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A Critical Approach to Ancestry in Forensic Anthropology: An Assessment of Fordisc 3.1 and AncesTrees

By

Carmen Skalic

A Thesis
Submitted to the Faculty of Graduate Studies
through the Department of Sociology, Anthropology, and Criminology
in Partial Fulfillment of the Requirements for
the Degree of Master of Arts
at the University of Windsor

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A Critical Approach to Ancestry in Forensic Anthropology: An Assessment of Fordisc 3.1 and AncesTrees

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September 14th, 2018

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ABSTRACT

Many forensic anthropologists and law enforcement agencies are still using racial categories for identification purposes since it aids in narrowing the search for identifying an individual and also aids the public when a description of an unknown is given in hopes that someone will identify them. Forensic techniques have been developed based on biased race determination methods that do not work. Problems are then created when discussing the topic of race because race can mean many different things to any one individual, especially to anthropologists who cannot find a common methodology to determine “race” within these police investigations. Due to this, the computer software accuracy of AncesTrees and Fordisc used be forensic anthropologists in these investigations has come into question. This thesis explores the use of race within forensic anthropology and criminology (specifically police forces). The results from this thesis show that race is a social construct and promotes racialization for investigators and forensic anthropologists and does not prove to be beneficial in identification investigations.

DEDICATION

To my loving and supportive mother and father – thank you for being there for me throughout my academic journey. Everything that I have accomplished is because of the love and belief that you had in me and for that, I am truly grateful. Without the two of you, none of this would have been possible.

To my amazing brother and sister – thank you for always being an inspiration, even if you were not aware of it. I will forever have two best friends who I will love unconditionally and continue to guide and assist in all your life's adventures.

To my incredible grandparents – thank you for your prayers and wise words to help me realize that I can achieve anything I put my mind to. Your stories and lives have continued to provide me wisdom and guidance and I will always cherish all the lessons you have taught me.

To all those who have been there for me throughout this chapter – thank you for always supporting and encouraging me to get where I am today.

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Introduction

Forensic anthropology is the application of anthropology methods and theory, primarily human skeletal biology, taphonomy, and archaeology in medico-legal investigations. This subfield of physical anthropology provides aid to authorities in investigations that involve human skeletal remains. These cases can include human skeletal remains that have been burnt, decomposed, or completely skeletonized. Regardless the state of the skeletal remains, one of the main goals of the forensic anthropologist is to assist with a preliminary identification by determining a biological profile from the remains. The preliminary identification includes estimating the sex, age, stature, and in some jurisdictions race (more recently referred to as ancestry), which may aid in positive identification. A forensic anthropologist can also assist in reconstructing perimortem events such as any defense wounds prior to time of death, reconstructing a face using specific markers on the skull, assisting local authorities when a piece of bone is found by a civilian to determine if it is human or nonhuman, as well as helping authorities in human rights violations internationally.

The terminology trend in forensic anthropology has been to replace the term "race" with "ancestry" in literature (Albanese & Saunders, 2006). The term "ancestry" relates to a geographical explanation for categorization of humans where as "race" takes a more biological and socially constructed meaning to the population. Therefore, when the term "race" is used in this paper it is in reference to the old and perceived definition of race that is most commonly known within society. When "ancestry" is used, it is used to discuss the new terminology[1] used in forensic anthropology and trying to incorporate concepts of variation associated with geographic origin.

Forensic anthropologists assist with identifying skeletal remains by attempting to answer four main questions of skeletal identification: what is the age at death, sex, stature and race of the unknown (see Buikstra & Ubelkaer, 1999; Albanese, 2013; Albanese et al 2016; Saunders, et al.1995; Ubelaker,

[1] Although the trend in forensic anthropology has been to use "ancestry" in place of "race", the underlying 19th century concepts of human variation have remained the same (Albanese & Saunders, 2006).

2008; Williams et. al., 2005). The forensic anthropologist works closely with law enforcement in order to produce accurate information to come up with a missing persons or use the information to compare to a missing persons list. According to Gill (2001), approximately three-quarters of forensic anthropologists reject the concept of race and constantly battle with the question presented by Sauer "if races don't exist, why are forensic anthropologists so good at identifying them" (1992)? In fact, there is some clear evidence that they are not very good at identifying "them" (Albanese et al 2018).

Traditionally, there have been two major types of approaches to assessing variation using skeletal data. Morphological approaches assess shape variation, and metric approaches use measurements of bones to capture variation. However, as Albanese (2003) has demonstrated the two approaches capture the same variation. Metric data is used because it allows for the efficient systematic testing of methods using large samples. Furthermore, the metric approach is used within two computer programs that are emerging as major tools in forensic anthropology: Fordisc (Ousley & Jantz, 1998; Jantz & Ousley, n.d.) and AncesTrees (Navega et al., 2015).

Fordisc, currently in version 3.1, is the computer program, that is used in Canada and the United States to aid in the estimation of stature, race and sex (Ousley & Jantz, 2013). The program is beginning to be used on a more international scale due to the huge reference sample that the program uses to estimate any of the three concepts through linear discriminant function analysis (see also Elliott & Collard, 2009). The utility of the program has become subject to much debate with some anthropologists (for example see: Elliott & Collard, 2009; Smay & Armalegos, 2000; Navega et al., 2014; Albanese et al 2018) concluding that the program is flawed and should not be used while others, as well as the developers (Ousley & Jantz, 2013) arguing that the system is only flawed because the user is not accurately inputing the measurements into the program.

AncesTrees is a newer computer program that was developed for ancestry estimation using random forest algorithms as a classification technique currently being used by University of Coimbra in

Portugal (Navega et. al., 2015). Since this program is much newer than Fordisc, there is not much research done on the accuracy of the results that are produced. Although the statistical approaches are different than Fordisc, the same reference sample is used in both applications.

The focus of this research is a critical assessment of the use of race estimation in forensic anthropology by testing Fordisc and AncesTrees using skeletal data from a large sample of identified individuals. Thus, by testing both applications it will be possible to address the problems with the race concept within forensic anthropology rather than problems with any one statistical approach. The problematic nature of race in forensic anthropology and policing will be discussed.

