	**-7.11**
Terry 672	153	Outlier	M	0.90	-3.77	**-5.70**	**	**	**
Terry 918	209	Outlier	M	-2.48	-3.27	**-7.61**	-0.33	-1.53	**-10.46**
Terry 373	90	Outlier	F	**	**	**	0.51	-1.46	**-8.47**
Terry 1629	306	Outlier	F	**	**	**	0.43	-1.21	**-8.50**

The analysis of BD-H-IP5 for the seven individuals with brachydactyly suggests the possibility that IP4 is mildly affected by brachydactyly in IP5 and possibly PP5 and IP2. This is consistent with the results of the Mann-Whitney test above. Excluding Terry 202, the other six skeletons all show lower Z-scores for IP4 than the control bone IP3. The difference ranges from -0.34 standard deviation units to -1.09 standard deviation units on the left side and -0.12 to -1.07 standard deviation units on the right side for the six skeletons. Including Terry 202, the median difference is -0.64 standard deviation units on the left and -0.35 standard deviation units on the right. Terry 202 does not follow the trend, showing almost identical Z-scores for IP3 and IP4 on the left side and a slightly larger Z-score for IP4 than IP3 (+0.29 standard deviation units) on the right.

A less consistent trend for the BD-H-IP5 case study is that IP2 shows lower Z-scores than IP3 in a majority of the BD-H-IP5 brachydactyly sample, this time including Terry 202. The exceptions this time are Terry 1186 and Terry 1058 (see below). The range for five of the seven skeletons that follow the trend is -0.23 to -5.53 standard deviation units on the left side and -.05 to -1.02 on the right. The median difference, including Terry 1058 and Terry 1186, is -0.70 standard deviation units on the left side and -0.46 on the right. These median values are similar to those seen for IP4 compared with IP3 above, but the trend only affects five of seven skeletons. It should be noted that Terry 1058, one of the skeletons with a higher Z-score for IP2 than for IP3, was only affected by brachydactyly unilaterally.

Data from PP5 are perhaps somewhat less convincing because there are no Z-scores for the other proximal phalanges, but these bones, too, show generally lower Z-scores for PP5, which underlies the brachydactylous bone, than for IP3, which is found in the same row as IP5. All six skeletons with data show a lower Z-score for left PP5 than for left IP3, with a range of -

0.07 to -1.55 and a median value of -0.82. For the right side, six of the seven skeletons with data show a lower Z-score for PP5 than IP3, ranging from -0.57 standard deviation units to -1.58. The median for the right side (including Terry 813, which showed a slightly higher Z-score for PP5) is -0.76 standard deviation units. Terry 813 is interesting because PP5 showed a slightly lower Z-score on the left side (-0.07 standard deviation. units) and a slightly higher one on the right (+0.19 units).

Unfortunately, the pattern is not completely universal for any of these bones, but there does seem to be a tendency for individuals with brachydactyly to show relatively smaller bones immediately adjacent to the brachydactylous bones in the same row and the same ray and on the far side of the hand in Ray 2 when compared to Ray 3, which would seem to reflect both adjacent and marginal effects, which will be further expanded upon in the next chapter.

For BD-F-MT4, PedPP4 for Terry 867, the individual brachydactyly of MT3 and MT4, as discussed in the previous chapter, is immediately adjacent to MT4 in the same ray and shows the lowest Z-score (-3.02) of all the other bones except for those with brachydactyly. However, the difference compared to the control bone is only -0.26, and the same is not seen in Terry 230, who has a PedPP4 Z-score of -0.09, which is higher than the Z-score of -0.76 for the control bone. Thus, the results from this case study analysis are unclear, except that MT3 is clearly impacted by the same issue as MT4 in one case.

For BD-H-DP1, there seems to be a very strong trend toward DP3 being affected when there is brachydactyly in DP1. This trend is seen more so on the right side due to a lack of measurements on the left side when brachydactyly was present.

The outliers for all three types follow the same pattern of impacts seen in the brachydactylous sample. However, the Z-scores are significantly lower amongst the neighboring bones in the outlier samples for each type, showing more impact than the brachydactylous sample.

Chapter 5: Discussion and Conclusions

This chapter will discuss the results from the previous chapter and how these results can be incorporated into a skeletal analysis. A concluding statement on this and future research potential will also be made. The sections of this chapter that will discuss this information are results and sexual dimorphism with subsections for BD-H-IP5, BD-F-MT4, and BD-H-DP1, and other sections for results in practice, followed by limitations and future research.

The research goal and aim of this thesis was to provide useful information for researchers working with skeletal collections or osteological data in bioarchaeological, forensic, and clinical contexts. The purpose of this thesis was to provide three things: 1) an analysis of the impact of brachydactyly on the neighboring bones of the hands and feet, if any, 2) an answer to the question of whether biological sex has an impact on relative length variation in an individual, and 3) with the data used, to provide information on the normal ranges of length variation within these bones that can then help future researchers to identify abnormal length variation in the digital bones of the hands or feet when conducting skeletal analysis. The findings related to these goals are further expanded upon in this final chapter.

Results and Sexual Dimorphism

In previous studies, brachydactyly has been studied in relation to the skeleton as a genetic malformation, often described as an isolated anomaly affecting a single bone (Bell 1951, Temtamy and McKusick 1978). This thesis, however, has sought to determine whether isolated cases of brachydactyly impact the neighboring bones of the hands and feet. In the process, it has also evaluated the impact of sexual dimorphism on the relative lengths of certain digital bones of the hands and feet and attempted to define a normal range of variation for individuals who appear to lack growth disturbances such as brachydactyly to help determine how brachydactyly might be better recognized metrically. The descriptive analysis of BD-H-IP5 (Table 9), BD-F-MT4 (Table 10), and BD-H-DP1 (Table 11) shows that the average bone lengths amongst the non-brachydactylous and brachydactylous individuals show a general pattern of sexual dimorphism, with females having smaller average measurements than males. This matches with expectations as males are well-known to generally have longer bones than females on average. Less clear is whether the ratios of certain bones are identical between the sexes despite these gross differences in length. The question is important because it determines whether the sexes can be combined to develop ranges for bone ratios that can be used to help identify probable cases of brachydactyly or whether the sexes must be treated separately. Sexual dimorphism results for bone ratios related to each of the three types of brachydactyly are discussed in the next section.

As for the main theme of the thesis, both the Mann-Whitney analysis and the brachydactyly case studies appear to show that brachydactyly can impact neighboring bones of the hands and feet. The Mann-Whitney tests for all three types presented in Tables 25-27 do show brachydactylous impacts on the neighboring bones of the hands and feet. The observed impact of brachydactyly on other bones studied is generally seen to be the greatest on the bones directly adjacent or neighboring to the bone with brachydactyly, not on the whole row. For example, evidence for an impact appears strongest for IP4 and PP5 when there is brachydactyly of IP5 and MT5 (and in one obvious case, MT3) when there is brachydactyly of MT4. There is some evidence of an impact on IP2 in the case of BD-H-IP5, but the trend is slightly less consistent. This finding fits to some extent with expectations from previous literature about how growth factors impact the bones of the hands (e.g., Lewenz & Whitely 1902, Hewitt 1963). The expectation from past research is that row-related factors have more influence on bone growth and size similarity than ray-related ones and that there should be a greater similarity between adjacent than non-adjacent bones, whether in the same ray or same row, which has been called a "rule of neighborhood" (Lewenz & Whitely 1902). Since this was found during the literature review of this thesis, the bone ratios used in the Mann-Whitney non-parametric statistical analysis were of the bones directly neighboring or adjacent to the brachydactylous bone. The case studies showed that the neighboring and adjacent bones tended to have a greater impact observed from brachydactyly. Still, in some cases, such as the bones studied to assess BD-H-IP5, other bones seemed to be affected as well, though not as consistently.

BD-H-IP5

The ANOVA results (Table 22) for the bones involved in the analysis of BD-H-IP5 showed that sex has a highly statistically significant impact on all bone lengths within the non-brachydactylous sample on both sides and for most of the bone ratios as well. The most interesting result, however, is from one of the ratios that showed no difference between the sexes - IP3/IP2. This was the only ratio that included the control bone that showed no difference between the sexes. The others - IP3/IP4, IP3/IP5, and IP3/PP5, all showed a difference. Since some ratios involving IP2 showed no significant differences between the sexes when all other ratios showed differences, this would suggest that there is something different about IP2 compared to the other bones, most likely that IP2 is relatively longer in females than males. This finding may help explain sexual dimorphism in the ratio of the lengths of the second finger to the fourth finger in the hand, called 2D:4D (Park 1977, Voracek 2009, Hönekopp and Watson 2010, Manning & Fink 2018). The ratios identified here (Table 18) combined with the ANOVA results (Table 22) show evidence that IP2 may be the bone in the second ray that causes the second digit to be longer in females than males. While not definitive, it is a possible explanation. The 2D:4D ratio is usually studied in living humans and involves the measurement of the total lengths of the 2nd and 4th fingers. Researchers report consistent differences in these ratios between the sexes (Park 1977, Voracek 2009, Hönekopp and Watson 2010, Manning & Fink 2018), and it would appear from the results of this study that the length of IP2 may be partly responsible for 2D:4D variation.

The bone ratios involved in the BD-H-IP5 (Table 18) analysis also show how the control bone (IP3) and the bone in question (IP5) directly impact the neighboring bones in the hands. Any ratio of IP5/IP3 above 1.80 has a high probability of indicating brachydactyly of IP5 in females, and any ratio above 1.70 has a high probability of indicating brachydactyly of IP5 in males. Table 28 showed more neighboring impact on the left rather than the right side, which may indicate directional asymmetry; however, further analysis would need to be conducted on a larger sample to see if this pattern continues.

Given the results produced and at least as far as this thesis could conclude, combined with the literature and explanation, Type A3 (BD-H-IP5) brachydactyly impacts the neighboring bones in the hands of both sexes. The Mann-Whitney non-parametric test (Table 25) showed that statistical significance for the neighboring impact caused by brachydactyly was seen on PP5 and IP4, as well as RIP2. There are other forms of brachydactyly Type A that Bell (1951) explored, such as Type A1, which affects all four of the intermediate phalanges, or Type A2, which, while rarer, affects the second digit of the hand, so it could be that these types and Type A3 are more closely related than may have been believed in the past. The bone ratios IP5/IP4 and IP5/PP5 in the Mann-Whitney test on both sides for each sex show high statistical significance. This neighboring impact was further explored through the brachydactyly case study analysis (Table 28), which did show some brachydactylous impact as well. The outliers in the case study showed neighboring impacts on all of the included bones for the analysis of IP5. There was female sex bias according to the ANOVA analysis (Table 22) and a left side bias from the brachydactyly case study using Z-scores (Table 28).

BD-F-MT4

The ANOVA analysis (Table 23) for BD-F-MT4 shows that sex has a highly statistically significant impact on all bone lengths for the normal sample on both sides, and the ratios RMT2/RPedPP4, RMT4/ RPedPP4, andRMT2/RMT5. Two of the ratios involving MT2 (RMT2/RMT3 and RMT2/RMT4) show no difference in males and females, and the same is true for two ratios involving MT4 (RMT4/RMT3 and RMT4/RMT5). Thus, just over half of the ratios in the foot suggest no male and female differences in relative length, and just under half show differences, two of which are significant at $p < 0.001$. Pedal PP4 is a common element in two ratios that show differences between the sexes, and MT2 is also a common element in two of the three ratios, suggesting that they may be the bones primarily responsible for the differences in relative size between the sexes. The ratios (Table 19) show how the control bone (MT2) and the bone in question (MT4) directly impact one another and the neighboring bones in the hands. Any ratio of MT2/MT4 above 1.31 has a high probability of indicating brachydactyly of MT4 in males. Table 29 showed neighboring impact on both sides, with no evident side bias, which may indicate that this type of brachydactyly is not subject to directional asymmetry; however, further analysis would need to be conducted on a larger sample to see if this pattern continues and is the case.

Given the results produced and at least as far as this thesis could conclude, combined with the literature and explanation, Type E1 (BD-F-MT4) brachydactyly impacts the neighboring bones in the foot in both sexes. The Mann-Whitney non-parametric test (Table 26) showed statistical significance for the neighboring impact caused by brachydactyly was seen on RMT5, with RMT3 approaching statistical significance. The ratios RMT4/RMT5 and RMT4/RPedPP4 show high statistical significance, but not for RMT4/RMT3. This neighboring impact was further explored through the brachydactyly case study analysis (Table 29), showing that while RMT2 had some impacts, the strongest impact was seen on RMT3 and RPedPP4. However, since this is only seen in one person, it should not be considered a trend. The outliers in the case study showed neighboring impacts on all of the included bones for the analysis of MT4. It is crucial to note that another reason for the impact could be because MT3 was also affected in one of the two cases (the same individual where this trend was seen), which is an uncommon finding. There was no sex bias according to the ANOVA analysis (Table 23) and no side bias from the brachydactyly case study using Z-scores (Table 29) due to only having the right foot measurement provided for this study.

BD-H-DP1

The ANOVA results (Table 24) of the analysis of the bones related to BD-H-DP1 show that all bone lengths differ significantly by sex for the non-brachydactylous sample, and DP3/PP1 and DP1/PP1 ratios show significant differences for both sides. Interestingly, PP1 is a common element of the two ratios that do show significant differences between the sexes, suggesting that this bone may differ in relative size in males and females.

Intriguingly, the DP3/DP1 ratios are not significantly different by sex on either the left or right sides. This might suggest that there may be more similarity between the sexes in the development of the distal phalanges when compared to the intermediate phalanges. However, it is impossible to compare IP3 to IP1 for a more direct comparison of the digits since there is no IP1 in humans. For the ratio analysis (Table 20), any ratio above 0.99 has a high probability of indicating brachydactyly of DP1 in females, and any ratio above 0.95 has a high probability of indicating brachydactyly of DP1 in males.

The case study (Table 30) indicates radically smaller Z-scores for DP3, showing a strong trend towards DP3 being impacted if there is brachydactyly of DP1. This pattern is seen more on the right side due to available measurements, but it is also observed where there are measurements for the left. A larger sample will need to be used in future research to see if this pattern continues. The outliers in the case study showed neighboring impacts on all of the included bones for the analysis of DP1. They followed the same trend of the brachydactylous individual having a significant brachydactylous impact seen on DP3.

Given the results produced and at least as far as this thesis could conclude, combined with the literature and explanation, Type D (BD-H-DP1) brachydactyly impacts the neighboring bones in the hands of both sexes. The Mann-Whitney non-parametric test (Table 27) showed no statistical significance for neighboring impact caused by brachydactyly for bone lengths, with the only significance being observed on the brachydactylous bone. However, the ratios LDP1/LPP1 and RDP1/RPP1 showed statistical significance for brachydactylous impacts on the adjacent bone for both sides in males and on the right side in females. The brachydactyly case study analysis (Table 30) showed a neighboring impact as well. There was no sex bias according to the ANOVA analysis (Table 27) and no side bias from the brachydactyly case study using Z-scores (Table 30) due to having more right-side measurements available.

Results in Practice

An important goal of this thesis was to create a non-brachydactylous range of bone measurements for each type of brachydactyly analyzed to compare with the brachydactylous individuals. While there was some overlap and similarities between the non-brachydactylous sample and the brachydactylous samples with bone measurement ranges, once the ratios of those measurements were taken between the control and other applicable digits for each type, as well as the brachydactylous bone in question, the ratio ranges show a clear difference, for each type of brachydactyly, albeit with some limited overlap, as discussed below.

A biological anthropologist should be able to use these ratios and ranges to help identify whether an individual is likely to have brachydactyly or not, even if they have not spent much time analyzing digital bones of the hands and feet. The bone measurement ranges for the non-brachydactylous sample (Tables 15-17) can be used to understand an individual skeleton and whether they may have brachydactyly, which can be seen through metric comparison. The bone ratio ranges (Tables 18-20) from the non-brachydactylous sample can be used to understand the relationships between the neighboring digits of an individual skeleton and can also be used to scan for digits showing possible brachydactyly using the ratio benchmarks (Table 21) discussed. Given the neighborhood effects identified in this thesis, it is probably best to use ratios that exclude the nearest neighbor bone, where possible.

Biological anthropologists should be able to use the results outlined in this thesis to support an unknown individual's biological profile. Sex estimation must be done before analyzing the skeleton metrically for brachydactyly. Within the skeletal analysis being conducted, if a skeleton is ambiguous, it is recommended that the researcher use the applicable non-brachydactylous measurements (Tables 12-14) or ratios (Tables 15-17) with a minimum of females and a maximum of males; otherwise, use the applicable ranges for the appropriate estimated sex of the individual.

The presence of brachydactyly in an individual can convey information to a researcher due to its heritability, but the absence of the genetic malformation does not carry the same meaning. As outlined in the Literature Review Chapter, kinship is a component of bioarchaeological research regarding brachydactyly that can tell anthropologists about an individual's potential relationship to a community. Case et al. (2016) studied kinship analysis through developmental anomalies of the feet, including brachydactyly, among skeletons from archaeological sites in Denmark and England. It was found that among the traits analyzed, brachydactyly was a good candidate to be a potential indicator for skeletal kinship (Case et al. 2016, 203). This is because among the successful traits, brachydactyly included, it shows no evidence of age or sex bias (Case et al. 2016, 203). It was also found in less than 5% of individuals in the European sample (Case et al. 2016, 203), which suggests that the prevalence of this trait found in Cybulski's (1988) sample of potentially related ancient Native Americans was unusually high. Through this understanding of kinship in a bioarchaeological context, it can be understood how this trait could be applied in a forensic context. Brachydactyly is an inherited trait, so victim identities could be linked to an unknown skeleton through this trait as well, if present. Analyzing a family for brachydactyly could help narrow the scope of possible identities for unknown remains.

A majority of the literature that was read for this thesis involved the use of radiographic studies. So, radiographic studies can be done within a clinical setting to further analyze the impact of brachydactyly in the neighboring digits and if similar digits are affected across generations. This would be population specific, given the findings in the literature review, but it would be beneficial data to have and explore. Given the findings of this thesis, future research should expand upon these findings to investigate whether brachydactylous impacts on the immediately neighboring and adjacent bones by a brachydactylous bone continue or whether the impact is specific to the types analyzed in this thesis. Incorporating radiographic data would allow studies to gather more data on this question.

Atypical variation in relative bone proportions, even if they do not qualify as brachydactyly, might suggest other types of syndromes, as seen with Temtamy and McKusick (1978). This might include some of the more common syndromes, such as Turner's syndrome, previously researched by Park (1977). A researcher could use the information on bone length ratios presented here to identify both brachydactyly and other potentially anomalous bone size relationships that might indicate a syndrome. If one or both could be seen in the skeleton, a more in-depth analysis could be achieved to understand the bigger picture of the individual and their lived experiences.

