12-2005

A Test of the Transition Analysis Method for Estimation of Age-at-Death in Adult Human Skeletal Remains

Jonathan D. Bethard
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Jonathan D. Bethard entitled "A Test of the Transition Analysis Method for Estimation of Age-at-Death in Adult Human Skeletal Remains." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Susan R. Frankenberg, Major Professor

We have read this thesis and recommend its acceptance:

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Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Test of the Transition Analysis Method for Estimation of Age-at-Death in Adult Human Skeletal Remains

A Thesis
Presented for the
Master of Arts
Degree

The University of Tennessee, Knoxville

Jonathan Daniel Bethard
December 2005

DEDICATION

This thesis is dedicated to those individuals and their families who have supported the William M. Bass Donated Skeletal Collection. May your selflessness benefit humankind by advancing our knowledge of the human condition.

ACKNOWLEDGEMENTS

This thesis would have not been possible without assistance from numerous individuals who deserve credit at this time. First, I have to thank Drs. Walter Klippel and Murray Marks for taking a chance on a wide-eyed undergraduate. Without your help, I may never have had the opportunity to pursue my academic goals in anthropology.

I would also like to thank my committee members, Drs. Susan Frankenberg, Nicholas Herrmann, Lyle Konigsberg, and Lee Meadows Jantz for seeing this work come to fruition. I would especially like to extend thanks to Dr. Frankenberg for her help during this research. She has provided excellent guidance and support as well as focusing my writing on the key components of this research. Her editorial assistance is appreciated and greatly improved the overall quality of this work. Dr. Nick Herrmann was extremely helpful early on in the process by helping clarify both morphological markers and the statistical framework used. I would also like to extend many thanks to Dr. Lyle Konigsberg for his patient explanation of several statistical methods that improved results immensely. Finally, I would like to thank Dr. Lee Meadows Jantz for her support throughout my graduate career in addition to her assistance with facilitating access to the Bass Collection.

I would also like to extend sincere thanks to Dr. Jane E. Buikstra for initially introducing this method to me. My osteological skills have been greatly improved by studying for countless hours for her bone quizzes. In addition, I would like to thank Drs. Jesper Boldsen and George Milner for providing a copy of the ADBOU computer program to me.

I would also like to thank my fellow graduate students at the University of Tennessee for their collegial support and friendship during this process. In particular, Donna McCarthy was patient and helpful during data collection. She never seemed to get annoyed that I was always in the way. Also thanks to Megan Moore and Francisco Baires for providing friendship, sour patch kids, Krystals, and great meeting traveling companions. Billie Seet and Meta Pike deserve credit for numerous trips to Jerseyville, ferry rides, and saving me from mayflies.

In addition to individuals in the Department of Anthropology, I would also like to thank several individuals (past and present), who are associated with the Department of University Housing at UT. During my graduate career, I have been able to work for the department while completing my academic goals. First, Mr. Jim Grubb and Dr. Kristi Nelms have demonstrated unyielding support of my plans to participate in archaeological projects during the summer. Without their support, my fieldwork experience would not have been the same. The RA staffs of North Carrick Hall are also credited with making the last three years a fun time. Thanks guys for putting up with all of the talk about old bones! Finally, Dave Mac and Kim Morrow are dually thanked for their friendship and support.

Lastly and most importantly, I would like to thank my friends and family for their support during my graduate school career. Lots of friends from both Virginia and Tennessee have kept me in touch with life outside of this academic bubble. Specifically, Annette, Anna, Ben, Bennett, Christie, Felecity, Garren, Jill, John, Mark Clark, Mark, and Meredith have been awesome friends who I am exceedingly thankful for.

Mom, Larry, Amy, and Lelia have provided more love and support than one person deserves. My parents, Debbie and Larry Mays have been constant pillars of support during this process, both emotionally and financially, and I could not have done it without them. I am truly blessed with an awesome family! I would also like to thank Grandpa, Grandma, Don, Edie, and Hazel for their support for always reminding me about what is really important in life.

Finally, Liz and Jake DiGangi have been the best addition to my life in the last year and eight months. I am grateful for Liz's support and patience, along with her willingness to pull os coxae and crania from 225 boxes. I hope to return the favor in McClung Museum, Chile, and throughout our careers together.

ABSTRACT

Physical anthropologists and bioarchaeologists often seek to generate biological profiles of individuals represented by skeletal remains. One particularly informative component of the biological profile is skeletal age-at-death. Age-at-death estimation is vital to numerous contexts in both paleodemography and forensic anthropology. Throughout the history of the discipline, numerous authors have published methods for adult age-at-death estimation. These methods have proved invaluable, but they are not free from error. As a result, workers have continually worked to improve the methodological toolkit for estimating age-at-death.

In June of 1999, researchers gathered in Rostock, Germany for the sole purpose of evaluating and testing age-at-death estimation methods. The hallmark of this symposium was a theoretical framework known as the Rostock Manifesto published in volume edited by Hoppa and Vaupel (2002a) entitled *Paleodemography: age distributions from skeletal samples*. Included in this work was a new age-at-death estimation method called transition analysis published by Boldsen and colleagues. Transition analysis utilizes traits of the pubic symphysis, auricular surface, and cranial sutures to produce likelihood age-at-death estimates. In their publication, Boldsen *et al.* (2002) report a remarkable correlation between estimated age and real age in addition to asserting that this method adequately ages individuals in the 50+ years category.

This purpose of this research was to perform a validation study of the transition analysis method by utilizing 225 skeletons from the William M. Bass Donated Skeletal Collection curated by the Forensic Anthropology Center at the University of Tennessee. Data were collected in the manner of Boldsen *et al.* (2002) and used to generate age-at-death estimates. These results were then statistically compared to known ages from the Bass Collection. Results from the study were not as favorable as those published by Boldsen and colleagues. Correlation coefficients were low and analyses of data using the forward continuation ratio, ordinal cumulative probit, and unrestrictive cumulative probit models suggest such problems arise from a combination of the method's statistical framework and its lack of applicability.

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1. Introduction

Physical anthropologists and bioarchaeologists often seek to generate biological profiles of individuals represented by skeletal remains. Such profiles commonly consist of information regarding an individual's sex, age-at-death, stature, and ancestry (Krogman and Iscan 1986; Bass 1987; White and Folkens 2000). According to Milner *et al.* (2000), these estimates are vital to anthropological interpretations of mortuary practices, paleopathological analyses of skeletal and dental lesions, and research on the demographic parameters of past populations. The patterns that emerge from analyses of such biological data also permit workers to identify and "isolate biological as well as social life history factors" (Kemkes-Grottenthaler 2002:48).

While identifying factors of the biological profile is critical in numerous anthropological contexts, workers agree that assessing each component of the osteobiography with equal accuracy is difficult (Kemkes-Grottenthaler 2002; Prince 2004). Specifically, precise age-at-death estimation has proven to be an exasperating task. According to Prince (2004:1), age-at-death estimates are troublesome because they attempt to "correlate physiological age with chronological age in a system that has differential development and deterioration." Despite the strong association between senescence and skeletal change, the aging process is highly dependent on numerous genetic and environmental factors (Buckberry and Chamberlain 2002; Kemkes-Grottehthaler 2002).

As physical anthropology has progressed from its early beginnings, numerous scholars have investigated adult age-at-death estimation from skeletal remains with varying degrees of success (Krogman and Iscan 1986; Iscan 1989). Although many of these methods have proven useful, they also carry some degree of error due to placing a skeletal element into an ordinal phase category. Moreover, workers have found that superior age-at-death estimates are derived from evaluating multiple skeletal traits rather than isolated indicators. While singe-trait systems sometimes produce informative age-at-death estimates, such methods do not consider the innumerable factors that influence senescent changes (Kemkes-Grottenthaler 2002). On the contrary, multiple-trait approaches have yielded a far better representation of the sequential aging process. As Kemkes-Grottenthaler (2002:58-59) notes, "in order to minimize errors by aberrant individual indicators, the combined analytical approach is desirable, whenever complete individuals are available for analysis." The purpose of this thesis is to test a new, multiple-trait method of adult age-at-death estimation on a sample of contemporary, known-age skeletons in order to discern the method's accuracy and utility.

Using criteria suggested in the Rostock Manifesto, Boldsen and coworkers (2002) present a new method for age-at-death estimation. Specifically, this method utilizes a scoring system that incorporates characteristics of the pubic symphysis, auricular surface of the ilium, and cranial suture closure to generate "likelihood of death estimates occurring at different ages for each character" (Kemkes-Grottenthaler 2002: 61). Boldsen and coworkers (2002:74) call their method *transition analysis* since "the results allow us to make inferences about the timing of transitions from one stage to the next." While results achieved in their initial study are favorable, Boldsen *et al.* maintain that additional validation studies are needed. This thesis seeks to test the transition analysis aging method on The William M. Bass Donated Collection curated by the Forensic Anthropology Center at the University of Tennessee.

In their conclusion, Boldsen *et al.* (2002:96) assert "it is also essential to conduct further validation studies. Preferably this work will be done on known-age samples as dissimilar to the Terry Collection as possible. After all, it would be useful to know whether this method is applicable to skeletal samples other than the indigents who died during the early to mid 20th century in the USA." The William M. Bass Donated Collection is a contemporary skeletal collection of 20th to early 21st century Americans that continues in time where the Terry and Hammann-Todd collections cease (Bassett *et al.* 2003). The Bass Collection serves as an excellent validation sample for the method because it is a well-documented collection of known-age individuals that differs from those in the Terry and Hammann-Todd collections in terms of socioeconomic class, temporal context, and regional variation.

The research presented in this thesis is designed to answer the following questions regarding the Boldsen *et al.* (2002) method:

1) Are the components of the Boldsen et al. aging method clearly defined for conventional use?

2) Does the ADBOU software program produce age-at-death estimates in the manner described by the original researchers?

3) Do age-at-death estimates rendered from the ADBOU software program have a high degree of correlation with real age?

4) Do the results indicate that this method should be adopted by workers for adult age-at-death estimation?

While these questions are elementary in nature, they are entirely appropriate. In their discussion, Boldsen and colleagues make a compelling argument for adopting the transition analysis aging method. The authors argue that the technique improves upon estimating age-at-death in old adults and no longer forces workers to use an open-ended interval such as 50+ years (Boldsen *et al.* 2002). In addition, the authors suggest that their approach of combining multiple components from several morphological structures helps account for variability in the aging process. Moreover, Boldsen and colleagues argue that they have produced a robust statistical package that utilizes an appropriate framework to produce age-at-death estimates. Since it is given that not all physical anthropologists are equally trained as statisticians, this research is designed to test the user-friendliness of the method as well as its accuracy.

This introduction has summarized the role of estimating adult age-at-death from human skeletal remains in anthropological contexts. In addition, it has briefly addressed concerns associated with phase-based aging methodologies along with a method recently developed to correct such problems. The next chapter continues by reviewing problems with adult age-at-death estimation along with detailing a framework advocated to alleviate such problems. It concludes by describing the transition analysis aging method developed by Boldsen and colleagues. Chapter 3 describes the sample utilized and outlines input and output of the transition analysis software. It also details the methods used to evaluate the accuracy of Boldsen and colleagues' method for estimating age-at-death from the pubic symphysis, auricular surface, and cranial sutures. Moreover, this chapter presents additional statistical methods employed to evaluate the relationship between individual skeletal indicators and real age. Chapters 4 presents results generated from both Boldsen and colleagues' software package and the forward continuation ratio and proportional odds models. Chapter 5 addresses the method's overall efficacy and Chapter 6 presents conclusions and suggestions for future research.

2. Literature Review

Workers who rely on age-at-death estimates as part of their dataset must first recognize the uniformitarian assumption that allows for such inferences in the first place. According to Howell (1976:26),

> "a uniformitarian position in paleodemography implies that the human animal has not basically changed in its direct biological response to the environment in processes of ovulation, spermatogenesis, length of pregnancy, degree of helplessness of the young and rates of maturation and senility over time. This does not imply that humans have not changed in the rates of performance of these processes, but only that the processes still respond in the same way to variations in environment, including the cultural and technological aspects of human society as part of the external environment."

The fundamental point is that while aging is a variable process, such variation is constrained in a predictable pattern (Milner *et al.* 2000). Under this assumption, workers who seek to estimate age-at-death in archaeological or forensic skeletal samples should be able to apply osteological standards developed from documented anatomical skeletal collections. However, workers should also recognize that there is individual variability in rates and degrees of the aging process.

For example, Kemkes-Grottehthaler (2002:48) argues that "the aging process is merely universal to the extent that it applies to both sexes and all populations. Beyond that, there is remarkable interpersonal heterogeneity due to distinctive genetic differences, behavior variation, diverse predispositions, and the individual's lifetime interaction with the environment." Spirduso (1995) further complicates the subject and notes that there is evidence of significant intra-subject variability. As a result of such variability, the expressions "biological age" and "chronological age" are not synonymous (Kemkes-Grottenthaler 2002). More exactly, biological age is deduced from variables that are correlated with chronological aging (Arking 1998). As a result, biological age markers do not represent chronological age, but simply estimate the chronological state of the individual (Kemkes-Grottenthaler 2002:49-50). The tenuous relationship between chronological age and biological age, and the factors influencing both age expression and age estimation are shown graphically in Figure 1.

Although the precise correlation between skeletal markers and chronological age remains elusive, skeletal biologists have made great strides in improving age estimation techniques. In the early days of skeletal biology, most "skeletal biologists…relied almost solely on the cranial sutures and pubic symphysis for age estimation in the adult" (İşcan 1989:7). These estimates, and others, were derived by comparing morphological structures from unknown skeletons with methodological standards developed from known-age collections. With time, multiple-trait assessment systems were utilized more frequently, but even these multi-trait systems relied heavily on phase-based aging techniques (Kemkes-Grottenthaler 2002).

Numerous methods for age-at-death estimation have been developed and utilized in physical anthropology (Todd 1920; Todd 1921a; Todd 1921b; Todd and Lyon 1924; Todd and Lyon 1925; Gustafson 1950; Brooks 1955; McKern and Stewart 1957; Gilbertand McKern 1973; Lovejoy *et al.* 1985; Meindl and Lovejoy 1985; Katz and Suchey 1986; Brooks and Suchey 1990; Stout 1989; Buckberry and Chamberlain 2002). Those methods that continue to be commonly used are summarized by anatomical area, method type, source, and commentary in Table 1. The commentary lists and describes characteristics of each method type as understood by this author.

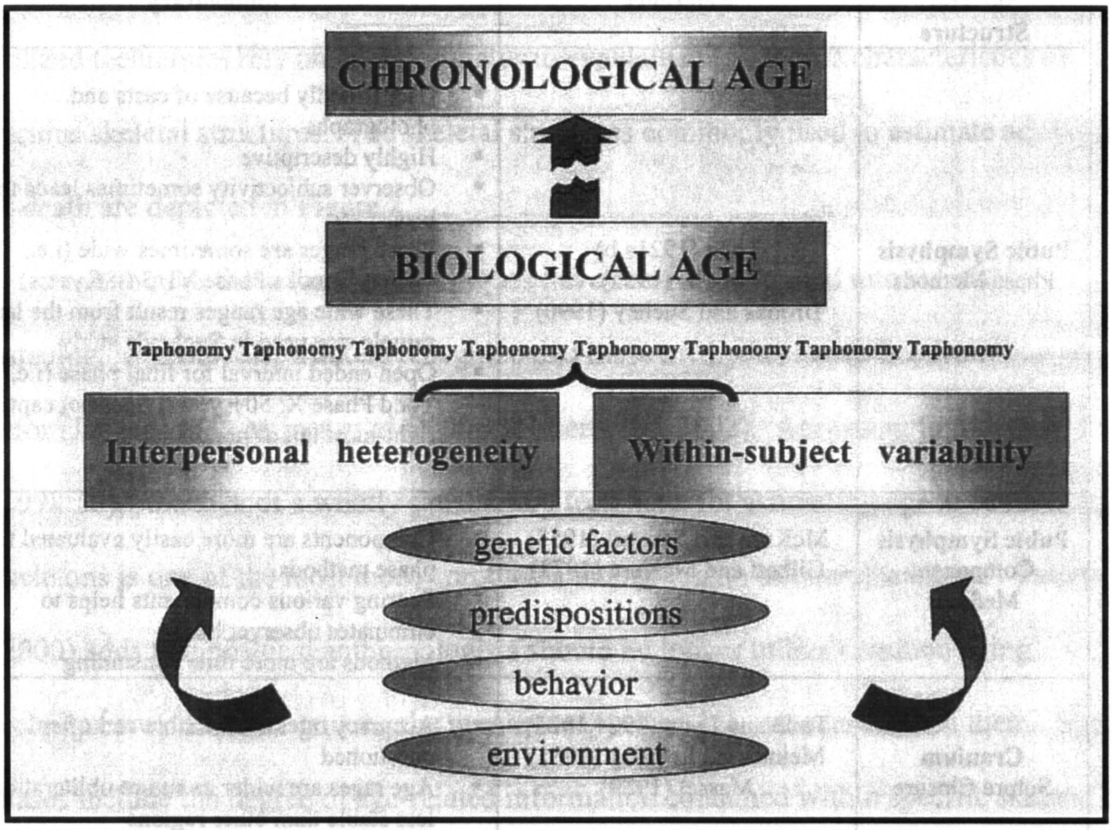

Figure 1. Factors influencing age-at-death estimation. Note the broken arrow between biological age and chronological age which highlights the confounding influence of biological skeletal traits on chronological age-at-death estimates.

(From Kemkes-Grottenthaler 2002:50)

Table 1. Skeletal aging methods commonly utilized by physical anthropologists.

Skeletal Structure	Reference	Commentary
Pubic Symphysis Phase Methods	Todd (1921a,b) Brooks (1955) Brooks and Suchey (1990)	▪ User friendly because of casts and photographs ▪ Highly descriptive ▪ Observer subjectivity sometimes leads to bias. ▪ Phase ranges are sometimes wide (i.e., Suchey-Brooks Phase VI: 34-86 years) ▪ These wide age ranges result from the large sample size used in Suchey's study ▪ Open ended interval for final phase (i.e, Todd Phase X: 50+ years) does not capture right-most tail of population
Pubic Symphysis Component Methods	McKern and Stewart (1957) Gilbert and McKern (1973)	▪ Components are more easily evaluated than phase methods ▪ Scoring various components helps to eliminates observer bias ▪ Methods are more time consuming
Cranium Suture Closure	Todd and Lyon (1924,1925) Meindl and Lovejoy (1985) Masset (1989)	▪ Accuracy rates are variable and often questioned ▪ Age rages are wider as suture obliteration is less stable than other regions
Ilium Auricular Surface	Lovejoy et al. (1985) Buckberry and Chamberlain (2002)	▪ No casts and rely on photographs and highly descriptive text ▪ Observer subjectivity is problematic ▪ Open ended interval for final phase (i.e, Lovejoy Phase 8: 60+ years) does not capture right-most tail of population
Rib Sternal aspect	Iscan and Loth (1986a,1986b)	▪ Preservation sometimes prohibits analysis ▪ Wide phase ranges
Long bone cortices Histology (osteon counting)	Kerley (1965) Stout (1989)	▪ Samples require technical preparation ▪ Methods limited to certain skeletal elements ▪ Accuracy is dependent on source and origin of thin section
Teeth Dental Indicators (i.e., apical transparency)	Gustafson (1950) Lamendin et al. (1992) Prince and Ubelaker (2002)	▪ High correlation with real ages are reported ▪ Multiple methods provide choices for estimating age-at-death from the dentition

While some methods utilize the histomorphometric structure of bones and teeth (Stout 1989; Kemkes-Grottenthaler 2002) to derive age-at-death estimates, the most commonly utilized techniques rely on an investigator to evaluate macroscopic characteristics of various skeletal structures. The skeletal structures commonly used to estimate adult age-at-death are depicted in Figure 2.

Although these familiar techniques have been incorporated into standard osteological protocols, workers recognize that these methods are not free from bias or error (Jackes 2000, Milner *et al.* 2000; Boldsen *et al.* 2002). According to Mays (1998:50), "the lack of a wholly satisfactory technique for estimating age at death in adult skeletons is one of the most thorny problems facing human osteoarchaeology." Jackes (2000) adds that physical anthropologists should no longer utilize common aging techniques without recognizing the numerous types of bias associated with them. Such biases include the degree of age-related information contained within specific skeletal traits, as well as sampling strategies and statistical methods used the develop age estimation methods (Jackes 2000). Jackes (2000:418) underscores the importance of accurately documenting skeletal assemblages in a systematized and standardized manner. She argues that anthropological interpretations require inter-site comparisons and without standardized protocol for documenting adult age-at-death, such comparisons are increasingly difficult.