Background and Literature Review

Origins of race in forensic anthropology

The main concept of race within anthropology and skeletal biology is influenced by the ***apparent*** biological differences that are filtered through the lens of cultural prejudices (Armelagos & Van Gerven, 2003; Armelagos et. al., 1982; Blakey, 1987; Armelagos et. al., 1982; Blakey, 1987). The roots of race within anthropology were developed in order to describe human variation which seemed to all stemm from the evaluation of craniological differences (Blakey 1987; Armelagos et al., 1982; Armelagos & Van Gerven, 2003). Samuel Morton measured crania from around the world in an attempt to rank races as well as prove that differences within the human species exist outside of the observable phenotypic variation (Gould, 1996). Thus, polygenism[2] was supported and continued to prove that God created many unequal human species instead of just one. This allowed for a hierarchy of beings to be confirmed and it was thought that the reason for these variations was due to migration patterns from the expansion of Caucasians and the exposure to different environmental and cultural factors.

Next came the evolutionist era which had the potential to reevaluate the race concept. Darwin did end the polygenism debate with the increase of scientific discoveries, but instead of changing the concept and potentially discrediting the hierarchy of humans, there was only a shift from an ascent from Adam to an evolution from ape (Gould, 1981). This then allowed genetics to spawn more questions concerning racial differences and traits rather than challenge the race concepts that had already been developed in the social sciences. With genetics came both the phylogenic and genotypic traits that can be inherited by individuals and the quest to understand the non-adaptive traits that went against the genetic-race approach. Therefore, “race-science” (Armelagos & Van Gerven, 2003; Armelagos et. al., 1982; Blakey, 1987) became an exploration into culture history in which the origin of the social concept of race began.

[2] Polygeny is theory that humans evolved from several independent ancestors.

Although race is constantly argued to be social construct by social scientists, it is still continuing to be used in a biostatistical analysis when forensic anthropologists are trying to identify an individual's "race taxonomy" (for example, Gill, 1998). Anthropologists are still using craniofacial methods and techniques that have been developed to describe human variation through observations of the human skull.

Estimating Race from Cranial Variation

Variation within the skull has been used in an attempt to classify individuals into different groups. Cranial length and width measurements were the first correlations developed and opened more doors for many other anthropologists to publish more correlations using craniometric data (for example, Lee, 1901; Fawcett, 1902; MacDonnell, 1901 as summarized by Armelagos, Carlson & Van Gerven, 1982). These observed differences were accredited to the assumed genetic differences resulting in differences amongst the human species. All of these correlations were ***presumed*** by anthropologists to be significant when it came to proving race and were carried on throughout the 20th century.

Again, the difference in size and shape were used by anthropologists to develop techniques that could be used in order to determine the race of an individual through statistics and measurements which seemed to be consistent among groups of individuals. However, the biological significance of these differences were not of importance to anthropologists and others in the social sciences which lead the questioning of the influence of skeletal biology to be pushed aside. This provided the help that was needed to establish race and differences between skeletal collections into the discipline of anthropology as well as the social sciences. This is clear in W.W. Howell's collection of craniofacial growth and development; he stated that his research was clearly focused on the taxonomy of race in humans and did not proceed to understand the reasons or causes of the skeletal differences (Howells, 1973). Anthropologists were just using phenotypic variation seen on the skeleton to help defend the notion that people of the same race had the same skeletal anatomy.

Accurate ancestry estimation has also been considered an important necessity when a forensic anthropologist is attempting to estimate other concepts that are necessary for building a biological profile: ancestry is believed to help with the accuracy of estimating sex, stature and age. However, there has been much research done on this concept which has resulted in many critiques of the methods used and how necessary ancestry/race is. This has led to what Sauer (1992) has termed as the "race/non-race debate" (see also Brace 1995; Armelagos & Salzman, 1976; Ginter, 2001; Kennedy, 1995; Blakey, 1987; Keita & Kittles, 1997; Ousley et al., 2018). This debate stems from the problem of anthropologists not fully understanding the definition of the term "race" and how they are to perceive the concept. Although many anthropologists have rejected the biological model of race, the concept itself is still socially used within society and continues to be a focus of forensic identification and research. Research already done on the technology and methodology techniques used by anthropologists has created a race/non-race debate within the realm of physical anthropology, but has not made any impact when the concept of race arises within a forensic anthropology/ police investigation (See: Albanese, 2013; L'Abbé et. al., 2013; Liebenberg et. al., 2015) The concept still remains "stuck" with the same categories of classification for human variation and little research has been done on changing these techniques (Saunders & Albanese, 2006).

Estimating Race in Forensic Contexts in the Early 21st Century

As a discipline of the social sciences, anthropology has had to continuously develop to keep up with the introduction of new applications and techniques that can assist in answering the question of who the individual was through the use of the skeleton. With new technology and biocultural approaches becoming more common, physical anthropology began to be both interdisciplinary and intradisciplinary in committing to an adaptive and evolutionary perspective. These perspectives would then allow the discipline to become cross-cultural when it came to understanding adaptation. However, the varying degrees of new technologies combined with old methodologies, the concept of "new physical anthropology" has become lost (Armalegos & Van Gerven, 2003). This is because the new techniques and methodologies that are continuously being developed today which bring about new questions. This means that these new developments fail to address the old questions that the old methodologies brought about. So, although many anthropologists reject the concept of race, they continue to answer these new questions which does not allow for the discipline to move forward in a positive direction (which would then be the new physical anthropology) it, instead, brings the discipline back to where it once was. The issue of how ancestry is perceived within the discipline is no exception: the idea of race is socially constructed throughout society and is not a fixed entity so race, as a concept or idea, is difficult to determine. But, some anthropologists (see Albanese, 2018; Armalegos & Goodman, 1998; Brace, 1995) have developed alternative discussions and research that uses biological and genetic data in order to study patterns of human variation.

The first issue that needs to be addressed by anthropologists is the vague and baseless definition of race that is being used within anthropology as well as policing. Therefore, the social construction of race will be used throughout this paper in order to critique how the concept of race is currently being used in criminology and anthropology, specifically within police investigations and forensic anthropology cases.

The issue of race has been debated amongst anthropologists resulting in many anthropologists (see Albanese and Saunders 2006 and Armelagos and Goodman, 1998) denouncing the race concept all together. However, the problem is that although the anthropology community is beginning to reject the concept of race, much of the general public still believes in the existence of the bounded racial groups that have been created (see Appiah, 2016). By this I mean that the ways in which individuals are categorized can come from self-defining individuals or groups, through socially defined and accepted categories within society or a combination of both of these methods. Society has created and adopted the social norms associated with different race categories that are seen within society. For example, a person is placed into such a category as soon as they are born, not necessarily documented on a piece of paper but instead due to the perceived traits that the individual possess. One of these traits is typically the colour of one's skin which is directly associated with race. Race is, within the social sciences, still a concept that easily influences and can be influenced by society (Armelagos & Goodman, 2008; Albanese & Saunders, 2006).