Limitations and Future Research

A researcher must recognize the limitations of their research and find ways that research can be improved and expanded upon in the future. The primary limitation of this thesis was the sample size. Brachydactyly is not a common malformation (Temtamy and McKusick, 1978). As such, it would require a much larger sample to fully understand the impact of brachydactyly on the neighboring digits of the hands and feet. A larger sample would increase the odds of having more brachydactylous individuals in the sample to analyze further. Also, because of the small size of the brachydactyly sample, both overall and once separated by sex, the standard deviation of and between the bones could not be used for straightforward identification of brachydactyly. Instead, a comparison of means and ANOVA applied to a normal population was necessary to understand the variation and relationships between bones. Once larger sample sizes are obtained, statistical techniques could be applied directly to the brachydactylous individuals to better understand the impact of brachydactyly on the neighboring bones of the hands and feet. It is possible that with a slightly larger sample size for the brachydactylous sample, the results of the Mann-Whitney non-parametric test would all be statistically significant for each type analyzed. Time was another limitation of this thesis, which also connected to needing a larger sample. It would take extensive time to collect and analyze the relevant data to better answer if brachydactyly impacts the neighboring digits of the hands and feet. The last limitation of this thesis was that only the right foot measurements were available for analysis, so BD-F-MT4 could not be analyzed for a side bias, which was done for BD-H-IP5 and BD-H-DP1. This side bias could possibly be explained by directional asymmetry, although this would need further analysis in a separate study.

Morphological analysis is a key component of a biological profile that biological anthropologists use to understand an unknown individual, either in a bioarchaeological or forensic context. Due to this, new methods are developed and used to assist with this process. This thesis sought to understand if brachydactyly, as a genetic malformation, impacts the neighboring bones of the hands and feet by looking at three of the more common types. Seven individuals in the total sample were estimated to have BD-H-IP5, three individuals in the total sample were estimated to have BD-F-MT4 and seven individuals in the total sample were estimated to have BD-H-DP1. The data collector, Dr. Case, found these sample sizes through morphological analysis. It is possible that others may have had major or minor brachydactyly, not identified morphologically, which raises the question, can brachydactyly be seen metrically where it may not have been observed morphologically?

To test this question, the outliers of the brachydactylous bones in question (Tables 12-14) were included in the brachydactyly case studies (Tables 28-30). The outliers, as seen in the brachydactyly case studies, show that some individuals with one type of brachydactyly also show relatively short bones in other parts of the hands or feet. This is seen by having the same individuals (CaseNum, as referenced in Table 12-14) featured in different brachydactyly case study types, which may indicate that these individuals may have had abnormally short bones in their hands and feet. The Z-scores produced in the brachydactyly case studies for the lower-end outliers of IP5, MT4, and DP1 followed the same pattern of neighboring digital impacts in the hand and feet as seen with the brachydactylous bones for each type. Given this same pattern, it appears that it is possible that a skeleton can have brachydactyly identified metrically, where it may not have been observed morphologically. However, this is still a question that would require future additional research to be done. The outliers included in the brachydactyly case studies are possible cases of brachydactyly that were missed due to a data collection error. In some cases, these individuals may have had more mild cases of brachydactyly. The standard deviation values for the brachydactylous bones were calculated based on the non-brachydactylous population to determine how far the visually identified brachydactylous bones were below the mean, which future researchers can use to aid in the diagnosis of the condition metrically. With a larger overall sample, combining the outlier and brachydactylous samples might have been significant in all the cases within this thesis, showing how future research on this topic and question could advance our understanding of brachydactyly.

Another topic from this thesis that needs to be investigated in the future is fibroblast-growth-factor-receptor mutations, discussed in the Literature Review chapter. Kraus & Choi's (1958) theory that these are determined genetically obtains some backing from the existence of hereditary abnormalities affecting the lengths of certain phalanges. Muenke & Schell (1995) discuss how fibroblast-growth-factor-receptor-related skeletal disorders include dwarfism, which has connections to brachydactyly, as Temtamy & McKusick (1978) explained. These authors discuss syndromes associated with brachydactyly. The information presented in the article by Muenke & Schell (1995) shows significant evidence for how disruptions and mutations of this fibroblast-growth-factor-receptor affect the timing of skeletal development. Suppose that fibroblast-growth-factor-receptor works with homeobox D13 genes, as Robledo et al. (2002) discussed. Hewitt (1963) discovered that the fifth intermediate phalanx displays the least well-integrated growth pattern with the rest of the hand. Kraus & Choi (1958) theorized different components are responsible for different growth factors under genetic influence. If that is the case, a single mutant gene (Muenke & Schell 1995) might lead to effects in a single row of bones under the control of that gene. From a genetic viewpoint, this could explain the premature fusion of brachydactylous bones in the hands and feet and the neighborhood effects observed here, though confirmation would require further analysis.

Overall, there is an issue with the literature available on brachydactyly. For the older articles, much of the primary research done on brachydactyly was between the 1920s-1950s. With the basic research already done, the more current authors often do not re-examine those same issues. For the more current sources, research on brachydactyly is more specialized instead of generalized as in the older literature. However, the more specialized research being conducted today is more from a clinical perspective than a personal or anthropological perspective. More anthropological research needs to be conducted on brachydactyly so that it can be further incorporated into bioarchaeological and forensic contexts within an individual's biological profile.

Relating to the Literature Review chapter, another topic that needs further research is lived experiences of individuals with brachydactyly. The skeleton is the foundation and support for the rest of the body. Given this fact, if there are skeletal anomalies, it is possible the consequences of this can have subsequent effects on the lived experience of an individual. According to the literature, however, difficulty with gripping and walking only arises from extreme cases of brachydactyly. Because of this, most surgical procedures to correct brachydactyly are not for functional reasons but for cosmetic ones (Temtamy and McKusick 1978, Vickers 1987). The problem is that there is not much information on the lived experiences of brachydactyly as told from personal accounts. Additional research, possibly through surveys, is needed to understand how those affected by brachydactyly live and if having this genetic malformation affects how they view and interact with the world. If one can shed light on the lived experiences of these affected people to see how the presence of brachydactyly affected them, this information could be used presently within the medical community to help improve the quality of life of these individuals. This would be done by seeing where in the hands and feet the brachydactyly is present and any complications that could arise because of the location of the brachydactyly.

Given the results produced in this thesis, there is evidence of brachydactyly impacting the neighboring bones of the hands and feet. However, due to small sample sizes, this should not be considered fully conclusive, and rather, seen as a step towards finding evidence for this connection, enabling a path for future research to expand upon brachydactyly.

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APPENDICES

Appendix A, Part I-III Key

The appendices contain every ratio calculated for all skeletons used in the non-brachydactylous, brachydactylous, and outlier samples. The ratios are ordered by the case number, which is the order they were analyzed. The biological sex of the individual is indicated. For the brachydactyly column:

- 3 indicates a non-brachydactylous individual.
- 4 indicates a brachydactylous individual; the BD indicator and ratios are bolded.
- 5 indicates an outlier individual; the BD indicator and ratios are italicized.

Data starts on the next page

Appendix A, Part I. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 1R	1	3	F	1.25	1.06	1.64	0.90	0.76	0.64	0.55
Terry 6RR	2	3	F		1.08	1.60	0.91		0.68	0.57
Terry 12R	3	3	F	1.22	0.99	1.34	0.78	0.91	0.74	0.58
Terry 14R	4	3	M	1.24	1.01	1.46	0.92	0.85	0.70	0.63
Terry 15R3	5	3	F	1.21		1.49	0.87	0.82		0.59
Terry 16RR	6	3	F	1.19	1.06	1.58	0.88	0.76	0.67	0.56
Terry 34R	7	3	M	1.26	1.02	1.56	0.85	0.81	0.66	0.55
Terry 448	8	3	M	1.18	1.01	1.38	0.86	0.86	0.73	0.62
Terry 37R	9	*5*	F	*1.24*	*1.04*	*1.45*	*0.84*	*0.85*	*0.72*	*0.58*
Terry 41R	10	3	F	1.27	1.06	1.59	0.92	0.80	0.67	0.58
Terry 53R	11	3	F	1.25	1.08		0.90			
Terry 59R	12	3	M	1.21	0.99	1.31	0.88	0.92	0.75	0.67
Terry 62RR	13	3	M	1.21	1.06	1.43	0.89	0.84	0.74	0.62
Terry 64R	14	3	F	1.19	1.09	1.50	0.89	0.79	0.72	0.60
Terry 69R	15	3	F	1.18	1.03	1.42	0.88	0.83	0.73	0.62
Terry 73R	16	3	M	1.18	1.04	1.43	0.94	0.83	0.73	0.66
Terry 79R	17	3	F	1.20	1.04	1.42	0.82	0.84	0.73	0.58
Terry 80RR	18	3	F	1.20	1.08	1.55	0.89	0.77	0.69	0.57
Terry 109	19	3	M	1.23	1.02	1.47	0.87	0.84	0.70	0.59
Terry 111R	20	*5*	M	*1.25*	*1.07*	*1.49*	*0.86*	*0.84*	*0.71*	*0.58*
Terry 112R	21	3	F	1.22	1.09	1.43	0.88	0.85	0.76	0.62
Terry 113R	22	3	M	1.19	1.03	1.37	0.85	0.87	0.75	0.62
Terry 114R	23	3	F	1.26	1.07	1.62	0.83	0.78	0.66	0.51
Terry 126R	24	3	M	1.24	1.01	1.35	0.84	0.92	0.75	0.62
Terry 131R	25	3	M	1.19	1.03	1.44	0.86	0.83	0.72	0.60
Terry 135R	26	3	F	1.18	1.03	1.36	0.88	0.87	0.76	0.65
Terry 136R	27	3	M	1.27	1.06	1.55	0.86	0.82	0.68	0.55
Terry 139R	28	3	F							
Terry 147	29	3	M	1.19	1.09	1.48	0.88	0.81	0.73	0.60
Terry 148RR	30	3	F	1.22	1.03	1.50	0.90	0.81	0.68	0.60
Terry 161R	31	3	F	1.24	1.08	1.47	0.96	0.84	0.74	0.65
Terry 162R	32	3	F	1.19	1.04	1.40	0.88	0.85	0.75	0.63
Terry 164R	33	3	F	1.31	1.05	1.58	0.94	0.83	0.66	0.60
Terry 174R	34	3	F	1.21	1.05	1.60	0.88	0.76	0.66	0.55
Terry 195	35	3	M	1.17	1.02	1.36	0.87	0.86	0.75	0.64
Terry 196	36	3	M	1.27	1.10	1.61	0.96	0.78	0.68	0.59
Terry 197R	37	3	F	1.19	1.04		0.82			
Terry 198R	38	3	M	1.19	1.06	1.54	0.92	0.78	0.69	0.60

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 201	39	3	M	1.26	1.04	1.52	0.87	0.83	0.69	0.57
Terry 202	40	**4**	M		**1.04**	**1.87**	**0.98**		**0.55**	**0.52**
Terry 207	41	3	M							
Terry 215	42	3	M	1.22	1.03	1.44	0.86	0.85	0.72	0.60
Terry 216	43	3	M	1.24	1.05	1.39	0.91	0.89	0.75	0.65
Terry 220	44	3	M	1.22	1.03	1.38	0.87	0.88	0.75	0.63
Terry 225R	46	3	F	1.20	1.03	1.39	0.85	0.87	0.74	0.62
Terry 227	47	3	M	1.21	1.04	1.46	0.93	0.83	0.71	0.64
Terry 230	49	3	M	1.25	1.02	1.42	0.88	0.88	0.72	0.62
Terry 233	50	3	M	1.21	1.06	1.55	0.84	0.78	0.68	0.54
Terry 234	51	3	M	1.18	1.02	1.37	0.90	0.86	0.75	0.66
Terry 236R	52	3	F	1.20	1.02	1.48	0.91	0.81	0.69	0.61
Terry 237	53	3	M	1.19	1.04	1.42	0.91	0.83	0.73	0.64
Terry 250	54	3	M	1.26	1.04	1.39	0.89	0.90	0.75	0.64
Terry 259	56	3	M	1.22	1.03	1.39	0.94	0.88	0.74	0.68
Terry 260	57	3	M	1.19	1.03	1.44	0.88	0.83	0.72	0.61
Terry 261	58	**4**	M	**1.30**	**1.06**	**1.81**	**0.93**	**0.72**	**0.59**	**0.51**
Terry 263	59	3	M	1.19	1.04	1.42	0.94	0.84	0.74	0.67
Terry 267	60	3	M	1.23	1.04	1.48	0.91	0.83	0.70	0.62
Terry 271	61	*5*	M	*1.27*	*1.00*	*1.40*	*0.93*	*0.91*	*0.71*	*0.67*
Terry 273	62	*5*	M	*1.18*	*1.03*	*1.49*	*0.92*	*0.79*	*0.69*	*0.62*
Terry 274	63	3	M							
Terry 277	64	*5*	M	*1.18*	*1.03*	*1.56*	*0.86*	*0.76*	*0.66*	*0.55*
Terry 279	65	3	M	1.22	1.08	1.55	0.89	0.79	0.69	0.58
Terry 282	66	*5*	M	*0.99*	*1.32*	*1.41*	*0.85*	*0.70*	*0.93*	*0.60*
Terry 285	67	3	M	1.22	1.02	1.46	0.90	0.83	0.70	0.62
Terry 289R	68	3	F	1.17	1.03	1.42	0.86	0.82	0.73	0.60
Terry 293R	69	3	F	1.22	1.06	1.50	0.91	0.82	0.71	0.61
Terry 297	70	3	M	1.22	1.08	1.46	0.88	0.84	0.74	0.60
Terry 298	71	3	M	1.24			0.87			
Terry 301R	72	3	M					0.79		0.58
Terry 303R	73	3	M	1.27	1.03	1.42	0.88	0.89	0.72	0.62
Terry 305	74	3	M	1.24	1.06	1.44	0.87	0.86	0.74	0.60
Terry 306R	75	3	F	1.23	1.07	1.63	0.93	0.76	0.66	0.57
Terry 311R	76	3	M	1.16	1.11	1.46	0.95	0.79	0.76	0.65

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 315	77	*5*	M	*1.24*	*1.06*	*1.73*	*1.00*	*0.72*	*0.61*	*0.57*
Terry 316	78	3	M	1.22	0.99	1.47	0.89	0.83	0.67	0.60
Terry 318	79	3	M	1.20	1.00	1.39	0.92	0.87	0.72	0.66
Terry 320	80	3	M	1.30	1.07	1.58	0.95	0.82	0.68	0.60
Terry 332	81	3	M	1.19	1.06	1.52	0.92	0.78	0.70	0.61
Terry 335	82	3	M	1.21	1.02	1.37	0.80	0.88	0.74	0.58
Terry 342	83	3	M	1.19	1.04	1.45	0.84	0.82	0.72	0.58
Terry 343	84	*5*	M	*1.17*	*1.07*	*1.36*	*0.93*	*0.86*	*0.79*	*0.69*
Terry 346RR	85	3	F	1.23	1.03	1.52	0.88	0.81	0.68	0.58
Terry 351R	86	3	F	1.22	1.01	1.38	0.86	0.89	0.73	0.62
Terry 365	87	3	M	1.16	1.01	1.44	0.94	0.81	0.70	0.65
Terry 366	88	3	M	1.23		1.54	0.94	0.80		0.61
Terry 367	89	3	M	1.19	1.06	1.50	0.93	0.79	0.71	0.62
Terry 373	90	*5*	F	*1.23*	*1.05*	*1.51*	*0.86*	*0.81*	*0.69*	*0.57*
Terry 379	91	3	M	1.36	0.98	1.23	0.89	1.10	0.80	0.72
Terry 387R	93	3	F	1.23	1.09	1.73	0.88	0.71	0.63	0.51
Terry 395	95	3	M							
Terry 397	96	3	M	1.15	0.99	1.41	0.87	0.82	0.71	0.62
Terry 405R	97	3	F	1.23	1.07	1.51	0.90	0.81	0.70	0.59
Terry 407	98	3	M	1.18	1.06	1.41	0.87	0.83	0.75	0.62
Terry 409	99	3	M	1.24	1.02	1.50	0.94	0.83	0.68	0.63
Terry 411	100	3	M		1.07	1.54	0.92		0.70	0.60
Terry 413	101	3	M	1.24	1.06	1.52	0.89	0.81	0.70	0.59
Terry 414	102	3	M	1.25	1.07	1.46	0.91	0.86	0.73	0.62
Terry 415	103	*5*	M					*1.19*		*0.86*
Terry 417	104	3	M	1.23	1.02	1.48	0.82	0.83	0.69	0.56
Terry 433	106	3	M							
Terry 437R	108	3	F	1.19	1.03	1.59	0.89	0.75	0.65	0.56
Terry 440	109	3	M	1.28	1.04	1.66	0.94	0.77	0.63	0.56
Terry 442	110	3	M	1.29	1.03	1.47	0.92	0.88	0.70	0.62
Terry 451R	111	3	F	1.20	1.06	1.55	0.86	0.77	0.69	0.56
Terry 453	112	3	M	1.15	1.03	1.42	0.88	0.81	0.72	0.62
Terry 184R	113	3	M	1.24	1.02	1.37	0.93	0.91	0.74	0.68
Terry 463	115	3	M	1.23	1.07	1.54	0.91	0.80	0.69	0.59
Terry 476RR	116	3	F	1.18	1.05	1.54	0.87	0.77	0.68	0.56