Another difficulty associated with adult age-at-death estimation deals with estimating age-at-death in older skeletons. Traditional methodologies have left little room for more than a lumped, 50+ age category (Milner *et al.* 2000). Consequently, such methodological shortcomings have impacted anthropological interpretations of life

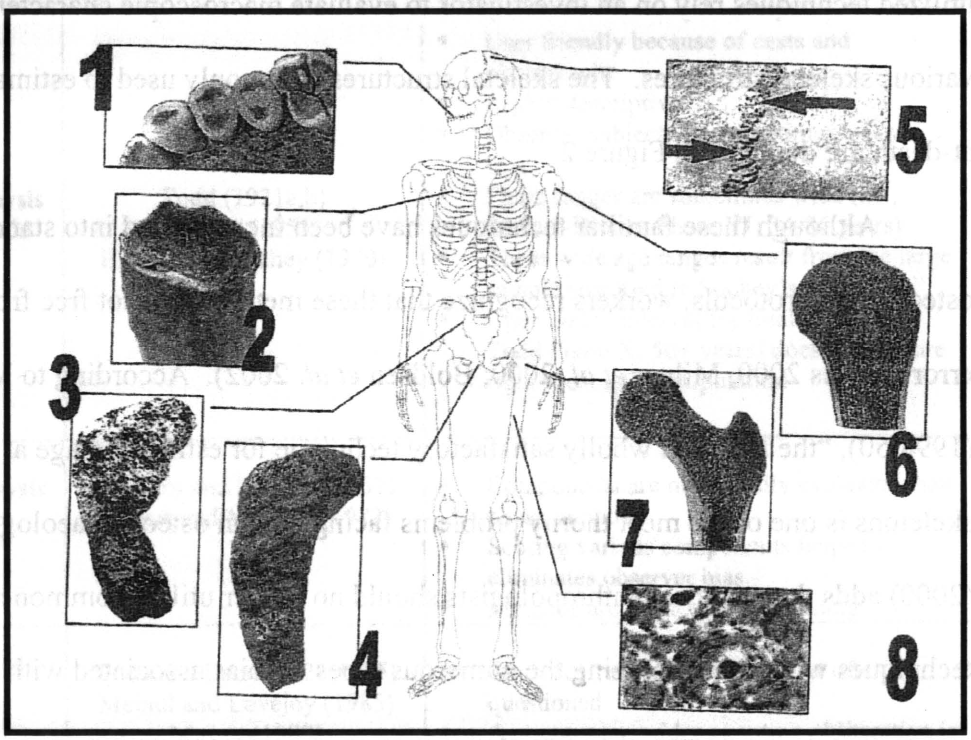

Figure 2. Depiction of skeletal structures used in adult age-at-death estimation. (Reproduced from Kemkes-Grottenthaler 2002:49)

expectancy by implying that prehistoric people did not enjoy a life expectancy past 50 years. Jackes (2000:418) disagrees and argues that "there can be little doubt that people lived into old age–even in times of conflict, disease and famine–despite the fact that standard paleodemographic methods would give no indication of this." Milner (personal communication, 2005) agrees and argues that it is unwise to assume that individuals in archaeological populations do not live past 50 years.

An additional problem regarding age-at-death estimation was outlined by Prince (2004) and involves missing data due to taphonomic processes. A majority of aging methods utilize skeletal elements that do not withstand taphonomic pressures (Buikstra and Cook 1980; Walker *et al.* 1988; Jackes 2000; Milner *et al.* 2000; Paine and Boldsen 2002; Wittwer-Backofen and Buba 2002). Soil characteristics, sometimes destroy skeletal tissues, animal activity may result in missing and/or damaged elements, and poor excavation techniques can damage or fail to recover skeletal elements. According to Walker *et al.* (1988), poor preservation often makes age determinations difficult and sometimes forces workers to use methods that yield far-less superior results. Specific skeletal structures like the pubic symphysis, auricular surface and sternal ends of the ribs are commonly subjected to taphonomic processes and are often unrecovered or too damaged to contribute to an osteological analysis. Additional taphonomic biases result from differential burial practices that can lead to missing or underrepresented sex and age cohorts.

In order to reconcile the aforementioned problems (Jackes 2000; Milner *et al.* 2000), numerous researchers participated in a three-day workshop conducted by the Laboratory of Survival and Longevity at the Max Planck Institute for Demographic

Research in Rostock, Germany in June of 1999. The purpose of the workshop was to provide workers with an identical, known-age dataset to test and assess their statistical techniques (Hoppa and Vaupel 2002). Although workers were able to test and refine methods, a more fundamental discourse emerged during the workshop. A theoretical framework coined the "Rostock Manifesto" was adopted by all scholars in attendance (Hoppa and Vaupel 2002:2-3). The Manifesto has four major elements that offer suggestions for accurate paleodemographic analyses. Those elements are paraphrased below:

1. Osteologists must develop more reliable and robustly validated age indicators that correlate well with chronological age. Such indicators should be developed from suitable reference collections.

2. A multi-disciplinary approach should be initiated to estimate $\Pr(c|a)$, the probability of observing a suite of skeletal characteristics c, given known age a.

3. Osteologists must recognize that most pressing to age-at-death estimation is $\Pr(c|a)$, the probability that the skeletal remains are from a person who died at age a, given the evidence concerning c, the characteristics of the skeletal remains. This probability, $\Pr(a|c)$, is NOT equal to $\Pr(c|a)$, the latter being known from reference samples. Rather $\Pr(a|c)$ must be calculated from $\Pr(c|a)$ using Bayes' theorem, along with data concerning $f(a)$, the probability distribution of ages-at-death (i.e., lifespan) in the target population of interest.

4. As a result, $f(a)$ must be estimated *before* $\Pr(a|c)$ can be estimated. In order to estimate $f(a)$, a model is needed of how the likelihood of death varies with age. Furthermore a method is needed to relate empirical observations of skeletal characteristics in the target population to the probability of observing the skeletal characteristics in this population. The empirical observations generally will be counts of how many skeletons are classified into each of the stages or categories c.

As mentioned, the Rostock Manifesto outlines a protocol for grappling with problems associated with adult age-at-death estimation. When followed, workers agree that it provides a suitable framework for producing accurate adult age-at-death estimates

(Jackes 2002; Igarashi *et al.* 2005). While a key component of the Rostock protocol calls for estimating the entire age-at-death distribution $f(a)$ before estimating the age-at-death of any individual skeleton, Boldsen and coworkers (2002) assert that target populations must be large enough to generate acceptable estimates of $f(a)$. They argue that many samples in both archaeological and forensic contexts are too small to apply such an approach and present a new method to reconcile this problem.

Boldsen and colleagues present a transition analysis method for age-at-death estimation that they believe addresses the four "analytical difficulties" regarding adult age-at-death estimation (Boldsen *et al.* 2002:75). These difficulties include: 1) avoiding the large uncertainty associated with age estimation; 2) age mimicry that results from the age-at-death distribution of the reference sample; 3) the most effective way to correlate multiple skeletal indicators of age; and 4) developing methods that code morphological changes as they relate to age.

In order to combat the problem of uncertainty associated with assessing age-at-death, skeletal biologists often employ fixed age intervals to correct some of the intrinsic imprecision associated with estimating age-at-death (Boldsen *et al.* 2002). While utilized quite often, these age intervals are not infallible. As Boldsen and coworkers (2002:75) point out, "just as no osteologists believes that an exact age can be assigned to any particular skeleton, no one would claim that all skeletons that appear to be roughly the same age can be assigned with equal confidence to a single age interval." As mentioned previously, every skeleton is subject to a myriad of agents that influence its morphological state and degree of preservation. When these factors are coupled with the variability of the aging process and taphonomic influences, it becomes clear why workers hesitate to conclude that every skeleton exhibiting similar macroscopic features is from the same age cohort.

According to Boldsen and colleagues (2002), point estimates of age or discrete age intervals are not what are needed for age-at-death estimation. On the contrary, they argue that the entire probability density function $\Pr(a|c_j)$ should be computed individually for each skeleton and for every value of a. The function $\Pr(a|c_j)$ is the probability that an individual skeleton died at age a given that it expresses characteristics c_j, where c_j is the group of skeletal traits observed in the j^{th} skeleton in the sample. Furthermore, if workers estimate a confidence interval around a point estimate of the j^{th} skeleton, that estimate should be based directly on the probability density function $\Pr(a|c_j)$ (Boldsen *et al.* 2002:76). When utilized, such an approach eliminates the need for an arbitrary age interval since some of the uncertainty with aging is reconciled statistically.

The second problem of age mimicry, first identified by Bocquet-Appel and Masset (1982), results from the type of regression analysis used to elucidate the relationship between age and skeletal indicator in a reference sample. When actual age a is regressed on skeletal characteristics c_j, the estimates of age a obtained for each indicator state c_j are dependent on the age distribution of the reference sample. In this case, the target age distribution will heavily mimic the reference population (Bocquet Appel and Masset 1982; Van Gerven and Armelagos 1983; Buikstra and Konigsberg 1985; Konigsberg and Frankenberg 1992; Aykroyd *et al.* 1997; Milner *et al.* 2000; Boldsen *et al.* 2002; Holman *et al.* 2002; Hoppa and Vaupel 2002b; Kemkes-Grottenthaler 2002; Love and Müller 2002; Wittwer-Backofen and Buba 2002). Masset (1989:81) refers to the issue of age mimicry as "the attraction to the middle." Such regression methods usually overestimate age in younger adults while underestimating age in older adults (Aykroyd *et al.* 1997; Aykroyd *et al.* 1999). As a result, age mimicry may be partially responsible for previously-mentioned biases regarding prehistoric longevity.

In order solve the problem of mimicry, Boldsen and coworkers argue that estimates of $\Pr(c_j|a)$ should be obtained from an adequate reference sample, even though the probability of presenting a particular age indicator state c_j given age a is not the ultimate aim of age-at-death estimation. After $\Pr(c_j|a)$ is projected, estimates of $\Pr(a|c_j)$ can be derived from regression analysis and the use of Bayes' theorem which states that:

$$\Pr(a|c_j) = \frac{\Pr(c_j|a)f(a)}{\int \Pr(c_j|x)f(x)\mathrm{d}x},$$

where $f(a)$ is the age-at-death distribution of the population in question, x is age, and d is a unit of age. In Bayesian terms, $f(a)$ is referred to as the prior distribution of ages-at-death since it must be calculated prior to the likelihood $\Pr(c_j|a)$ (Boldsen *et al.* 2002:77).

According to the Rostock protocol, Bayesian treatment of $\Pr(a|c_j)$ should occur only after $f(a)$ is estimated for the entire sample. While Boldsen and colleagues agree that this is the correct way to estimate an individual skeleton's age-at-death, they argue that "target samples in archaeological and forensic research will often be too small to support estimation of $f(a)$...So a method is needed that is applicable to the kinds of small samples (including single skeletons) that are typical of much osteological research" (Boldsen *et al.* 2002: 77). Boldsen and coworkers assert that their method can be based on a uniform prior distribution or on documentary $f(a)$ data that is independent from the skeletal sample in question. They advocate the use of two different informative priors, one for archaeological contexts (i.e., 17th century parish burial records) and another for forensic contexts (i.e., ages of homicide victims from the general public), and argue that the resultant age estimates will be entirely free of undesirable mimicry (Boldsen *et al.* 2002).

The third analytical difficulty discussed by Boldsen *et al.* (2002) is the intercorrelation among age indicators, which means that the data they contain is not independent. Boldsen and colleagues (2002:78) assume "that any correlation among traits is purely attributable to age, so that the traits would be independent if they could be conditioned on age." They call this assumption conditional independence and cite an evolutionary theory of senescence – the mutation accumulation mechanism (Rose 1991:72-78) – as justification for this claim. The mutation accumulation mechanism hypothesizes that aging might "arise from a process of accumulation of exclusively late-acting deleterious mutations, where such mutations are allelic variants that preserve all early functions of the locus" (Rose 1991:72). Boldsen *et al.* (2002) caution that this assumption is not applicable in all cases, particularly in juveniles, but is reasonable for the transition analysis method.

The fourth and final difficulty described by Boldsen and colleagues relates to the classification of morphologically useful skeletal indicators of age-at-death. The approach that the authors present is derived from previous work of McKern and Stewart (1957) who evaluated the pubic symphysis in terms of three distinct components. Boldsen *et al.* (2002:79) argue that component classificatory systems are superior to systems that evaluate a morphological structure in its entirety "because senescent changes in morphology do not occur in lockstep…it is typically difficult to classify adult skeletons unambiguously. That said, it is often difficult to shoehorn a complex anatomical structure, such as the sacroiliac joint, into one particular developmental stage." As a result, Boldsen and colleagues advocate a method that evaluates morphological structures of the bony pelvis and cranial sutures in terms of multiple components or segments.

Boldsen *et al.* (2002) developed their transition analysis method on a sample of 186 skeletons from the Smithsonian Institution's Terry Collection. The authors oversampled individuals who were less than 40 years old to thoroughly account for morphological changes that occur rapidly in early adulthood (Boldsen *et al.* 2002:80), and scored a total of nineteen morphological features of the bony pelvis and cranium based work of McKern and Stewart (1957), Lovejoy *et al.* (1985), and Meindl and Lovejoy (1985). The statistical methodology underlying Boldsen and colleagues' transition analysis is based on the assumption that a particular trait moves from stage i to $i + 1$, never in a negative direction, and never from i to $i + 2$ or higher (Boldsen *et al.* 2002:82).

For a two-state skeletal feature, y_j is the trait value of 0 or 1 in the j-th individual. They fit a general linear model $\Pr(y_j = 1 | a_j) = \Lambda(\alpha + \beta a_j)$, where a_j is the age-at-death in the j-th skeleton, α and β are parameters estimated from the reference sample, and Λ represents an inverse link function (Boldsen *et al.* 2002). This model is referred to as transition analysis because the intercept and slope of the equation $\Pr(y_j = 1 | a_j) = \Lambda(\alpha + \beta a_j)$ indicate the timing of the transition from one stage to the next. More specifically, the intercept is the age at which an individual passes from one indicator state to the next, and the slope is the rate of transition.

For skeletal traits with more than two states Boldsen and colleagues first use a cumulative logit or proportional odds model that is written as $\Pr(y_j \geq i | a_j) = \Lambda(\alpha_i + \beta a_j)$.

Within this model, standard deviations for each transition remain the same, a result that counters conventional wisdom about the senescent process, "as everything we know about developmental biology indicates that the standard deviations of age-to-transition increase with increasing stages" (Boldsen *et al.* 2002:83). To solve this problem, Boldsen and coworkers then employ a continuation ratio model. To extend transition analysis to multiple skeletal indicators Boldsen and colleagues treat each skeletal trait as conditionally independent of all other traits and utilize a combined likelihood function to calculate age-at-death by multiplying the stage likelihoods for each trait (Boldsen *et al.* 2002:85).

Boldsen and colleagues advocate using multiple aging indicators, a multivariate transition analysis, because it is more informative and more robust. They bolster this argument by reporting correlation coefficients between estimated age and reported age for the pubic symphysis (0.86), auricular surface (0.82), cranial sutures (0.86), and a combination of all three morphological complexes (0.88). They point out that while the pubic symphysis worked almost as well as all three indicators combined, it should not be used exclusively because of taphonomic factors that often damage and destroy the surface (Boldsen *et al.* 2002). They further argue that the morphological features of the three anatomical complexes are conditionally independent because of "an invariant biological relationship between age and c_j which means that the partial correlations remain constant among all samples" (Boldsen *et al.* 2002:91).

To test their multivariate transition analysis, Boldsen and coworkers estimate age-at-death for 84 skeletons randomly selected from the Terry Collection. Using a uniform prior, this test yields similar age-at-death distributions for the reference and target samples, but the authors argue that the target sample does not display any noticeable relationship with the reference sample, and that age mimicry is not a problem for the transition analysis technique. Boldsen and colleagues further assert that their methodology opens the door for analyses of a previously underrepresented cohort of individuals: those above 50 years. They argue that the morphological indicators that they have identified coupled with the statistical framework they present accounts for that "part of the mortality distribution that was once beyond the reach of paleodemographers" (Boldsen *et al.* 2002:95). Finally, in concluding that using multiple indicators of age greatly enhances age-at-death estimates, Boldsen and colleagues argue that their methodological approach "should serve as incentive for osteologists to continue the search for the considerable amount of age-related morphological variation that surely exists in skeletons" (Boldsen *et al.* 2002). The authors believe that estimating age-at-death will continue to improve as additional age-related morphological features are identified and incorporated into their methodological protocol.

3. Materials and Methods

In order to test the transition analysis aging technique developed by Boldsen *et al.* (2002), blind analyses of a documented skeletal series were necessary. The skeletons utilized in this study were drawn from the William M. Bass Donated Collection curated by the Forensic Anthropology Center (FAC) at the University of Tennessee. As mentioned in the introduction, the Bass Collection overlaps with and continues in time from the point that the other major American reference collections end. In addition, the majority of the adult population of the Bass Collection is older than 50 years of age. Such sample demographics were necessary to test the utility of Boldsen *et al.'s* (2002) method for estimating the age-at-death of older people in the 50+ years category.

The Bass Collection currently contains the remains of over 425 individuals donated for research purposes to the Anthropological Research Facility (ARF) (Bassett *et al.* 2002). While the primary research goals of the ARF are to document human decomposition and refine methods of time-since-death estimation, the Bass Donated Collection, which began in 1981, also is available for osteological research. Demographic data and medical information for each donation are gathered by FAC personnel through direct contact with individuals before death or the individual's family after death (Bassett *et al.* 2002).

Two-hundred twenty-five individuals drawn from the Bass Collection were used in this study. Skeletons in this sample were selected on the basis of availability of recorded/known sex, age, and ancestry data, and order of skeletal accession into the Bass Collection. The earliest donated skeletons were evaluated first and skeletons were evaluated in that manner until time constraints prohibited additional data collection. The breakdown of this sample by sex and ancestry is listed in Table 2. As can be seen from this table, the uneven distribution of the sample across the sexes and ancestry reflects the overall composition of collection. Since the Bass Collection is primarily derived from donated individuals from East Tennessee, its composition partially reflects the region's demography. Moreover, the uneven sex ratio is an additional artifact of the collection, as more male donations are received annually than females. The age-at-death distribution of the test sample is shown in Figure 3 for the whole sample and in Figure 4 separated by sex. The test sample was comprised of 45 females and 180 males, and was heavily biased towards individuals of white ancestry. The mean age-at-death for the sample was 59.89 years and age-at-death ranged from 25 years to 101 years (Figure 3). Mean age-at-death differed by sex with 58.32 years for males and 66.18 years for females (Figure 4).

From the test sample, data were collected in the manner of Boldsen *et al.* (2002: 96-104). Skeletal traits of the pubic symphysis, auricular surface, and cranial sutures were coded following the author's protocol. Specific skeletal traits and the associated coding system are abridged and presented in Table 3. As can be seen from Table 3,

Table 2. Distribution of the study sample by sex and ancestry.

		Ancestry				
		Black	Hispanic	American Indian	White	Total
Sex	F	1	0	0	44	45
	M	19	1	1	159	180
Total		20	1	1	203	225

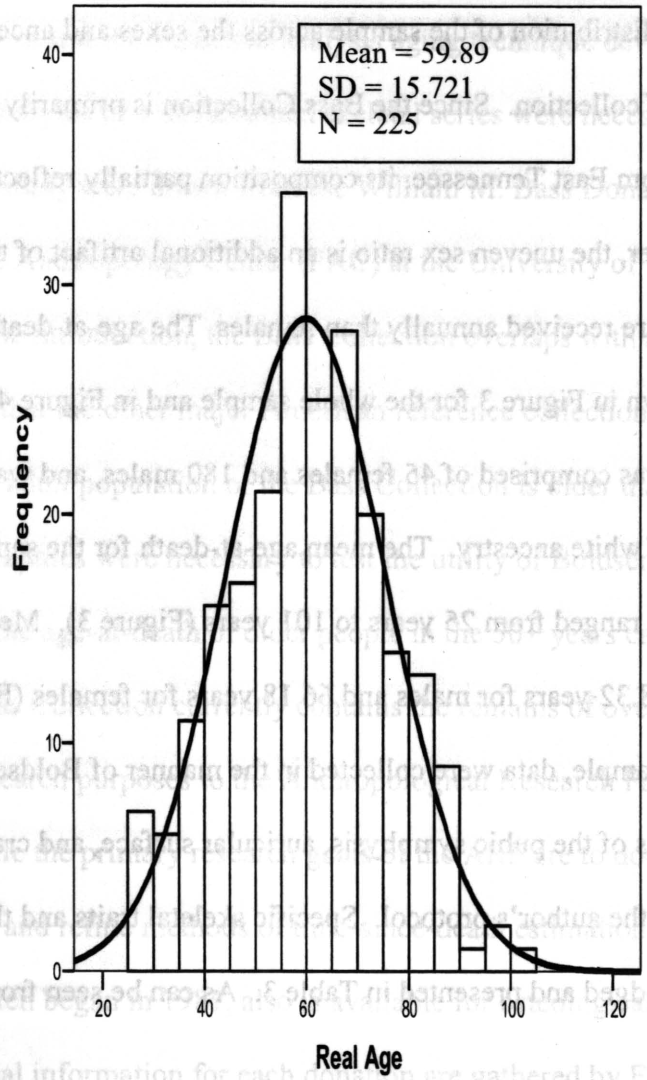

Figure 3. Actual age-at-death distribution of the test sample.