Racial classifications can be used as a cultural tool that can inform us more about society (Armelagos & Goodman, 2008). Social class in Brazil is an example of social race and the classification of hierarchies (Harris, 1964). Two individuals can have same phenotypic traits, but the individual that has more money "whitens" their status within society. Harris (1964) also describes the principle of hypodescent. This means that an individual that has "mixed race" characteristics will always be associated with the race that possesses the lower economic status regardless of "racial percentage". Therefore, differences between groups and within groups are influenced by social, economic and political factors.

Thus, the smokescreen of globalization and the link to race and crime has become a natural discourse in today's society (Lianos, 2003). For example, stereotyping can play a major role when police, prosecuting attorneys, etc. discuss characteristics of an individual of interest or to identify a missing person for law enforcement purposes. The topic of race comes up whether asked directly or not due to the social constructionism (Lippert & Stenson, 2010; Valverde, 2010). This idea is also in line with the shaping of the public's conception of social problems and their reactions (Lippert & Stenson, 2010; Donzelot, J.,1991; Foucault, 1999). This form of social control theory, the idea that an individual can be labelled and/or categorized, has allowed for institutions to capitalize on racial profiling and allowing the public to believe that race and the law intertwine somehow. These factors have influenced the public's belief that different races exist outside and within their own society. These notions are reinforced through government censuses and the mass media, and have been developed through exaggerated and incorrectly interpreted work done by forensic anthropologists.

A forensic anthropologist would use the classification that FORDISC and/or AncesTrees produces to identify the individual's race when being involved in an investigation. These classifications that are constructed to follow the underlying assumptions of social and bureaucratic race. Therefore, these concepts are deemed to be real and can have an impact on the identification process of an individual (Saunders & Albanese, 2006). Again, in the United States, forensic anthropologists are asked to assess ancestry in respect to five categories of "White," "Black," "Asian," "Native American," and "Hispanic." US law enforcement uses these categories in order to assign an unknown individual into a racial category in order to narrow down the possibilities of the remains (Byers, 2011). Therefore, Armelagos and Goodman (2008) argue that racial classifications are social constructs that use varying biological traits as their classifications. This can create issues when addressing the race debate within a forensic context: the notion of race does not exist but there is still the need to classify individuals into taxonomic groupings for society to support human variation.

Forensic methods have also been heavily influenced by the social and biological constructs of society. The methods have been developed in order to determine sex, age, stature and race/ancestry of modern skeletal remains using anatomy school human cadavers whose age, sex, and "race" were documented (Thompson, 1982). The problem here is that the methodologies that were developed were created through biases since all of the cadavers' information was known, thus similarities that seem to be present in skeletons of the same race only seem prominent because they were seen in the already determined racial category. An example of this is the use of the skull when an anthropologist is trying to determine race (Bass, 2005). Using the skull has resulted in both morphological (shape) and metric techniques to address the question of race. Using discrete traits such as the shape of the nasal sill, are commonly used in forensic anthropology. However, these techniques have been called into question by many anthropologists regarding the reproducibility and high levels of inter-observer error, again circling back to the biases that were present during the development of the techniques. Due to this unreliability of morphological techniques and the perceived reliability and objectivity of metric methods, anthropologists who still are using or accept the race method use the latter. Because of the wide acceptance of the metric method, statistical methods and computer technology have been developed in order to manipulate data sets (Giles & Elliott, 1962; Jantz & Ousely, 2013; Navega et. al, 2015). This allowed for computer software applications to be designed in order to determine race and have become popular amongst forensic anthropologists. Furthermore, the line between the social and biological has become blurred and the racial techniques and methodologies used by forensic anthropologists continue to have both of these assumptions ingrained in both the methods and computer technology that is used today.

Fordisc

Fordisc is a computer program used in North America when a biological profile is needed, specifically when it comes to determining sex and race. Fordisc 3.1 uses discriminant function analysis (DFA) which is a variant of linear regression that has been use for predictive purposes in forensic anthropology since the 1950s (Albanese, 2003; Jantz & Ousley, 2013). Once an equation is calculated, it can be used to allocate an unknown to a given group and has been used to estimate sex and/or race/ancestry (Albanese 2003). Thus, the known reference groups form the foundation for the classification of new, unknown individuals. Since DFA is not a probabilistic approach and it will force an allocation into one of the groups even if the unknown is a member of none of those groups, two statistics are calculated *post hoc* to assess the likelihood of a correct allocation to a given group (Albanese et al 2018; Van Vark, 1992). The first is the posterior probability, which is the probability of the membership of the unknown individual into each group based on the relative distances to each group centroid and add up to the sum of one. In other words, the posterior probability evaluates the likelihood that the individual belongs to each group under the assumption that the unknown actually belongs to one of the groups considered within the function (Tatsuoka, 1971; Van Vark, 1992). The second statistic that Fordisc uses is the typicality probability, which is calculated three different ways. This statistic provides a p-value between 0 and 1 and is intended to deal with the situation where the unknown belongs to none of the groups considered. Any typicality probability that is above 0.05 is accepted since there is not enough grounds to reject the possibility that the unknown comes from a particular group; it may indicate that the unknown belongs to several or none of the groups that are in question (Tatsuoka, 1971; Jantz & Ousley, 2013). Thus, the typicality probability is important in evaluating the "fit" of an individual to a classification. For example, if a cranium is classified as a "White Male" you could see a posterior probability of 0.452 and a typicality probability possibly laying between 0.956 to 0.960.

A reference sample of identified individuals is required to calculate a discriminant function. Fordisc calculates a new equation for each analysis based on which measurements are input into the application. The user of the application must also select from one of two reference samples that Fordisc 3.1 uses to calculate the discriminant function: the Forensic Anthropology Database (FDB) and the Howells database (Ousley and Jantz, 2013).