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 478	117	3	M	1.24	1.07	1.60	0.83	0.78	0.67	0.52
Terry 482	118	3	F	1.18	1.04	1.51	0.90	0.78	0.69	0.59
Terry 496	119	3	M	1.18	1.01	1.34	0.89	0.88	0.75	0.66
Terry 505	120	3	M	1.21	1.07	1.51	0.94	0.80	0.71	0.62
Terry 506	121	3	M	1.20		1.49	0.92	0.80		0.62
Terry 517	122	3	M	1.28	1.04	1.52	0.96	0.84	0.68	0.63
Terry 525	123	*5*	M	*1.21*	*1.08*	*1.50*	*0.93*	*0.81*	*0.72*	*0.62*
Terry 536	124	3	M	1.31	1.01	1.48	0.92	0.89	0.68	0.62
Terry 545	125	3	M	1.16	1.04	1.41	0.90	0.82	0.74	0.64
Terry 546	126	3	M	1.20	1.05	1.50	0.94	0.80	0.70	0.62
Terry 548	127	3	M	1.20	1.07	1.41	0.90	0.85	0.75	0.63
Terry 554R	128	3	F	1.18	1.05	1.61	0.92	0.73	0.65	0.57
Terry 555	129	3	M	1.27	1.08	1.62	0.96	0.78	0.66	0.60
Terry 557	130	*5*	M	*1.33*	*1.09*	*1.63*	*0.86*	*0.82*	*0.67*	*0.53*
Terry 564	132	3	M	1.19	1.04	1.42	0.86	0.84	0.73	0.60
Terry 566	133	3	M	1.22	1.06	1.47	0.94	0.82	0.72	0.63
Terry 573	134	3	M	1.22	1.02	1.61	0.85	0.76	0.64	0.53
Terry 575	135	*5*	M	*1.15*	*0.87*	*0.89*	*0.78*	*1.30*	*0.97*	*0.87*
Terry 577	136	3	M	1.26	1.00	1.44	0.92	0.87	0.69	0.64
Terry 588	137	3	M	1.19	1.06	1.51	0.95	0.78	0.70	0.62
Terry 591	138	3	M	1.20	1.10	1.67	0.95	0.72	0.66	0.57
Terry 602	142	3	M	1.26	1.03	1.46	0.91	0.86	0.70	0.62
Terry 605R	143	3	M	1.22	1.02	1.41	0.90	0.86	0.72	0.64
Terry 608	144	3	M	1.10	1.11	1.48	0.83	0.74	0.75	0.56
Terry 614	145	3	M	1.27	1.13	1.57	0.92	0.81	0.72	0.58
Terry 620	146	3	M	1.25	1.06	1.49	0.88	0.84	0.71	0.59
Terry 622R	147	3	M	1.28	0.99	1.39	0.87	0.92	0.71	0.63
Terry 636	148	3	M	1.24	1.05	1.44	0.89	0.86	0.73	0.62
Terry 641	149	3	M	1.21	1.04	1.50	0.93	0.81	0.69	0.62
Terry 644	150	3	M	1.21	1.06	1.48	0.90	0.82	0.72	0.61
Terry 645	151	3	M	1.28	1.06	1.47	0.88	0.87	0.72	0.60
Terry 670	152	3	M	1.20	1.04	1.42	0.88	0.84	0.73	0.62
Terry 672	153	3	M	1.24	1.01	1.44	0.88	0.86	0.70	0.61
Terry 674	154	3	M	1.19	1.05	1.38	0.90	0.86	0.76	0.65
Terry 680	155	3	F	1.25	1.04	1.38	0.81	0.90	0.75	0.58

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 681	156	3	M	1.20	1.03	1.45	0.92	0.83	0.71	0.64
Terry 687	157	3	M	1.27	0.99	1.38	0.89	0.92	0.72	0.64
Terry 693	158	3	M	1.20	1.05	1.46	0.91	0.82	0.71	0.62
Terry 696	159	3	M	1.17	1.00	1.34	0.82	0.88	0.75	0.61
Terry 701	160	3	M	1.22	1.07	1.35	0.89	0.90	0.79	0.66
Terry 709	161	3	M					0.89	0.77	0.60
Terry 710R	162	3	F	1.30	1.07	1.55	0.92	0.84	0.69	0.59
Terry 720	163	3	M	1.27	1.03	1.49	0.90	0.85	0.69	0.60
Terry 721	164	3	M	1.23	1.00	1.51	0.94	0.81	0.66	0.62
Terry 736	165	3	F	1.24	1.06	1.49	0.91	0.83	0.71	0.61
Terry 739	166	3	M	1.24	1.05	1.62	0.91	0.77	0.65	0.56
Terry 743	167	3	M	1.30	1.00	1.39	0.90	0.93	0.72	0.65
Terry 745R	168	3	F	1.19	1.06	1.51	0.92	0.79	0.70	0.61
Terry 747	169	3	M	1.23	1.02	1.48	0.89	0.83	0.69	0.60
Terry 751	170	3	M	1.22	1.03	1.46	0.88	0.84	0.70	0.60
Terry 762	173	3	M	1.25	1.03	1.50	0.90	0.84	0.69	0.60
Terry 763	174	3	M	1.20	1.06	1.49	0.88	0.81	0.71	0.59
Terry 764	175	3	M	1.21	1.07	1.46	0.93	0.83	0.73	0.64
Terry 768	176	3	M	1.18	0.99	1.35	0.89	0.88	0.74	0.66
Terry 772	177	*5*	M	*1.16*	*1.03*	*1.41*	*0.91*	*0.82*	*0.73*	*0.65*
Terry 778	178	3	M	1.20	1.07	1.44	0.94	0.84	0.74	0.65
Terry 785	179	3	M	1.50	1.03	1.25	0.91	1.20	0.83	0.73
Terry 787	180	3	M	1.20	1.06	1.48	0.87	0.81	0.71	0.59
Terry 795	181	3	M	1.20	1.04	1.40	0.90	0.85	0.74	0.64
Terry 802	182	3	M	1.22	1.06	1.58	0.92	0.77	0.67	0.58
Terry 810	183	3	M	1.20	1.06	1.47	0.90	0.81	0.72	0.61
Terry 813	184	**4**	M	**1.25**	**1.08**	**1.68**	**0.89**	**0.74**	**0.64**	**0.53**
Terry 814	185	3	M	1.19	1.05	1.49	0.92	0.80	0.71	0.61
Terry 828	186	3	M	1.29		1.58	0.86	0.82		0.55
Terry 839	187	3	M	1.25	1.05	1.48	0.85	0.85	0.71	0.57
Terry 843	188	3	M	1.18	1.03	1.36	0.89	0.86	0.75	0.65
Terry 846	189	3	M	1.25	1.01	1.41	0.87	0.89	0.72	0.62
Terry 847	190	3	F	1.21	1.07	1.44	0.89	0.84	0.74	0.62
Terry 849	191	3	M	1.22	1.03	1.48	0.88	0.82	0.69	0.60
Terry 866	192	3	M	1.21	1.03	1.53	0.87	0.79	0.68	0.57

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 867	193	3	M	1.22	1.03	1.37	0.85	0.89	0.75	0.62
Terry 868	194	3	M	1.22	1.04	1.47	0.92	0.83	0.71	0.63
Terry 869	195	3	F					0.84	0.72	0.60
Terry 870	196	3	M	1.22	1.06	1.34	0.86	0.91	0.79	0.64
Terry 871	197	3	M	1.28	1.06	1.58	0.93	0.81	0.67	0.59
Terry 872	198	3	M	1.17	1.01	1.34	0.88	0.88	0.76	0.66
Terry 877	199	*5*	M	*1.23*	*1.03*	*1.41*	*0.92*	*0.87*	*0.73*	*0.65*
Terry 879	200	3	M	1.19	1.08	1.59	0.87	0.74	0.68	0.55
Terry 880	201	3	F	1.12	1.05	1.46	0.82	0.77	0.72	0.56
Terry 888	202	3	M	1.19	1.02	1.39	0.94	0.85	0.73	0.67
Terry 892	203	3	M	1.22	1.02					
Terry 895	204	3	M	1.23	1.04	1.51	0.91	0.82	0.69	0.60
Terry 897	205	3	M	1.16	1.07		0.86			
Terry 901R	206	3	M	1.22	1.04	1.47	0.87	0.84	0.71	0.59
Terry 904R	207	3	F	1.31	1.04	1.54	0.86	0.85	0.68	0.56
Terry 908	208	3	M	1.13	1.05	1.61	0.94	0.70	0.65	0.58
Terry 918	209	3	M	1.20	1.07	1.58	0.90	0.76	0.67	0.57
Terry 924	210	3	M	1.25	1.05	1.57	0.86	0.80	0.67	0.55
Terry 928R	211	3	F	1.28	1.05	1.44	0.89	0.89	0.73	0.62
Terry 946	212	3	M	1.25	1.06	1.60	0.95	0.78	0.66	0.59
Terry 954	213	3	M	1.19	1.06					
Terry 975	214	3	M	1.17	1.03	1.46	0.94	0.80	0.71	0.65
Terry 983	215	3	F	1.17	1.02	1.42	0.86	0.82	0.72	0.61
Terry 989	216	3	M	1.22	1.01	1.43	0.86	0.86	0.71	0.60
Terry 1009	218	3	M	1.20	1.05	1.50	0.89	0.80	0.70	0.60
Terry 1016R	219	3	F	1.19	1.09	1.69	0.91	0.70	0.64	0.53
Terry 1023	220	*5*	M	*1.03*	*0.83*	*0.86*	*0.72*	*1.21*	*0.96*	*0.85*
Terry 1037	221	*5*	M	*1.04*	*0.81*	*1.29*	*0.71*	*0.81*	*0.63*	*0.55*
Terry 1043	222	3	M	1.27	1.03	1.43	0.94	0.89	0.72	0.66
Terry 1080RR	223	3	F	1.24	1.09	1.55	0.91	0.80	0.70	0.59
Terry 1094	224	3	F	1.23	1.12	1.65	0.93	0.75	0.68	0.57
Terry 1153	225	**4**	F	**1.30**	**1.15**	**2.43**	**0.93**	**0.53**	**0.48**	**0.38**
Terry 1174	226	3	F	1.27	1.01	1.41	0.86	0.91	0.72	0.61
Terry 1186	227	**4**	F	**1.17**	**1.13**	**1.70**	**0.92**	**0.69**	**0.66**	**0.54**
Terry 1199R	228	3	F	1.23	1.11	1.69	0.95	0.73	0.65	0.56

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 1202R	229	3	F	1.22	1.03	1.44	0.91	0.85	0.72	0.63
Terry 1239R	230	3	F	1.23	1.06	1.56	0.88	0.79	0.68	0.57
Terry 1243R	231	3	F	1.22	1.05	1.51	0.92	0.81	0.70	0.61
Terry 1270R	232	3	F	1.27	1.02	1.54	0.93	0.82	0.66	0.60
Terry 1296R	233	3	F	1.19	1.09	1.55	0.91	0.77	0.71	0.59
Terry 1353R	234	3	F	1.24	1.07	1.33	0.82	0.93	0.81	0.62
Terry 1456	235	*5*	F	*1.25*	*1.09*	*1.64*	*0.92*	*0.76*	*0.66*	*0.56*
Terry 1476	236	3	F	1.20	0.95	1.41	0.85	0.85	0.67	0.60
Terry 1482R	237	3	F	1.20	1.03	1.55	0.85	0.77	0.66	0.55
Terry 1512	238	3	F	1.23	1.03	1.49	0.91	0.82	0.69	0.61
Terry 1523	239	3	F	1.23	1.08	1.56	0.94	0.78	0.69	0.60
Terry 1541R	240	3	F	1.15	1.03	1.43	0.88	0.80	0.72	0.61
Terry 1562	241	3	F	1.18	1.05	1.41	0.85	0.84	0.75	0.61
Terry 1563	242	3	F	1.29	1.01	1.52	0.88	0.85	0.66	0.58
Terry 1566	243	3	F	1.21	1.04	1.47	0.85	0.82	0.71	0.58
Terry 1571	244	3	F	1.25	1.03	1.41	0.84	0.89	0.73	0.60
Terry 1572	245	3	F	1.16	1.10	1.62	0.89	0.72	0.68	0.55
Terry 1574	246	3	F	1.20	1.07	1.47	0.87	0.82	0.73	0.59
Terry 1575	247	3	F	1.22	1.03	1.61	0.87	0.76	0.64	0.54
Terry 1578	248	3	F	1.26	1.08	1.61	0.89	0.78	0.67	0.55
Terry 1579	249	3	F	1.21	1.05	1.41	0.89	0.86	0.74	0.63
Terry 1580	250	3	F	1.26	1.07	1.51	0.85	0.84	0.71	0.56
Terry 1582	251	*5*	F	*1.00*	*1.06*	*1.45*	*1.20*	*0.69*	*0.73*	*0.83*
Terry 1592	252	3	F	1.30	1.06	1.41	0.86	0.92	0.75	0.61
Terry 1593	253	3	F	1.20	1.06	1.42	0.91	0.84	0.75	0.64
Terry 1594	254	3	F	1.24	1.06	1.44	0.89	0.86	0.74	0.62
Terry 1595	255	3	F	1.15	1.09	1.52	0.93	0.76	0.72	0.61
Terry 1596	256	3	F	1.20	1.07	1.59	0.85	0.76	0.67	0.53
Terry 1599	257	3	F	1.19	1.04	1.45	0.88	0.82	0.72	0.61
Terry 1603	258	3	F	1.19	1.09	1.64	0.85	0.73	0.66	0.52
Terry 1608	259	3	F	1.20	1.09	1.55	0.88	0.78	0.70	0.57
Terry 1612	260	3	F	1.27	1.08	1.51	0.89	0.84	0.71	0.59
Terry 1616	262	3	F	1.22	1.07	1.48	0.88	0.82	0.72	0.59
Terry 1617	263	*5*	F	*1.18*	*1.04*	*1.54*	*0.86*	*0.76*	*0.68*	*0.55*
Terry 1622	264	3	F	1.23	1.04	1.39	0.87	0.89	0.75	0.62

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 1624	265	3	F	1.24	1.10	1.70	0.93	0.73	0.65	0.55
Terry 1625	266	3	F	1.27	1.04	1.47	0.86	0.86	0.70	0.58
Terry 166R	267	3	F	1.21	1.09	1.42	0.91	0.85	0.76	0.64
Terry 580	268	3	F	1.23	1.03	1.48	0.85	0.83	0.69	0.58
Terry 1601	269	3	F	1.25	1.05	1.45	0.85	0.86	0.73	0.59
Terry 1610	270	3	F	1.17	1.03	1.48	0.91	0.79	0.70	0.62
Terry 1628	271	3	F	1.15	1.07	1.51	0.89	0.76	0.71	0.59
Terry 76R	272	3	F	1.25	1.05	1.55	0.89	0.80	0.68	0.57
Terry 934	273	3	F	1.19	1.03	1.44	0.84	0.82	0.72	0.58
Terry 951R	274	3	F	1.23	1.06	1.46	0.91	0.84	0.72	0.62
Terry 1568	275	3	F	1.20	1.04	1.50	0.87	0.80	0.69	0.58
Terry 1570	276	3	F	1.20	1.09	1.49	0.96	0.80	0.73	0.64
Terry 22RR	277	3	F	1.26	1.11	1.73	0.94	0.73	0.64	0.54
Terry 240R	278	3	F	1.25	1.05	1.76	0.86	0.71	0.60	0.49
Terry 1119	279	3	F	1.31	1.09	1.65	0.87	0.79	0.66	0.53
Terry 1233R	280	3	F	1.20	1.06	1.58	0.92	0.76	0.67	0.58
Terry 1560	281	3	F	1.26	1.07	1.49	0.90	0.85	0.72	0.60
Terry 115R	283	3	F	1.21	1.08	1.49	0.94	0.81	0.73	0.63
Terry 312R	284	3	F	1.16	1.06	1.58	0.95	0.73	0.67	0.60
Terry 464	285	3	F	1.16	1.06	1.56	0.88	0.75	0.68	0.56
Terry 1155	286	3	F	1.21	1.10	1.55	0.92	0.78	0.71	0.60
Terry 1480	287	3	F	1.21	1.04	1.43	0.91	0.84	0.72	0.64
Terry 1557	288	3	F	1.20	1.08	1.47	0.89	0.82	0.73	0.61
Terry 1581	289	3	F	1.18	1.03	1.41	0.85	0.84	0.73	0.60
Terry 91R	290	3	F	1.25	1.04	1.48	0.83	0.84	0.70	0.56
Terry 99RR	291	3	F	1.27	1.08	1.46	0.88	0.87	0.74	0.60
Terry 359R	292	3	F	1.24	1.03	1.47	0.90	0.85	0.70	0.61
Terry 491R	293	3	F	1.25	1.05	1.54	0.89	0.81	0.68	0.58
Terry 611	294	3	F							
Terry 899R	295	*5*	F	*1.29*	*0.99*	*1.49*	*0.82*	*0.87*	*0.67*	*0.55*
Terry 1201	296	3	F	1.17	1.05	1.45	0.89	0.81	0.73	0.62
Terry 1463	297	3	F					0.89	0.78	0.64
Terry 17R	298	3	F	1.26	1.09	1.56	0.91	0.81	0.70	0.59
Terry 55R	299	3	F	1.23	1.03	1.52	0.87	0.80	0.68	0.57
Terry 110R	300	3	F	1.21	1.09	1.68	0.94	0.72	0.65	0.56

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 134R	301	3	F							
Terry 791	302	3	F	1.28	1.09	1.80	0.86	0.71	0.61	0.48
Terry 985RR	303	3	F	1.17	1.09	1.43	0.88	0.82	0.76	0.61
Terry 1435	304	3	F	1.24	1.05	1.47	0.86	0.85	0.71	0.58
Terry 1626	305	3	F	1.17	1.07	1.60	0.91	0.73	0.67	0.57
Terry 92R	307	**4**	F	**1.24**	**1.11**	**1.67**	**0.90**	**0.74**	**0.67**	**0.54**
Terry 169R	308	3	F	1.15	1.01	1.36	0.84	0.84	0.74	0.61
Terry 170R	309	3	F	1.25	1.01	1.34	0.85	0.93	0.75	0.64
Terry 188R	310	3	F	1.26	1.05	1.52	0.87	0.83	0.69	0.57
Terry 481R	311	3	F	1.14	1.07	1.62	0.83	0.71	0.66	0.52
Terry 722R	312	3	F							
Terry 1075RR	313	3	F	1.33	1.02	1.44	0.89	0.92	0.71	0.62
Terry 1154R	314	*5*	F	*1.20*	*1.03*	*1.53*	*0.88*	*0.78*	*0.67*	*0.58*
Terry 1405	315	*5*	F	*1.25*	*1.08*	*1.68*	*0.91*	*0.74*	*0.64*	*0.54*
Terry 1542	316	3	F	1.18	1.04	1.40	0.85	0.85	0.75	0.61
Terry 275RR	318	3	F	1.21	1.06	1.51	0.94	0.80	0.71	0.63
Terry 1058	319	**4**	F	**1.23**	**1.04**	**1.68**	**0.92**	**0.73**	**0.62**	**0.55**
Terry 1189R	320	3	F	1.21	1.06	1.57	0.95	0.77	0.68	0.61
Terry 97R	321	3	F	1.21	1.11	1.74		0.70	0.64	
Terry 1109R	322	3	F	1.20	1.02	1.43	0.81	0.84	0.71	0.57
Terry 1496	323	3	F	1.24	1.05	1.40	0.93	0.88	0.75	0.66
Terry 1567	324	3	F	1.21	1.04	1.44	0.81	0.84	0.73	0.57
Terry 28R	326	3	F	1.15	1.02	1.45	0.79	0.80	0.71	0.55
Terry 108R	327	3	F	1.19	1.01	1.48	0.87	0.81	0.68	0.59
Terry 149R	328	3	F	1.21	1.08	1.46	0.90	0.83	0.74	0.62
Terry 248R	329	3	F		1.09	1.55	0.86		0.70	0.56
Terry 295R	330	3	F	1.25	1.03	1.42	0.86	0.89	0.73	0.61
Terry 349RR	331	3	F	1.26	1.09		0.89			
Terry 1069	332	3	F	1.17			0.89			
Terry 1583	333	3	F	1.16	1.02	1.46	0.88	0.80	0.70	0.60
Terry 75R	334	3	F	1.16	1.03	1.43	0.86	0.81	0.72	0.60
Terry 83R	335	3	F	1.24	1.04	1.48	0.86	0.84	0.70	0.58
Terry 543	336	3	F	1.20	1.06	1.44	0.86	0.83	0.73	0.60
Terry 925	337	3	F	1.14	1.05	1.41	0.87	0.81	0.74	0.62
Terry 992R	338	3	F	1.14	1.06	1.53	0.90	0.75	0.69	0.59