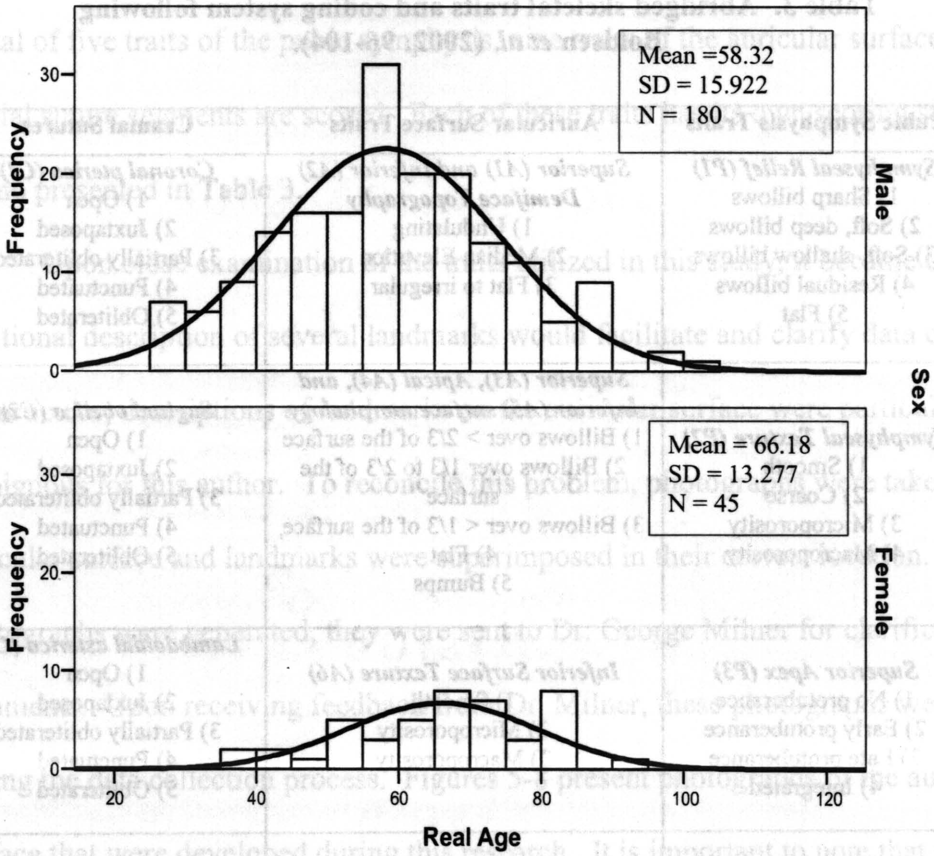

Figure 4. Sex-specific age-at-death distribution of the test sample.

Table 3. Abridged skeletal traits and coding system following Boldsen *et al.* (2002: 96-104).

Pubic Symphysis Traits	Auricular Surface Traits	Cranial Sutures
Symphyseal Relief (P1) 1) Sharp billows 2) Soft, deep billows 3) Soft, shallow billows 4) Residual billows 5) Flat	***Superior (A1) and Inferior (A2) Demiface Topography*** 1) Undulating 2) Median Elevation 3) Flat to irregular	***Coronal pterica (C1)*** 1) Open 2) Juxtaposed 3) Partially obliterated 4) Punctuated 5) Obliterated
Symphyseal Texture (P2) 1) Smooth 2) Coarse 3) Microporosity 4) Macroporosity	***Superior (A3), Apical (A4), and Inferior (A5) surface morphology*** 1) Billows over > 2/3 of the surface 2) Billows over 1/3 to 2/3 of the surface 3) Billows over < 1/3 of the surface 4) Flat 5) Bumps	***Sagittal obelica (C2)*** 1) Open 2) Juxtaposed 3) Partially obliterated 4) Punctuated 5) Obliterated
Superior Apex (P3) 1) No protuberance 2) Early protuberance 3) Late protuberance 4) Integrated	***Inferior Surface Texture (A6)*** 1) Smooth 2) Microporosity 3) Macroporosity	***Lambdoidal asterica (C3)*** 1) Open 2) Juxtaposed 3) Partially obliterated 4) Punctuated 5) Obliterated
Ventral Symphyseal Margin (P4) 1) Serrated 2) Beveled 3) Rampart formation 4) Rampart completion I 5) Rampart completion II 6) Rim 7) Breakdown	***Superior (A7) and Inferior (A8) posterior iliac exostoses*** 1) Smooth 2) Rounded exostoses 3) Pointed exostoses 4) Jagged exostoses 5) Touching exostoses 6) Fused	***Zygomaticomaxillary (C4)*** 1) Open 2) Juxtaposed 3) Partially obliterated 4) Punctuated 5) Obliterated
Dorsal Symphyseal Margin (P5) 1) Serrated 2) Flattening incomplete 3) Flattening complete 4) Rim 5) Breakdown	***Posterior iliac exostoses (A9)*** 1) Smooth 2) Rounded exostoses 3) Pointed spicules	***Interpalatine (medial palatine, posterior portion) (C5)***[1] 1) Open 3) Partially obliterated 4) Punctuated 5) Obliterated *1* – The 'juxtaposed' category is not scored here following Boldsen et al. 2002:103.

a total of five traits of the pubic symphysis, nine traits of the auricular surface, and five cranial suture segments are scored. Each of these traits has its own scoring system which is also presented in Table 3.

Upon close examination of the traits utilized in this study, it became clear that additional description of several landmarks would facilitate and clarify data collection. In particular, descriptions of landmarks on the auricular surface were particularly ambiguous for this author. To reconcile this problem, photographs were taken of the auricular surface and landmarks were superimposed in their correct location. After these photographs were generated, they were sent to Dr. George Milner for clarification and comments. Upon receiving feedback from Dr. Milner, these photographs were utilized during the data collection process. Figures 5-8 present photographs of the auricular surface that were developed during this research. It is important to note that photographs of the pubic symphysis and cranial sutures were not generated since those morphological structures are referred to with terminology commonly used in osteological analyses and were more familiar to this author.

Raw scores (Appendix 1) were used to calculate age-at-death estimates in Beta Version 1.10 of the ADBOU age-at-death estimation program furnished to the author by Dr. Jesper Boldsen, director of the Anthropological Database at Odense University (ADBOU) in Denmark. An updated, Windows XP-compatible version was provided to the author by Dr. George Milner. Raw scores were input into appropriate fields and demographic parameters were set for each case. While sex and ancestry diagnoses were initiated at the time of data collection by this author, these data were verified from the

Figure 5. Superior and inferior demiface topography. Photograph by Jonathan Bethard.

Superior and inferior demiface topography
"The superior and inferior demifaces are divided by a line extending posteriorly from the most anterior part of the apex to the posterior border of the joint surface" (Boldsen *et al.* 2002: 101).

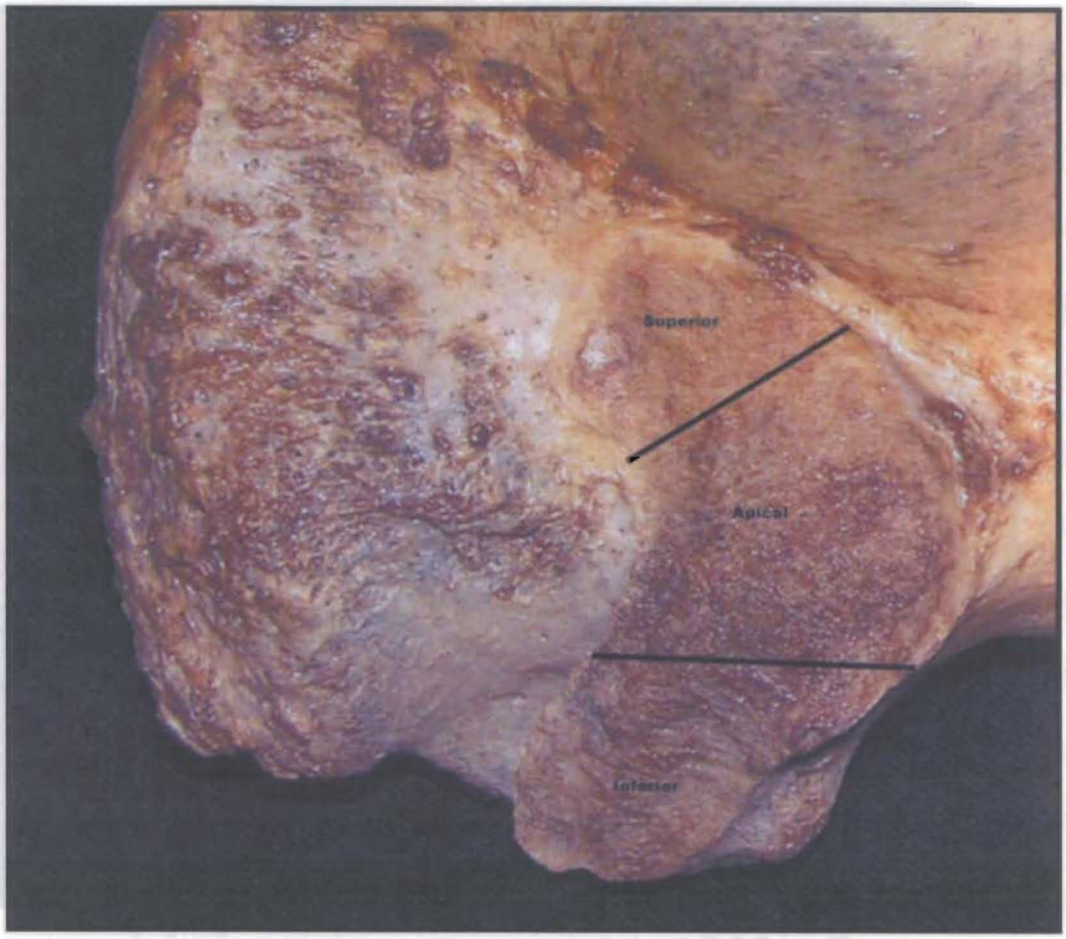

Figure 6. Superior, apical, and inferior surface morphology. Photograph by Jonathan Bethard.

Superior, apical, and inferior surface morphology

"The joint surface is divided into three segments labeled, for convenience, as superior, apical (middle), and inferior. The superior part of the joint extends from the superior end to a point half of the way to the apex of the joint. The apical (middle) portion stretches from that point to the apex and then beyond it for another 1cm. The inferior part of the joint is the remainder of the joint surface" (Boldsen *et al.* 2002: 101).

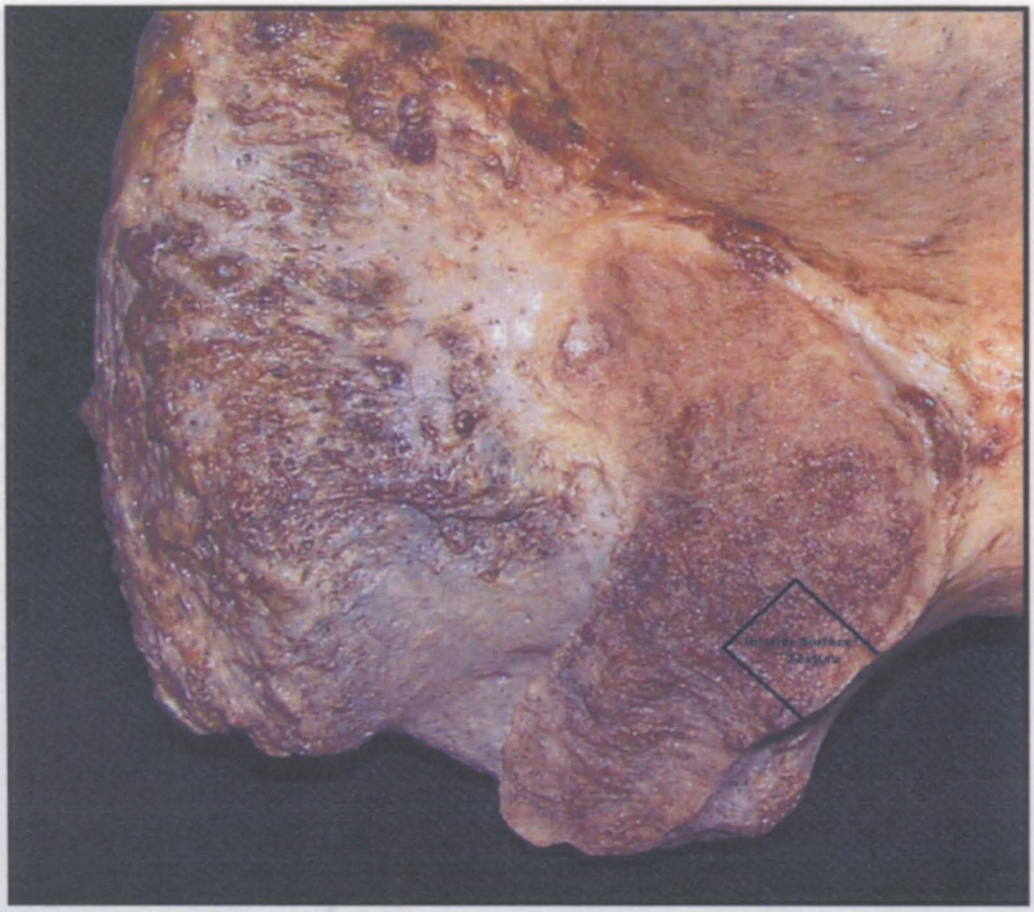

Figure 7. Inferior surface texture. Photography by Jonathan Bethard.

Inferior Surface Texture

"This part of the joint surface is 1cm long, as measured in a superior to inferior direction. Its lowermost point is a line defined by the margin of the greater sciatic notch on either side of the sacroiliac joint" (Boldsen *et al.* 2002: 102).

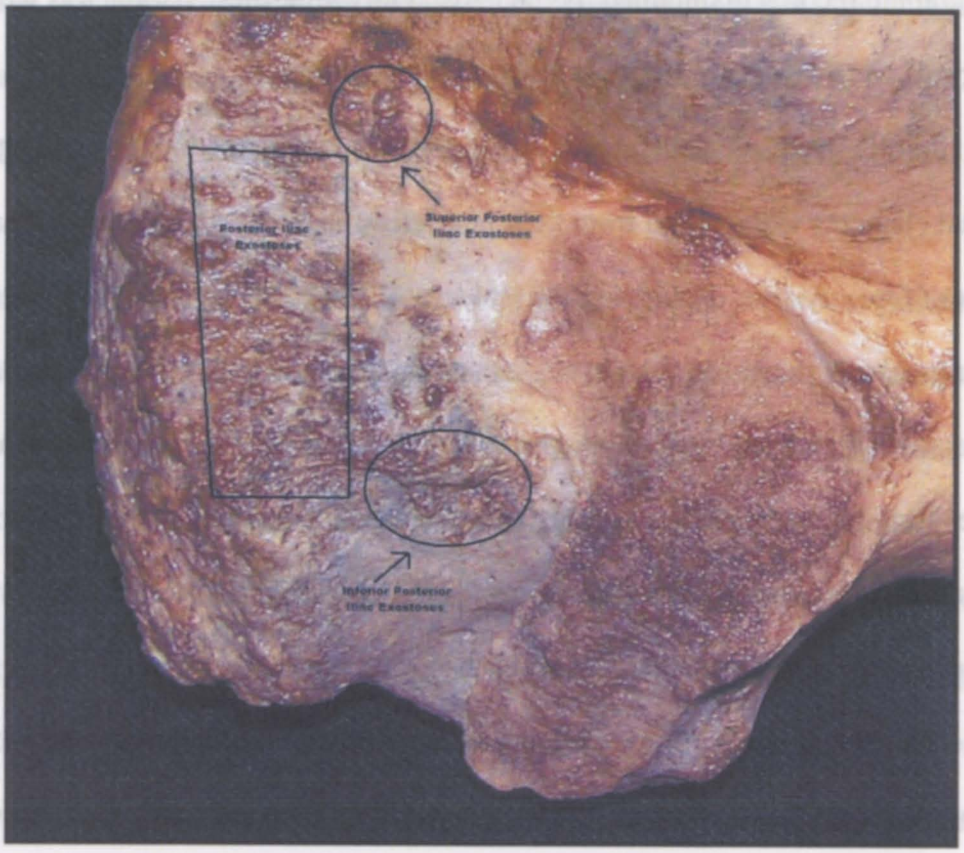

Figure 8. Superior and inferior posterior iliac exostoses/posterior iliac exostoses. Photograph by Jonathan Bethard.

Superior and inferior posterior iliac exostoses

"The two areas examined are located on the medial surface of the posterior ilium where ligaments attach during life. The superior area is superior to the sacroiliac joint surface; i.e., to a line that passes from the anterior superior iliac spine to the most superior point of the joint surface (the superior angle), and on through the posterior part of the ilium. The inferior area is located inferior to that line. It is immediately posterior to the middle of the sacroiliac joint; i.e., it lies behind the most anteriorly projecting part of the joint's posterior margin. Exostoses appear on all but the bones of the youngest adults (with rare exceptions), and they tend to be clustered together to form nicely defined and easily identifiable patches of rough bone" (Boldsen *et al.* 2002: 102).

Posterior iliac exostoses

"The area that is examined is the medial side of the ilium bordered posteriorly by the iliac crest, anteriorly by the sacroiliac auricular surface, superiorly by a slightly raised area often surmounted by exostoses (superior posterior iliac exostoses), and inferiorly by a similarly raised area also typically covered by exostoses (inferior posterior iliac exostoses). As opposed to the areas where the superior and posterior iliac exostoses are located, the part of the ilium of interest here is much less likely to have enough bony projections to be counted (i.e, rounded or pointed)" (Boldsen *et al.* 2002: 103).

demographic records maintained by the FAC. Only after these parameters were confirmed were raw scores input into the ADBOU program.

In this study, all skeletal data collection was conducted blind to real age. All skeletal elements were pulled from their respective boxes by another individual (EAD) in batches of twenty-five. Following the Boldsen *et al.* (2002) protocol, data were collected on landmarks of the pubic symphysis, auricular surface, and five cranial sutural segments. Pubic symphyseal data were coded first, auricular surface second, and cranial sutures last. Right and left sides were coded independently from each other to reduce intra-observer bias.Moreover, raw scores for pubic symphyses and auricular surfaces were coded blind to each other to further reduce intra-observer bias.

In order to calculate age-at-death estimates, the ADBOU program requires that an appropriate hazard, or informed prior of the population age-at-death distribution $f(a)$, be chosen. While Boldsen *et al.* suggest the use of a uniform prior in the absence of information about the age structure of population (2002:92), they also argue that $f(a)$ data can be gleaned from the target sample's historical or archaeological context and incorporated into the analytical framework. Specifically,

> "information on the distribution of age-at-death from many parts of the modern world and for some places in the past that can serve as general models for our archaeological populations. For example, here we use an age-at-death distribution from 17th century Danish rural parish records to provide estimates of $f(a)$....For forensic purposes, one would use national homicide data, such as the 1996 figures for the USA that are incorporated in the transition analysis computer program" (Bolden *et al.* 2002:88).

In this research, the forensic hazard was selected since the sample derived from the Bass Collection is more contemporaneous with the 1996 data. The forensic hazard is probably not the best choice for analyzing data from the Bass Collection since the age structure of the 1996 homicide data differs from this particular target population. However, the other alternative, with is the archaeological hazard derived from 17th century Danish parish records, is even less appropriate. Unfortunately, ADBOU will not run without choosing one or the other prior.

Once raw data was entered into in the ADBOU program, output was generated for each individual both numerically and graphically. Figure 9 illustrates an example of the graphical output generated for each individual from the ADBOU program. This output includes five posterior distribution curves that depict age-at-death estimates for aggregated morphological complexes (with both flat and informed priors) and individual age indicators. Boldsen and colleagues emphasize that workers should seek to generate "the probability that death occurred at each possible age, not just the single age when it was most likely to have occurred" (Boldsen *et al.* 2002:93). The age distributions depicted in Figure 9, therefore, should be considered to represent an individual's skeletal age better than a single point estimate.