The FDB was started in 1984 after concerns about the usefulness of the Hamann-Todd and Terry collections arose (Ousley and Jantz, 1998). The Robert J. Terry Anatomical Skeletal Collection is a collection of 1728 human skeletons with recorded pre-mortem information including name, sex, age, race, and cause and date of death (Albanese & Hunt, 2005). It is currently housed in the Smithsonian Institution's National Museum of Natural History in the Department of Anthropology. The Hamann-Todd Collection is a collection of approximately 3,000 human skeletal remains that were collected between 1912 and 1938 (Kern, 2006, Albanese & Hunt, 2005).

Although both collections were, and continue to be useful in skeletal biology, there is still concern about the extent to which they represent human populations from other "gene pools, geographic areas, and time periods" (Katzenburg & Saunders, 2008). Since the birth dates for both collections range from the 1850s to the 1900s, the samples have been described as inappropriate due to the biases that were created from these collections (Ousley and Jantz 1998). The concept for a new databank was seen as needed since forensic anthropology, as a discipline, grew throughout North America. With a new databank, forensic anthropologists would be able to gather noninvasive metric data, complete a standardized form, and submit it to the Forensic Anthropology Center at the University of Tennessee where Richard Jantz and Stephen Ousley (1998; 2013) worked and developed on the Fordisc program.

The FDB has approximately 3400 cases and continues to use modern cases to keep up with the continuously developing population variation of North America (Ousley & Jantz, 2013). For various reasons (lack of positive identification, missing data, etc) not all of the 3400 cases in the FDB are used as the reference sample in Fordisc is less than about 900 (Jantz & Ousely, 2013). Furthermore, despite the perceived limitations of anatomical collections, a significant portion of the reference sample used in Fordisc consists of Terry Collection and Hamann-Todd Collection individuals born after 1900 because these individuals are more similar to the earlier individuals that were entered into the FDB born in the 20th century (Ousley & Jantz, 1998).

There are 13 population samples that were created using the FDB which include: American Black males and females, American Indian males and females, American White males and females, Chinese males, Guatemalan males, Hispanic males and females, Japanese males and females, and Vietnamese males (Appendix F). According to Jantz & Ousely (2013) some unknown individuals were assigned sex and race using soft tissue features. This could create some issues since these individuals could be wrongly identified in either category resulting in incorrect data being used for any forensic anthropologist who needs to identify an individual who may have similar measurements as those that were assigned either a sex or race. Another example where accuracy of Fordisc is discussed is when Thomas et al. (2017) looked at cases that were already accurately determined and did not include cases that had indicated an "undetermined" estimation of ancestry. By doing this, the authors were not demonstrating a real-world case scenario. They, instead, used estimations that were potentially biased or misconstrued by the anthropologist. Therefore, their results are not accurate and do not portray real-life scenarios. They address this issue by stating that any possible multiple ancestries were still considered accurate because "it did not falsely limit the pool of possible missing persons" (2017, pg. 972). By this, the authors assume that because the program and methods do not accommodate for multiple ancestries there was no need for undetermined cases. However, this does not accurately address real-world cases since ancestry determination techniques are not straightforward.

The second reference sample that can be selected in Fordisc is Howell's (1973) database of craniometric variables from 18 groups from similar measurements between the skeletal collections. Howells (1989) used archaeological samples since he studied human cranial variation and how they relate to geography. So he attempted to enhance comparability of both size and shape by gathering measurements of all individuals in the collections based on mean and standard deviations. Howells then created a list of 65 different cranial measurements which include both the name and the abbreviation of the measurement. He also came up with 28 categories that include: Ainu, Andaman Island, Anyang, Arikara, Atayla, Australia, Berg, Buriat, Bushman, Dogon, Easter Island, Egypt, Eskimo, Guam, Hainan, Mokapu, Moriori, Norse, North Japan, Peru, Philippines, Santa Cruz, South Japan, Tasmania, Teita, Tolai, Zalavar, and Zulu (Appendix F). His collection process for these groups were not random, but instead he carefully selected crania that he considered to be typical of each group (Howells, 1995). Howells justified his selection process by corroborating his estimates with previous research that had been done on the same remains. Howells did not include crania that were 'morphologically unusual for the population as a whole' (Howells, 1989, p.89) biasing the reference samples to create artificially homogenous groups that did not sample the actual range of variation in any given group. Since classification using discriminant function analysis is inversely related to the degree of overlap among groups (Elliott & Collard, 2009) all results are exaggerated. That is why Fordisc uses Howells' reference sample as a secondary option and uses his measurements in order to produce a race estimate and is recommended to be used for older specimens due the collection being composed of archaeological specimen.

Fordisc has been researched on the accuracy level on the sex estimation, race or a combination of both (Kosiba 2000; Leathers et al., 2002; Ubelaker et al., 2002; Freid et al., 2005; Williams et al., 2005; Naar et al., 2006; Hubbe & Neves 2007; Keita 2007; Ousley et al., 2009; Albanese et al., 2018).

Williams et al. (2005) found that Fordisc is flawed since the program misclassified an overwhelming number of crania due to the fact that statistically defined populations cannot adequately represent the biological variations that characterizes individuals within and outside of their classification (pg. 343).

AncesTrees

AncesTrees is a computer program that relies on algorithms and random forest methods to classify human skulls into their "assigned" race (Navega et. al., 2015). AncesTrees can be accessed through the University of Coimbra's website and will be used for this research. Random forest algorithm, simply put, is an ensemble earning method that constructs multiple decision trees at the beginning and generates the most likely output or mean prediction for an individual (Navega et. al., 2015).

The database, just like Fordisc's secondary collection, is comprised of Howell's 30 craniometric variables that are associated with his primary ancestral groups or clusters. Like Fordisc, these craniometric variables describe overall cranial morphology such as the length, height and width along with specific regions of the skull and can be easily collected using sliding calipers (Navega et. al., 2015). However, the random forest method used in AncesTrees is a machine learning technique that allows for opposing data approaches to be integrated into a large database within a computer.

AncesTrees runs in a web browser and the user inputs the measurements that were taken from a skull and selects which ancestral groups should be included when the data are run. The results of the algorithm are then outputted in a separate table showing probabilities of the membership to the ancestral groups that were selected (Navega et al., 2015).