Appendix A, Part I continued. Ratios for BD-H-IP5, left

SkelNum	CaseNum	BD	Sex	LIP3/LIP2	LIP3/LIP4	LIP3/LIP5	LIP3/LPP5	LIP5/LIP2	LIP5/LIP4	LIP5/LPP5
Terry 1085R	339	3	F	1.23	1.08	1.48	0.92	0.83	0.73	0.62
Terry 1123R	340	3	F	1.24	1.07	1.53	0.92	0.81	0.70	0.60
Terry 1584	341	3	F	1.21	1.09	1.58	0.90	0.77	0.69	0.57
Terry 127R	342	3	F							
Terry 154R	343	3	F	1.27	1.03	1.51	0.91	0.84	0.69	0.61
Terry 596	141A	3	M	1.34	1.07	1.68	0.93	0.79	0.63	0.55
Terry 599	141B	3	M							0.61

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 1R	1	3	F	1.27	1.06	1.67		0.76	0.64	0.54
Terry 6RR	2	3	F	1.21	1.08	1.69	0.93	0.72	0.64	0.55
Terry 12R	3	3	F	1.20	0.98	1.34	0.77	0.90	0.73	0.57
Terry 14R	4	3	M	1.22	1.04	1.50	0.93	0.82	0.70	0.62
Terry 15R3	5	3	F	1.21	1.05		0.87			
Terry 16RR	6	3	F	1.21	1.05	1.62	0.89	0.75	0.65	0.55
Terry 34R	7	3	M	1.25	1.06	1.61	0.85	0.77	0.66	0.53
Terry 448	8	3	M	1.16	1.03	1.39	0.83	0.84	0.74	0.60
Terry 37R	9	*5*	F	*1.26*	*1.04*	*1.46*	*0.83*	*0.86*	*0.71*	*0.57*
Terry 41R	10	3	F	1.27	1.07	1.63	0.92	0.78	0.66	0.56
Terry 53R	11	3	F	1.22	1.09	1.54	0.88	0.80	0.71	0.57
Terry 59R	12	3	M	1.20	0.99	1.33	0.86	0.90	0.74	0.65
Terry 62RR	13	3	M	1.21	1.07	1.40	0.87	0.87	0.77	0.62
Terry 64R	14	3	F	1.20	1.08	1.49	0.88	0.81	0.73	0.59
Terry 69R	15	3	F	1.17	1.05	1.43	0.89	0.82	0.73	0.62
Terry 73R	16	3	M	1.19	1.06	1.40	0.91	0.85	0.76	0.65
Terry 79R	17	3	F	1.19	1.07	1.48	0.83	0.81	0.72	0.56
Terry 80RR	18	3	F	1.20	1.17	1.60	0.91	0.75	0.73	0.57
Terry 109	19	3	M	1.20	1.01	1.41	0.84	0.86	0.72	0.60
Terry 111R	20	*5*	M	*1.25*	*1.06*	*1.51*	*0.86*	*0.83*	*0.70*	*0.57*
Terry 112R	21	3	F	1.19	1.09	1.46	0.88	0.82	0.75	0.60
Terry 113R	22	3	M	1.21	1.05	1.38	0.84	0.87	0.76	0.61
Terry 114R	23	3	F	1.22	1.05	1.58	0.80	0.78	0.67	0.51
Terry 126R	24	3	M	1.21	1.05	1.39	0.85	0.87	0.76	0.61
Terry 131R	25	3	M	1.18	1.00	1.41	0.83	0.84	0.71	0.59
Terry 135R	26	3	F	1.18	1.04	1.42	0.85	0.83	0.73	0.60
Terry 136R	27	3	M	1.24	1.08	1.53	0.88	0.81	0.70	0.57
Terry 139R	28	3	F	1.25	1.01	1.34	0.80	0.93	0.76	0.60
Terry 147	29	3	M	1.22	1.08	1.45	0.87	0.84	0.75	0.60
Terry 148RR	30	3	F	1.23	1.05	1.50	0.88	0.82	0.70	0.59
Terry 161R	31	3	F	1.24	1.08	1.50	0.96	0.83	0.72	0.64
Terry 162R	32	3	F	1.20	1.08	1.48	0.90	0.81	0.73	0.61
Terry 164R	33	3	F	1.28	1.07	1.59	0.94	0.81	0.67	0.59
Terry 174R	34	3	F	1.21	1.05	1.72	0.89	0.71	0.61	0.52
Terry 195	35	3	M	1.18	1.07	1.41	0.87	0.84	0.76	0.62
Terry 196	36	3	M	1.25	1.09	1.62	0.93	0.77	0.67	0.57
Terry 197R	37	3	F	1.21	1.04	1.46	0.81	0.82	0.71	0.56
Terry 198R	38	3	M	1.16	1.07	1.59	0.93	0.73	0.67	0.58

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 201	39	3	M	1.24	1.04	1.48	0.84	0.84	0.70	0.57
Terry 202	40	**4**	M	**1.28**	**1.03**	**1.88**	**0.97**	**0.68**	**0.54**	**0.52**
Terry 207	41	3	M	1.27	1.07	1.45	0.89	0.87	0.74	0.61
Terry 215	42	3	M	1.22	1.03	1.45	0.85	0.84	0.71	0.59
Terry 216	43	3	M	1.26	1.06	1.46	0.98	0.87	0.72	0.67
Terry 220	44	3	M	1.22	1.04	1.47	0.87	0.83	0.71	0.59
Terry 225R	46	3	F	1.22	1.02	1.40	0.86	0.87	0.73	0.62
Terry 227	47	3	M	1.22	1.06	1.47	0.89	0.84	0.72	0.61
Terry 230	49	3	M	1.26	1.04	1.44	0.88	0.88	0.72	0.61
Terry 233	50	3	M	1.17	1.07	1.54	0.80	0.76	0.70	0.52
Terry 234	51	3	M	1.18	1.01	1.34	0.88	0.88	0.75	0.66
Terry 236R	52	3	F	1.20	1.02	1.51	0.91	0.80	0.67	0.60
Terry 237	53	3	M	1.17	1.05	1.43	0.89	0.82	0.74	0.63
Terry 250	54	3	M	1.23	1.06	1.46	0.89	0.85	0.73	0.61
Terry 259	56	3	M	1.23	1.06	1.46	0.96	0.84	0.72	0.66
Terry 260	57	3	M	1.20	1.05	1.46	0.89	0.83	0.72	0.61
Terry 261	58	**4**	M	**1.30**	**1.07**	**1.79**	**0.92**	**0.73**	**0.60**	**0.51**
Terry 263	59	3	M	1.18	1.04	1.48	0.94	0.80	0.70	0.63
Terry 267	60	3	M	1.23	1.06	1.55	0.91	0.79	0.68	0.58
Terry 271	61	*5*	M	*1.00*	*1.27*	*1.40*	*0.92*	*0.71*	*0.91*	*0.66*
Terry 273	62	*5*	M	*1.05*	*0.87*	*0.90*	*0.77*	*1.16*	*0.97*	*0.86*
Terry 274	63	3	M	1.03	1.24	1.44	0.85	0.72	0.86	0.59
Terry 277	64	*5*	M	*1.23*	*1.05*	*1.61*	*0.88*	*0.77*	*0.65*	*0.55*
Terry 279	65	3	M	1.21	1.07	1.54	0.87	0.79	0.69	0.57
Terry 282	66	*5*	M	*1.23*	*1.03*	*1.44*	*0.87*	*0.85*	*0.71*	*0.60*
Terry 285	67	3	M	1.20	1.01	1.41	0.86	0.85	0.71	0.61
Terry 289R	68	3	F							
Terry 293R	69	3	F	1.22	1.06	1.48	0.88	0.82	0.72	0.59
Terry 297	70	3	M	1.21	1.04	1.44	0.88	0.84	0.72	0.61
Terry 298	71	3	M	1.24	1.04	1.39	0.89	0.89	0.74	0.64
Terry 301R	72	3	M	1.17	1.06	1.45	0.86	0.81	0.73	0.59
Terry 303R	73	3	M	1.27	1.04	1.48	0.88	0.86	0.70	0.60
Terry 305	74	3	M	1.20	1.02	1.48	0.87	0.81	0.69	0.59
Terry 306R	75	3	F	1.15	1.00	1.52	0.93	0.75	0.66	0.61
Terry 311R	76	3	M	1.15	1.08	1.43	0.92	0.80	0.75	0.64

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 315	77	*5*	M	*1.03*	*0.82*	*0.88*	*0.81*	*1.17*	*0.93*	*0.92*
Terry 316	78	3	M	1.20	1.03	1.49	0.88	0.81	0.69	0.59
Terry 318	79	3	M	1.25	1.06	1.51	0.90	0.83	0.70	0.60
Terry 320	80	3	M	1.27	1.04	1.62	0.94	0.79	0.65	0.58
Terry 332	81	3	M	1.20	1.07	1.59	0.91	0.75	0.68	0.58
Terry 335	82	3	M	1.19	1.03	1.38	0.79	0.86	0.74	0.57
Terry 342	83	3	M	1.24	1.05	1.53	0.87	0.81	0.68	0.57
Terry 343	84	*5*	M	*1.02*	*0.90*	*0.91*	*0.80*	*1.12*	*0.98*	*0.87*
Terry 346RR	85	3	F	1.20	0.97	1.47	0.85	0.81	0.66	0.58
Terry 351R	86	3	F	1.21	0.99	1.32	0.83	0.91	0.75	0.63
Terry 365	87	3	M	1.19	1.05	1.44	0.94	0.83	0.73	0.65
Terry 366	88	3	M	1.24	1.05	1.56	0.94	0.80	0.67	0.61
Terry 367	89	3	M							
Terry 373	90	*5*	F	*0.97*	*0.81*	*0.86*	*0.68*	*1.12*	*0.93*	*0.79*
Terry 379	91	3	M	1.28	1.03	1.37	0.91	0.93	0.75	0.66
Terry 387R	93	3	F	1.22						
Terry 395	95	3	M							0.59
Terry 397	96	3	M	1.22	1.01	1.44	0.89	0.85	0.70	0.62
Terry 405R	97	3	F	1.21	1.06	1.49	0.90	0.81	0.71	0.60
Terry 407	98	3	M	1.19	1.05	1.47	0.88	0.81	0.71	0.60
Terry 409	99	3	M	1.37	1.04	1.51	0.91	0.90	0.69	0.60
Terry 411	100	3	M	1.22	1.07	1.54	0.92	0.79	0.69	0.60
Terry 413	101	3	M	1.19	1.06	1.61	0.90	0.74	0.65	0.56
Terry 414	102	3	M	1.25	1.03	1.57	0.87	0.79	0.66	0.55
Terry 415	103	*5*	M	*1.23*	*1.05*	*1.44*	*0.90*	*0.85*	*0.72*	*0.63*
Terry 417	104	3	M	1.25	1.02	1.50	0.85	0.83	0.68	0.57
Terry 433	106	3	M	1.24	1.10	1.57	0.87	0.79	0.70	0.55
Terry 437R	108	3	F	1.21	1.07	1.63	0.91	0.74	0.66	0.56
Terry 440	109	3	M	1.24	1.05	1.60	0.90	0.78	0.66	0.56
Terry 442	110	3	M	1.24	1.01	1.49	0.88	0.83	0.68	0.59
Terry 451R	111	3	F	1.21	1.07	1.59	0.86	0.76	0.67	0.54
Terry 453	112	3	M	1.19	1.04	1.45	0.87	0.82	0.72	0.60
Terry 184R	113	3	M	1.20	1.01	1.40	0.93	0.85	0.72	0.66
Terry 463	115	3	M	1.21	1.11	1.56	0.92	0.77	0.71	0.59
Terry 476RR	116	3	F	1.21	1.07	1.60	0.84	0.75	0.67	0.53

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 478	117	3	M	1.23	1.07	1.57	0.80	0.78	0.68	0.51
Terry 482	118	3	F	1.21	1.07	1.52	0.89	0.80	0.70	0.58
Terry 496	119	3	M	1.15	1.02	1.37	0.84	0.84	0.74	0.62
Terry 505	120	3	M	1.21	1.10	1.58	0.94	0.77	0.69	0.59
Terry 506	121	3	M	1.19	1.05	1.45	0.89	0.82	0.73	0.61
Terry 517	122	3	M	1.29	1.06	1.49	0.95	0.87	0.71	0.64
Terry 525	123	*5*	M	*1.09*	*0.82*	*0.90*	*0.76*	*1.21*	*0.91*	*0.84*
Terry 536	124	3	M	1.33	1.02	1.50	0.93	0.89	0.68	0.62
Terry 545	125	3	M	1.14	1.05	1.39	0.89	0.82	0.76	0.64
Terry 546	126	3	M	1.20	1.07	1.50	0.95	0.80	0.72	0.63
Terry 548	127	3	M	1.19	1.06	1.50	0.91	0.80	0.71	0.61
Terry 554R	128	3	F	1.20	1.06	1.59	0.90	0.76	0.67	0.56
Terry 555	129	3	M	1.25	1.05	1.63	0.95	0.77	0.65	0.58
Terry 557	130	*5*	M	*1.25*	*1.10*	*1.60*	*0.84*	*0.78*	*0.69*	*0.52*
Terry 564	132	3	M	1.19	1.02	1.41	0.86	0.85	0.73	0.61
Terry 566	133	3	M	1.20	1.04	1.46	0.91	0.82	0.71	0.62
Terry 573	134	3	M	1.23	1.06	1.66	0.84	0.74	0.64	0.51
Terry 575	135	*5*	M	*1.16*	*1.05*	*1.44*	*0.91*	*0.81*	*0.73*	*0.63*
Terry 577	136	3	M	1.23	1.00	1.45	0.91	0.85	0.69	0.63
Terry 588	137	3	M	1.19	1.08	1.50	0.95	0.79	0.72	0.63
Terry 591	138	3	M	1.07	1.19	1.58	0.91	0.68	0.75	0.58
Terry 602	142	3	M	1.28	1.05	1.50	0.89	0.86	0.70	0.59
Terry 605R	143	3	M	1.21	1.05	1.44	0.89	0.84	0.73	0.62
Terry 608	144	3	M	1.08	1.00	1.60	0.90	0.67	0.63	0.56
Terry 614	145	3	M	1.26	1.08	1.57	0.90	0.81	0.69	0.58
Terry 620	146	3	M	1.21	1.02	1.45	0.84	0.83	0.70	0.58
Terry 622R	147	3	M	1.28	0.99	1.42	0.87	0.90	0.69	0.61
Terry 636	148	3	M	1.24	1.06	1.46	0.90	0.85	0.73	0.62
Terry 641	149	3	M	1.20	1.06	1.52	0.89	0.79	0.70	0.58
Terry 644	150	3	M	1.21	1.04	1.49	0.91	0.81	0.70	0.61
Terry 645	151	3	M	1.30	1.08	1.55	0.90	0.84	0.69	0.58
Terry 670	152	3	M	1.20	1.04	1.43	0.88	0.84	0.72	0.62
Terry 672	153	3	M	1.29	1.03	1.48	0.92	0.87	0.70	0.62
Terry 674	154	3	M	1.21	1.08	1.46	0.92	0.83	0.73	0.63
Terry 680	155	3	F	1.24	1.04	1.44	0.82	0.86	0.72	0.57

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 681	156	3	M	1.22	1.04	1.52	0.92	0.80	0.69	0.61
Terry 687	157	3	M	1.21	0.99	1.38	0.86	0.88	0.72	0.63
Terry 693	158	3	M	1.18	1.02	1.39	0.87	0.84	0.74	0.63
Terry 696	159	3	M	1.18	1.02	1.38	0.84	0.86	0.74	0.61
Terry 701	160	3	M	1.20	1.07	1.35	0.88	0.89	0.79	0.65
Terry 709	161	3	M	1.23	1.06	1.43	0.83	0.86	0.74	0.58
Terry 710R	162	3	F	1.26	1.03	1.50	0.90	0.84	0.69	0.60
Terry 720	163	3	M	1.22	1.07	1.56	0.89	0.78	0.68	0.57
Terry 721	164	3	M	1.23	1.02	1.52	0.94	0.81	0.68	0.62
Terry 736	165	3	F	1.23	1.04	1.50	0.88	0.82	0.69	0.59
Terry 739	166	3	M	1.23	1.04	1.61	0.89	0.76	0.64	0.55
Terry 743	167	3	M	1.29	1.03	1.40	0.89	0.92	0.74	0.64
Terry 745R	168	3	F	1.19	1.08	1.52	0.89	0.78	0.71	0.59
Terry 747	169	3	M	1.26	1.06	1.53	0.89	0.82	0.69	0.58
Terry 751	170	3	M	1.19	1.02	1.50	0.86	0.79	0.68	0.58
Terry 762	173	3	M	1.26	1.03	1.55	0.92	0.81	0.67	0.60
Terry 763	174	3	M	1.18	1.04	1.46	0.84	0.81	0.71	0.58
Terry 764	175	3	M	1.23	1.04	1.46	0.88	0.84	0.71	0.61
Terry 768	176	3	M	1.18	1.00	1.42	0.89	0.83	0.71	0.63
Terry 772	177	*5*	M	*1.15*	*1.04*	*1.39*	*0.91*	*0.83*	*0.75*	*0.65*
Terry 778	178	3	M	1.22	1.05	1.41	0.93	0.86	0.74	0.66
Terry 785	179	3	M	1.24	1.04	1.47	0.91	0.84	0.71	0.62
Terry 787	180	3	M	1.19	1.05	1.47	0.85	0.81	0.72	0.58
Terry 795	181	3	M	1.20	1.09	1.44	0.90	0.83	0.76	0.63
Terry 802	182	3	M	1.19	1.07	1.52	0.91	0.78	0.71	0.60
Terry 810	183	3	M	1.21	1.09	1.52	0.91	0.79	0.72	0.60
Terry 813	184	**4**	M	**1.25**	**1.08**	**1.70**	**0.87**	**0.73**	**0.64**	**0.51**
Terry 814	185	3	M	1.17	1.06	1.55	0.93	0.75	0.69	0.60
Terry 828	186	3	M	1.29	1.07	1.60	0.86	0.81	0.67	0.54
Terry 839	187	3	M	1.23	1.03	1.46	0.84	0.84	0.70	0.57
Terry 843	188	3	M	1.23	1.03	1.36	0.88	0.90	0.75	0.65
Terry 846	189	3	M	1.27	1.04	1.41	0.86	0.90	0.74	0.61
Terry 847	190	3	F	1.20	1.08	1.45	0.88	0.83	0.75	0.61
Terry 849	191	3	M	1.28	1.07	1.49	0.91	0.86	0.72	0.61
Terry 866	192	3	M	1.18	1.03	1.53	0.86	0.77	0.67	0.56