The real recorded ages and ages-at-death estimated from ADBOU for each individual in the test sample are presented in Appendix 2. The estimated ages-at-death are notated differently in Appendix 2 than in Figure 9. In the appendix, the output is reported as MLA-All, MLA-Hazard, MLA-Pubis, MLA-Auricular, and MLA-Sutures, each of which are maximum likelihood age-at-death estimates taken from peaks of the likelihood curves illustrated in Figure 9. MLA-All and MLA-Hazard present age-at-death estimates that combine age indicator data from the pubic symphysis, auricular surface, and cranial sutures. MLA-All utilizes a flat prior while MLA-Hazard uses 1996 homicide data as an informed prior. MLA-Pubis, MLA-Auricular, and MLA-Sutures also

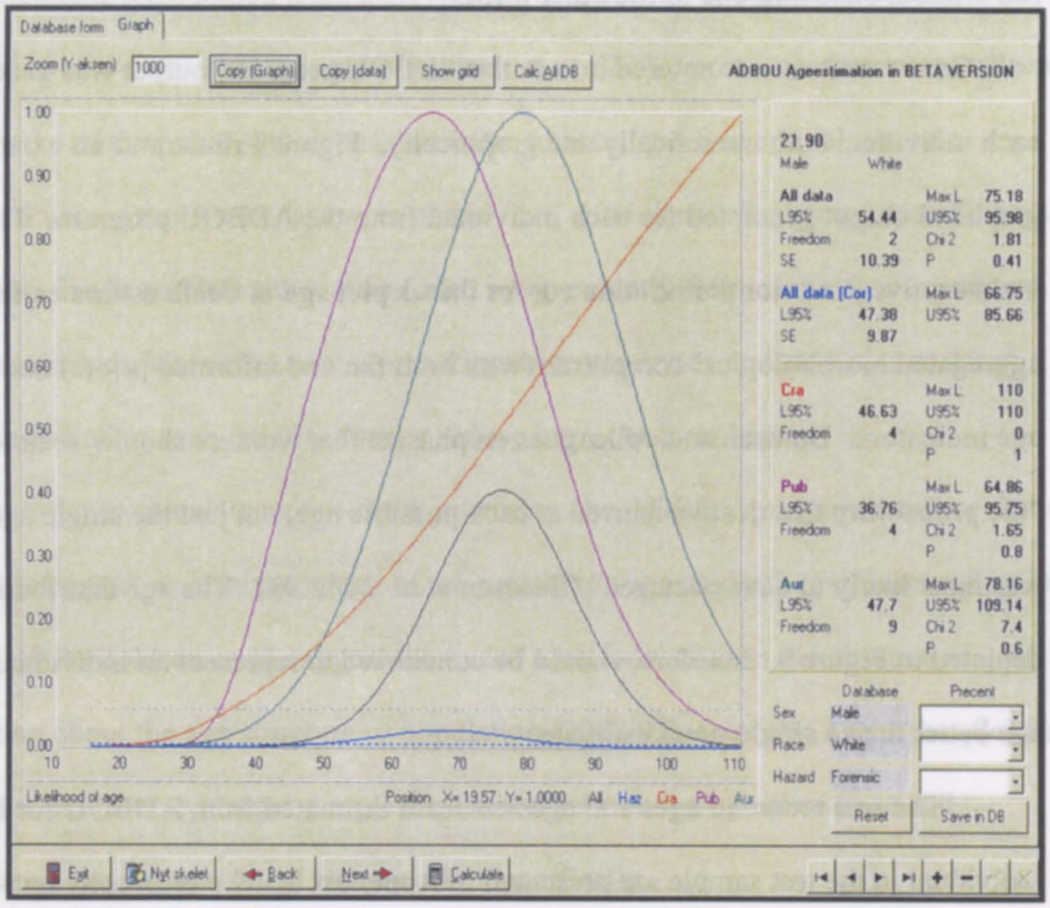

Figure 9. Graphical output from ADBOU program depicting maximum-likelihood age-at-death curves.

utilize 1996 homicide data as an informed prior and present age-at-death estimates for each morphological complex individually.

In order to evaluate the ability of the Boldsen *et al.* (2002) method to return accurate ages, maximum-likelihood age-at-death estimates were statistically compared to real age values using linear regression in the SPSS Version 13.0 statistics package (SPSS Inc., Chicago IL). Scatterplots of real age by estimated age were generated, and the relationship between real and estimated age was measured by calculating regression and correlation coefficients. The dependent variables were the maximum-likelihood age-at-death estimates and the independent variables were the real ages. 95% confidence intervals around the line of best fit were calculated. Five correlation coefficients between real age and estimated age were generated using peaks of likelihood curves for each estimated age from the MLA-All, MLA-Hazard, MLA-Pubis, MLA-Auricular, and MLA-Sutures ADBOU runs. These correlation coefficients allow us to evaluate the relationship between real age and estimated age-at-death for both aggregated and individual anatomical complexes.

Two additional forms of analysis were performed on the raw scores in order to further evaluate the relationship between individual traits and real age. The goal of these analyses was to assess if the traits from Boldsen *et al.'s* scoring protocol were in fact age-dependent in the Bass Collection test sample. The first form of analysis involved trait-by-trait analyses using a forward continuation ratio model written by Dr. Lyle Konigsberg (Konigsberg, 2005). This model is synonymous with the single-trait transition analysis utilized by Boldsen and colleagues (2002). While the results of the forward continuation ratio model, which consist of a mean estimated age-at-transition an standard deviation, can be used to evaluate age-dependence, these results are difficult to interpret for individual transitions because of the way in which one transition is compared to all others that occur after it. As a consequence of how the model is constructed, and as correctly noted by Boldsen *et al.* (2002), the forward and backward continuation ratio models usually give different probabilities of being in a particular stage at a given age.

The second form of analysis consists of unrestrictive cumulative probit, or standard deviation model, that also is applied to single traits. Unlike the forward continuation ration model, the cumulative probit treats each transition as a distinct event. As a consequence, the cumulative probit will be used to evaluate whether each component of the scoring system is age informative. The cumulative probit model, described by Long (1997) and available as NPHASES2, a FORTAN program written by Konigsberg (2005), is run first as a proportional odds probit that generates transition estimates that have a common standard deviation and then as an unrestricted cumulative probit that produces estimates with varying standard deviations. While the proportional odds probit is generally not a good model of age transitions, it was considered a good check on the results of the unrestricted cumulative probit (Konigsberg and Herrmann 2002). The purpose of the cumulative probit was to evaluate stage-to-stage transitions for each indicator of the pubic symphysis, auricular surface, and cranial sutures. Results from these analyses were scrutinized on the individual trait level for insight into the methodological protocol advanced by Boldsen and colleagues.

4. Results

The ADBOU computer program was used to generate age-at-death estimates for each individual from the test sample. As mentioned previously, five estimates were generated: one based on all scored features using a flat prior (MLA-All), one on all features with the forensic prior (MLA-Hazard), and one for each anatomical trait using the forensic prior (MLA-Pubis, MLA-Auricular, and MLA-Sutures). These estimates, which represent mean age-at-death estimates taken from the peaks of the likelihood curves, form the basis of the analyses reported here.

Figures 10 – 14 present scatterplots of real age by estimated age-at-deaths. Different shapes are used to distinguish males from females. Superimposed on each scatterplot is the regression line for estimated age on real age together with the 95% prediction interval for the line. The equation that defines the regression line is shown to the right of each plot as is the R-Square, or correlation coefficient, for each regression. The clustering of individuals along the upper boundary, especially in Figures 10, 11, 12, 13, and 14, is due to age truncation built into the ADBOU program.

As can be seen in Figures 10 – 14, the relationship between estimated age and real age is weak based on the lack of individuals falling within the 95% confidence interval. With the exception of MLA-Sutures regressed on real age (Figure 14), where more females fall below and more males fall above the 95% confidence interval, patterning between the sexes does not indicate a significant difference. In all other cases (Figures 10-13), males and females and females appear to be randomly scattered around the prediction line and 95% confidence intervals, reiterating the weak relationship between estimated and real age-at-death in this study. Moreover, while all regression analyses

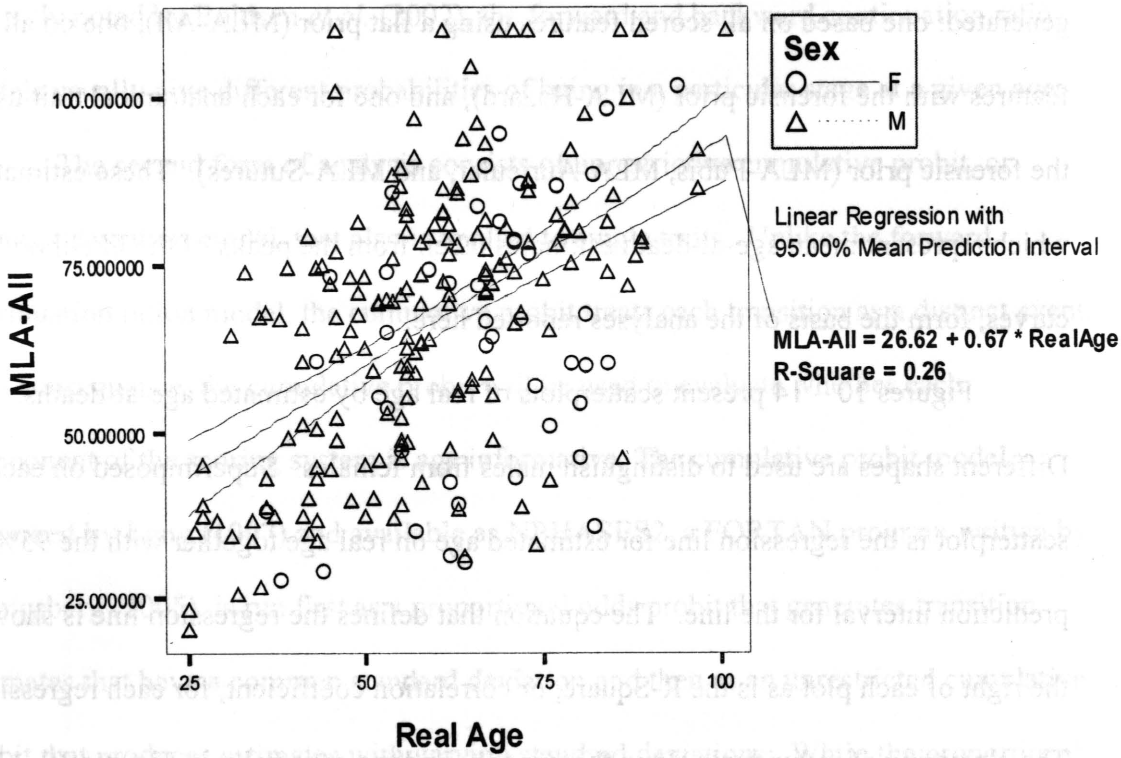

Figure 10. MLA-All regressed on real age.

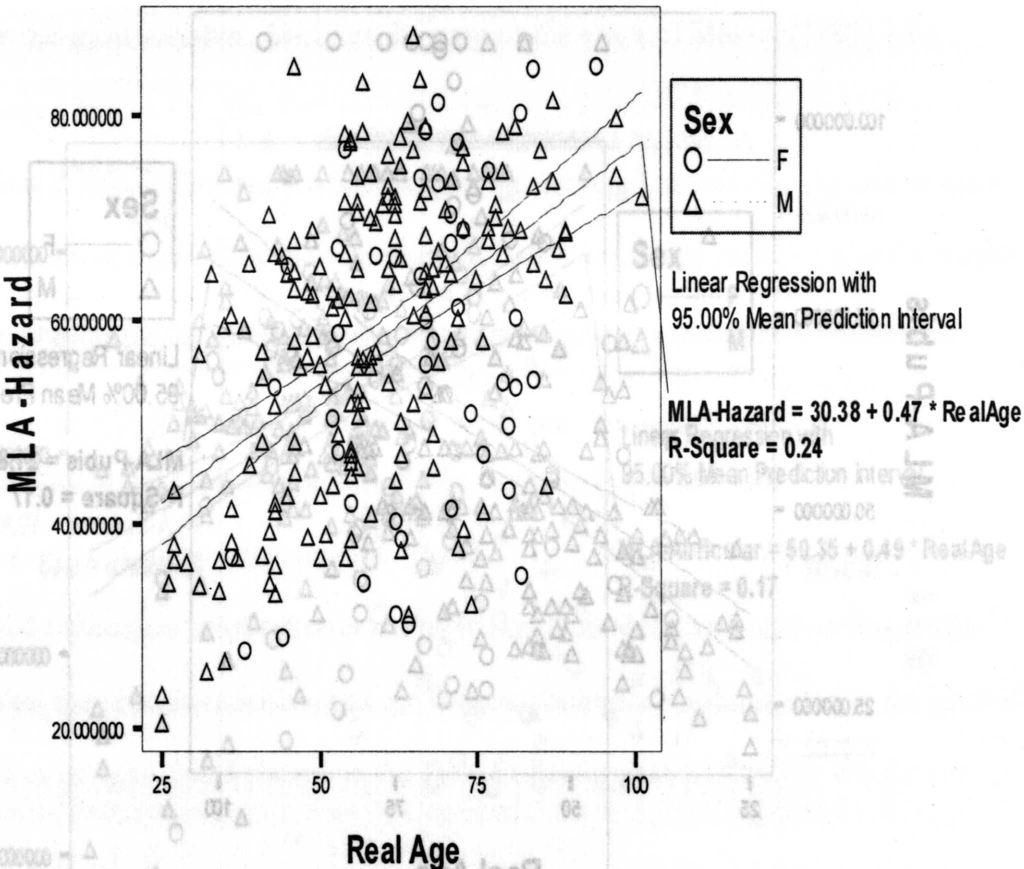

Figure 11. MLA-Hazard regressed on real age.

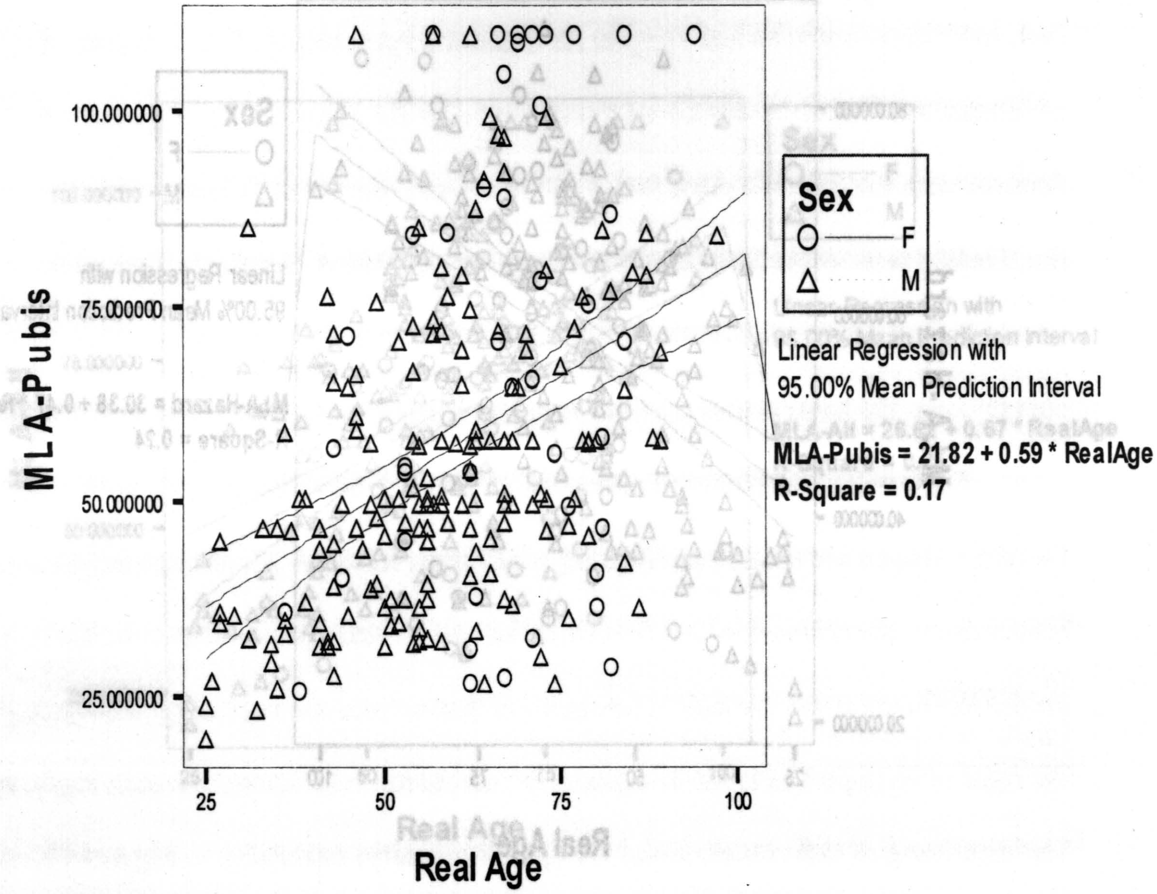

Figure 12. MLA-Pubis regressed on real age.

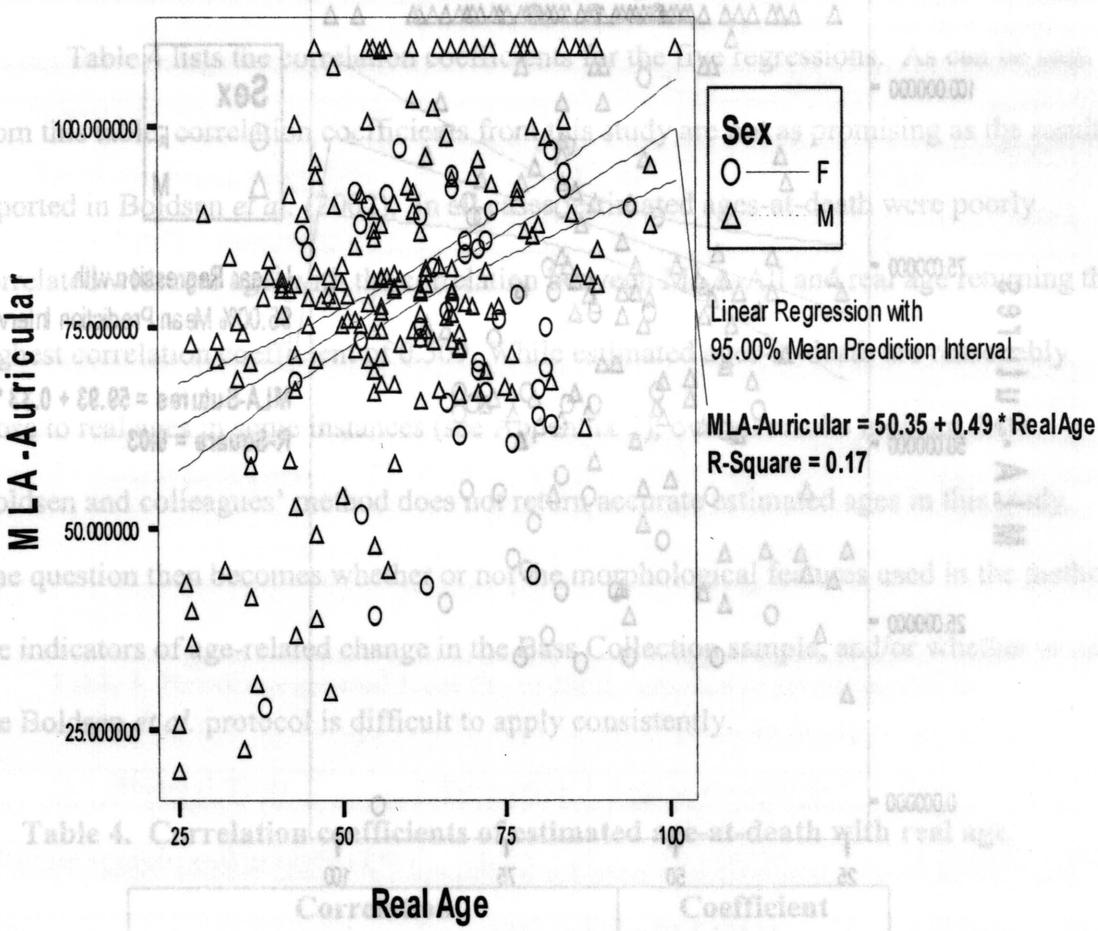

Figure 13. MLA-Auricular regressed on real age.

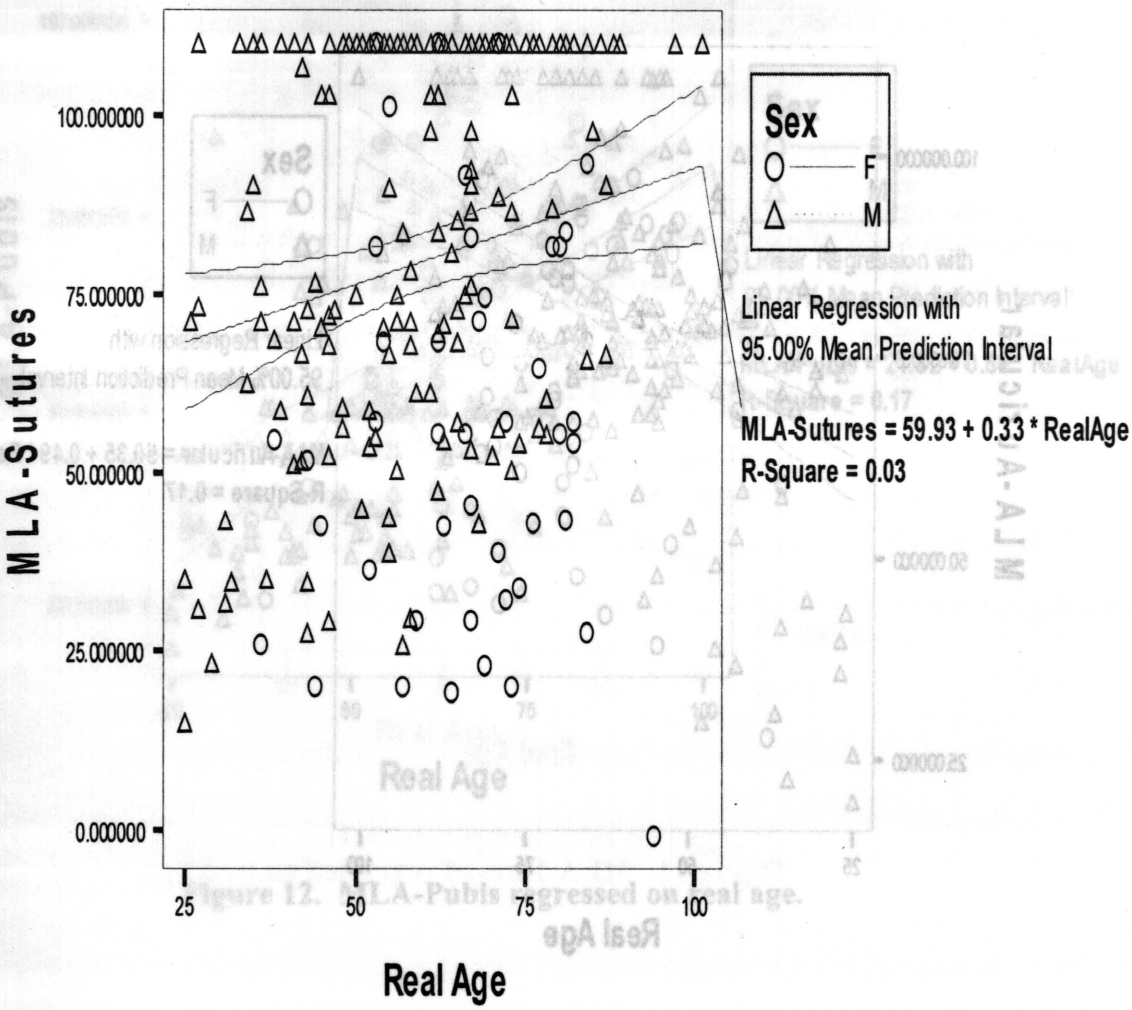

Figure 14. MLA-Sutures regressed on real age.

demonstrate the ADBOU program's propensity to over-age some individuals as 110 years old, Figure 14 demonstrates that age-at-death estimates based on cranial sutures are the most variable. Such results support the work of Masset (1989) who demonstrates a low correlation between estimated age from cranial sutures and real age.