Methodology

The materials that will be used for this research are: the Fordisc computer program, the AncesTrees computer program, and cranial measurements from 108 individuals. These data were previously collected by Dr. John Albanese (See Albanese, 2003, 2006, 2013). There are 65 individuals from the Terry Collection, 40 individuals from the Coimbra Collection[3] and two archaeological specimens. The first archaeological case is a late Archaic First Nation[4] cranium to approximately 3000-3500 BP, and is included to determine if Fordisc and AncesTrees are able to identify the case as not forensically relevant. Meanwhile, the second archaeological case is a high-quality cast of an artificially deformed Peruvian cranium, which is included to test the ability of Fordisc and AncesTrees to allocate a sample that may not fit any "normal" race category because of intentional cultural alterations made to the skull.

An excel spreadsheet was created with randomly assigned specimen numbers by Dr. John Albanese and the analysis was done blind by the author (see Appendix B). The cranial measurements that were used in the analysis are as follows: maximum cranial length, maximum cranial breadth, bizygomatic breath, basion-bregma height, cranial base length, basion-prosthion length, maxilla-aveolar breadth, upper facial height, and minimum frontal breadth (Appendix A).

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[3]The Coimbra Identified Skeletal Collection is a collection of 505 identified human skeletons that mainly consist of skeletal remains that were unclaimed during a large cemetery excavation in Coimbra, Portugal (Coqueugniot & Weaver, 2007).

[4] These remains were analyzed with permission of the Walpole Island First Nation and have since been repatriated.

AncesTrees

AncesTrees was used first because this program is not as widely known in forensic anthropology as Fordisc is and seemed to be more user friendly. The "Craniometric Analysis" (University of Coimbra, 2018) page had all 30 of Howell's measurements available for the user to input the necessary measurements (See Appendix C). However, as mentioned above, only nine measurements were taken by Dr. John Albanese and those would be the only measurements used. There are no published guidelines for the minimum number of measurements to use and in which combinations. For this study the cranial measurements were selected because they are less likely to be affected by trauma and postmortem modification, and thus could be collected in a wide range of realistic cases when a complete skull is not recovered.

All twelve biogeographic ancestry codes were used as well as the pre-set algorithms for the tournament forests that implements an elimination style "tournament" where the least likely ancestral group is discarded until two groups remain. This means that the program will cluster Howells' race categories into nine and find the most approximate category for the unknown specimen. The p-value, classification, group membership, accuracy level, and process of elimination will be recorded. The process of elimination is simply which group category was eliminated during each random forest trial.

Once the data were input, the results were collected. This was done for all 108 cases and compiled in a spreadsheet that included: the primary group; the group membership percentage; and the p-value; the racial group that was the next likely to match the measurements; the group membership percentage; and the p-value. After the first and second groups were entered, the next ten columns were the "Elimination Tournaments" (University of Coimbra, 2018). Each cluster was eliminated by rounds (1-10) while AncesTrees was predicting the top two ancestry. These eliminated clusters were also recorded in order to see at which round each category was eliminated (See Appendix E).

Fordisc – Howells Data

Each unknown individual's measurements were inputted into Fordisc – Howell's data - and all reference group samples were checked off. The data from Dr. Albanese's cases were entered, one case at a time and processed to get the results (see Appendix D). This was done on all 108 unknown cases.

Using the same data collection excel document as the AncesTrees data, but creating another sheet for Fordisc, data collection using Howell's data was made having the same first column using the same ID number that were on the original excel spreadsheet provided by Dr Albanese followed by the first reference group that was given. This was considered to be the most likely categorization of the unidentified individual, which is indicated by asterisks. The Mahalanobis distance from the unknown to each reference group is also given, along with the posterior and typicality probabilities.

The top two reference group's data was collected on the excel spreadsheet including all probabilities and the Mahalanobis distance. The reason for collecting only the top two reference groups is because AncesTrees gives their top two group memberships with their probabilities so in order to compare the results only the top two were needed from Fordisc as well (see Appendix E).

Fordisc – FDB Database

When it came to using the FDB, all 108 of the unknown cases had already been analyzed (see Albanese et al., 2018; Dagdag & Albanese, 2015) using the same procedure as with the Howell's database. These 108 cases were also done blindly when using Fordisc, and all reference group samples were checked off including all males and females and when using Fordisc (See Appendix D).

Since this research was already conducted by Dagdag & Albanese (2015), the Mahalanobis distance, the posterior probability as well as the typicality probabilities were already collected for all 13 groups that the FDB uses. The results from each individual's data were collected on the results excel spreadsheet that was created that already contained the results from AncesTrees and Fordisc – Howells'. These results were also compared and scored from the known biological profile and discussed below.

After the all the data were collected using both Fordisc and AncesTrees, the results were compared to their documented biological profiles and scored either zero for not possible and one for possibly being from that group. What was considered to be possibly correct were any individuals that fell into the social norms of "White" and "Black." This means that the geographical locations that are associated with majority of their populations considered to be "White" and/or "Black" scored as a one. All other ancestral categories were scored as zero. What was considered "possible" when using AncesTrees was any case that resulted in the category of: North America, Northern and Central Europe, Sub-Saharan Africa, Australia and Melanesia and South Western Europe. For Fordisc (Howells) the categories were: Siberia, Hungary, California, Norway, the Chatham Islands, Mali, South Africa, and Kenya (See Appendix F). When using FDB the "correct" classification categories were: American Blacks and Whites (Appendix F). All other categories for all three software systems were considered not possible.

Results

The allocation accuracy was determined for all three trials once the scoring of each of the 107 cases was done. It was found that AncesTrees had a 37% accuracy for their first group membership and 40.7% accuracy for the second group membership. Fordisc, using Howell's data had a 36.1% accuracy for their first reference group and 39.8% respectfully. For Fordisc using the forensic databank data, there was an all around accuracy of 47.6% (Albanese et al., 2018). That meant that AncesTrees was wrong 62.9% of the time for the first group and 59.3% for the second. Fordisc - Howell's data - had an error of 62% for the first classification and 58.3% for the second, and FDB was wrong 52.4% of the time. The results are shown in Tables 1, 2 and 3 (Appendix E).