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 867	193	3	M	1.21	1.02	1.37	0.84	0.89	0.74	0.61
Terry 868	194	3	M	1.19	1.03	1.45	0.89	0.82	0.71	0.61
Terry 869	195	3	F	1.20	1.05	1.39	0.87	0.86	0.75	0.63
Terry 870	196	3	M	1.19	1.09	1.40	0.88	0.85	0.78	0.63
Terry 871	197	3	M	1.31	1.05	1.54	0.89	0.85	0.68	0.58
Terry 872	198	3	M	1.19	1.02	1.34	0.88	0.88	0.76	0.65
Terry 877	199	*5*	M	*1.23*	*1.02*	*1.41*	*0.91*	*0.87*	*0.72*	*0.65*
Terry 879	200	3	M	1.19	1.08	1.52	0.85	0.78	0.71	0.56
Terry 880	201	3	F	1.12	1.09	1.59	0.82	0.71	0.68	0.52
Terry 888	202	3	M	1.18	1.04	1.42	0.92	0.83	0.73	0.65
Terry 892	203	3	M	1.18	1.01	1.42	0.90	0.83	0.72	0.63
Terry 895	204	3	M	1.26	1.02	1.50	0.90	0.84	0.68	0.60
Terry 897	205	3	M	1.19	1.04	1.53	0.83	0.78	0.68	0.54
Terry 901R	206	3	M	1.24	1.06	1.49	0.87	0.83	0.71	0.58
Terry 904R	207	3	F	1.33	1.03	1.48	0.86	0.90	0.69	0.58
Terry 908	208	3	M	1.15	1.09	1.68	0.95	0.68	0.65	0.56
Terry 918	209	3	M	1.22	1.06	1.51	0.88	0.81	0.70	0.58
Terry 924	210	3	M	1.20	1.04	1.50	0.82	0.80	0.69	0.55
Terry 928R	211	3	F	1.26	1.07	1.48	0.90	0.85	0.72	0.61
Terry 946	212	3	M	1.18	1.05	1.54	0.92	0.77	0.68	0.60
Terry 954	213	3	M	1.21	1.06	1.67	0.91	0.72	0.63	0.54
Terry 975	214	3	M	1.19	1.07	1.49	0.98	0.80	0.72	0.66
Terry 983	215	3	F	1.21	1.06	1.43	0.89	0.85	0.74	0.62
Terry 989	216	3	M	1.25	1.04	1.47	0.87	0.85	0.71	0.59
Terry 1009	218	3	M	1.17	1.04	1.49	0.87	0.79	0.70	0.58
Terry 1016R	219	3	F	1.18	1.07	1.73	0.88	0.68	0.62	0.51
Terry 1023	220	*5*	M	*1.19*	*1.02*	*1.38*	*0.85*	*0.87*	*0.74*	*0.62*
Terry 1037	221	*5*	M	*1.23*	*1.10*	*1.61*	*0.88*	*0.77*	*0.68*	*0.54*
Terry 1043	222	3	M	1.31	1.05	1.45	0.93	0.91	0.72	0.64
Terry 1080RR	223	3	F	1.22	1.11	1.50	0.92	0.82	0.74	0.61
Terry 1094	224	3	F	1.23	1.13	1.71	0.93	0.72	0.66	0.54
Terry 1153	225	**4**	F	**1.26**	**1.14**	**1.90**	**0.92**	**0.66**	**0.60**	**0.48**
Terry 1174	226	3	F	1.23	1.01	1.41	0.83	0.87	0.72	0.59
Terry 1186	227	**4**	F	**1.18**	**1.13**	**1.78**	**0.89**	**0.66**	**0.64**	**0.50**
Terry 1199R	228	3	F	1.22	1.03	1.70	0.88	0.72	0.61	0.52

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 1202R	229	3	F	1.24	1.05	1.51	0.91	0.82	0.70	0.60
Terry 1239R	230	3	F	1.26	1.06	1.59	0.90	0.79	0.66	0.57
Terry 1243R	231	3	F	1.23	1.04	1.51	0.93	0.81	0.69	0.61
Terry 1270R	232	3	F	1.14	1.01	1.39	0.84	0.82	0.73	0.61
Terry 1296R	233	3	F	1.18	1.07	1.56	0.91	0.76	0.69	0.58
Terry 1353R	234	3	F	1.23	1.03	1.36	0.83	0.90	0.76	0.61
Terry 1456	235	*5*	F	*1.24*	*1.10*	*1.67*	*0.91*	*0.74*	*0.66*	*0.55*
Terry 1476	236	3	F	1.26	1.05	1.53	0.90	0.82	0.69	0.59
Terry 1482R	237	3	F	1.19	1.06	1.51	0.85	0.79	0.70	0.56
Terry 1512	238	3	F	1.27	1.03	1.44	0.88	0.89	0.71	0.61
Terry 1523	239	3	F	1.21	1.07	1.59	0.94	0.76	0.67	0.59
Terry 1541R	240	3	F	1.13	1.04	1.41	0.86	0.80	0.74	0.61
Terry 1562	241	3	F	1.17	1.04	1.41	0.85	0.83	0.74	0.61
Terry 1563	242	3	F	1.28	1.03	1.52	0.87	0.84	0.68	0.57
Terry 1566	243	3	F	1.21	1.05	1.47	0.85	0.82	0.71	0.58
Terry 1571	244	3	F	1.19	1.01	1.32	0.78	0.90	0.76	0.59
Terry 1572	245	3	F	1.20	1.11	1.73	0.91	0.69	0.64	0.53
Terry 1574	246	3	F	1.23	1.08	1.49	0.88	0.83	0.73	0.59
Terry 1575	247	3	F	1.18	1.06	1.54	0.87	0.77	0.69	0.56
Terry 1578	248	3	F	1.25	1.08	1.62	0.89	0.77	0.67	0.55
Terry 1579	249	3	F	1.22	1.00	1.36	0.84	0.90	0.74	0.62
Terry 1580	250	3	F	1.25	1.11	1.55	0.85	0.81	0.72	0.55
Terry 1582	251	*5*	F	*1.24*	*1.08*	*1.55*	*0.85*	*0.80*	*0.70*	*0.55*
Terry 1592	252	3	F	1.20	1.03	1.40	0.83	0.86	0.74	0.59
Terry 1593	253	3	F	1.22	1.06	1.46	0.93	0.84	0.73	0.64
Terry 1594	254	3	F	1.23	1.04	1.44	0.86	0.85	0.72	0.59
Terry 1595	255	3	F	1.16	1.11	1.60	0.94	0.73	0.69	0.59
Terry 1596	256	3	F	1.21	1.09	1.60	0.85	0.75	0.68	0.53
Terry 1599	257	3	F	1.16	1.02	1.47	0.87	0.79	0.70	0.59
Terry 1603	258	3	F	1.19	1.07	1.60	0.85	0.74	0.67	0.53
Terry 1608	259	3	F	1.23	1.10	1.58	0.90	0.78	0.69	0.57
Terry 1612	260	3	F	1.28	1.08	1.61	0.91	0.79	0.67	0.57
Terry 1616	262	3	F	1.24	1.08	1.48	0.89	0.84	0.73	0.60
Terry 1617	263	*5*	F	*1.29*	*1.07*	*1.52*	*0.85*	*0.85*	*0.70*	*0.55*
Terry 1622	264	3	F	1.23	1.07	1.39	0.84	0.88	0.77	0.61

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 1624	265	3	F	1.25	1.11	1.75	0.92	0.72	0.64	0.53
Terry 1625	266	3	F	1.23	1.04	1.44	0.84	0.86	0.72	0.58
Terry 166R	267	3	F	1.20	1.04	1.38	0.88	0.87	0.75	0.64
Terry 580	268	3	F	1.25	1.04	1.54	0.85	0.81	0.68	0.56
Terry 1601	269	3	F	1.23	1.05	1.45	0.88	0.85	0.72	0.60
Terry 1610	270	3	F	1.23	1.08	1.56	0.94	0.79	0.69	0.60
Terry 1628	271	3	F	1.18	1.07	1.47	0.88	0.81	0.73	0.60
Terry 76R	272	3	F	1.22	1.08	1.49	0.87	0.82	0.73	0.59
Terry 934	273	3	F	1.17	1.02	1.51	0.83	0.77	0.68	0.55
Terry 951R	274	3	F	1.23	1.04	1.44	0.88	0.85	0.72	0.61
Terry 1568	275	3	F	1.07	1.21	1.50	0.89	0.71	0.81	0.59
Terry 1570	276	3	F	1.25	1.10	1.54	0.94	0.81	0.71	0.61
Terry 22RR	277	3	F	1.23	1.07	1.65	0.90	0.75	0.65	0.55
Terry 240R	278	3	F	1.22	1.07	1.76	0.85	0.69	0.61	0.48
Terry 1119	279	3	F	1.31	1.09	1.69	0.86	0.78	0.64	0.51
Terry 1233R	280	3	F	1.08	1.17	1.62	0.89	0.67	0.72	0.55
Terry 1560	281	3	F	1.27	1.04	1.45	0.86	0.88	0.72	0.59
Terry 115R	283	3	F	1.19	1.08	1.49	0.94	0.80	0.72	0.63
Terry 312R	284	3	F	1.20	1.06	1.59	0.94	0.75	0.67	0.59
Terry 464	285	3	F	1.18	1.05	1.61	0.86	0.73	0.65	0.54
Terry 1155	286	3	F	1.23	1.08	1.55	0.89	0.79	0.69	0.57
Terry 1480	287	3	F	1.21	0.98	1.45	0.89	0.83	0.68	0.61
Terry 1557	288	3	F	1.20	1.08	1.52	0.89	0.79	0.71	0.59
Terry 1581	289	3	F	1.18	1.02	1.47	0.83	0.80	0.70	0.56
Terry 91R	290	3	F	1.24	1.03	1.45	0.85	0.86	0.71	0.59
Terry 99RR	291	3	F	1.21	1.01	1.42	0.85	0.85	0.71	0.60
Terry 359R	292	3	F	1.26	1.08	1.54	0.93	0.82	0.70	0.61
Terry 491R	293	3	F	1.25	1.04	1.50	0.87	0.83	0.70	0.58
Terry 611	294	3	F							
Terry 899R	295	*5*	F	*1.36*	*1.06*	*1.57*	*0.82*	*0.87*	*0.68*	*0.52*
Terry 1201	296	3	F	1.14	1.04	1.41	0.88	0.81	0.73	0.63
Terry 1463	297	3	F	1.19	1.04	1.38	0.84	0.87	0.76	0.61
Terry 17R	298	3	F	1.25	1.11	1.52	0.90	0.83	0.73	0.59
Terry 55R	299	3	F	1.26	1.01	1.48	0.85	0.85	0.68	0.58
Terry 110R	300	3	F	1.22	1.09	1.61	0.93	0.76	0.68	0.58

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 134R	301	3	F	1.31	1.06	1.64	0.91	0.80	0.65	0.56
Terry 791	302	3	F	1.23	1.10	1.58	0.82	0.78	0.70	0.52
Terry 985RR	303	3	F	1.17	1.08	1.47	0.86	0.80	0.74	0.58
Terry 1435	304	3	F	1.27	1.06	1.48	0.84	0.85	0.71	0.57
Terry 1626	305	3	F	1.16	1.07	1.59	0.91	0.73	0.67	0.57
Terry 92R	307	**4**	F	**1.29**	**1.14**	**1.79**	**0.93**	**0.72**	**0.64**	**0.52**
Terry 169R	308	3	F	1.13	0.99	1.44	0.84	0.78	0.69	0.59
Terry 170R	309	3	F	1.23	1.01	1.39	0.86	0.88	0.72	0.62
Terry 188R	310	3	F	1.24	1.02	1.53	0.88	0.81	0.67	0.57
Terry 481R	311	3	F	1.19	1.11	1.70	0.89	0.70	0.65	0.52
Terry 722R	312	3	F		1.02		0.85			
Terry 1075RR	313	3	F	1.29	1.02	1.44	0.87	0.90	0.71	0.61
Terry 1154R	314	*5*	F	*1.20*	*1.04*	*1.46*	*0.89*	*0.82*	*0.71*	*0.61*
Terry 1405	315	*5*	F	*1.20*	*1.06*	*1.62*	*0.90*	*0.74*	*0.66*	*0.56*
Terry 1542	316	3	F	1.17	1.07	1.42	0.84	0.83	0.76	0.59
Terry 275RR	318	3	F	1.19	1.06	1.52	0.92	0.78	0.70	0.61
Terry 1058	319	**4**	F	**1.20**	**1.07**	**1.72**	**0.90**	**0.70**	**0.62**	**0.53**
Terry 1189R	320	3	F	1.20	1.07	1.53	0.95	0.79	0.70	0.62
Terry 97R	321	3	F	1.30	1.12	1.82		0.72	0.62	
Terry 1109R	322	3	F	1.20	1.04	1.40	0.80	0.85	0.74	0.57
Terry 1496	323	3	F					0.86	0.75	0.63
Terry 1567	324	3	F	1.18	1.08	1.49	0.81	0.79	0.73	0.54
Terry 28R	326	3	F	1.17	1.05	1.47	0.79	0.80	0.71	0.54
Terry 108R	327	3	F	1.21	1.03	1.49	0.85	0.81	0.69	0.57
Terry 149R	328	3	F	1.20	1.06	1.45	0.90	0.83	0.73	0.62
Terry 248R	329	3	F	1.18	1.11	1.58	0.85	0.75	0.70	0.54
Terry 295R	330	3	F	1.25	1.05	1.38	0.87	0.91	0.76	0.62
Terry 349RR	331	3	F	1.28	1.06	1.57	0.89	0.82	0.68	0.57
Terry 1069	332	3	F	1.16			0.87			
Terry 1583	333	3	F	1.19	1.03	1.38	0.88	0.86	0.75	0.64
Terry 75R	334	3	F	1.20	1.05	1.45	0.86	0.83	0.72	0.60
Terry 83R	335	3	F	1.24	1.05	1.46	0.83	0.85	0.72	0.57
Terry 543	336	3	F	1.20	1.04	1.43	0.83	0.84	0.73	0.58
Terry 925	337	3	F	1.13	1.04	1.43	0.84	0.79	0.73	0.59
Terry 992R	338	3	F	1.16	1.06	1.52	0.88	0.77	0.70	0.58

Appendix A, Part I continued. Ratios for BD-H-IP5, right

SkelNum	CaseNum	BD	Sex	RIP3/RIP2	RIP3/RIP4	RIP3/RIP5	RIP3/RPP5	RIP5/RIP2	RIP5/RIP4	RIP5/RPP5
Terry 1085R	339	3	F	1.24	1.04	1.56	0.93	0.80	0.67	0.59
Terry 1123R	340	3	F	1.20	1.06	1.45	0.91	0.82	0.73	0.62
Terry 1584	341	3	F	1.22	1.10	1.57	0.90	0.78	0.70	0.57
Terry 127R	342	3	F							
Terry 154R	343	3	F	1.28	1.04	1.58	0.93	0.81	0.66	0.59
Terry 596	141A	3	M	1.31	1.09	1.70	0.92	0.77	0.64	0.54
Terry 599	141B	3	M	1.25	1.08	1.49	0.92	0.84	0.73	0.62

Appendix A, Part II. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 1R	1	3	F	1.09	1.08	1.06	3.23	1.01	0.97	2.98
Terry 6RR	2	3	F	1.07	1.12	1.10	3.09	0.96	0.98	2.77
Terry 12R	3	3	F	1.08	1.09	1.05	3.11	0.99	0.96	2.85
Terry 14R	4	3	M	1.10	1.11	1.04	2.93	0.99	0.93	2.63
Terry 16RR	6	3	F							
Terry 34R	7	3	M	1.07	1.07	1.01	2.97	1.00	0.95	2.78
Terry 448	8	3	M	1.08	1.10	1.08	2.83	0.98	0.97	2.56
Terry 37R	9	3	F	1.05	1.10	1.08	3.16	0.96	0.98	2.88
Terry 41R	10	3	F	1.07	1.08	1.06	2.96	0.99	0.98	2.73
Terry 53R	11	3	F	1.05	1.10	1.08	3.00	0.95	0.98	2.72
Terry 59R	12	3	M	1.08	1.11	1.04	2.87	0.97	0.94	2.59
Terry 62RR	13	3	M	1.09	1.07	1.02	2.92	1.02	0.96	2.73
Terry 64R	14	3	F	1.10	1.09	1.09	3.05	1.00	1.00	2.79
Terry 69R	15	3	F	1.09	1.10	1.10	2.95	0.99	1.00	2.69
Terry 73R	16	3	M	1.09	1.10	1.08	2.82	0.99	0.98	2.58
Terry 79R	17	3	F	1.07	1.10	1.12	3.33	0.97	1.01	3.01
Terry 80RR	18	3	F	1.05	1.06	1.06	2.92	0.99	1.00	2.75
Terry 109	19	3	M	0.94	1.03	0.97	2.87	0.92	0.95	2.80
Terry 111R	20	*5*	M	*1.06*	*1.08*	*1.10*	*2.87*	*0.98*	*1.02*	*2.66*
Terry 112R	21	3	F	1.07	1.10	1.09	2.82	0.97	0.99	2.57
Terry 113R	22	3	M	1.07	1.06	1.04	3.00	1.00	0.98	2.82
Terry 126R	24	3	M	1.04	1.03	1.00	2.79	1.01	0.98	2.72
Terry 131R	25	3	M	1.09	1.04	1.04	2.80	1.04	1.00	2.68
Terry 135R	26	3	F	1.08	1.09	1.02	2.91	0.99	0.93	2.66
Terry 136R	27	3	M	1.09	1.09	1.05	2.72	1.00	0.97	2.51
Terry 139R	28	3	F	1.07	1.08	1.03	2.94	0.99	0.96	2.73
Terry 147	29	3	M	1.07	1.07	1.05	2.87	1.00	0.98	2.68
Terry 148RR	30	3	F	1.03	1.05	1.01	2.70	0.98	0.96	2.57
Terry 161R	31	3	F	1.05	1.06	1.03	2.90	0.99	0.97	2.75
Terry 162R	32	3	F	1.07	1.09	1.10	2.75	0.99	1.01	2.53
Terry 164R	33	3	F	1.08	1.09	1.02	2.99	0.99	0.93	2.73
Terry 195	35	3	M	1.03	1.08	1.09	2.91	0.96	1.01	2.70
Terry 196	36	3	M	1.05	1.10	1.11	2.83	0.95	1.01	2.58
Terry 197R	37	3	F	1.11	1.11	1.15	2.81	1.00	1.04	2.53
Terry 198R	38	3	M	1.13	1.06	1.10	3.02	1.06	1.03	2.84
Terry 201	39	3	M	1.05	1.10	1.09	3.10	0.96	0.99	2.83
Terry 202	40	3	M	1.06	1.10	1.13	2.99	0.96	1.02	2.71