Table 4 lists the correlation coefficients for the five regressions. As can be seen from this table, correlation coefficients from this study are not as promising as the results reported in Boldsen *et al.* (2002). In all cases, estimated ages-at-death were poorly correlated with real age, with the correlation between MLA-All and real age returning the highest correlation coefficient of 0.509. While estimated ages-at-death are reasonably close to real ages in some instances (see Appendix 2), overall results indicate that Boldsen and colleagues' method does not return accurate estimated ages in this study. The question then becomes whether or not the morphological features used in the method are indicators of age-related change in the Bass Collection sample, and/or whether or not the Boldsen *et al.* protocol is difficult to apply consistently.

Table 4. Correlation coefficients of estimated age-at-death with real age.

Correlation	Coefficient
MLA-All/Real age	0.509
MLA-Hazard/Real age	0.498
MLA-Pubis/Real age	0.412
MLA-Auricular/Real age	0.412
MLA-Sutures/Real age	0.173

The two forms of analysis used to evaluate the relationship between individual traits and real age were the forward continuation ratio model and the cumulative probit model. Table 5 presents results for select skeletal traits from the forward continuation ratio model. The age-at-transition and associated standard deviations are included for skeletal traits that generated a positive age-at-transition. Obviously, since age-at-transition cannot be negative, those skeletal traits producing negative age-at-transition were not included in Table 5. As can be seen from Table 5, mean-at-transition was highly erratic. Utilizing the ventral symphyseal margin (P4) as an example, age-at-transitions for four transitions were 11.40 ± 21.90 years, 7.04 ± 35.09 years, -88.60 ± 99.73 years, and 77.06 ± 30.20 years, respectively. Such inconsistent transitions indicate a weak relationship between real age and skeletal traits in this study. Thus, while traits from Boldsen *et al.* protocol performed well in the original author's study (2002), the associations in the current study are weak. Such findings suggest that Boldsen *et al.'s* transition analysis method is difficult if not impossible to replicate in terms of scoring, and/or that the traits are only age-dependent in some populations (and not in the current study sample). At the very least, these results demonstrate a need for additional validation studies, possibly on other documented reference collections.

The results from the cumulative probit model similarly are not promising. The cumulative probit model was run first as an ordinal or proportional odds probit with a single standard deviation calculated across all transition states of a trait and then as an unrestricted cumulative probit with variable standard deviations calculated for each transition state. The results from the ordinal probit are listed in Table 6 for two traits, the dorsal symphyseal margin (P5) and the posterior iliac exostoses (A9). The results from

Table 5. Mean age-at-transition ± one standard deviation estimated from the forward continuation ratio model for particular Boldsen *et al.* (2002)traits.

Anatomical Trait	Transition			
Pubic symphyseal texture (P2)	**1|2**	**2|3**	**3|4**	
	11.76 ± 20.61	53.72 ± 37.95	422.26 ± 352.93	
Pubic symphyseal apex (P3)	**1,2|3**	**3|4,5**		
	13.50 ± 30.16	46.94 ± 57.72		
Ventral symphyseal margin (P4)	**1,2,3|4**	**4|5**	**5|6**	**6|7**
	11.40 ± 21.90	7.04 ± 35.09	-88.60 ± 99.73	77.06 ± 30.20
Dorsal symphyseal margin (P5)	**1,2,3|4**	**4|5,6,7**		
	20.66 ± 36.34	103.24 ± 41.45		
Superior demiface topography (A1)	**1|2**	**2|3**		
	30.35 ± 5.53	36.20 ± 93.03		
Inferior demiface topography (A2)	**1|2**	**2|3**		
	30.27 ± 5.74	24.23 ± 78.64		
Inferior surface texture (A6)	**1|2**	**2|3,4**		
	47.85 ± 22.91	121.86 ± 72.35		
Posterior iliac exostoses (A9)	**1|2**	**2|3**		
	39.34 ± 74.60	97.09 ± 49.29		
Coronal pterica (C1)	**1,2|3**	**3|4**	**4|5**	
	10.92 ± 26.19	24.54 ± 54.91	44.19 ± 36.92	

Table 6. Results generated from the ordinal cumulative probit model for the dorsal symphyseal margin (P5) and posterior iliac exostoses (A9).

Skeletal Trait	**Transition**	**Age-at-transition estimates**	**Standard Error**
Dorsal symphyseal margin (P5)	1,2|3	-19.656220	14.956006
	3|4	23.444168	6.972490
	4|5	98.842615	7.571898
	SD	33.643832	
Posterior iliac exostoses (A9)	1|2	42.48911	7.480940
	2|3	126.112300	19.887451
	SD	61.550616	

the unrestricted cumulative probit model of the same two traits are given in Table 7. The results for these traits are presented here because the dorsal margin of the pubic symphysis (P5) and posterior exostoses of the ilium were identified as "old-age" markers by Boldsen and coworkers (2002:94-95) and the present sample contains large numbers of old individuals. Unfortunately, even these "old-age" traits fail to show a strong age-dependence. As can be seen from Tables 6 and 7 age-at-transitions are widely variable. In the case of the dorsal symphyseal margin (P5) (Table 6), a negative age-at-transition was generated, further indicating a weak relationship between skeletal indicators and age-related change in this sample. Similarly, age-at-transitions of 39.340574 ± 74.630487 years and 109.283372 ± 45.109205 years generated for posterior iliac exostoses (A9) in Table 7 encompass too much of the adult lifespan to suggest consideration of the trait as an accurate old-age marker in paleodemographic or forensic contexts.

Table 7. Results generated from the unrestrictive cumulative probit model for dorsal symphyseal margin (P5) and posterior iliac exostoses (A9).

Skeletal Trait	Transition	Age-at-transition estimates	SD
Dorsal symphyseal margin (P5)	1,2|3	24.652447	4.716673
	3|4	19.760310	37.196460
	4|5	102.283298	36.981798
Posterior iliac exostoses (A9)	1|2	39.340574	74.630487
	2|3	109.283372	45.109205

5. Discussion

The age-at-death estimates generated from the ADBOU program do not accurately estimate age-at-death for individuals in this test sample. Linear regression analysis demonstrated this trend for each estimate produced from the ADBOU program. Poor correlation coefficients were generated between five estimated ages and real age that ranged from 0.173 – 0.509. Such results clearly demonstrate a weak relationship between estimated and real age. Additionally, the results of the ordinal cumulative probit and unrestrictive cumulative probit models presented in this thesis show only weak relationships between real age and age-at-death estimated by Boldsen *et al.'s* (2002) method. In all cases, age-at-transition was erratic and associated standard deviations did not generate results applicable to osteological contexts.

Numerous factors might account for the poor results achieved in this research. Failure to apply the Boldsen *et al.* (2002) protocol correctly to the test sample is one possibility. If skeletal traits were scored incorrectly, inaccurate results are the likely product of such misapplication. Secular differences in aging between the reference population and the test sample may also account for the error achieved in this study. Since the Terry and Bass Collections are not contemporaneous, standards developed from the former might not apply to the latter.

Another reason for the results generated from this study may involve the ADBOU program used to estimate age-at-death. As mentioned previously, the program requires the selection of an informed prior, or information regarding $f(a)$–the probability distribution of ages-at-death in the sample. In this case, a forensic prior modeled from 1996 homicide data (Peters *et al.* 1998) was selected in ADBOU. While this dataset did not reflect the age-at-death distribution of the test sample, it was used regardless in order to produce age-at-death estimates. Moreover, the selection of the $f(a)$ parameter in this manner is not entirely compliant with Rostock protocol as discussed in Chapter 2. Such values should be estimated before addressing $Pr(a|c)$, and not treated as an aftereffect as it is in the ADBOU program. When evaluated together, these factors answer some of the important questions posed in Chapter 1.

1) Are the components of the Boldsen et al. aging method clearly defined for conventional use?

From the outset, Boldsen and colleagues assert that their methodological protocol should only be attempted after some degree of experience. According to Boldsen and colleagues (2002:97), "it will be immediately apparent that there is no substitute for experience when classifying anatomical features. Like anything else that relies on good judgment, researchers should know what they are doing before using this age estimation method." This researcher agrees and argues that workers looking to gain experience with or test this method should thoroughly understand the coding system prior to beginning data collection. After careful examination of the definitions describing the anatomical landmarks and coding system presented in their study, applying Boldsen and colleagues' method became much easier. Initially, several structures were difficult to locate (i.e., posterior iliac exostoses), however, after photographs were generated (see Figures 5-8) landmark identification was much easier. If additional workers seek to test Boldsen and colleagues' method, obtaining photographs of the morphological traits and different skeletal stages would be highly advantageous.

While definitions of specific codes were helpful, further clarification of several stages might be helpful. For example, the code for "rampart formation" under the category ventral symphyseal margin is ambiguous. In this stage, loss of billowing associated with a developing ventral rampart is described as "a roll of gum laid across a shallowly furrowed surface" (Boldsen *et al.* 2002:99). While this description is meant to help researchers clarify morphological development, it succeeds at confounding the analytical process since researchers may interpret this particular description in multiple ways. Moreover, further illumination or visual representation will greatly enhance the applicability of Boldsen *et al.'s* protocol. As it stands currently, definitions of landmarks and the coding system are rather cumbersome even though they are highly descriptive. Coupling high-resolution photographs of skeletal traits and examples of particular stages with a written description from Bolsen *et al.* (2002) would greatly reduce inter-observer interpretations of each. If such were achieved, more researchers would be adequately equipped to score other known-age individuals for validation purposes.

2) Does the ADBOU software program produce age-at-death estimates in the manner described by the original researchers?

In their chapter, Boldsen and colleagues provide a world-wide-web address that provides the computer program for all analyses outlined in their work. Unfortunately, that address is defunct and does not provide the software. As a result, interested workers must contact the first or second author directly. The ADBOU software package provided by Dr. Jesper Boldsen provided a somewhat user-friendly way to generate age-at-death estimates from raw scores based on the Boldsen *et al.* (2002) protocol. For the first part of analyses conducted by this author, the ADBOU program was problematic in that the version used was only compatible with the Windows 98 Operating System. As a result, very few machines were available for transforming raw scores into age-at-death estimates. After corresponding with Dr. George Milner, an updated version of the software was provided and analyses were rapidly accelerated. If additional researchers wish to perform validation studies of this method, I suggest that they contact Drs. Boldsen and Milner *before* collecting raw data. This would ensure that future workers have proper computer system capabilities.

With regard to the program itself, age-at-death estimates were produced relatively easily once the software program was correctly installed. I caution that researchers should take care to familiarize themselves with the program before initiating any large-scale analyses since the program itself presents a few idiosyncrasies. For instance, workers must ensure that the sex, race, and hazard parameters they select are really utilized in each analysis. Experience with the software demonstrated that sex, race, and/or hazard parameters would sometimes change between cases without keyboard input, requiring the author to double-check and sometimes correct the parameters for each individual in question. While this problem is easily fixed, it requires that workers take notice of each ADBOU run. Moreover, workers should recognize the inherent limits of the program with regard to the selection of the informative prior. In the case of the ADBOU program, only two informative priors are possible, neither of which might be appropriate in certain anthropological contexts. For example, while the archaeological hazard derived from 17th century parish records is more appropriate for bioarchaeological contexts, workers have demonstrated that "population-specific models are absolutely necessary" (Schmitt *et al.* 2002:1208). Although the use of population-specific models is widely advocated (Hoppa and Vaupel 2002a; Schmitt *et al.* 2002), workers realize that such data are not always available or just do not exist. As is the case sometimes, researchers are not always able to work under ideal analytical conditions.

3) Do age-at-death estimates rendered from the ADBOU software program have a high degree of correlation with real age?

As was shown by calculating correlation coefficients between estimated ages-at-death and real age, there is a very weak relationship between real ages and the ages estimated by the ADBOU program. While some individual age-at-death estimates were extremely close to real age, overall results indicate that Boldsen *et al.'s* (2002) method does not accurately estimate age-at-death for most individuals in this study.

As can be seen from Table 8, even when generous age ranges are considered (ages within the 95% confidence intervals generated from ADBOU), a large number of cases still fall outside of that range. Another way to understand the poor performance of ADBOU for the Bass Collection test sample is to consider the percentages of individuals whose estimated ages fall outside of the 95% confidence interval for their recorded ages. This information is given in Table 8. This point illustrates the fact that even though anthropologists are accustomed to working with somewhat broad age ranges, a low percent of correct classification at even 95% confidence intervals is a problem.

The attractions of Boldsen *et al.'s* (2002) transition analysis were that it should produce accurate age-at-death estimates, but also that it should accurately age older adults. Contrary to Boldsen and colleagues findings, this method did not produce

Table 8. Percent of estimated ages from ADBOU within 95% confidence interval.

Age-at-death estimation model	N	# of cases within the 95% confidence interval	% of cases within the 95% confidence interval
MLA-All	225	146	64.8
MLA-Hazard	225	163	72.4
MLA-Pubis	215	160	74.4
MLA-Auricular	223	159	71.3
MLA-Sutures	215	177	82.3

overwhelmingly accurate age-at-death estimates for individuals in the 50+ years category. Table 9 lists the percentages of individuals 50 years or older whose estimated ages fell within ± 5, ±10, or ±15 years of their real age. As can be seen from this table, individuals above 50 years were not aged well within the ± 5 or ± 10 years cutoff points. Interestingly, over-half of the sample above 50 years was aged correctly when the cutoff points were expanded to ± 15 years of real age. Such findings from Table 9 indicate that individuals above 50 were somewhat successfully aged. While close estimates of ± 5 years were not possible from individuals in this study, results indicate that the ADBOU program generated some informative age-at-death estimates for individuals above 50.

Table 9. Age-at-death estimates for individuals ≥ 50 years old.

Age-at-death estimation model	N	% aged 50 or over estimated within ± 5 years of actual age	% aged 50 or over estimated within ± 10 years of actual age	% aged 50 or over estimated within ± 15 years of actual age
MLA-All	168	18.4	40.4	56.5
MLA-Hazard	168	26.7	46.4	67.2
MLA-Pubis	158	16.4	33.5	43.0
MLA-Auricular	167	13.7	25.7	41.9
MLA-Sutures	162	7.4	17.9	25.3

4) Do results indicate that this method should be adopted by workers for adult age-at-death estimation?

This study does not produce results similar to those published by Boldsen and coworkers (2002). To the contrary, the results presented here indicate that their method does not produce accurate age-at-death estimates. In all models, correlations between estimated age and real age are too low for the method to be useful in paleodemographic or forensic contexts. One possible reason for such low performance is the assumption of conditional independence utilized by Boldsen and colleagues to build the transition analysis model. While the authors argue that such an assumption should not hinder analyses, they admit that they have not examined the correlation between morphological components after conditioning on age (Boldsen *et al.* 2002:91).

In addition, the assumption that components of one morphological structure (i.e., the pubic symphysis) are independent from one another does not take functional or biomechanical relationships among indicators into account. Age estimation techniques that utilize joint surfaces of the bony pelvis have, until the publication of this method, used a combination of morphological indicators to arrive at an age-at-death estimate. Such methods are based on the assumption that skeletal traits are heavily influenced by each other as the result biological and environmental factors (Schmitt *et al.* 2002). While describing the method of Boldsen and colleagues, Holman *et al.* (2002:195) write "we are required to make the possibly erroneous assumption that the indicators are independent of each other conditional on age." Results from this research lead this author to agree with numerous other workers who assume that there is indeed a dependent relationship among age indicators utilized in this method.

Another reason that results from this research are remarkably less promising than originally expected might relate to the sample that was utilized. Since it is widely known that the senescent process becomes much more variable with age, a known sample with an older age-at-death distribution lends itself more age-related variability. The mean age-at-death of the sample from the William M. Bass Collection was 59.89 years. Such demographic information clearly indicates a sample biased towards older individuals. The age dependence seen in this study may be the result of what skeletal biologists have known for many years–skeletons older than 50 years produce highly variable age-at-death estimates. Accurately capturing such variability may remain elusive regardless of reported methodological advances by Boldsen and colleagues.

A final reason for the poor performance of ADBOU in this study may be methodological. While the method is described in some detail in their publication, illustrations of anatomical landmarks and the subsequent coding system are absent. In a few instances, specific descriptions of the coding system are confounding and prohibited this author from applying the method with the same degree of efficacy as described in Boldsen *et al.* (2002). Moreover, the chapter was published without photographs which made locating landmarks like the superior and inferior posterior iliac exostoses difficult. When coupled together, any combination of these methodological factors may have heavily influenced the outcome of this study. On a cautionary note, while landmarks presented by Boldsen *et al.* (2002) are distinguishable after careful review of the descriptions, workers who wish to use this coding system are encouraged to confirm the location of all landmarks before initiating analyses. An additional publication by Boldsen and colleagues that presents photographs of skeletal traits and a clearer description of the coding system would facilitate a broader use of this method by interested researchers.

6. CONCLUSIONS

While results from this study are not promising, some hope for continued appraisal of the transition analysis method described by Boldsen and colleagues (2002) remains. At the very least, Boldsen and colleagues have advanced a robust statistical framework for anthropologists and other workers to consider. The continuation ratio model that is the basis for Boldsen and colleagues' transition analysis method offers potential for teasing age-related change from skeletal features. Moreover, no longer is it acceptable for workers to estimate age-at-death in either archaeological or forensic contexts without discussing problems associated with their aging methods (Hoppa and Vaupel 2002). Additionally, the authors' method demonstrates that individuals in the 50+ years cohort can be identified in that category with some certainty, even though more precise estimates remain elusive. With such methodological advances, it is now time for workers to discuss to what level such age-at-death estimates can be taken. While refining age-at-death estimates in the 50+ years category is obviously desirable, researchers should come to a consensus about recognizing the limits of age-at-death estimation. It is suggested here that anthropologists will need additional methodological tools to further tease out age-at-death estimates for individuals over the age of 50. It has proven unrealistic to argue that methodological advances presented in this study can accurately estimate age-at-death above 50 years ± 5, ± 10, or ± 15 years. Such findings indicate that anthropologists must still continue to discuss this topic and continue evaluating skeletal traits for the age-related information contained in them.

While results achieved from this test sample did not produce results similar to those of Boldsen and colleagues, additional analyses of the transition analysis method can be conducted on the Bass Collection. Since all raw scores have been retained, tests for intra-and inter-observer can easily be run to quantify the degree to which the coding system itself influences age-at-death estimates from the ADBOU program. Logistically speaking, it would be rather easy for other workers to code a subset of the skeletons used in this study for just that purpose. Once additional raw data are collected by other workers, the forward continuation ratio and cumulative probit models can be fit to new data to see if trends regarding the Boldsen *et al.* protocol remain as they did in this study. Models that produce weight functions could also be run, to further test individual skeletal trait data. Findings generated from those weight function models might reiterate results encountered in this research and/or indicate that application of the scoring system was the largest type of bias in this research.

While the work of Boldsen and colleagues has taken a step in the right direction, more work remains to be done. As has been widely reported, senescence is a variable process on the individual level. Therefore, workers should continually seek to refine methodological tools that produce the most statistically-robust methods possible. Moreover, tests for intra and inter-observer should be applied in order to determine the broad-range applicability of the method. While results from this research do not produce results similar to the authors' original study, workers should seek to understand the overarching framework of the transition analysis method. To further test the reliability of the Boldsen and colleagues' method, additional validation studies on other reference collections should be conducted. If such is achieved by the physical anthropological community, this critical component of paleodemographic and forensic analysis will surely improve.

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Appendices

Appendix 1– Raw scores following Boldsen *et al.* (2002) protocol.