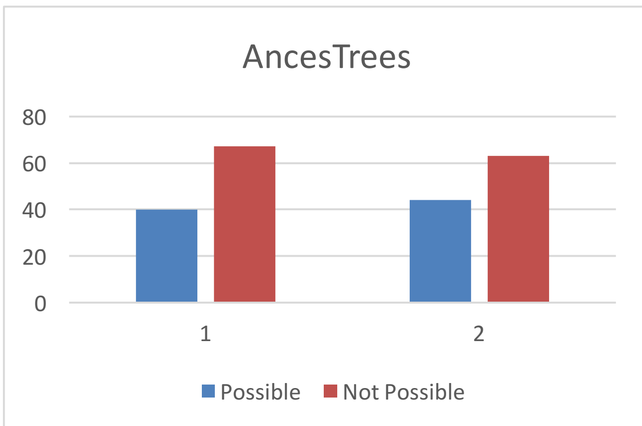

Figure 1: AncesTrees Number of Possible and Not Possible Race Prediction

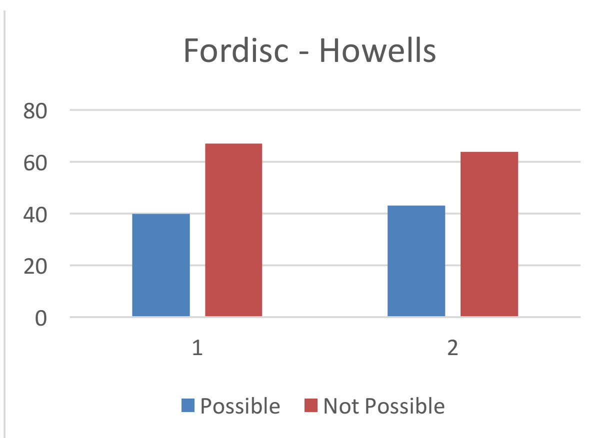

Figure 2: Fordisc using Howell's Data of Possible and Not Possible Race Prediction

Discussion

The overall results obtained in this research show that the systems are not as accurate as what the developers and other research has found (see Ousley & Jantz, 2013; Navega et al., 2015; Freid et al., 1991Elliott & Collard, 2013; Fawcett & Lee, 2009; Lienburg et al, 2015. The results and research also shows that these programs cannot be used in a non-biased way; the user is forced into using the underlying assumptions of race when comparing the results to an unknown individual in a forensic investigation.

As shown in the results, all three programs had over 50 percent inaccuracies; there was no better program than the other. This is important information because Fordisc and discriminant function analysis are described as useful tools for determining ancestry despite cultural, historical and environmental differences between individuals (see L'Abee et. al., 2013). This seemed to also be the case in the literature in regards to random forest sampling. Navega et. al. (2015) state that using a random forest algorithm in forensic cases, the system will find the best hypothesis that suits the specific scenario (case). However, the results here say otherwise.

Since the Terry and Coimbra collections were established in the 1900's and contained either white or black males/females they created limitations to the race categories that the results could be assigned to. These collections, were and continue to be useful for anthropologists the lack of variation within these collections prove to be more biased and pushes for today's research to continue on the collection's biased identified individuals.

Again, these collections were only composed of "white" or "black" individuals because those social groups, at that time, were the most dominant in North America and Portugal (Western Europe). Due to the limitations that are seen within anthropological collections these racial categories became the norm within criminology (policing and forensics) when it came to identifying unknown individuals in unknown cases. These identification techniques have continuously been used within these professions even though societies today (such as the United States) are ethnically diverse: the issue of "black" and "white" is still around. Matthews (2009) states that this is a monochromatic criminology and finds that the criminological literature done within the police forces make identification either "black" or "white" and is slowly incorporating the "hispanic" categorization since it is the second largest ethnic group within the United States (see Matthews, 2009). While conducting this research, it had become obvious that when analyzing the results and determining whether they fell within the "white" or "black" categories meant that racial stereotyping was necessary. Due to the necessary stereotyping, the unknown cases could only result in being possible or not possible of being correct. This meant that any categorization that lay outside the societies conventional definition of where "white" and "black" individuals geographically populate was considered not possible. So, the "possible" categorization, in itself, forces stereotyping and racialization. Race, as shown, has failed to describe any form of variation, but instead types individuals which supports existing structures of power within the police force creating racial stereotyping when it comes to identification practices (Armelagos and Goodman, 1998:259).

As mentioned above, forensic anthropologists are typically the ones that use specialized computer programs, such as FORDISC and AncesTrees in order to assist law enforcement to create a profile of an unknown individual. However, the use of these programs as well as the use of the morphological and metric techniques used to develop the programs have created a problem for the forensic anthropologist (Saunders & Albanese, 2006). Although almost all physical and biological anthropologists agree that distinct differences in race do not exist and classification is nearly impossible, many still believe that for forensic contexts this dilemma is not one to consider when trying to develop a profile of an unknown individual. On the other hand, many think that the methodology is still so flawed that it yields more false information than positive (Iscan & Steyn, 2013).

For example, Canadian anthropologists and law enforcement use two main categories for identification of unknown remains: White or non-white. These two racial categories do not allow for much help in identifying an unknown individual since Canada is one of the largest countries for immigration (Saunders & Albanese, 2006). Forensic anthropologists are encouraged to continue to use these types of categorization to identify the individual since the discourse of race is still very prominent within the realm of law enforcement and criminology.

When looking at the two archaeological cases, AncesTrees and Fordisc (Howell's) should have had a better accuracy percentage than what the results showed. Howell's collection is comprised of archaeological specimens from different parts of the world. This unique feature should have given both programs an advantage when attempting to determine the two specimens' race, however this did not prove to be true.

In the case of the Late Archaic cranium, when looking at AncesTrees the results showed that it came from South Western Europe, and for the second grouping it suggested that the individual was from East Asia. Fordisc, using Howell's data, resulted in inaccurate results with typicality probabilities that suggest the individual may belong to the Asian race (ANY and HAI [see Table 5]). The FDB suggests that it is likely belonging to the Americas which is possible, however it is a very vague description and does not offer a very accurate prediction.

The Peruvian cranium with artificial deformation was classified from AncesTrees as an individual from South Western Europe (group one) and East Asia (group two) which is not correct classification. For a closer and accurate prediction at least one of the two groups should have resulted in South America as a classification since Howell's data contains measurements from this region. On the other hand, Fordisc using Howell's data did have a typicality of 0.143 for the second possible classification group as PER (see Table 5). However, the top classification suggested the individual came from New Britain with a typicality score 0.301. FDB resulted in low typicality scores of less than 0.05, which generally indicates that it may be unlikely that the sample belongs in the categories represented in the FDB.

The misclassified allocations of these two special cases suggests that Fordisc or AncesTrees may not be a useful tool when examining unknown remains because they are unable to distinguish forensic cases apart from archaeological cases. In investigation cases where the remains are yet to be identified all three program software will more likely produce inaccurate results which could lead the investigation in a completely wrong direction.