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 207	41	3	M	1.08	1.09	1.05	2.87	0.99	0.97	2.63
Terry 215	42	3	M	1.13		1.04	2.91			
Terry 216	43	*5*	M	*1.08*	*1.11*	*1.11*	*2.61*	*0.98*	*1.01*	*2.35*
Terry 220	44	3	M	1.06	1.02	1.01	2.60	1.05	0.99	2.56
Terry 225R	46	3	F	1.08	1.10	1.08	3.12	0.98	0.99	2.85
Terry 227	47	3	M	1.05	1.04	0.99	3.02	1.01	0.95	2.89
Terry 229	48	3	M	1.10	1.06	0.99	2.88	1.04	0.93	2.71
Terry 230	49	**4**	M	**1.08**	**1.33**	**1.14**	**2.80**	**0.81**	**0.86**	**2.11**
Terry 233	50	3	M	1.04	1.05	1.07	2.73	1.00	1.02	2.61
Terry 236R	52	3	F	1.07	1.09	1.04	2.77	0.98	0.95	2.55
Terry 250	54	3	M	1.06	1.08	1.08	2.75	0.98	1.00	2.54
Terry 256R	55	3	F	1.07	1.09	1.00	2.89	0.99	0.92	2.66
Terry 259	56	3	M	1.12	1.12	1.11	3.12	1.00	0.99	2.78
Terry 260	57	3	M	1.04	1.07	1.10	2.82	0.97	1.02	2.63
Terry 261	58	3	M	1.09	1.10	1.09	2.79	0.99	0.98	2.52
Terry 263	59	3	M	1.07	1.13	1.12	3.24	0.95	0.99	2.87
Terry 267	60	3	M	1.08	1.09	1.03	2.91	0.99	0.95	2.67
Terry 271	61	3	M	1.05	1.02	0.98	2.93	1.03	0.96	2.87
Terry 273	62	3	M	1.06	1.08	1.06	3.03	0.99	0.98	2.82
Terry 274	63	3	M	1.04	1.05	1.02	2.81	0.99	0.97	2.68
Terry 277	64	*5*	M	*1.09*	*1.09*	*1.03*	*2.92*	*1.00*	*0.95*	*2.68*
Terry 279	65	3	M	1.07	1.08	0.94	2.58	0.99	0.87	2.39
Terry 282	66	3	M	1.08	1.12	1.07	3.06	0.97	0.96	2.74
Terry 285	67	*5*	M	*1.10*	*1.12*	*1.02*	*2.59*	*0.98*	*0.91*	*2.31*
Terry 293R	69	3	F	1.06	1.07	1.04	2.96	0.99	0.97	2.77
Terry 297	70	3	M	1.06	1.08	1.00	3.05	0.98	0.92	2.81
Terry 298	71	3	M	1.03	1.06	1.07	2.90	0.97	1.01	2.73
Terry 301R	72	3	M	1.06	1.07	1.01	3.14	0.98	0.94	2.92
Terry 303R	73	3	M	1.06	1.06	0.97	2.87	1.00	0.91	2.70
Terry 305	74	3	M	1.07	1.07	1.03	2.97	1.00	0.96	2.78
Terry 306R	75	3	F	1.07	1.11	1.16	3.08	0.97	1.05	2.78
Terry 311R	76	3	M	1.11	1.14	1.10	2.86	0.97	0.97	2.51

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 315	77	3	M	1.06	1.08	1.09	2.86	0.98	1.01	2.65
Terry 316	78	3	M	1.09	1.06	1.01	2.70	1.03	0.95	2.54
Terry 318	79	3	M	1.05	1.05	1.00	2.99	1.01	0.96	2.86
Terry 320	80	3	M	1.08	1.09	1.10	3.12	1.00	1.01	2.88
Terry 332	81	3	M	1.07	1.11	1.09	2.80	0.97	0.98	2.53
Terry 335	82	*5*	M	*1.10*	*1.10*	*1.12*	*3.03*	*1.00*	*1.02*	*2.75*
Terry 342	83	3	M	1.06	1.08	0.99	2.85	0.98	0.92	2.64
Terry 343	84	3	M	1.08	1.07	1.05	2.83	1.00	0.98	2.63
Terry 346RR	85	3	F	1.04	1.08	1.02	3.06	0.96	0.95	2.84
Terry 351R	86	3	F	1.05	1.04	1.05	2.87	1.01	1.00	2.76
Terry 365	87	3	M	1.05	1.10	1.09	2.80	0.95	0.99	2.54
Terry 366	88	3	M	1.06	1.07	1.05	2.85	0.99	0.98	2.66
Terry 367	89	3	M	1.08	1.09	1.07	2.71	0.99	0.98	2.49
Terry 373	90	3	F	1.06	1.09	1.05	3.06	0.97	0.97	2.81
Terry 379	91	3	M	1.06	1.07	1.00	2.87	0.99	0.94	2.69
Terry 387R	93	3	F							
Terry 395	95	3	M	1.08	1.06	1.08	3.09	1.02	1.02	2.93
Terry 397	96	3	M	1.08	1.12	1.07	2.82	0.97	0.95	2.53
Terry 405R	97	3	F	1.09	1.13	1.05	2.97	0.96	0.93	2.63
Terry 407	98	3	M	1.11	1.08	1.11	2.83	1.03	1.03	2.62
Terry 409	99	3	M		1.06	0.99	2.85		0.94	2.69
Terry 411	100	*5*	M	*1.04*	*1.07*	*1.09*	*3.03*	*0.97*	*1.02*	*2.84*
Terry 413	101	3	M	1.04	1.08	1.04	2.92	0.97	0.96	2.71
Terry 414	102	3	M	1.11	1.08	1.11	2.84	1.03	1.03	2.62
Terry 415	103	3	M	1.07	1.10	1.02	2.83	0.97	0.93	2.57
Terry 417	104	3	M	1.09	1.12	1.09	2.96	0.97	0.97	2.64
Terry 431	105	3	M	1.05	1.10	1.09	3.03	0.96	0.99	2.76
Terry 433	106	3	M							
Terry 434	107	3	M	1.09	1.09	1.01	2.96	1.00	0.92	2.71
Terry 437R	108	3	F	1.09	1.09	1.02	3.14	1.00	0.93	2.87
Terry 440	109	3	M							

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 442	110	3	M	1.06	1.09	1.09	3.02	0.97	1.00	2.78
Terry 451R	111	3	F	1.09	1.10	1.15	3.60	0.99	1.05	3.27
Terry 453	112	3	M	1.06	1.07	1.09	2.75	0.99	1.02	2.56
Terry 184R	113	3	M	1.06	1.06	1.03	2.91	1.00	0.97	2.74
Terry 459	114	3	M	1.07	1.10	1.03	2.80	0.97	0.94	2.54
Terry 476RR	116	3	F	1.08	1.11	1.05	3.22	0.97	0.95	2.91
Terry 478	117	3	M	1.09	1.16	1.08	2.87	0.94	0.93	2.46
Terry 482	118	3	F	1.07	1.08	1.06	2.92	0.99	0.98	2.71
Terry 496	119	3	M	1.09	1.10	1.13	2.99	0.99	1.03	2.71
Terry 505	120	3	M							
Terry 506	121	3	M	1.06	1.08	1.00	2.74	0.98	0.92	2.53
Terry 517	122	3	M	1.04	1.06	1.10	2.83	0.98	1.04	2.68
Terry 525	123	3	M	1.10	1.12	1.05	2.89	0.98	0.94	2.57
Terry 536	124	3	M	1.08	1.08	1.01	2.98	0.99	0.94	2.75
Terry 545	125	3	M	1.09	1.11	1.05	3.00	0.98	0.94	2.69
Terry 546	126	3	M	1.07	1.08	1.04	3.01	1.00	0.96	2.79
Terry 548	127	3	M	1.09	1.09	1.03	3.01	1.00	0.95	2.77
Terry 554R	128	3	F	1.09	1.10	1.07	2.72	0.99	0.97	2.47
Terry 555	129	3	M	1.06	1.10	1.09	2.89	0.97	0.99	2.63
Terry 557	130	*5*	M	*1.09*	*1.10*	*1.13*	*3.32*	*0.99*	*1.04*	*3.03*
Terry 563	131	3	M	1.05	1.08	1.02	2.60	0.97	0.94	2.40
Terry 564	132	*5*	M	*1.08*	*1.09*	*1.06*	*2.84*	*1.00*	*0.98*	*2.62*
Terry 566	133	3	M	1.05	1.11	1.08	3.06	0.95	0.98	2.77
Terry 573	134	3	M	1.06	1.08	1.09	2.99	0.98	1.01	2.76
Terry 575	135	3	M	1.11	1.12	1.08	3.03	0.99	0.96	2.69
Terry 577	136	3	M	1.07	1.07	1.05	2.94	1.00	0.98	2.75
Terry 588	137	3	M	1.04	1.08	1.06	2.88	0.96	0.98	2.66
Terry 591	138	3	M	1.06	1.08	0.99	2.89	0.98	0.91	2.67
Terry 602	142	3	M	1.08	1.13	1.10	2.82	0.95	0.97	2.49
Terry 605R	143	3	M	1.08	1.13	1.05	2.87	0.95	0.92	2.53
Terry 608	144	3	M	1.09	1.14	1.06	3.13	0.95	0.93	2.74

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 614	145	3	M	1.03	1.04	1.01	2.88	1.00	0.97	2.78
Terry 620	146	3	M	1.10	1.12	1.08	2.94	0.98	0.96	2.63
Terry 622R	147	3	M							
Terry 636	148	3	M	1.05	1.06	1.01	3.00	0.99	0.95	2.82
Terry 641	149	3	M	1.08	1.09	1.07	2.90	0.99	0.98	2.65
Terry 644	150	3	M	1.07	1.10	0.99	2.94	0.97	0.90	2.68
Terry 645	151	3	M	1.08	1.09	1.02	2.68	0.98	0.94	2.45
Terry 670	152	3	M	1.09	1.11	1.04	3.04	0.98	0.94	2.75
Terry 672	153	3	M	1.09	1.10	1.10		0.99	1.01	
Terry 674	154	3	M	1.11	1.14	1.09	3.06	0.97	0.96	2.70
Terry 680	155	3	F	1.06	1.11	1.12	3.11	0.96	1.01	2.81
Terry 681	156	3	M	1.08	1.10	1.19	3.04	0.98	1.08	2.75
Terry 687	157	3	M	1.07	1.06	1.05	2.75	1.00	0.99	2.58
Terry 693	158	3	M	1.07	1.09	1.08	3.01	0.98	0.98	2.75
Terry 696	159	3	M	1.09	1.11	1.16	3.18	0.98	1.04	2.86
Terry 701	160	3	M	1.05	1.04	1.02	2.75	1.00	0.98	2.63
Terry 709	161	3	M	1.06	1.05	1.03	2.76	1.00	0.98	2.61
Terry 710R	162	3	F	1.06	1.09	1.05	2.97	0.97	0.96	2.72
Terry 720	163	3	M	1.06	1.11	1.09	2.88	0.96	0.98	2.60
Terry 721	164	3	M	1.08	1.06	1.08	2.85	1.01	1.01	2.68
Terry 736	165	3	F	1.07	1.07	1.10	2.95	1.00	1.03	2.75
Terry 739	166	*5*	M	*1.08*	*1.10*	*1.12*	*3.39*	*0.98*	*1.02*	*3.08*
Terry 743	167	3	M	1.10	1.11	1.15	3.12	0.99	1.03	2.81
Terry 745R	168	3	F	1.11	1.09	1.04	3.04	1.01	0.95	2.78
Terry 747	169	3	M	1.10	1.09	0.94	3.05	1.00	0.86	2.79
Terry 751	170	3	M	1.08	1.11	1.02	2.74	0.97	0.92	2.48
Terry 755	171	3	M	1.05	1.05	1.03	2.64	1.00	0.99	2.52
Terry 756	172	3	M	1.06	1.09	1.06	2.80	0.97	0.97	2.56
Terry 762	173	3	M	1.09	1.12	1.09	2.97	0.97	0.97	2.65
Terry 763	174	3	M	1.06	1.06	1.02	2.96	1.00	0.97	2.80
Terry 764	175	3	M	1.05	1.07	1.07	2.85	0.98	1.00	2.66

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 768	176	3	M	1.05	1.06	1.03	3.00	0.99	0.97	2.83
Terry 772	177	*5*	M	*1.04*	*1.07*	*1.12*	*2.91*	*0.97*	*1.05*	*2.72*
Terry 778	178	3	M	1.08	1.08	1.01	2.83	1.00	0.94	2.63
Terry 785	179	3	M	1.04	1.06	1.06	2.86	0.98	1.01	2.71
Terry 787	180	3	M	1.06	1.09	1.06	3.05	0.97	0.98	2.79
Terry 795	181	3	M	1.11	1.12	1.06	3.09	0.99	0.95	2.76
Terry 802	182	3	M					0.98	0.99	2.43
Terry 810	183	3	M	1.04	1.05	1.05	2.87	0.99	1.00	2.73
Terry 813	184	3	M	1.04	1.07			0.96		
Terry 814	185	3	M	1.06	1.04	1.06	3.02	1.03	1.02	2.91
Terry 828	186	*5*	M	*1.12*	*1.17*	*1.09*	*2.95*	*0.95*	*0.93*	*2.52*
Terry 839	187	3	M	1.09	1.14	1.07	2.80	0.95	0.94	2.44
Terry 843	188	3	M	1.07	1.11	1.08	2.75	0.96	0.97	2.47
Terry 846	189	*5*	M	*1.07*	*1.09*	*1.04*	*3.14*	*0.99*	*0.95*	*2.89*
Terry 847	190	3	F	1.07	1.11	1.12	3.13	0.96	1.00	2.81
Terry 849	191	3	M	1.10	1.12	1.05	3.15	0.98	0.93	2.80
Terry 866	192	3	M	1.05	1.09	1.07	3.03	0.96	0.98	2.78
Terry 867	193	**4**	M	**1.28**	**1.31**	**1.05**	**3.00**	**0.98**	**0.81**	**2.29**
Terry 868	194	3	M	1.04	1.07	1.09	2.67	0.97	1.01	2.50
Terry 870	196	3	M	1.05	1.05	1.04	3.03	1.00	0.99	2.88
Terry 871	197	3	M	1.06	1.07	1.09	2.88	0.98	1.02	2.69
Terry 872	198	3	M	1.06	1.07	1.05	2.82	0.99	0.98	2.63
Terry 877	199	*5*	M	*1.06*	*1.15*	*1.05*	*2.71*	*0.93*	*0.91*	*2.36*
Terry 879	200	3	M	1.07	1.12	1.10	2.93	0.95	0.98	2.61
Terry 880	201	3	F	1.04	1.05	1.03	3.36	0.99	0.98	3.19
Terry 888	202	3	M	1.09	1.11	1.11	2.90	0.98	1.00	2.61
Terry 892	203	3	M	1.06	1.09	1.12	2.93	0.97	1.03	2.68
Terry 895	204	3	M	1.08	1.11	1.02	3.19	0.97	0.92	2.88
Terry 897	205	3	M	1.05	1.05	1.05	2.78	1.00	1.00	2.64
Terry 901R	206	3	M	1.03	1.05	1.02	2.71	0.98	0.97	2.59
Terry 904R	207	3	F	1.10	1.22	1.09	3.02	0.90	0.90	2.48

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 908	208	*5*	M	*1.05*	*1.08*	*1.12*	*3.25*	*0.98*	*1.04*	*3.02*
Terry 924	210	3	M	1.04	1.06	1.01	2.68	0.98	0.95	2.53
Terry 928R	211	3	F	1.04	1.06	1.05	3.01	0.98	0.99	2.84
Terry 946	212	3	M	1.07	1.11	1.09	2.79	0.96	0.98	2.51
Terry 954	213	3	M	1.06	1.11	1.01	2.90	0.96	0.91	2.62
Terry 975	214	3	M	1.08	1.08	1.03	3.04	1.00	0.95	2.81
Terry 983	215	3	F	1.10	1.10	1.09	2.88	1.00	0.98	2.61
Terry 989	216	3	M	1.03	1.04	1.01	2.49	1.00	0.98	2.40
Terry 1009	218	3	M	1.08	1.09	1.05	2.77	0.99	0.97	2.54
Terry 1016R	219	3	F	1.08	1.08	1.07	2.86	1.00	1.00	2.66
Terry 1023	220	3	M	1.07	1.08	1.01	3.11	0.99	0.93	2.87
Terry 1037	221	3	M	1.09	1.10	1.09	3.24	0.99	0.98	2.93
Terry 1043	222	3	M	1.10	1.12	1.04	3.06	0.99	0.93	2.74
Terry 1080RR	223	3	F	1.05	1.06	1.01	3.18	0.99	0.95	2.99
Terry 1094	224	3	F	1.08	1.07	1.04	2.89	1.01	0.97	2.70
Terry 1153	225	3	F	1.06	1.06	1.08	2.88	1.00	1.01	2.70
Terry 1174	226	3	F	1.06	1.11	1.13	3.11	0.96	1.02	2.80
Terry 1186	227	3	F	1.06	1.07	1.01	2.88	0.99	0.94	2.68
Terry 1202R	229	3	F	1.08	1.08	1.06	2.79	1.01	0.99	2.59
Terry 1239R	230	3	F				3.06			
Terry 1243R	231	3	F	1.03	1.05	1.06	2.79	0.98	1.01	2.65
Terry 1270R	232	**4**	F	**0.98**	**1.06**	**1.08**	**2.74**	**0.93**	**1.02**	**2.58**
Terry 1296R	233	3	F	1.08	1.08	1.07	2.99	1.00	0.99	2.76
Terry 1353R	234	3	F	1.09	1.11	1.14	2.77	0.98	1.02	2.49
Terry 1456	235	*5*	F	*1.05*	*1.06*	*1.08*	*3.14*	*0.99*	*1.02*	*2.96*
Terry 1482R	237	3	F	1.04	1.07	1.12	3.18	0.97	1.05	2.98
Terry 1512	238	3	F	1.08	1.10	1.07	2.80	0.98	0.97	2.54
Terry 1523	239	3	F	1.05	1.10	1.13	2.94	0.95	1.02	2.67
Terry 1541R	240	3	F	1.08	1.09	1.03	2.81	1.00	0.95	2.59
Terry 1562	241	3	F	1.06	1.10	1.06	3.17	0.97	0.97	2.88
Terry 1563	242	3	F	1.09	1.11	1.07	3.08	0.99	0.97	2.79