The following designations correspond to morphological structures from Boldsen *et al.* (2002) protocol:

Pubic Symphysis
RP1/LP1: Symphyseal relief
RP2/LP2: Symphyseal texture
RP3/LP3: Superior apex
RP4/LP4: Ventral symphyseal margin
RP4/LP5: Dorsal symphyseal margin

Auricular Surface
RA1/LA1: Superior demiface topography
RA2/LA2: Inferior demiface topography
RA3/LA3: Superior surface morphology
RA4/LA4: Apical surface morphology
RA5/LA5: Inferior surface morphology
RA6/LA6: Inferior surface texture
RA7/LA7: Superior posterior iliac exostoses
RA8/LA8: Inferior posterior iliax exostoses
RA9/LA9: Posterior iliax exostoses

Cranial Sutures
C1: Coronoal pterica
C2: Sagittal obelica
C3: Lambdoidal asterica
C4: Zygomaticomaxillary
C5: Interpalatine (median palatine, posterior portion)

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
1.00	5	3	3	6	4	5	3	3	6	4
1.01	5	3	4	7	5	5	2	4	7	4/5
1.81	4	3	4	6	4	4	2	3	6	4
1.82	5	4	3	6	4	5	2	4	6	4
1.83	5/6	3	4	6	5	5	3	4	6	3/4
1.84	5	2	3	6	4	5	2	4	6	
1.88	4	2	2	6	4	4	3	2	6	4
1.91	5	3	4	7	4	4	3	3	6	4
1.92	5	2	4	6	4	5	2	3	6	4
1.93	5	4	4		3					
1.94	5	2	4	6/7	4	4	3	2	6	4
1.96	6	4	4	7	5	6	4	4	7	5
1.97	5	2	4	6	4	5	3	4	6	4
1.98	5	3	2	6	3	5	3	4	6	4
2.00	5	3	4	6	4	5	3	4	7	5
2.02	5	3	4	6	4	5	2	3	7	4
2.83	5	3	3	4	4	5	2	4	6	4
2.84	5	2	3	6	4	4	2	2/3	6	4
2.85	5	3	4	7	4	6	2	4	7	4
2.87	4	3	4	6	4	5	2	4	7	4
2.88	5	3	4	6	4	5	3/4	3	7	4
2.89						6	2	3	6	4
2.91	5	3	4	7	4	5	3	4	7	4
2.92	5	2	3	4	3	5	2	2	4	3
2.94	5	2/3	4	6	4	5	2	3	6/7	4
2.95	4	3	3	5/6	3	4	3	3	6	4
2.96	5	2	4	7	4	5	2	4	7	4
2.97	6	4	4	7	5	6	4	3	7	5
2.98	5	3	4	7	4	5	2	3	6	3
2.99	5	3	4	6	4	5	4	3	6	4
3.00	5	4	3	6	4	5	4	4	7	4
3.01	5	3	3	6	3	5	3	4	7	4
3.81	5	2	2	5/6	3/4	3	2	4	5/6	4
3.83	4	2	3	6	4					
3.87	5	2	2	4	4	6	2	3	6	4
3.88	4	2		6	4					
3.89	5	2	4	6	4	5	2/3	4	6	5
3.90	5/6	2	4	6	4	6	2	2/3	6	4
3.91	5	2	3	7	4	5	2	4	6	4
3.93	5	2	3	6	3	5	2	4	5	3
3.96										
3.98										
3.99	5/6	3	3	6/7	5	5/6	3	4	6	4
4.00	5	2/3	4	6	4	5	2	3	6	4
4.83	5/6	2	4	5/6	4	5	2	4	5	3/4
4.87	5	3	4	4	3	6	2	4	6	3
4.88	5	3	4	6	4	5	2	3	6	4

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
4.93	5	2	3	6	4	4/5	2	2	4/5	3
4.94										
4.95	5	2	3	6	4	5	2	3	6	4
4.96	5	2	3	6	4	5	2	2	5	4
4.97	5	2	3	6	4	5	2	3	6	4
4.98	5	3	3	6	4	5	3	3	6	4
4.99	5	3	4	6	4	5	3	4	7	4
5.00	5	3	4	6	4	5	3	4	6	4
5.83	5	2	3	5	4	4/5	3	3	6	4
5.87	5	2	3	6	4	5	3	4	6	4
5.88	5	3	3/4	6	4	6	2	4	6	4
5.93	5	2	3	6	3	5	3	3	6	4
5.94	5	3	4	6	4	5	3	4	6	4
5.97	5	3	3	7	5	6	3	3	7	5
5.98	5	2	3	6	4	5/6	2	3	6	3
5.99	5	2	4	6	4	5	3	3	6	4
6.00										
6.02										
6.87										
6.88	3	2	2	3	2	4	1	4	3	2
6.91	5	2	3	7	4	5	2	4	6	3
6.92	4	1	2	3	2	4	2	2	4	3
6.93	5	3	4	5	3	5	3	3	4	3
6.95	6	4	4	7	5	6	4	4	7	5
6.98	5	3	4	6	4	5	3	3	6	4
6.99	5	2	3	6	4	5	3	4	6	4
7.86				6	4					
7.87	4	3	4	6	4	4	3	4	6	4
7.89	4	3	3	6	4	5	2	3	6	4
7.91	6	2	3	6	4	5	2	3	6	4
7.92	6	3	6	6/7		6	2	4	7	
7.93	3	1	2	3	3	3	2	3	5	3
7.94	5	2	4	5	3	5	2	4	6	3
7.95	6	4	4	7	5	6	4	4	7	5
7.96	6	4	4	7	5	6	3/4	4	7	5
7.97	6	2	4	7	4	4	3	4	7	5
7.98	5	4	4	6/7	5	6	4	4	7	4
8.87	2	1	1	2	2	2	1	1	1	1/2
8.89	5	4	3	6	4	5/6	3	4	7	4
8.91	6	3	3	6	4	6	4	4	7	4
8.93	4	3	3	5/6	4	4	2	3	5	3
8.94	5	4	4	6	4	6	4	3/4	7	5
8.95	4	2	3	5/6	3/4	5	2	3	6	4
8.96	4	4	4	6	4	5	3/4	4	7	4
8.98	4	3	3	6	3	4	3	3	6	3
8.99	5	1	2/3	5	3	4	1	2	5	3
9.00	6	2	4	4	4	5	2/3	4	4	4

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
9.88	5	2/3	3	6	4	6	2	4	6	7
9.89	5	2	3	4	4	5	2	4	6	4
9.93	5	3	3	6	4	5	2	2	6	3
9.94	5	3	4	6	4					
9.95	6	4	4	7	5	6	4	4	7	5
9.96	5	3	3	7	4	5	4	4	7	4
9.97	5	2	3	6	4	5	2	3	6	4
9.98	5	3	4	6	4	5	3	4	6	4
9.99	4	2	4	6/7	4	6	3	4	7	4
10.00	5	2	4	6	4	5		4	6	4
10.87	4	2	3	6	4	5	3	3	6/7	4
10.88	4	3	4	6	5	5	2	3	6	3
10.89	5	2/	3	6	4	5	2	4	6	4
10.90	4	3	3	6	4	5	3	4	6	4
10.91						5	2	3	6	4
10.92	5	3	4	6	4	5	2	3	5/ 6	4
10.94	5	4	3	7	5	6	4	3	7	5
10.95	4	2	3/4	6	4	4	2	2	6	4
10.96	5	3	3	6	4	5	3	4	6	4
10.97	5	3	4	7	5	5	3	3	7	5
10.98	5	3	4	7	5	6	4	4	7	5
11.89	5	3	3	6	4	5	2	3	6	4
11.90	5	2	3	7	4	4	2	4	7	4
11.94	5	3	3	5/6	3/4	5	2	3	5	3
11.97	5	3	4	6	4	4	2	4	6	4
11.98	5	3	4	6	4	5	3	3	6	4
12.00	3	2/3	2			3	2	3		
12.87	5	3	4	6	4	6	3	4	7	4
12.88	5	2	3	6	4	5	2	2/3	6	4
12.89	5	2	4	6	4	5	2	4	6	4
12.90	5	3/4	4	6	4	6	3	4	6	4
12.91						5	3	3	4	3
12.97	5	3	4	6	4	5	2	4	6	4
12.99	6	3	4	7	5	5	3	4	7	5
13.00	5	3	4	6	4	5	3	3	6	4
13.01										
13.88	6	3	3	7	4/5					
13.91	5	2	3	6	4	4	2	2	4	3
13.97	4	3	3	7	4	4	3	4	7	4
14.87	4	1	2	4	4	5	1	3	6	4
14.88	5	2	4	4	3/4	5	2	4	6	4
14.90	5	2	3	6	4	4/5	2	3	6	4
14.92	5	3	3	6	4	5	3	4	6	4
14.93	3	1	2	3	2	3	1	2/3	3	2
14.98	5	3	4	6	4	5	3	3	6	4
15.89	5	2	3	6	4	5	2	3/4	6	4

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
15.93	5	2	4	6	4	5	2	4	7	3
15.98	5	3	3	7	4	5	3	4	7	4
15.99	6	3	4	6	4	5/	3	3	7	4
16.00	6	2	4	6	4	5	2	4	6	4
16.89	5	2	4	7	3	4	2	3	6/7	4
16.91	6	2	3/4	6	4	5	2	3	6	4
16.92	5	2	3	6	4	6	2	3	5	3
16.98	5	3	4	6	4	5	3	4	6	4
16.99	6	4	4	7	5	5	3	4	6	4
17.00	4	1	2	3	3	4	1	2	3	3
17.91						4	1/2	2/3	4	2
17.97	6	4	3	7	5	6	3	4	7	5
18.88	5	3	3	7	5	5	2	3/4	7	4
18.90	5/6	3	4	7	3	4	2	3	3	3
18.91	5	2	3	6	4	5	2	4	6	4
18.92										
18.97	5	3	4	6	4	5	3	4	6	4
18.98	5	3	3	6/7	4	5	2	4	6	4
18.99	5	3	4	7	5	6	3	3	7	4
19.00	6	3	4	7	4	5	3	3	6	4
19.01	4	3	4	6	4	5	3	3	6	4
19.88	5	3	3	6	4	5	3	3	6	4
19.90	5	4	4	7	4	6		4	7	
19.91	5	2	3	6	4	5	2	2	4	3
19.92	5	2	4	4	3	5	2	3	4	4
19.93	5	2	3	5	4	4	3	4	5	4
19.94	5	3	3	7	5	6	4	4	4	5
19.98	5	3	4	6	4	5	3	4	7	5
19.99	5	3	3	7	5	5	3	3	7	4
20.03	5	2	3	5	3	5	2	3	6	4
20.88	4	2	2/3	4	3	5/6	3		7	4
20.90	4/5	2	2	6	4	4	½	3	4	3
20.91	5	3	4	6	4	5	2			4
20.92	5	3	4	6	4	5	3	4	6	4
20.95	6	4	3	7	5	6	4	4	7	5
20.98	6	3	4	7	3	5/6	2/3	3	5	3/4
20.99	5	2	3	6	4	5	2	3	6	4
21.00	5	2	4	6	4	5	2	3	6	4
21.02	7	3	4	7	5	6	4	4	7	5
21.90	5	3	4	6	4	5	3	3	7	4
21.91						5	3	3	6	4
21.92	3	1/2	2	3	3	3	2	2	2	2
21.93	4	2	4		3	3	2	2	4	
21.94	5	2	3	7	4	5	3	4	7	4
21.95	4	2	3	6	4	4	2	3	6	3
21.98	5	2	3	6	4	5	3	4	6	4
21.99	5	3	4	6	4	5	2/3	3	6	4

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
22.00	6	3	4	7	5					
22.90	5	2	4	6	4	5	4	4	7	6
22.91	5	2	3	5	3	5	2	3	5	3
22.93										
22.94	5	3	2	6	4	5	2	4	6	4
22.95	5	2	3	6	4	5	2	2/3	6	4
22.99	4	3	3	6	4	5	3	3	6	4
23.00	5	3	4	7	3	5	2	4	7	4
23.88	6	3	4	7	5	5	2/3	3	7	4
23.93	4	2	4	5	3	5	3	4	5	4
23.94	5	3	4	6	4	5	3	4	6	4
23.99	4	3	4	6	4	4	3	3	6	4
24.00	6	4	4	7	5	6	3	4	7	5
24.04										
24.88	5	3	3	6	4	5	3	4	6	4
23.00	5	2	3/4	6	4	5		4	6	4
25.02	5	4	4	7	5	5	2	4	6	4
25.91	5	2	3	6	4	5	2	4	6	4
25.99	5	3	4	7	5	5	4	4	7	5
26.00	5/6	3	3	7	4	5	3	4	7	4
26.91	4/5	2	2	4	3	5	3	4	6	4
26.93	5	3	2	6	4	5	3	3	6	4
26.99	4	2		5	4	5	3		7	4
27.90	6	2	3	4	6	6	3	4	7	4
27.91	3	2	2	3	3					
27.93	5	3	3/4	6	4	5	3	3	6	3
27.99	5	3	4	6/7	4	5	3	4	6	4
28.90						6	3		6	4
29.00	5	3	4	6	4	5	2	3	6	4
29.04	3	2	3	3	3	3	2	4	4	3
29.93	5	2	4	6	4	5	2	3	6	4
29.99	5	3	4			5	3	4	7	4
30.93	5	2	3	6	4	5	2	3	6	4
30.99	6	3	4	7	5	6	3	4	7	4
31.00	5	3	4	6	4	5	2	4	6	4
31.93	5	3	3	6	3	5	3	3	6	4
31.99	5	3	4	6	4	5	3	3	7	4
32.93	6	3	4	7	5	6	4	3	7	5
32.99	5	3	4	7	4/5	5	3	3	7	5
33.99	5 or 6	3	4	7	5	6	4	4	7	5
34.01	6	3	3	7	5	4	3	4	5	3
34.93	4	2	2	5 6	4	5	2	4	6	4
36.93	5	2	4	6	3					
37.93	5	4	3	6	3	5	3	3	7	3
38.01	5	3	4	7	4	5	3	4	6	4
38.93	5	4	4	6	4	5	3	4	6	4
39.01	5	2	2	6	4	4	2	3	6	4

ID	RP1	RP2	RP3	RP4	RP5	LP1	LP2	LP3	LP4	LP5
42.05	4	2	2	4	3	4	2	2	6	4
45.93	5	3	4	6	4	5	2	3	6	4
48.04										
49.04	6	3	4	7	5	5	2	4	7	4
60.03	5	3	4	6	4	5	3	4	6	4

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
1.00	2	2	4	4	4	2	4	4	2
1.01	3	3	5	5	5	2	4		
1.81	3	3	4	5	5	3	4	2	3
1.82	2	2	4	3	4/5	1	4	2	2
1.83	2	2	4	4		2			
1.84	3	3	4	4	4	1	4		
1.88	2	2	4	5	5	2	4	1	1
1.91	3	3	4	4	4	1	4	2	2
1.92	3	3	5	5	4	1	3	3	1
1.93	2	2	4	4	3	2	4		1
1.94	2	2	4	4	4	1/2	4	4	1
1.96	3	3	4	4	4	3	2	2	2
1.97	3	3	5	5	5	2	4	4	2
1.98	2	3	4	4	5	2	4	1	3
2.00	3	3	4	5	5	2	4	3	2
2.02							6		
2.83	2	2	4	4	5	2	2	2	2
2.84	3	3	4	5	4/5	3	2	2	2
2.85	3	3	4	4	4	3	3	2	2
2.87							6	6	
2.88	2	2	4	5	4	2	4	2	1
2.89	2	2	4	4	4/5	1	4	2	2
2.91	4	4	5	5	5	3	4	2/3	1/2
2.92	2	2	4	5	3	1	4	4	1
2.94	2	2	4	4	4	2	4	4	2
2.95	3	3	5	4	4	2	2	4	1
2.96							6		
2.97	3	3	4	4	4	5	4		
2.98	3	3	5	4	4	1	4		
2.99	3	3	4	5	4	1	4	2	2
3.00	2	2	4	4	4	2	4	3	1
3.01	3	3	4	4	5	2	5	5	3
3.81	3	3	5	5	4	1	1	1	1
3.83									
3.87	2		4	4			1	2	1
3.88	2	3	4	5	4	2	2	2	2
3.89	3	3	4	5	4	1	3	2	1
3.90	2	2	4	4/5	4	1	4	2	2
3.91	3	3	4	4/5	4	3	4	1	2
3.93	3	3	4	4	4	2	3	2	2
3.96	2	2	3	3	3	2	3	3	2
3.98							6		
3.99	3	3	4	4	4	2	5	4	1
4.00	3	3	5	5	5	2	5	4	2

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
4.93	3	3	4	4	4	2	2	2	2
4.94							6	6	
4.95	2	2	3	3	3	1	2	4	1
4.96	3	2	5	5	4	1	4	4	2
4.97	3	3	4	4	4	3	4	2	1
4.98	3	3	4	4	2	4	4	2	2
4.99	3	3	5	5	5	2	4	2	3
5.00	3	3	4	4	4	2	4	4	1
5.83	2	2	3	3	4	1	2	2	1
5.87	3	3	4	4	4	1	3	4	2
5.88	2	3	4	5	4	1	4/5	3	2
5.93	2	3	4	4	4	1	4	2	2
5.94	3	2	4	4	4	2	4	4	1
5.97	3	3	4	4	4	3	4	4	3
5.98	3	3	4	4	5	2	4	2	2
5.99	2	3	4	4	4	2	4	4	2
6.00							6		
6.02							6		
6.87							6		
6.88	3	3	4	3	4	2	3	3	1/2
6.91	2	2	5	4/5	4	2	4	4/5	2
6.92									
6.93	2	3	4	3	4	2	2/3	2/3	3
6.95	3	3	4	5	5	2	4	4	1
6.98	3	3	4	4	5	2	4	3	2
6.99	3	3	4	4	4	2	4	2	2/3
7.86	2	2	4	5	5	2	2	2	2
7.87	3	2	4	4	5	1	2	2	1
7.89	3	3	4	4	5	2	4	4	2
7.91	2	2	5	5	5	1	4	2	2
7.92	3	3	4	5	4	2	4	4	2
7.93	3	3	4	4	4	2	2	2	2
7.94	2	2	4	4	4	1	4	4	2
7.95	3	2	4	3	5	2	4	3	2
7.96	3	3	5	5	5	3	5	5	1
7.97	2	2	4	3	5	1	3	3	1
7.98									
8.87	1	1	4	3	2	1	2	2	1/2
8.89	2	2	4	4	4	2	4	2	1
8.91	2		4/5					2	1
8.93	3	3	4	4	4	1	2	2	1
8.94	3	3	4	5	4	2	4	2/3	2
8.95	3	2	4	4	4	2	4	3	2
8.96	2	2/3	3	3	3	1	4	2	2
8.98	1	1	4	3	3	2	4	2	2

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
8.99	3	3	4	4	4	1	3	4	2
9.00									
9.88	3	3	4	4	4	1	2	2	1
9.89	2	2	4	5	5	1	4	1	1
9.93	3	3	5	4	5	1	4	3	1
9.94	2	2	4	4	5	2	4	2	2
9.95								6	
9.96	3	3	4	4	4	2	2	2	2
9.97	3	2	4	3	5	1	2	2	2
9.98	3	3	4	5	5	2	4	4	3
9.99	2	3	4	4	4	2	4	5	4
10.00							6		
10.87	3	3	4	4	5	1	5	1/2	3
10.88	2	2	5	5	5	1	2	2	1
10.89	2	3	2	4	4	1	2	2	1
10.90	3	3	4	4	4	2	4	2	2
10.91	3	3	4	4	5	1	3	2	2
10.92	3	3	4	4	4	2	4	3	3
10.94	3	3	4	4			4	2/3	2
10.95	3	3	4	4	4	2	4	4	2
10.96	3	3	4	4	4	1	4	4	2
10.97	3	2	4	4	4	2	4	4	3
10.98	3	2	5	4	4	2	4	3	1
11.89	2	2	5	5	4	1	4	2	2
11.90	2	2	4	4	4	2	4	1	2
11.94	2	2	4	4	4	2	4	4	2
11.97	3	3	4	4	4	2	4	2	1
11.98	3	3	4	4	5	2	4	2	1
12.00	3	3	4	4			4		
12.87	2	2	4	4	4	2	5	4	2
12.88	3	3	4	4	4	1	4	3	1
12.89									
12.90	3	3	4	4	4/5	2	4	2	2
12.91	3	3	4	4	4	2	4	3	1
12.97	3	3	4	5	5	2	4	4	3
12.99	3	3	4	5	4	2	4	4	2
13.00	3	3	4	4	4	2/3	4	2	2
13.01							6		
13.88	3	3	4	4	4	1	2	1	1
13.91	2	2	4	4	5	1	3	3	1
13.97	3	3	4	4	4	2	4	3	2
14.87	3	3	4	4	5	1	4	2	1
14.88	3	3	4	4	4	1	3	2	1
14.90	2	2	3	3	3	1	4	2	2
14.92	3	3	5	5	5	1	4	2	1