Conclusion

Many forensic anthropologists and law enforcement agencies are still using racial categories for identification purposes since it aids in narrowing the search for identifying an individual and also aids the public when a description of an unknown is given in hopes that someone will identify them. The results show that the computer programs that are used in these identification investigations promote racial stereotyping because they contain vague definitions for each racial group forcing these individuals to condone these classifications.

This results in the definition and description of what race is and how it is can be perceived within the discipline as well as in society is becoming even more complicated. This is because we, as a society, still have a poor understanding of what actual human variation is and that this variation does not have to involve race determination. Therefore, no matter the push within forensic anthropology to reject the concept of race law enforcement, society and the computer programs used in investigations force the forensic anthropologist into using the race concept. By doing this, the forensic anthropologist is also forced to then become racist and adopt societies stereotyping in order to provide an answer to what the race of the unknown was.

The results from this thesis will hopefully help with others who have questioned these programs and the category of race itself in conducting their own research on this topic. It can also allow for more research to be done to look into the usefulness of these computer programs in an identification investigation. Finally, these results can also develop new research (through a more criminological approach) into police training and techniques when it comes to the definition and concept of race in law enforcement agencies.

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Appendix A: Table of Cranial Measurements Used

Maximum cranial length	The distance of Glabella from opisthocranion in the mid-sagittal plane in a straight line; measured with spreading caliper
Maximum cranial breadth	The maximum width of the skull perpendicular to the mid-sagittal plane wherever it is located with the exception of the inferior temporal line and the immediate area surround the latter; measured with spreading caliper
Bizygomatic breadth	The direct distance between both zygia located at their most lateral points of the zygomatic arches; measured with sliding caliper
Basion-bregma height	The direct distance from the lowest point on the anterior margin of the foramen magnum, basion, to bregma; measured with spreading caliper
Cranial base length	The direct distance from nasion to basion; measured with spreading caliper
Basion-prosthion length	The direct distance from basion to prosthion; measured with spreading caliper or sliding caliper
Maxillo-alveolar breadth	The maximum breadth across the alveolar borders of the maxilla measured on the lateral surfaces at the location of the second maxillary molars; measured with spreading calipe
Upper facial height	The direct distance from nasion to prosthion; measured with sliding caliper
Minimum frontal breadth	The direct distance between the two frontotemporale; measured with sliding caliper

Figure 3: Description of standard osteological measurements (Moore-Janses, Ousley & Jantz, 1994)

Appendix B: Excel Spreadsheet with Specimen ID and Cranial Measurements

	A	B	C	D	E	F	G	H	I
1	ID	MAX CRANIAL LENGTH (G-OP)(GOL	MAX CRANIAL BREADTH (EU-EU)(XCB	ZYGOMATIC BREADTH (ZY-ZY)(ZYB	BASION-BREGMA (BA-B) (SKULL HEIGHT)(bbh	CRANIAL BASE LENGTH (BA-N)(BNL	BASION-PROSTHION (BA-PR)(BPL	MAXILLO-ALVEOLAR (ECM-ECM)(MAB	UPPER FACIAL HEIGHT (N-PR)(NPH
2	12	180	156	140	130	98	100	56	79
3	50	183	144	132	139	104	99	62	70
4	58	178	131	123	131	101	101	62	74
5	196	165	132	121	115	80	78	66	76
6	239	173	132	118	123	94	92	57	65
7	254	190	138	123	136	103	97	60	63
8	255	178	143	127	127	94	96	65	64
9	265	174	139	126	136	102	99	65	67
10	305	185	137	129	132	102	102	74	76
11	326	180	137	125	132	95	97	64	76
12	426	193	133	128	144	104	96	65	74
13	472	176	137	124	131	96	94	56	64
14	633	184	134	121	137	98	89	55	70
15	649	181	130	122	133	97	87	58	60
16	704	197	132	128	139	109	99	63	77
17	732	182	129	120	125	100	101	64	65
18	766	197	138	130	137	104	105	64	79
19	812	177	151	126	129	98	95	58	77
20	1045	191	145	130	134	97	94	61	71
21	1050	182	145	129	125	102	107	64	66
22	1056	181	141	129	122	97	95	61	71
23	1069	182	132	120	127	99	89	50	65
24	1086	175	131	119	121	95	98	61	69
25	1108	183	139	127	136	101	99	63	74
26	1149	178	137	115	126	94	91	60	70
27	1153	181	131	125	125	102	96	64	72
28	1154	194	140	143	136	110	118	72	83
29	1199	187	139	129	143	106	91	58	78
30	1223	190	131	130	136	108	107	67	75
31	1229	185	131	125	127	100	102	64	70
32	1315	185	132	128	129	96	101	71	72
33	1467	177	136	133	129	104	111	67	83
34	1523	176	126	116	130	95	94	60	81
35	1559	185	143	126	140	103	93	61	75
36	1587	187	141	125	142	105	103	71	74
37	1617	194	136	130	136	107	103	62	74
38	1655	179	135	137	127	97	102	69	77
39	1687	182	134	123	130	97	94	56	64
40	1708	182	137	124	134	96	97	70	68
41	1714	187	144	130	148	106	96	62	80
42	1715	181	138	129	135	100	94	61	70
43	1725	188	137	132	135	98	92	56	72
44	1730	171	127	118	129	98	103	69	68
45	1751	181	135	126	121	99	101	64	64
46	1826	180	134	129	133	99	98	68	78
47	1835	183	136	127	128	101	97	61	63
48	1869	188	145	129	125	99	101	63	79
49	1874	191	136	137	139	110	117	73	71
50	1887	188	137	135	132	102	95	64	65
51	2040	178	137	130	133	100	102	71	71
52	2058	163	126	115	124	93	91	55	64
53	2160	186	140	129	139	104	110	66	69
54	2172	186	135	132	128	100	103	63	65
55	2200	182	141	126	129	96	100	70	70
56	2238	180	133	123	126	99	96	62	65
57	2295	195	148	134	133	105	102	67	75
58	2298	184	127	115	125	101	102	64	70