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 1566	243	3	F	1.07	1.05	1.01	2.88	1.02	0.96	2.73
Terry 1571	244	3	F	1.06	1.10	1.07	3.01	0.96	0.97	2.73
Terry 1572	245	3	F	1.05	1.06	1.03	2.94	0.99	0.97	2.77
Terry 1574	246	*5*	F	*1.05*	*1.10*	*1.08*	*3.01*	*0.96*	*0.99*	*2.75*
Terry 1575	247	3	F	1.06	1.09	1.04	3.18	0.97	0.95	2.92
Terry 1578	248	3	F	1.07	1.09	1.10	2.89	0.97	1.00	2.64
Terry 1579	249	3	F	1.10	1.14	1.11	3.14	0.96	0.97	2.75
Terry 1580	250	3	F	1.09	1.13	1.11	3.15	0.97	0.98	2.79
Terry 1582	251	3	F	1.05	1.08	1.03	3.16	0.97	0.95	2.93
Terry 1592	252	3	F	1.05	1.07	1.05	2.89	0.98	0.97	2.70
Terry 1593	253	3	F	1.09	1.11	1.09	3.13	0.99	0.98	2.82
Terry 1594	254	3	F	1.08	1.10	1.09	2.95	0.98	1.00	2.69
Terry 1596	256	3	F	1.08	1.09	1.10	3.09	0.99	1.00	2.82
Terry 1599	257	3	F	1.04	1.03	1.04	2.84	1.01	1.00	2.74
Terry 1603	258	3	F	1.01	1.04	1.09	3.02	0.97	1.05	2.90
Terry 1608	259	3	F	1.09	1.10	1.05	3.22	0.99	0.96	2.93
Terry 1612	260	3	F	1.12	1.08	1.12	3.04	1.04	1.04	2.82
Terry 1614	261	3	F	1.09	1.11	1.05	3.02	0.99	0.95	2.73
Terry 1616	262	3	F	1.07	1.08	1.04	2.93	0.99	0.97	2.73
Terry 1617	263	3	F	1.12	1.15	1.11	3.51	0.98	0.96	3.05
Terry 1622	264	3	F	1.08	1.12	1.04	2.85	0.96	0.92	2.53
Terry 1624	265	3	F	1.07	1.11	1.08	3.39	0.97	0.98	3.06
Terry 166R	267	3	F	1.04	1.07	1.07	2.97	0.97	1.00	2.79
Terry 580	268	3	F	1.10	1.08	1.01	2.89	1.02	0.93	2.68
Terry 1628	271	3	F	1.06	1.07	1.02	3.04	1.00	0.96	2.85
Terry 76R	272	3	F	1.02	1.04	1.06	2.92	0.98	1.02	2.81
Terry 934	273	3	F	1.06	1.08	1.07	2.98	0.99	0.99	2.76
Terry 951R	274	3	F	1.08	1.09	1.11	2.71	0.99	1.02	2.48
Terry 1568	275	3	F	1.05	1.04	1.06	3.10	1.01	1.02	2.98
Terry 1570	276	3	F	1.04	1.08	1.12	3.03	0.96	1.03	2.80
Terry 22RR	277	3	F	1.09	1.11	1.03	3.01	0.99	0.93	2.72

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 240R	278	3	F	1.05	1.11	1.11	3.04	0.95	1.01	2.75
Terry 1119	279	3	F	1.06	1.07	1.03	2.98	0.99	0.97	2.79
Terry 1233R	280	3	F	1.06	1.09	1.08	2.68	0.97	0.99	2.46
Terry 1560	281	3	F	1.09	1.08	1.06	2.97	1.01	0.98	2.75
Terry 115R	283	3	F	1.15	1.11	1.10	2.98	1.04	0.99	2.68
Terry 312R	284	3	F	1.08	1.07	1.07	3.08	1.01	1.01	2.89
Terry 464	285	3	F	1.04	1.06	1.01	2.99	0.97	0.95	2.81
Terry 1155	286	3	F	1.07	1.07	1.06	2.87	1.00	0.99	2.68
Terry 1480	287	3	F	1.07	1.05	1.05	2.97	1.02	1.00	2.83
Terry 1557	288	3	F	1.06	1.07	1.06	3.03	0.99	0.99	2.83
Terry 1581	289	3	F	1.09	1.07	1.08	3.02	1.02	1.01	2.82
Terry 91R	290	3	F	1.11	1.12	1.09	3.05	0.99	0.98	2.73
Terry 99RR	291	3	F	1.05	1.05	1.03	3.14	1.00	0.98	2.98
Terry 359R	292	3	F	1.07	1.11	1.05	3.09	0.97	0.94	2.79
Terry 491R	293	3	F	1.04	1.07	1.05	2.93	0.96	0.97	2.73
Terry 611	294	3	F	1.06	1.12	1.07	2.95	0.95	0.95	2.64
Terry 899R	295	*5*	F	*1.01*	*1.00*	*0.90*	*3.07*	*1.01*	*0.90*	*3.07*
Terry 1201	296	3	F	1.08	1.12	1.10	2.84	0.97	0.98	2.55
Terry 1463	297	3	F	1.06	1.08	1.03	2.85	0.99	0.96	2.65
Terry 17R	298	3	F	1.08	1.17	1.13	2.83	0.93	0.97	2.43
Terry 55R	299	3	F	1.07	1.09	1.01	2.75	0.99	0.93	2.54
Terry 110R	300	3	F	1.07	1.08	1.11	2.99	0.99	1.03	2.77
Terry 791	302	3	F	1.07	1.07	1.04	3.14	1.01	0.98	2.95
Terry 985RR	303	3	F	1.09	1.12	1.05	2.88	0.97	0.94	2.56
Terry 1435	304	3	F	1.11	1.14	1.15	3.15	0.98	1.01	2.77
Terry 1626	305	3	F	1.09	1.13	1.05	2.99	0.97	0.93	2.65
Terry 1629	306	3	F	1.08	1.09	1.03	3.03	0.99	0.94	2.77
Terry 92R	307	3	F							
Terry 169R	308	3	F	1.07	1.06	0.98	2.83	1.01	0.93	2.68
Terry 188R	310	3	F	1.11	1.15	1.04	3.04	0.96	0.90	2.64
Terry 481R	311	3	F	1.09	1.10	1.11	2.71	0.99	1.01	2.47

Appendix A, Part II continued. Ratios for BD-F-MT4

SkelNum	CaseNum	BD	Sex	RMT2/RMT3	RMT2/RMT4	RMT2/RMT5	RMT2/RPedPP4	RMT4/RMT3	RMT4/RMT5	RMT4/RPedPP4
Terry 722R	312	3	F	1.08	1.07	1.03	2.92	1.01	0.97	2.74
Terry 1075RR	313	3	F	1.06	1.08	1.06	2.92	0.98	0.98	2.70
Terry 1154R	314	3	F	1.08	1.11	1.07	3.02	0.97	0.96	2.71
Terry 1405	315	*5*	F	*1.05*	*1.06*	*1.10*	*2.74*	*0.99*	*1.04*	*2.59*
Terry 1542	316	3	F	1.07	1.07	1.03	2.98	0.99	0.96	2.78
Terry 275RR	318	3	F	1.08	1.07	1.03	3.45	1.01	0.96	3.22
Terry 1058	319	3	F	1.07	1.07	1.05	2.74	1.00	0.97	2.56
Terry 1189R	320	3	F	1.07	1.09	1.14	2.99	0.98	1.04	2.74
Terry 1109R	322	3	F	1.05	1.06	1.01	2.78	0.99	0.95	2.62
Terry 1496	323	3	F	1.07	1.07	1.12	2.68	1.00	1.05	2.52
Terry 1567	324	3	F	1.06	1.07	1.00	2.98	1.00	0.94	2.80
Terry 108R	327	3	F	1.08	1.07	1.07	2.89	1.01	1.00	2.70
Terry 149R	328	3	F	1.07	1.10	1.05	3.04	0.97	0.95	2.77
Terry 248R	329	3	F	1.12	1.16	1.16	3.00	0.96	1.00	2.59
Terry 295R	330	3	F	1.06	1.12	1.11	3.08	0.95	0.99	2.74
Terry 349RR	331	3	F	1.11	1.19	1.04	3.05	0.93	0.87	2.56
Terry 1583	333	3	F	1.05	1.08	1.07	3.13	0.97	0.98	2.89
Terry 83R	335	3	F	1.07	1.09	1.04	2.88	0.99	0.95	2.65
Terry 543	336	3	F	1.09	1.11	1.08	3.33	0.97	0.97	2.99
Terry 925	337	3	F	1.04	1.10	1.10	2.90	0.95	1.00	2.64
Terry 992R	338	3	F	1.05	1.11	1.10	3.02	0.95	0.99	2.71
Terry 1085R	339	3	F	1.09	1.12	1.13	2.93	0.98	1.01	2.62
Terry 1123R	340	3	F	1.03	1.06	1.04	3.08	0.97	0.98	2.90
Terry 127R	342	3	F	1.06	1.11	1.05	2.91	0.95	0.95	2.63
Terry 154R	343	3	F	1.07	1.09	1.05	2.92	0.98	0.96	2.67
Terry 596	141A	3	M	1.05	1.10	1.04	2.98	0.96	0.95	2.72
Terry 599	141B	3	M	1.09	1.20	1.14	2.89	0.90	0.95	2.40

Appendix A, Part III. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 1R	1	3	F	0.57	0.84	0.69	0.60	0.82	0.74
Terry 6RR	2	3	F	0.60	0.86	0.70	0.63	0.91	0.70
Terry 12R	3	3	F	0.62	0.80	0.78	0.61	0.78	0.78
Terry 14R	4	3	M	0.65	0.84	0.77	0.63	0.80	0.78
Terry 15R3	5	3	F			0.73	0.61	0.84	0.72
Terry 16RR	6	3	F	0.61	0.85	0.71			0.71
Terry 34R	7	*5*	M	*0.82*	*1.10*	*0.74*	*0.82*	*1.15*	*0.71*
Terry 448	8	3	M	0.65	0.81	0.81	0.63	0.80	0.79
Terry 41R	10	3	F	0.57	0.80	0.71	0.57	0.78	0.73
Terry 53R	11	3	F			0.74	0.59	0.78	0.75
Terry 59R	12	3	M	0.54	0.77	0.71	0.53	0.74	0.72
Terry 62RR	13	3	M	0.61	0.80	0.76	0.60	0.81	0.74
Terry 64R	14	3	F	0.55	0.76	0.73	0.56	0.78	0.73
Terry 69R	15	3	F	0.55	0.77	0.71	0.53	0.77	0.69
Terry 73R	16	3	M	0.63	0.79	0.79	0.62	0.80	0.77
Terry 79R	17	3	F	0.60	0.77	0.77	0.61	0.77	0.78
Terry 80RR	18	**4**	F	**0.54**	**0.75**	**0.71**	**0.60**	**1.00**	**0.60**
Terry 109	19	3	M	0.60	0.83	0.72	0.64	0.88	0.72
Terry 111R	20	*5*	M	*0.65*	*0.81*	*0.80*	*0.66*	*0.82*	*0.81*
Terry 112R	21	3	F	0.55	0.80	0.69	0.56	0.81	0.69
Terry 113R	22	3	M	0.57	0.75	0.76	0.57	0.73	0.78
Terry 114R	23	3	F	0.62	0.81	0.76	0.61	0.79	0.77
Terry 126R	24	3	M	0.60	0.80	0.74	0.62	0.81	0.77
Terry 131R	25	3	M	0.64	0.83	0.77	0.65	0.86	0.75
Terry 135R	26	3	F	0.59	0.80	0.73	0.60	0.86	0.70
Terry 136R	27	3	M	0.60	0.84	0.71	0.62	0.85	0.73
Terry 139R	28	3	F				0.59	0.78	0.76
Terry 148RR	30	3	F	0.58	0.80	0.72	0.55	0.77	0.71
Terry 161R	31	3	F	0.58	0.80	0.72	0.59	0.84	0.71
Terry 162R	32	3	F	0.55	0.80	0.68	0.59	0.86	0.68
Terry 174R	34	3	F	0.56	0.76	0.73	0.58	0.75	0.78
Terry 195	35	3	M	0.56	0.76	0.74	0.57	0.79	0.72
Terry 196	36	3	M	0.65	0.82	0.80	0.64	0.82	0.79
Terry 197R	37	3	F	0.59	0.77	0.76	0.58	0.78	0.75
Terry 198R	38	3	M	0.58	0.80	0.72	0.59	0.82	0.72
Terry 201	39	3	M	0.58	0.77	0.76	0.58	0.79	0.73
Terry 207	41	3	M				0.62	0.79	0.78
Terry 215	42	3	M	0.59	0.86	0.68	0.57	0.81	0.70
Terry 216	43	3	M	0.56	0.80	0.70	0.60	0.82	0.73
Terry 220	44	3	M	0.65	0.83	0.78	0.66	0.83	0.80
Terry 221	45	*5*	M	*0.54*	*0.78*	*0.70*	*0.54*	*0.78*	*0.70*
Terry 225R	46	3	F	0.58	0.80	0.73	0.60	0.81	0.74
Terry 227	47	3	M	0.65	0.84	0.78	0.61	0.81	0.75
Terry 229	48	3	M	0.56	0.76	0.74	0.49	0.67	0.73
Terry 230	49	3	M	0.58	0.83	0.70	0.60	0.84	0.72

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 233	50	3	M	0.61	0.81	0.75	0.61	0.79	0.77
Terry 234	51	3	M	0.63	0.77	0.81	0.63	0.79	0.80
Terry 236R	52	3	F	0.64	0.88	0.73	0.63	0.85	0.74
Terry 237	53	3	M	0.63	0.80	0.78	0.65	0.91	0.71
Terry 250	54	3	M	0.59	0.83	0.71	0.57	0.86	0.67
Terry 256R	55	3	F	0.61	0.79	0.77	0.61	0.81	0.76
Terry 259	56	3	M	0.62	0.72	0.86	0.63	0.74	0.85
Terry 260	57	3	M	0.64	0.81	0.79	0.64	0.81	0.79
Terry 261	58	3	M	0.61	0.87	0.70	0.61	0.87	0.70
Terry 263	59	3	M	0.63	0.88	0.71	0.67	0.93	0.72
Terry 267	60	3	M			0.80	0.65	0.81	0.79
Terry 271	61	3	M	0.64	0.85	0.75	0.62	0.82	0.76
Terry 273	62	*5*	M	*0.63*	*0.82*	*0.76*	*0.63*	*0.99*	*0.64*
Terry 274	63	3	M				0.59	0.78	0.76
Terry 277	64	3	M	0.60	0.81	0.74	0.62	0.86	0.72
Terry 279	65	3	M	0.60	0.85	0.71	0.59	0.81	0.74
Terry 282	66	3	M	0.56	0.80	0.70	0.63	0.93	0.68
Terry 285	67	3	M	0.55	0.80	0.69	0.57	0.82	0.69
Terry 289R	68	3	F	0.59	0.77	0.76			
Terry 293R	69	*5*	F	*0.64*	*0.81*	*0.80*	*0.61*	*0.75*	*0.81*
Terry 297	70	3	M	0.54	0.75	0.72	0.56	0.77	0.73
Terry 298	71	3	M			0.69	0.59	0.77	0.76
Terry 301R	72	3	M			0.75	0.57	0.75	0.76
Terry 303R	73	3	M	0.62	0.84	0.74	0.60	0.83	0.73
Terry 305	74	3	M	0.54	0.80	0.68	0.54	0.76	0.71
Terry 306R	75	3	F	0.63	0.84	0.75	0.64	0.93	0.69
Terry 311R	76	3	M	0.54	0.79	0.68	0.54	0.74	0.73
Terry 315	77	*5*	M	*0.65*	*0.81*	*0.80*	*0.66*	*1.19*	*0.55*
Terry 316	78	3	M	0.58	0.80	0.73	0.57	0.81	0.71
Terry 318	79	3	M	0.66	0.85	0.78	0.63	0.83	0.76
Terry 320	80	3	M	0.68	0.84	0.81	0.69	0.83	0.82
Terry 335	82	3	M	0.60	0.84	0.71	0.59	0.83	0.71
Terry 342	83	3	M	0.56	0.83	0.68	0.58	0.83	0.70
Terry 343	84	3	M	0.63	0.79	0.80	0.63	0.94	0.67
Terry 346RR	85	3	F			0.68	0.61	0.83	0.73
Terry 351R	86	3	F	0.57	0.78	0.73	0.58	0.78	0.74
Terry 365	87	3	M	0.60	0.85	0.71	0.61	0.86	0.71
Terry 366	88	3	M			0.76	0.65	0.80	0.82
Terry 373	90	*5*	F	*0.60*	*0.78*	*0.76*	*0.61*	*1.04*	*0.59*
Terry 379	91	3	M	0.65	0.82	0.79	0.68	0.86	0.79
Terry 380	92	3	M	0.62	0.88	0.70	0.61	0.82	0.74