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
14.93	1	1	4	4	4	1	4	4	2
14.98	3	3	5	5	5	3	4	4	1
15.89	3	3	4	4	4	1	3/4	2	1
15.91	3	3	4	4	4	1	4	3	2
15.93	3	3	4	4	4	2	4	4	3
15.98	2	3	4	5	4	2	5	4	3
15.99	2	3	4	4	4	3	4	3	3
16.00	3	3	4	4	5	2	4	4	3
16.89	2	2	4	4	4	1	5	2	1
16.91	1	1	4	4	4	1	2	2	1
16.92	3	3	4	4	4				
16.98							6		
16.99	3	3	5	4	4	2	4	4	3
17.00	1	1	3	3	4	1	4	2	1
17.91	1	1	4	3	4	1	4	4	2
17.97	3	3	5	4	4	2	4	4	2
18.88	2	3	4	4	5	1	4	2	2
18.90	1	1/2	4	4	4	1	4	1	2
18.91	2	2	4	5	5	1	4	3	2
18.92	1	1	4	4	2	1	1	1	1
18.97	3	3	5	4	4	2	4	4	3
18.98	3	3	4	4	4	2	4	4	3
18.99	2	3	4	4	5	1	4	3	2
19.00	3	3	4	4	4	2	4	2	1
19.01							6		
19.88	3	2	4	5	4	2	4	2	1
19.90	2	2	4	4	4	2	4	3	3
19.91	2	2	4	3	3	1	4	2	1
19.92	2	2	4	3	3/4	2/3	4	3	1
19.93	3	3	4	4	5	2	4	4	2
19.94	3	3	4	4	4	1	2	4	1
19.98	2	3	4	4	4	3	5	3	1
19.99	3	3	5	5	5	2	4	2	2
20.03	3	3	4	5	4	2	4	4	2
20.88									
20.90	3	3	4	5	4	1	2	3	2
20.91	2	2	4/5	4			2/3		
20.92	2	2	4	4	4	1	2	2/3	1
20.95	2	2	4	4	4	3	5	5	2
20.98	2	2	3	3	3	2	2	2	1
20.99	2	2	4	4	4	2	4	2	1
21.00	3	3	4	5	5	3	4	3	2
21.02	3	3	4	4	5	2	5	4	3
21.90	2	3	4	5	4	1	3	3	2
21.91	2	2	4	4	5	2	4	2	2

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
21.92	1	1	3	3	2	1	1	1	1
21.93	2	2	5	5	5	2	2	1	
21.94	2	2	4	4	4	3	5	2	1
21.95	3	3	4	4	3	1	4	2	1
21.98	3	3	4	4	4	2	4	4	2
21.99									
22.00	3	3	4	5	4	2	4	3	2
22.90	2	2	4	4/5	4	2	5	3	2
22.91	2	3	4	3	4	1	2	2	1
22.93							6		
22.94	3	2	4	4	3	1/2	4	3	2/3
22.95	3	3	4	4	4	1	2	2	3
22.99	1	1	4	5	4	2	2	2	1
23.00	3	3	4	3	4	2	4	2	2
23.88	3	3	5	5	4	1	4	2/ 3	1
23.93	2	3	4	3	4	2	4	4	2
23.94	2	2	4	4	4/5	1	4	4	2
23.99	3	3	4	5	5	2	4	3	1/2
24.00	2	3	4	4	4	3	3	3	3
24.04							6		
24.88							6	6	
23.00	3	3	4	4	4	2	4	2	1
25.02	3	3	4	4	4	1	4	4	2
25.91	3	3	4	4	4		3	3	
25.99	3	3	4	4	5	3	4	3	1
26.00	3	3	4	5	4	2	4	4	2
26.91	3	3	4	4	4	1	2	2	1
26.93	2	2	4	5	4	1	4	4	2
26.99								6	
27.90	3	3	5	5	5	2	4	4	2
27.91	1	1	3	3	4	2	2	2	1
27.93	2	2	4	3	4	1	2	2	1/2
27.99							6		
28.90	2	2	5	5	4	1	3	3	2
29.00	3	3	4	5	4	2	4	3	1
29.04	2	2	4	4	4	2	4	2	2
29.93	2	2	5	5	5	1	4	2	1
29.99	3	3	4	4	4		4	4	2
30.93	2	2	4	3	4	1	4	2	1
30.99	3	3	4	5	4	2	5		2/3
31.00	3	3	4	4	4	1	4	2	1
31.93	2	2	4	5	4/5	2	5	2	2
31.99	2	3	4	4	5	2	4	3	4
32.93	2	2	4	4	4	3	2	2	2
32.99	3	3	4	5	4	3	5	3	2 or 3

ID	RA1	RA2	RA3	RA4	RA5	RA6	RA7	RA8	RA9
33.99	3	3	4	4	4	2/3	4	4	3
34.01	3	3	5	5	5	2	4	4	2
34.93	3	3	4	4	4	2	4	2	1/2
36.93	2	3	4	4	4	2	4	4	2
37.93	2	2	4	4	4	2	4	2	2
38.01							5	6	
38.93	2	2	4	4	4	2	4	4	2
39.01	2	2	4	4	4	1	3	3	1
45.93	3	3	5	5	5	2	4	4	1
48.04							6		
49.04									
60.03	3	3	5	5	5	3	4	3	2
42.05									

ID	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8	LA9
1.00	3	3	4	4	4	1	4	4	2
1.01	2	2	4	4	4	3	4		
1.81	2	2	4	5	4	1/2	2	2	1
1.82	2	2	4	3	5	1	4	2	1
1.83	3	3	4	4	4	2	2	1	1
1.84									
1.88	2	2	4	5	5	3	4	3	1
1.91	3	2	4	4	5	2	4	2	2
1.92	3	3	5	5	5	1	4	2	1
1.93		2		4		2	4	2	1
1.94	2	2	4	4	5	2	4	4	1
1.96	3	3	4	4	4	2	4	2	
1.97	3	3	4	4	4	2	4	3	2
1.98	2	2	5	5	5	2	4	1	1
2.00	3	3	4	4	5	2	5	5	3
2.02	3	3	4	4	4	2	4	3	3
2.83	2	2	4	4	3	1	2	2	1
2.84	3	3	4	4	4	2	3	2	1
2.85	3	3		4	4	3	2		2
2.87	2	2	3	3	3	3	4	4	2
2.88	2	2	4	4	4	2	4	2	1
2.89	2	2	4	4	4	1	4/5	2	1
2.91	3	3	4	4	4	3	4	3	1
2.92	2	3	4	5	4	3	4	4	2
2.94	2	2	4	4	4	2	4	4	2
2.95	3	3	3	3		2	3	4	1
2.96	3	3	4	5	4	2	4	5	3
2.97	3	3	4	4	4	3			
2.98	3	3	5	5	4	1	3	2	1
2.99	3	3	4	4	4	2	5	4	2
3.00	3	2	4	4	4	2	4	4	1/2
3.01	2	2	4	4	5	2	4	4	2/3
3.81	2	3	5	5	5				1
3.83	2	2	4	5	4	1	4	1/2	1
3.87	3	3	4	4	4	1	2	2	2
3.88									
3.89	3	3	4	4	4	1	4	2	1
3.90	3	3	4	4	4	2	4		3
3.91	3	3	4	4	4	2/3	4	2	2
3.93	3	3	4	4	4	2	3	3	2
3.96	2	2	3	3	4	2	4	3	2
3.98									
3.99	3	3	4	4	3	2	4	3	1
4.00	3	3	4	4	5	2	4	4	3
4.83	2	2	¾	3/4	4/5	1	2	2	1

4.87	3	3	5	4	5	2/3	2	2	2
4.88	3	3	5	5	5	1	5	1	1
4.93	3	3	4	4	4	1	2	3	1
4.94									
4.95	2	2	4	4	3	1	4	4	1
4.96	3	2	4	4	4	1	4	4	2
4.97	3	3	4	4	4	2	4	2	1
4.98	2	2	4	4	4	2	4	3	3
4.99	3	3	5	5	5	3	4	3	3
5.00	2	3	4	4	4	3	4	4	1
5.83									
5.87	3	2/3	4	4	4/5	2	4/5	2	2
5.88	3	3	4	4	4	1	5	3	1
5.93	3	3	4	4	4	1	4	3	2
5.94	2	2	4	4	4	2	4	3	1
5.97	3	3	4	4	4	3	2	4	2/3
5.98	3	3	4	4	5	2	4	2	2
5.99	2	3	4	4	4	2	4	5	2
6.00							6		
6.02							6		
6.87							6		
6.88	3	2	4	4		1	3	2	1
6.91	2	2	4	4/5	4	1	4	3	1/2
6.92	2	3	4	4	4	1	4	4	2
6.93	2	2	4	3	3	2	2	4	2
6.95	2	2	4	5	5	3	4	4	1
6.98	3	3	5	4	5	2	4	2/3	2
6.99	3	3	4	4	4	2	4	3	3
7.86									
7.87	3	2/3	4/5	5	4/5	1	1/2	1	1/2
7.89	3	3	4	4/5	4	1	2	3	2
7.91	2	2	4	5	5	3	4	4	2
7.92	3	3	4	4	4	2	4	3	2
7.93	3	3	4	4	4	2	3	3	2
7.94	2	3	4	4	4	3	4	3	3
7.95	3	3	4	4	4	3	4	2	1
7.96	3	3	4	4	4	3	2	4	1
7.97	2	1	4	4	3	2	2	3	1
7.98	3	3	4	4	4	2	4	4	2
8.87	1	1	3	3	2	1	2	1	
8.89	2	3	5	4			3		2
8.91	2	3	5	5	4	1	4	2	1
8.93	3	3	4	4	5	1	2	2	2
8.94	2	3	4	¾	4	2	4	2/3	2
8.95	3	3	4	4	4	2	4	3	3
8.96	3	2	4	4	4	1	2	2	2

ID	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8	LA9
8.98	1	1	4	4	4	2	4	1/2	1
8.99	3	3	5	4	4	2	4	4	3
9.00	2	3	4	4	3	1	4	4	1
9.88	2	2	4	5	4	1	5	2	1
9.89	2	2	4	5	5	1	4	1	1
9.93	2	3	4	4	3	1	3	2	1
9.94									
9.95	3	3	5	5	5	2		5	
9.96	2	3	4	4	4	2	2	2	
9.97	3	2	4	4	4	1	2	2	2
9.98	3	3	5	5	5	2	4	4	3
9.99	3	3	4	5	5	2	5	5	3
10.00	3	3	4	4	5	3	4	2	2
10.87	3	3	4	4	4	1	1	1	
10.88	3	3	5	5	5	2	5	2	1
10.89	2	3	4	4	4	2	2	2	1
10.90							6		
10.91	3	2	4	4	5	1	2	2	2
10.92	2	3	3	4	4	2	4	4	2
10.94									
10.95	2	2	4	4	4	2	5	2	2
10.96	3	3	4	4	4	1	4	2	2
10.97	3	3	4	4	4	2	4	4	3
10.98	3	3	5	5	4	2	5	2	2
11.89	2	3	4	5	4	1	5	2	1
11.90	2	2	4	4/5	5	2	4	1	1
11.94	2	3	4	4	4	2	4	4	2
11.97	2	2	4	3	3	1	4	2	1
11.98	3	3	4	5	4	2	4	2	1
12.00	4	4	5			2	4		2
12.87	2	2	4	4	4	1	5	2	2
12.88	3	3	4	4	4	1	4	3	1
12.89	2	2	4	5	4	2	4	3	1
12.90	3	3	4	4	4	2	5	2	1/2
12.91	3	2	4	4	4	2	4	2/3	1
12.97	3	3	4	4	4	2	4	2	2
12.99	3	3	5	4	4	2	2/3	4	2
13.00	3	3	4	5	4	3	4	4	2
13.01							6		
13.88	3	3	4	5	4	1	4	2	1
13.91	2	2	4	5	5	1	4	2/3	1
13.97	3	3	4	5	4	2	4	4	2
14.87	3	3	4	4	5	1	4	3	1/2
14.88	3	3	4	4	4	1	4	4/4	2
14.90	1	1	4	3	4	1	2	2	1/2

ID	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8	LA9
14.92	3	3	4	5	5	3	2	2	1
14.93	1	1	4	4	3	2	4	2	2
14.98	2	4	5	2/3	4	4	1		
15.89	3	2	4	4	5	2	2	2	2
15.91	3	2	4	4	5	1	4	3	2
15.93	3	3	4	5	5	3	4	4	3
15.98	3	3	4	5	4	2	4	4	3
15.99	2	2	4	4	4	2	4	2	2
16.00	2	3	4	4	4	2	4	3	3
16.89	2	2	4	4	5	1	5	2	1
16.91	2	2	4	4	4	1	2	2	2
16.92									
16.98	2	2	3	3	3	2	5	4	2
16.99	3	3	4	5	4	2	4	4	1
17.00	1	1	3	3	3	1	4	2	1
17.91	2		4	4			4	3	2
17.97	3	3	4	5	4	2	5	4	2
18.88	2	3	4	4	5	1	4/5	2	3
18.90	1/2	1/2	4	4	5	1	4	1	2
18.91	2	2	5	4	5	1	4	3	2
18.92	1	1	4	3	4	1	1	1	1
18.97	3	3	4	4	4	3	4	4	3
18.98	3	3	4	4	5	2	4	3	3
18.99	2	3	4	5	5	2	4	4	1/2
19.00	3	3	4	4	4	3	2	4	2
19.01	3	3	4	5	4	3	4	4	3
19.88	2	3	4	4	4	2	4	2	1
19.90	2	2	4	4	4	2	4	3	2
19.91	2	2	5	5	5	1	3	3	1
19.92	2	3	4	3	4	3	4	2	2
19.93	3	3	4	4	5	1	4	4	2
19.94	3	3	4	4	4	1	4	2	1
19.98	3	3	4	5	5	2	5	3	1
19.99	3	3	5	5	5	2	4	2	2
20.03	3	3	4	4	5	2	4	5	
20.88	3	2	4	4	4	1	2	1	1
20.90	2	2	5	5	4	1	4	3	2/3
20.91	3	2	4	4			2/3	3	1
20.92	3	2	4	4	4	2	4	3	2
20.95	2	2	4	4	4	1	5	4	2
20.98	2	3	4	5	4	2	4	1	1
20.99	2	2	4	4	4	2	4	3	1
21.00	3	3	4	5	5	3	4	4	2
21.02							6		
21.90	2	3	4	5	4	1	4	2	1

ID	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8	LA9
21.91	2	2	4	5	4	2	3	2	2
21.92	1	1	4	4	3	1	2	1	1
21.93	2	2	4	4	5	2	4	2	
21.94	2/3	2/3	4	5	4	2	4		
21.95	3	3	4	4	4	1	4	2	1/2
21.98	3	3	4	4	5	2	4	2	2
21.99									
22.00	3	3	4	4	4	2	4	3	1
22.90	2	2	5	5	5	1	4/5	2	2
22.91	3	3	4	4	4	1	2	4	1
22.93							6		
22.94	3	3	4	4	5	1	3	3	3
22.95	3	3	4	4	4	2	4	3	2
22.99	1	1	4	5	4	1	1	2	1
23.00									
23.88	3	3	4	5	4	1	4	4	1
23.93	2	2	4	4	4	2	4	2	2
23.94	2	2	4	5	5	1	4	4	2
23.99	3	3	4	4	4	2	4	4	2
24.00	3	3	4	4	4	3	4	4	3
24.04							6		
24.88	2	2	4	4	3	4	3	1	
23.00	3	3	5	4	4	2	4	4	1/2
25.02	3	3	4	4	4	2	4	4	2
25.91	3	3	4	4	4	2	5	3	
25.99	3	3	4	5	4	2/3	3	4	1
26.00	2	3	4	4	5	3	4	3	3
26.91	3	3	4	4	4	1	3	2	1
26.93	3	3	4	4	4	2	3	3	1
26.99	3	3	4	4	4	2			1
27.90	3	3	5	4	5	2	4	4	2
27.91	3	3	4	4	3	2	3	3	1
27.93	3	3	4	5	5	1	4	3	1
27.99	3	3	4	4	4	3	5	4	3
28.90	2	2	4	5	4	1	4	4	2
29.00	2	3	4	4	4	2	4	2	1
29.04	2	2	4	4	4	2	4	4	1
29.93	3	3	5	5	5	1	4	3	1
29.99	3	3	4	4	5	2	4	4	3
30.93	2	2	4	4	4	1	4	1	1
30.99	3	3	5	5	5	2	4	4	2/3
31.00	3	3	4	4	4	1	4	2	1
31.93	3	3	4	5	5	2	2	1	
31.99	2	2	4	4	4	3	4	2	2
32.93	3	3	4	4	4	3	4	2	2

ID	LA1	LA2	LA3	LA4	LA5	LA6	LA7	LA8	LA9
32.99	2	3	4	4		2/3	4	3	
33.99	3	3	4	4	4	3	4	4	3
34.01	2	2	5	5	5	2	3	2	3
34.93	3	3	4	4	4	1	4	2	2
36.93	2	2	4	4	4	2	4	2	2
37.93	2	2	4	4	4	2	4	2	1
38.01	2	3	4	4	4	2	4	4	1
38.93	3	3	4	4	4	2	4	2	2
39.01	2	2	4	3	4	1	3	4	1
45.93	3	3	5	5	5	2	4	4	1
48.04							6		
49.04	3	3	4	5	4	1	4	2	1
60.03								6	
42.05									

ID	C1	C2	C3	C4	C5
1.00	3	4	3	2	3
1.01	3	5	1	5	4
1.81	5	5	3	3	3
1.82	5	5	4	4	4
1.83	4	3	3	3	4
1.84	5	5	4	4	5
1.88	5	4	3	3	3
1.91	2	3	1	3	3
1.92	5	3	3	3	5
1.93	5	3	3	3	4
1.94	5	5	3	3	3
1.96	3	3	1	5	4
1.97	3	4	3	3	3
1.98	5	4	3	3	3
2.00	3	4	3	2	4
2.02	4	4	3	2	3
2.83	3		3	3	
2.84	5	5	3	3	3
2.85	5	5	3	4	
2.87	5	3	3	4	5
2.88	5	4	3	4	3
2.89	3	3	2	3	4
2.91	5	5	3	4	4
2.92	5	3	3	3	3
2.94	5	5	3	4	4
2.95	5	3	3	3	4
2.96	5	3	3	3	3
2.97	3	3	3	3	4
2.98	4	4	3	3	4
2.99	5	5	3	4	3
3.00	3	3	2	2	3
3.01	4	4	3	3	3
3.81	5	5	3	4	5
3.83	3	3	3	2	5
3.87	2	4	3	3	4
3.88					
3.89	5	5	5	5	3
3.90	3	5	4	3	3
3.91	5	5	3	5	3
3.93	4	4	3	4	4
3.96	5	4	3	3	4
3.98	5	5	3	4	4
3.99	4	3	3	3	3
4.00	3	3	3	3	4
4.83	5	5	3	4	4

ID	C1	C2	C3	C4	C5
4.87	5	4	3	2	4
4.88	5	3	2	4	4
4.93	5	3	3	5	
4.94	5	5	3	5	5
4.95	5	5	3	3	4
4.96	3	3	1	2	4
4.97	5	3	3	4	4
4.98	5	5	3	2	3
4.99	4	5	3	4	3
5.00	5	5	3	4	5
5.83	4	5	3	2	4
5.87	5	5	3	3	3
5.88	5	5	3	5	5
5.93	4	5	3	4	4
5.94	3	3	3	3	3
5.97	4	4	3	2	3
5.98	5	4	4	3	4
5.99	4	5	2	3	3
6.00	5	4	3	5	5
6.02	5	5	3	5	4
6.87	5	5	3	5	3
6.88	2	3	3	3	3
6.91	3	5	3	3	3
6.92	5	5	3	5	5
6.93	5	3	3	3	3
6.95	5	3	1	3	4
6.98	5	4	3	3	5
6.99	3	4	3	4	5
7.86	3	3	2	3	4
7.87	4	3	2	3	3
7.89	4	3	3	3	4
7.91	5	5	5	5	5
7.92	3	5	3	1	1
7.93	4	4	3	5	3
7.94	5	4	4	4	4
7.95	5	5	3	3	1
7.96	5	5	5	3	1
7.97					
7.98	3	3	3	2	
8.87	4	1	2	2	3
8.89	4	5	3	5	4
8.91	4	4	3	5	5
8.93	5	4	3	3	5
8.94	3	4	3	4	4
8.95	5	4	3	3	5

ID	C1	C2	C3	C4	C5
8.96	3	3	3	3	4
8.98	4	4	3	4	4
8.99	5	5	3	5	3
9.00	2 or 3	4	3	3	3
9.88	3	5	3	3	4
9.89	2	4	1	2	5
9.93	4	4	3	2	4
9.94	3	4	3	4	4
9.95	4	3	3	3	4
9.96	3	5	43	3	
9.97					
9.98	5	3	2	4	4
9.99	5	4	3	3	3
10.00	5	5	4	4	5
10.87	5	5	3	3	5
10.88	5	5	3	3	5
10.89	5	3	3	3	4
10.90	5	2	3	4	3
10.91	5	3	3	3	3
10.92	4	5	3	4	4
10.94	4	5	3	3	4
10.95	5	4	3	3	4
10.96	5	4	3	4	3
10.97					
10.98	3	1	1	2	1
11.89	5	3	1	3	3
11.90	3	3	3	3	3
11.94					
11.97					
11.98	3	2	2	3	4
12.00	4	2	1	3	5
12.87	5	5	3	4	4
12.88	3	5	3	3	3
12.89	5	5	3	3	5
12.90	3	4	3	3	3
12.91	4	4	3	3	4
12.97					
12.99	5	5	3	3	3
13.00	3	4	3	3	4
13.01	5	5	3	3	4
13.88	1	3	1	3	4
13.91	2	33	3	3	5
13.97					
14.87	5	5	3	5	
14.88	3	5	3	3	5

ID	C1	C2	C3	C4	C5
14.90	2	3	1		
14.92	5	4	3 or 4	5	4
14.93	2	3	1	2	3
14.98	5	5	3	3	3
15.89	5	5	3	4	3
15.91	5	4	4	3	5
15.93	5	5	3	4	5
15.98	3	3	2	2	3
15.99	4	5	2	3	4
16.00	4	5	3	3	4
16.89	5	4	4	3	5
16.91	5	5	3	3	3
16.92	5	5	5	5	5
16.98	4	2	3	4	4
16.99	5	5	3	3	3
17.00	4	4	3	4	4
17.91	3	3	3	3	3
17.97	5	3	3	3	4
18.88	5	5	3	4	3
18.90	3	5	3	3	3
18.91	3	3	3	3	3
18.92	3	1	1	3	3
18.97	4	4	3	2	3
18.98	4	3	3	3	3
18.99	4	5	3	4	4
19.00	2		2	3	
19.01	5	3	2	2	4
19.88	5	4	3	3	4
19.90	5	5	2	4	5
19.91	3	3	3	3	3
19.92	4	4	3	3	3
19.93	5	5	3	3	3
19.94	4	5	3	4	5
19.98	5	4	3	4	3
19.99	5	4	2	2	3
20.03	5	2	4	2	1
20.88	3	4	1		
20.90	3	1	1	2	3
20.91	5	3	3	3	1
20.92	5	5	4	4	3
20.95	3	3	1	4	4
20.98	5	4	3	2	3
20.99	4	43	5	4	
21.00	4	3	2	3	4
21.02	3	3	3	3	4

ID	C1	C2	C3	C4	C5
21.90	5	5	4	5	5
21.91	5	4	3	3	5
21.92	2	1	1	2	1
21.93	5	3	2	3	3
21.94	5	4	3	3	4
21.95	5	4	3	3	3
21.98	4	5	3	3	3
21.99	5	3	3	3	3
22.00	2	4	2	2	5
22.90	3	3	3	4	3
22.91	3	4	3	2	3
22.93		2	2	3	3
22.94	5	4	3	3	4
22.95					
22.99		4	2	2	3
23.00	5	5	3	3	1
23.88	3	2	2	1	3
23.93	5	3 or 4	3	3	4
23.94	5	3	3	4	3
23.99	4	4	3	4	4
24.00	1	3	1	2	1
24.04	5	4	3	3	4
24.88	3	3	1	3	4
23.00	5	5	3	4	5
25.02	4	5	3	4	5
25.91	4	3	2	3	4
25.99	4	3	2	3	3
26.00	4	5	2	3	4
26.91	3			2	3
26.93	3	4	3	3	3
26.99	3	5	3	2	1
27.90	3	3	3	3	4
27.91	3	3	3	3	3
27.93	4	5	4	3	3
27.99	5	4	3	3	4
28.90	3	5	2	2	5
29.00	5	4	3	4	4
29.04	4	4	4	3	4
29.93	3	4	3	3	4
29.99	4	4	3	3	3
30.93	3	3	3	3	3
30.99	4	3	3	4	3
31.00	4	4	3	4	4
31.93	4	4	3	4	3

ID	C1	C2	C3	C4	C5
31.99	3	3	5	3	5
32.93	5	4	3	3	4
32.99	5	5	3	3	4
33.99					
34.01	5	4	3	3	3
34.93	5	2	3	3	5
36.93	5	4	3	3	4
37.93					
38.01	3	3	3	3	3
38.93	4	4	4	4	5
39.01	2	2	3	2	3
45.93	4	4	3	3	4
48.04	5	5	3	5	5
49.04	4	3	3	3	4
60.03	5	3	4	3	4
42.05	4	4	2	3/4	3/4

Appendix 2 – Real age and ages-at-death estimated from ADBOU.

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
1.00	41	60.696725	54.510755	46.800614	76.949768	51.262114
1.01	84	81.569358	73.119713	64.548998	100.959211	65.534057
1.81	73	78.417107	69.037446	46.56865	93.133096	102.801349
1.82	55	70.844507	62.346375	57.383353	69.667967	110
1.83	79	60.481977	53.8945	75.220485	44.176828	81.378274
1.84	62	69.360957	72.206615	54.293298	76.87052	102.616315
1.88	71	43.245273	41.386641	32.652345	70.711979	110
1.92	55	89.676543	77.436877	49.820775	110	110
1.93	53	53.742172	47.102503	45.096102	51.634813	81.378273
1.94	45	44.70639	42.745368	35.53173	75.278065	102.801349
1.96	66	83.85783	73.947507	110	65.480917	91.607709
1.97	79	84.583399	74.631408	57.783661	100.264855	86.984263
1.98	58	42.395318	40.94035	32.200638	81.987036	110
2.00	58	73.765152	74.515927	79.89108	90.538898	29.555741
2.02	46	61.604374	64.921251	66.390973	94.000017	29.12785
2.83	55	46.400346	46.870468	46.797812	48.073419	38.524057
2.84	65	57.837711	60.58804	45.517426	67.206568	56.860948
3.00	43	50.453323	51.666376	71.466362	67.421385	27.356333
2.99	62	76.733853	68.081993	57.383353	86.77417	83.624252
2.98	53	74.020591	66.967231	53.935703	88.055294	110
2.97	77	86.767756	74.791776	110	79.311162	64.2866
2.96	87	99.849763	81.625426	79.162294	110	90.228998
2.95	80	54.254162	49.595736	41.078651	67.380069	81.378274
2.94	72	68.16424	60.313253	51.104142	69.597485	110
2.92	62	42.607085	40.184798	31.241336	73.830938	55.419756
2.91	81	97.690362	79.111426	84.858507	98.707942	110
2.89	36	68.152436	60.363626	58.892732	70.745688	76.008056
2.88	61	72.772243	65.131026	64.952826	74.667778	97.797493
2.87	75	73.221512	64.152804	67.399662	67.607672	110
2.85	87	71.996443	73.601961	84.388265	62.478914	66.698439
3.01	62	72.540525	66.174407	53.835654	88.912834	68.215584
3.81	72	38.88343	37.616092	30.134985	82.313868	110
3.83	63	56.434618	50.025089	43.665492	80.597555	54.34363
3.87	36	38.978212	38.047672	33.228346	57.802635	71.261371
3.89	49	81.495169	68.973838	75.553626	78.335919	110
3.90	43	74.717838	66.701413	65.26034	80.499164	72.88968
3.91	68	72.587928	64.938169	64.863835	72.241556	110
3.93	56	55.238368	50.620292	37.653754	74.707737	110
3.96	55	47.336981	41.953608		39.318465	100.937554
3.98	89	110	62.444004		110	110
3.99	66	72.096121	64.418633	70.650632	77.14288	55.419756

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
4.00	56	83.487244	74.143259	50.339095	109.558099	71.118123
4.87	55	48.86163	46.025983	36.461159	86.124265	66.518366
4.93	54	37.166691	36.518097	31.847978	71.182647	110
4.94	101	110	72.270507		110	110
4.95	43	44.762815	42.075238	44.733432	36.797207	110
4.96	55	39.344142	38.351032	32.202645	89.719481	43.714826
4.97	33	74.142252	64.639082	46.800614	83.748154	110
4.98	56	62.559219	56.316385	46.800614	77.260387	50.245795
4.99	57	96.900459	83.400979	71.623032	110	83.624252
5.00	89	79.279998	68.890963	57.902386	84.77633	110
5.83	48	39.834783	38.64907	38.866834	29.742692	59.03594
5.87	53	65.150297	58.736633	54.415547	73.486559	56.860948
5.93	53	53.022006	48.801394	37.488548	75.510079	110
5.94	46	67.552455	57.998088	60.968736	70.909862	71.829101
5.97	67	66.602867	60.011143	88.973445	78.239791	29.12785
5.98	67	58.936744	53.157485	37.652864	82.648461	110
5.99	38	67.21624	59.450808	50.339095	78.742987	68.716823
6.00	71	110	73.638974		110	110
6.02	77	110	67.903489		110	110
6.87	69	110	55.892361		110	110
6.91	65	56.891549	51.837117	40.869338	83.030729	72.88968
6.92	62	31.609249	31.108215	26.876517	74.985746	110
6.93	80	46.115723	43.34121	36.518697	63.899981	55.419756
6.95	69	94.513448	81.298382	110	84.35679	74.569225
6.98	56	80.246609	70.556517	49.820775	87.948851	110
6.99	77	78.316417	69.035122	50.339095	91.213017	110
7.86	67	71.024959	60.704999	49.854129	76.951683	76.008056
7.87	58	63.761088	56.493684	50.902838	68.006661	67.883137
7.89	50	73.53598	65.315654	45.787005	82.966487	110
7.91	63	85.946189	75.302099	59.23714	96.403001	110
7.92	64	30.534053	30.115623	90.367092	82.611171	19.171532
7.93	64	31.401638	31.037159	26.8972	73.384193	110
7.94	41	51.400686	47.958874	34.697796	80.49007	110
7.95	71	78.958298	70.453954	110	69.722442	38.616558
7.98	67	63.02	55.79	27.48	92.34	82.81
7.96	57	35.112366	34.145997	110	91.616491	20.122726
7.97	52	55.259529	50.255123		91.834345	36.246453
8.87	25	20.386965	20.288411	19.472936	25.904843	34.933044
8.89	66	79.908357	71.640878	71.709064	76.545719	110
8.93	52	45.887783	43.74047	34.461375	76.095075	110
8.94	63	86.712626	78.047922	87.442046	81.814502	110
8.95	56	71.915774	65.056532	44.957997	81.569006	110
8.96	57	62.003952	56.117184	73.120545	44.874672	110
8.98	36	43.163711	41.334585	34.743636	41.71407	110

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
8.99	43	33.662011	33.002478	27.768579	100.591075	110
9.00	43	60.752596	53.391928	56.880307	68.350924	51.684929
9.88	58	78.550707	70.15422	71.769382	79.745925	110
9.89	43	43.084518	41.189903	39.322749	52.880512	60.908553
9.93	42	40.327258	39.241162	32.131057	91.77473	66.518366
9.94	68	72.587044	63.3668	57.902386	72.739564	110
9.96	59	79.523297	69.717251	76.313067	72.99759	110
9.97	56	59.942085	51.905421	46.800614	68.146046	
9.98	65	88.595371	76.66384	57.902386	110	85.433203
9.99	54	86.005929	76.84973	84.009677	90.203343	68.215584
10.00	54	84.381802	71.593312	57.902386	100.796208	110
10.87	76	65.320986	57.969265	46.961493	67.061175	110
10.88	49	71.190457	62.592327	39.471024	107.634333	110
10.89	50	62.802033	55.553683	50.339095	54.267345	110
10.90	59	64.135352	56.96415	47.397363	81.274789	61.246568
10.91	35	67.342345	59.545054	46.800614	74.47963	90.228998
10.92	62	70.716397	63.411057	46.597222	79.372612	110
10.94	67	93.252673	79.126049	96.633686	79.875808	110
10.95	56	48.641522	45.489865	32.470723	81.024665	110
10.96	67	71.369173	63.027296	49.820775	79.658584	97.797493
10.97	97	86.428064	74.303836	84.250509	87.844925	
10.98	69	81.414979	73.306095	108.759315	85.883987	22.696456
11.89	53	70.131697	61.933904	47.540136	91.511366	55.041085
11.90	68	64.296912	57.859806	64.591697	61.543199	71.118123
11.94	63	38.576536	37.339426	33.435259	74.612045	
11.97	56	64.29794	55.301452	53.185544	71.476925	
11.98	49	67.670121	58.352118	48.14371	90.433713	
12.00	74	32.969174	32.139738	26.585335	77.826452	54.159961
12.87	82	76.94597	68.963848	76.962756	68.430151	110
12.88	47	62.785803	55.331358	43.875017	78.467352	72.88968
12.89	63	78.251752	65.946819	57.902386	82.591518	110
12.90	52	69.487356	62.658448	70.375585	72.260614	53.839798
12.91	70	80.753532	70.962128	69.519658	77.829767	110
12.97	60	81.022191	71.31183	57.783661	92.529239	
12.99	72	87.351478	77.587425	100.669565	85.783579	56.860948
13.00	44	75.006065	66.431308	49.820775	89.200662	76.758448
13.01	86	110	63.986383		110	110
13.88	31	46.96566	43.646168	85.271884	71.073292	26.865002
13.91	34	36.943489	36.339625	31.785887	75.806806	62.259365
13.97	71	78.551116	67.634971	65.837944	84.947456	
14.87	50	37.466094	36.631766	31.376078	80.976785	110
14.88	56	59.064583	53.14914	39.652023	77.936794	110
14.90	37	37.648616	36.630321	46.276467	30.780267	34.723896
14.92	57	91.318582	78.418063	49.820775	110	110

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
14.93	32	25.788203	25.56633	23.358773	44.989611	34.718988
14.98	61	82.718914	72.193808	49.820775	103.617439	102.801349
15.89	81	67.631756	60.115377	46.875	75.169032	83.624252
15.91	51	59.427504	53.646143	37.647728	79.317745	110
15.93	84	74.019104	65.456283	42.335816	110	110
15.98	84	60.182928	54.191013	70.672637	92.378501	27.356333
15.99	62	79.264287	71.319859	74.688386	79.788037	110
16.00	61	86.657667	76.134687	69.468831	91.973224	110
16.91	46	52.198713	48.054449	59.247016	38.78614	102.801349
16.92	86	46.18929	43.703252	36.48422	81.818191	110
16.98	58	63.228433	55.31309	57.902386	58.308109	78.042384
16.99	82	88.717768	80.194142	86.970556	96.932406	56.860948
17.00	35	26.644477	26.383066	26.149225	22.713822	110
17.91	26	35.098749	34.134873	26.949653	43.391062	71.118123
17.97	84	98.21679	84.718932	110	94.428567	93.058396
18.90	27	37.354655	36.420029	35.850331	40.008397	73.18014
18.91	58	69.394989	61.74762	49.820775	80.327541	71.118123
18.97	78	80.413585	70.243723	57.902386	110	55.529984
18.98	67	77.593113	68.475822	51.104142	93.794831	90.228999
18.99	55	86.952045	77.764726	84.967957	81.339661	110
19.00	72	67.185501	61.342409	78.47423	66.8714	31.853069
19.01	67	74.466653	64.699362	47.397363	110	53.106214
19.88	46	77.053874	67.841307	46.800614	82.201442	110
19.90	67	81.962407	72.624579	92.161955	73.482943	92.534908
19.91	41	37.57005	36.900027	31.579788	79.917407	71.118123
19.92	27	45.190165	43.155248	34.538371	73.139047	110
19.94	54	69.834702	60.136751	51.800394	78.26191	110
19.98	85	85.494924	76.817486	79.444823	89.343584	97.797493
19.99	73	86.18432	75.344811	79.544866	110	50.230459
20.03	44	29.0457	28.768812	40.138583	86.707722	20.06874
20.90	29	36.731261	36.081812	35.398844	89.16198	23.445451
20.91	76	50.931595	46.7171	49.505872	60.542365	42.804168
20.92	71	66.283035	57.868224	57.902386	67.017513	88.485251
20.95	62	81.168519	70.482272	110	73.641092	47.44162
20.98	63	39.322984	38.347103	37.778906	43.14244	42.50468
20.99	55	60.170066	51.789979	46.800614	66.867669	89.92337
21.00	71	74.188187	64.642275	49.820775	96.143277	56.007422
21.02	46	101.159059	84.806416	110	95.755548	67.639813
21.90	69	75.184382	66.753247	64.863835	78.161451	110
21.92	25	23.273212	23.150275	23.959276	19.861514	15
21.93	82	35.857649	34.732382	28.771793	62.892576	53.946255
21.94	89	78.352457	68.617696	69.130461	80.485739	110
21.95	50	45.215189	42.646354	36.450498	75.604159	75.016611
21.98	52	69.882387	61.317689	50.339095	85.371761	58.625167

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
21.99	63	55.726642	46.700047	50.339095		70.788214
22.00	57	58.92038	52.173981	110	81.497319	25.701298
22.90	78	80.257742	71.481526	76.385457	87.381958	60.325845
22.91	43	36.840239	35.942746	32.072056	71.805023	34.504516
22.93	73	110	39.502188		110	71.599091
22.94	55	48.210387	44.752053	33.832088	87.160768	110
22.95	41	65.60037	57.039471	43.875017	81.022901	
22.99	27	39.307675	37.917948	45.060875	35.803797	30.596061
23.00	81	60.053618	53.432337	58.328581	69.930973	43.070499
23.88	59	74.312135	66.293796	84.436219	97.3227	29.277988
23.93	76	42.894201	41.203815	35.142115	71.664559	110
23.94	67	73.704261	64.777187	57.902386	79.832315	86.459735
23.99	79	75.617562	66.610096	45.841857	86.723625	110
24.00	73	76.816496	68.881264	110	89.769613	19.756495
24.04	61	110	53.86		110	110
24.88	68	55.782612	48.695451	49.820775	74.281878	42.756561
23.01	80	80.167592	69.115404	57.919072	88.034918	110
25.02	42	79.592543	70.468431	76.385457	79.799696	106.509911
25.91	48	65.442504	56.41204	49.820775	81.555752	56.007422
25.99	67	89.940021	78.381066	104.967141	94.004441	45.189425
26.00	77	82.448819	73.610465	72.138271	92.441404	55.955558
26.91	31	34.401842	33.966049	32.490953	73.390701	31.505613
26.99	74	56.890557	50.821614	56.273005	76.022086	33.566082
27.90	54	88.590748	78.34415	72.704407	110	70.412208
27.91	38	27.599807	27.503192	25.818092	27.687019	54.300555
27.93	39	49.327024	45.645931	37.139193	81.553388	58.625167
27.99	88	76.382489	67.168995	58.182252	81.636382	110
28.90	45	73.475137	65.196595	71.086488	84.441997	42.526567
29.00	39	74.899638	65.540852	50.339095	83.657346	110
29.04	34	33.775186	33.246787	29.376125	68.543214	86.459735
29.93	56	82.556708	71.539243	49.820775	109.50341	75.0282
29.99	61	83.268085	73.122133	79.162294	89.627403	61.216857
30.93	46	48.873265	44.944556	46.800614	49.246579	52.395245
30.99	65	104.825082	87.954345	99.518438	110	68.248198
31.00	48	73.36578	62.859947	57.783661	79.056782	110
31.93	68	48.832786	45.48601	36.859175	66.743011	110
31.99	45	72.342831	64.594206	64.863835	78.83336	70.412208
32.93	73	87.79492	76.943459	99.518438	77.084598	110
32.99	97	92.328458	79.882331	84.25054	95.483287	110
33.99	94	101.539178	84.776376	110	89.978628	-1
34.01	66	96.361966	83.621237	97.15755	98.664306	75.016611
34.93	51	40.219633	38.859375	34.02995	75.959796	45.110368
36.93	55	52.301397	47.25	36.541788	74.655351	110
37.93	62	47.703233	44.16723	40.762612	65.877064	69.564617

ID	Real Age	MLA-All	MLA-Hazard	MLA-Pubis	MLA-Auricular	MLA-Sutures
38.01	70	76.152797	65.6285	71.623032	93.960191	52.395245
38.93	54	76.279129	66.696245	66.822634	78.203073	110
39.01	36	38.132992	36.728696	35.877128	59.36859	25.799997
45.93	73	87.691325	75.3635	50.339095	110	86.459735
48.04	46	110	63.066159		110	110
49.04	64	93.999017	79.636634	91.331165	102.547095	80.722324
60.03	79	92.330251	78.431476	57.902386	110	110
42.05	42	34.661534	34.206455	31.324321	58.370849	51.398102

VITA

Jonathan Daniel Bethard was born on October 10, 1981 in Lynchburg, Virginia. He graduated from Jefferson Forest High School in 1999. That fall he entered the University of Tennessee as a music education major with the hopes of becoming a high school band director. Those plans quickly changed after his first anthropology class after which he changed his major to anthropology. During his time as an undergraduate, Jonathan pursued his anthropological interests under the tutelage of his advisor Dr. Walter Klippel. For two summers during his undergraduate days, Jonathan returned to the Old Dominion for archaeological training at Thomas Jefferson's Poplar Forest. It was this experience that confirmed his desire to pursue anthropology as a profession. In May 2002 Jonathan graduated summa cum laude with his Bachelor of Arts in Anthropology and a minor in applied music.

Jonathan entered graduate school at The University of Tennessee in August 2002 with the goal of earning a Master of Arts in Anthropology. While working towards his MA, Jonathan was fortunate to gain more fieldwork experience in west-central Illinois and north-central Peru. In December 2005 Jonathan was awarded the Master of Arts degree in anthropology.

Since he is a fan of the color orange, Jonathan will remain at the University of Tennessee to pursue his Ph.D. in anthropology.