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 387R	93	3	F	0.60	0.89	0.68			
Terry 393RR	94	3	F	0.57	0.74	0.76	0.57	0.75	0.77
Terry 397	96	3	M	0.62	0.81	0.77	0.58	0.78	0.74
Terry 405R	97	3	F	0.58	0.81	0.71	0.57	0.84	0.68
Terry 409	99	3	M			0.70	0.62	0.88	0.70
Terry 411	100	3	M		0.79			0.79	
Terry 413	101	3	M	0.63	0.79	0.79	0.66	0.84	0.78
Terry 414	102	3	M	0.56	0.88	0.63	0.64	0.77	0.82
Terry 415	103	3	M	0.57	0.81	0.71	0.52	0.78	0.66
Terry 417	104	3	M	0.57	0.81	0.70	0.56	0.79	0.71
Terry 433	106	3	M			0.77	0.68	0.84	0.80
Terry 434	107	3	M	0.58	0.87	0.67	0.56	0.83	0.67
Terry 437R	108	3	F	0.57	0.75	0.76	0.59	0.80	0.74
Terry 440	109	3	M	0.58	0.82	0.71	0.63	0.83	0.76
Terry 442	110	3	M	0.60	0.82	0.73	0.59	0.81	0.73
Terry 451R	111	3	F	0.53	0.76	0.70	0.55	0.77	0.71
Terry 453	112	3	M	0.53	0.76	0.69	0.56	0.82	0.68
Terry 184R	113	3	M	0.58	0.84	0.70	0.59	0.84	0.70
Terry 463	115	3	M	0.61	0.80	0.76	0.64	0.84	0.76
Terry 476RR	116	3	F	0.59	0.83	0.71	0.60	0.82	0.74
Terry 478	117	3	M	0.57			0.58		
Terry 482	118	3	F	0.54	0.81	0.67	0.66	0.86	0.77
Terry 505	120	3	M	0.53	0.69	0.76	0.60	0.82	0.74
Terry 506	121	3	M	0.55	0.83	0.67	0.53	0.79	0.67
Terry 517	122	3	M	0.63	0.81	0.78	0.61	0.81	0.76
Terry 525	123	3	M	0.62			0.59	0.95	0.62
Terry 536	124	3	M	0.61	0.74	0.82	0.61	0.76	0.80
Terry 545	125	3	M	0.53	0.78	0.69	0.57	0.84	0.68
Terry 546	126	3	M	0.60	0.77	0.78	0.57	0.71	0.80
Terry 548	127	3	M	0.54	0.80	0.67	0.61	0.83	0.73
Terry 555	129	3	M	0.63	0.84	0.76	0.64	0.85	0.75
Terry 557	130	3	M	0.61	0.81	0.75	0.62	0.81	0.77
Terry 564	132	3	M	0.62	0.82	0.76	0.61	0.82	0.74
Terry 566	133	3	M	0.63	0.87	0.72	0.64	0.88	0.72
Terry 573	134	3	M	0.60	0.74	0.80	0.64	0.77	0.83
Terry 575	135	3	M	0.61	0.86	0.71	0.59	0.81	0.72
Terry 577	136	3	M	0.64	0.81	0.78	0.65	0.82	0.80
Terry 588	137	3	M	0.60	0.81	0.74	0.63	0.84	0.75
Terry 591	138	3	M	0.57	0.82	0.69	0.55	0.79	0.70
Terry 602	142	3	M	0.62	0.82	0.76	0.64	0.83	0.77
Terry 605R	143	3	M	0.62	0.84	0.75	0.62	0.80	0.78

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 608	144	3	M				0.59	0.79	0.74
Terry 614	145	3	M			0.78	0.63	0.83	0.76
Terry 620	146	3	M	0.62	0.81	0.77	0.65	0.82	0.79
Terry 622R	147	3	M	0.59	0.77	0.76	0.67	0.86	0.78
Terry 636	148	3	M	0.61	0.83	0.73	0.63	0.84	0.75
Terry 641	149	3	M	0.67	0.83	0.81	0.63	0.80	0.78
Terry 644	150	3	M	0.53	0.80	0.67	0.55	0.84	0.66
Terry 645	151	3	M	0.65	0.80	0.81	0.63	0.79	0.80
Terry 672	153	*5*	M	*0.56*	*1.07*	*0.52*	*0.58*	*0.82*	*0.71*
Terry 674	154	3	M	0.60	0.80	0.75	0.62	0.85	0.73
Terry 680	155	3	F	0.57	0.80	0.71	0.59	0.81	0.72
Terry 681	156	3	M	0.60	0.80	0.75	0.61	0.83	0.74
Terry 687	157	3	M	0.58	0.83	0.70	0.58	0.86	0.68
Terry 693	158	3	M			0.77			0.81
Terry 696	159	3	M	0.56	0.78	0.72	0.54	0.74	0.73
Terry 701	160	3	M	0.55	0.78	0.71	0.58	0.80	0.73
Terry 709	161	**4**	M			**0.70**	**0.65**	**1.01**	**0.64**
Terry 710R	162	3	F	0.62	0.79	0.79	0.64	0.82	0.77
Terry 720	163	3	M	0.60	0.85	0.71	0.61	0.86	0.71
Terry 721	164	3	M	0.64	0.85	0.75	0.64	0.88	0.73
Terry 736	165	3	F	0.61	0.83	0.74	0.65	0.85	0.76
Terry 739	166	3	M	0.63	0.80	0.79	0.65	0.80	0.81
Terry 743	167	3	M	0.64	0.84	0.77	0.61	0.83	0.74
Terry 745R	168	3	F	0.61	0.81	0.74	0.59	0.79	0.75
Terry 747	169	3	M	0.58	0.78	0.74	0.56	0.78	0.72
Terry 751	170	3	M	0.52	0.76	0.69	0.54	0.78	0.69
Terry 755	171	3	M	0.62	0.81	0.76	0.65	0.87	0.75
Terry 756	172	3	M	0.55	0.75	0.74	0.64	0.86	0.75
Terry 762	173	3	M	0.63	0.85	0.74	0.65	0.80	0.81
Terry 763	174	3	M	0.59	0.81	0.73	0.58	0.80	0.73
Terry 764	175	3	M	0.61	0.88	0.70	0.61	0.83	0.74
Terry 768	176	3	M	0.59	0.82	0.72	0.61	0.82	0.75
Terry 772	177	3	M	0.52	0.73	0.72	0.55	0.77	0.72
Terry 778	178	**4**	M	**0.60**	**1.02**	**0.59**	**0.61**	**0.86**	**0.71**
Terry 785	179	3	M	0.55	0.80	0.68	0.57	0.81	0.70
Terry 787	180	3	M		0.79		0.60	0.82	0.73
Terry 795	181	3	M	0.56	0.75	0.76	0.55	0.76	0.73
Terry 802	182	3	M	0.57	0.81	0.69	0.57	0.83	0.69
Terry 810	183	3	M			0.78			0.77
Terry 813	184	3	M	0.63	0.82	0.76	0.62	0.85	0.73
Terry 814	185	3	M	0.60	0.83	0.72	0.60	0.81	0.74

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 828	186	3	M	0.61	0.78	0.79	0.62	0.80	0.77
Terry 839	187	**4**	M			**0.57**	**0.59**	**1.01**	**0.59**
Terry 843	188	3	M	0.58	0.80	0.73	0.64	0.85	0.76
Terry 846	189	3	M	0.66	0.84	0.79	0.61	0.79	0.77
Terry 847	190	3	F	0.52	0.71	0.73	0.53	0.73	0.73
Terry 849	191	3	M	0.63	0.81	0.78	0.62	0.76	0.82
Terry 866	192	3	M	0.62	0.78	0.79	0.60	0.77	0.77
Terry 867	193	3	M	0.61	0.82	0.74	0.60	0.81	0.74
Terry 868	194	3	M	0.54	0.78	0.70	0.51	0.76	0.67
Terry 869	195	3	F			0.78			0.77
Terry 870	196	3	M	0.61	0.81	0.75	0.63	0.81	0.78
Terry 871	197	3	M	0.58	0.83	0.70	0.57	0.80	0.71
Terry 872	198	3	M	0.56	0.80	0.70	0.59	0.82	0.72
Terry 879	200	3	M	0.70	0.85	0.82	0.68	0.84	0.80
Terry 880	201	3	F	0.50	0.81	0.62	0.50	0.81	0.62
Terry 892	203	3	M	0.54	0.70	0.77	0.61	0.81	0.75
Terry 895	204	3	M	0.57	0.80	0.71	0.59	0.83	0.72
Terry 897	205	3	M	0.57	0.73	0.79	0.55	0.76	0.73
Terry 901R	206	3	M	0.54	0.85	0.64	0.53	0.84	0.63
Terry 904R	207	3	F	0.55	0.80	0.69	0.53	0.76	0.70
Terry 908	208	3	M	0.60	0.78	0.77	0.60	0.77	0.77
Terry 918	209	*5*	M	*0.55*	*0.84*	*0.65*	*0.56*	*0.87*	*0.64*
Terry 924	210	3	M	0.55	0.82	0.68	0.55	0.83	0.67
Terry 928R	211	3	F	0.63	0.86	0.73	0.63	0.84	0.75
Terry 946	212	3	M	0.57	0.79	0.73	0.58	0.78	0.75
Terry 954	213	3	M			0.77	0.64	0.79	0.81
Terry 975	214	3	M	0.65	0.86	0.76	0.63	0.85	0.75
Terry 983	215	3	F	0.58	0.79	0.73	0.59	0.79	0.74
Terry 989	216	3	M	0.59	0.82	0.72	0.60	0.83	0.72
Terry 991R	217	3	M			0.76			0.76
Terry 1009	218	3	M	0.59	0.79	0.75	0.61	0.79	0.78
Terry 1016R	219	3	F	0.59	0.81	0.73	0.58	0.79	0.73
Terry 1023	220	3	M	0.60	0.91	0.66	0.61	0.81	0.75
Terry 1037	221	3	M			0.74			0.71
Terry 1043	222	3	M	0.62	0.84	0.75	0.62	0.80	0.77
Terry 1080RR	223	3	F	0.55	0.83	0.66	0.55	0.83	0.66
Terry 1094	224	3	F	0.57	0.80	0.71	0.57	0.80	0.71
Terry 1153	225	3	F	0.58	0.84	0.70	0.60	0.84	0.71
Terry 1174	226	3	F	0.62	0.83	0.74	0.62	0.85	0.74
Terry 1186	227	3	F	0.58	0.78	0.74	0.58	0.80	0.72
Terry 1202R	229	3	F	0.55	0.75	0.73	0.56	0.76	0.74

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 1239R	230	3	F	0.58	0.84	0.70	0.59	0.80	0.74
Terry 1243R	231	3	F	0.59	0.81	0.73	0.61	0.81	0.76
Terry 1270R	232	3	F	0.56	0.79	0.71	0.59	0.83	0.71
Terry 1296R	233	3	F	0.54	0.77	0.69	0.54	0.79	0.69
Terry 1353R	234	3	F		0.86		0.60	0.82	0.74
Terry 1456	235	3	F	0.62	0.81	0.76	0.68	0.86	0.78
Terry 1482R	237	3	F	0.61	0.81	0.75	0.57	0.77	0.74
Terry 1512	238	3	F	0.57	0.77	0.75	0.57	0.77	0.74
Terry 1523	239	3	F	0.56	0.77	0.72	0.56	0.76	0.74
Terry 1541R	240	3	F	0.53	0.80	0.67	0.57	0.82	0.70
Terry 1563	242	3	F	0.61	0.83	0.73	0.61	0.85	0.72
Terry 1566	243	3	F	0.53	0.79	0.66	0.52	0.76	0.69
Terry 1571	244	3	F	0.56	0.75	0.75	0.63	0.84	0.74
Terry 1572	245	3	F	0.57	0.84	0.68	0.59	0.86	0.69
Terry 1574	246	3	F	0.53	0.78	0.68	0.53	0.78	0.68
Terry 1575	247	3	F	0.51	0.75	0.68	0.52	0.73	0.72
Terry 1578	248	3	F	0.57	0.79	0.71	0.56	0.78	0.72
Terry 1579	249	3	F	0.60	0.83	0.71	0.61	0.81	0.76
Terry 1580	250	3	F	0.61	0.84	0.73	0.60	0.84	0.72
Terry 1582	251	3	F	0.56	0.80	0.70	0.58	0.80	0.73
Terry 1592	252	3	F	0.57	0.78	0.73	0.58	0.79	0.74
Terry 1593	253	3	F	0.51	0.79	0.65	0.53	0.79	0.66
Terry 1594	254	3	F	0.56	0.78	0.72	0.55	0.79	0.70
Terry 1595	255	3	F	0.61	0.80	0.76	0.64	0.83	0.77
Terry 1596	256	3	F	0.58	0.82	0.71	0.61	0.86	0.71
Terry 1599	257	3	F	0.58	0.81	0.71	0.58	0.80	0.73
Terry 1603	258	3	F	0.60	0.77	0.77	0.61	0.79	0.78
Terry 1608	259	3	F	0.61	0.81	0.75	0.61	0.81	0.75
Terry 1612	260	3	F	0.64	0.87	0.73	0.64	0.88	0.73
Terry 1616	262	3	F			0.73			0.72
Terry 1617	263	**4**	F	**0.48**	**0.79**	**0.61**	**0.52**	**0.99**	**0.52**
Terry 1622	264	3	F	0.60	0.86	0.70	0.57	0.83	0.70
Terry 1624	265	3	F	0.58	0.79	0.73	0.60	0.77	0.78
Terry 1625	266	3	F	0.64	0.84	0.76	0.63	0.80	0.79
Terry 166R	267	3	F	0.53	0.78	0.67	0.54	0.78	0.69
Terry 580	268	3	F	0.59	0.78	0.75	0.60	0.79	0.76
Terry 1601	269	3	F	0.62	0.78	0.79	0.59	0.80	0.74
Terry 1610	270	3	F	0.57	0.81	0.70	0.58	0.81	0.71
Terry 1628	271	3	F	0.58	0.83	0.70	0.60	0.87	0.68
Terry 76R	272	*5*	F	*0.57*	*0.81*	*0.70*	*0.38*	*0.56*	*0.68*
Terry 951R	274	3	F	0.71	0.83	0.85	0.70	0.84	0.84

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 1568	275	3	F			0.67	0.52	0.77	0.68
Terry 1570	276	3	F	0.61	0.78	0.78	0.61	0.78	0.78
Terry 22RR	277	3	F	0.55	0.77	0.72	0.57	0.79	0.72
Terry 240R	278	3	F	0.59	0.80	0.73	0.58	0.81	0.72
Terry 1119	279	3	F	0.60	0.78	0.77	0.63	0.77	0.81
Terry 1233R	280	3	F	0.64	0.84	0.77	0.60	0.83	0.72
Terry 1560	281	3	F	0.59	0.79	0.74	0.63	0.85	0.74
Terry 1634	282	3	F	0.50	0.82	0.61	0.49	0.85	0.58
Terry 312R	284	3	F	0.61	0.84	0.73	0.64	0.84	0.76
Terry 464	285	3	F			0.75			0.73
Terry 1155	286	3	F			0.72			0.75
Terry 1557	288	3	F	0.57	0.87	0.65	0.58	0.84	0.68
Terry 1581	289	3	F	0.56	0.76	0.74	0.60	0.79	0.77
Terry 91R	290	3	F			0.69			0.73
Terry 359R	292	3	F	0.55	0.80	0.69	0.57	0.81	0.71
Terry 491R	293	3	F	0.62	0.77	0.81	0.64	0.75	0.85
Terry 611	294	3	F			0.69	0.58	0.84	0.68
Terry 899R	295	**4**	F			**0.80**	**0.72**	**1.09**	**0.66**
Terry 1201	296	3	F	0.59	0.82	0.73	0.59	0.85	0.69
Terry 1463	297	3	F			0.72			0.73
Terry 17R	298	3	F	0.55	0.80	0.69	0.56	0.78	0.71
Terry 55R	299	3	F	0.61	0.80	0.76	0.64	0.86	0.75
Terry 110R	300	3	F	0.54	0.76	0.71	0.56	0.79	0.71
Terry 134R	301	3	F				0.60	0.88	0.68
Terry 791	302	3	F	0.65	0.85	0.77	0.64	0.84	0.77
Terry 985RR	303	3	F	0.53	0.73	0.72	0.56	0.78	0.72
Terry 1626	305	3	F	0.58	0.85	0.69	0.57	0.82	0.69
Terry 1629	306	*5*	F	*0.61*	*0.78*	*0.77*	*0.61*	*1.01*	*0.61*
Terry 92R	307	3	F			0.76	0.68	0.85	0.80
Terry 169R	308	3	F	0.59	0.81	0.73	0.59	0.77	0.76
Terry 170R	309	3	F	0.56	0.77	0.73	0.57	0.79	0.73
Terry 188R	310	*5*	F	*0.38*	*0.56*	*0.67*	*0.52*	*0.78*	*0.67*
Terry 481R	311	3	F	0.63	0.97	0.65	0.59	0.92	0.64
Terry 722R	312	3	F						
Terry 1075RR	313	3	F	0.60	0.81	0.74	0.57	0.78	0.74
Terry 1154R	314	*5*	F	*0.62*	*0.79*	*0.78*	*0.63*	*0.82*	*0.77*
Terry 1405	315	3	F	0.58	0.84	0.69	0.58	0.85	0.68
Terry 1542	316	3	F	0.63	0.82	0.77	0.62	0.87	0.72
Terry 159R	317	3	F	0.58	0.76	0.76	0.56	0.79	0.71
Terry 275RR	318	3	F	0.57	0.83	0.68	0.57	0.83	0.69
Terry 1058	319	3	F	0.59	0.90	0.66	0.62	0.86	0.71

Appendix A, Part III continued. Ratios for BD-H-DP1

SkelNum	CaseNum	BD	Sex	LDP3/LPP1	LDP3/LDP1	LDP1/LPP1	RDP3/RPP1	RDP3/RDP1	RDP1/RPP1
Terry 1189R	320	3	F	0.55	0.84	0.66	0.53	0.81	0.66
Terry 1109R	322	3	F	0.61	0.83	0.73	0.56	0.76	0.74
Terry 1496	323	3	F			0.78			0.76
Terry 1567	324	3	F	0.49	0.79	0.61	0.51	0.79	0.65
Terry 1576	325	3	F	0.56	0.80	0.70	0.56	0.79	0.70
Terry 28R	326	3	F			0.83	0.69	0.85	0.81
Terry 108R	327	3	F	0.60	0.81	0.74	0.59	0.77	0.76
Terry 149R	328	3	F			0.71			0.75
Terry 248R	329	3	F	0.54	0.81	0.67	0.54	0.80	0.67
Terry 295R	330	3	F			0.73			0.74
Terry 349RR	331	3	F	0.58	0.86	0.67	0.57	0.81	0.71
Terry 1583	333	3	F	0.58	0.82	0.70	0.62	0.86	0.72
Terry 75R	334	3	F	0.56	0.74	0.75	0.55	0.76	0.72
Terry 83R	335	3	F	0.60	0.82	0.73	0.61	0.82	0.75
Terry 543	336	3	F	0.57	0.85	0.67	0.57	0.84	0.68
Terry 925	337	3	F	0.58	0.81	0.72	0.58	0.82	0.71
Terry 992R	338	3	F			0.71			0.70
Terry 1085R	339	3	F	0.53	0.75	0.70	0.53	0.72	0.73
Terry 1123R	340	3	F	0.59	0.82	0.72	0.61	0.81	0.75
Terry 1584	341	3	F	0.60	0.80	0.76	0.63	0.85	0.74
Terry 127R	342	3	F						
Terry 154R	343	3	F			0.71			0.74
Terry 596	141A	3	M	0.59	0.72	0.81	0.60	0.77	0.78
Terry 599	141B	3	M			0.72	0.62	0.83	0.74