Figure 4: Excel spreadsheet provided by Dr. John Albanese

Appendix C: AncesTrees Computer Program

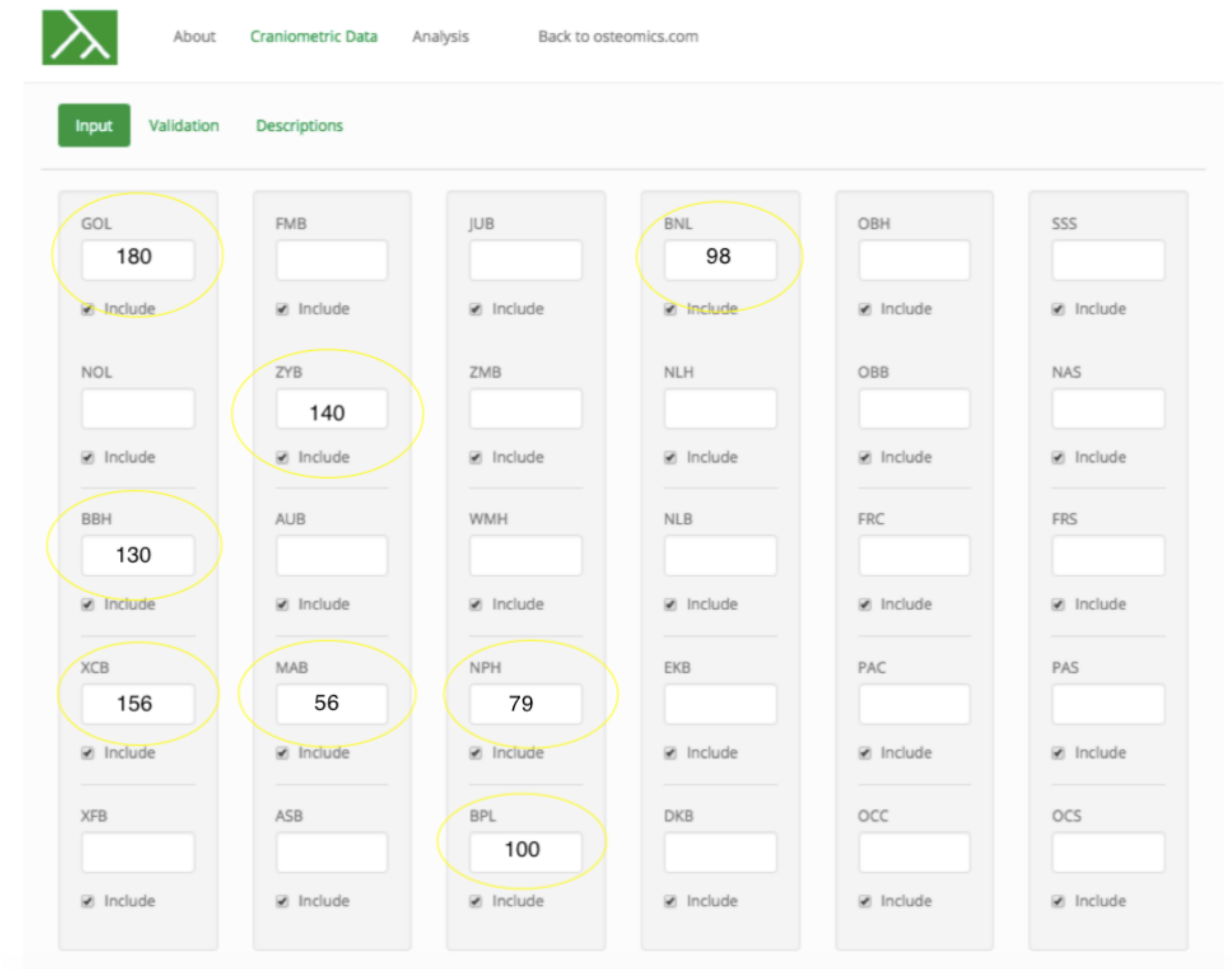

Figure 5: Howell's 30 Measurements used in AncesTrees and the measurements used (University of Coimbra, 2018)

Appendix D: Fordisc Computer Program

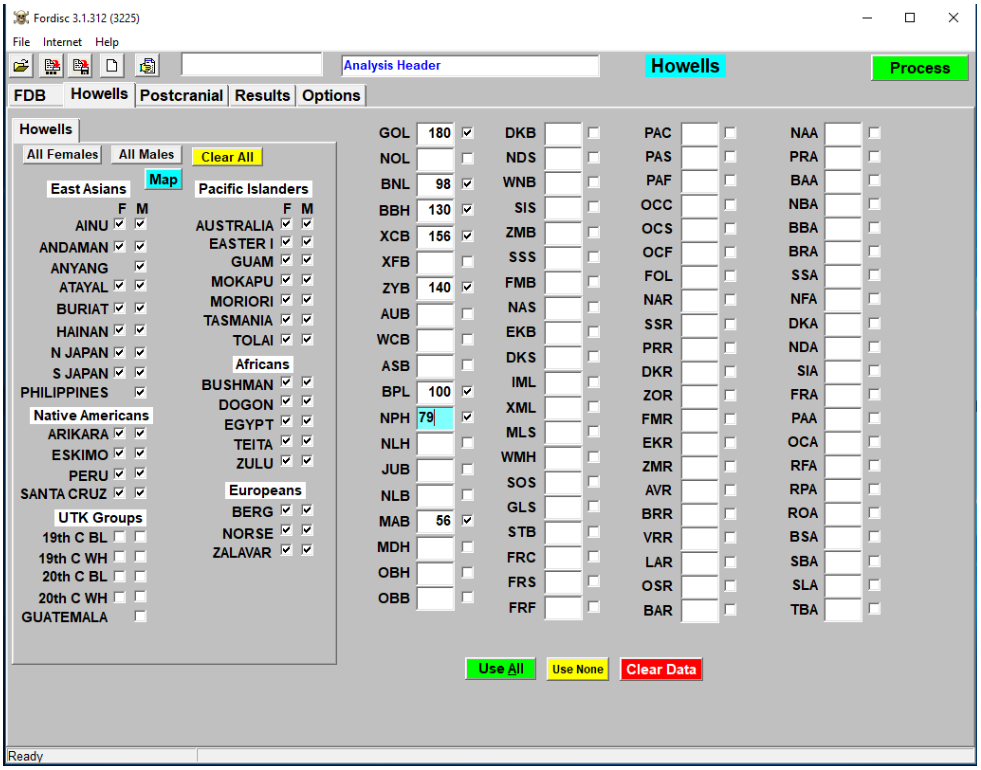

Figure 6: Fordisc - Howell's Databank

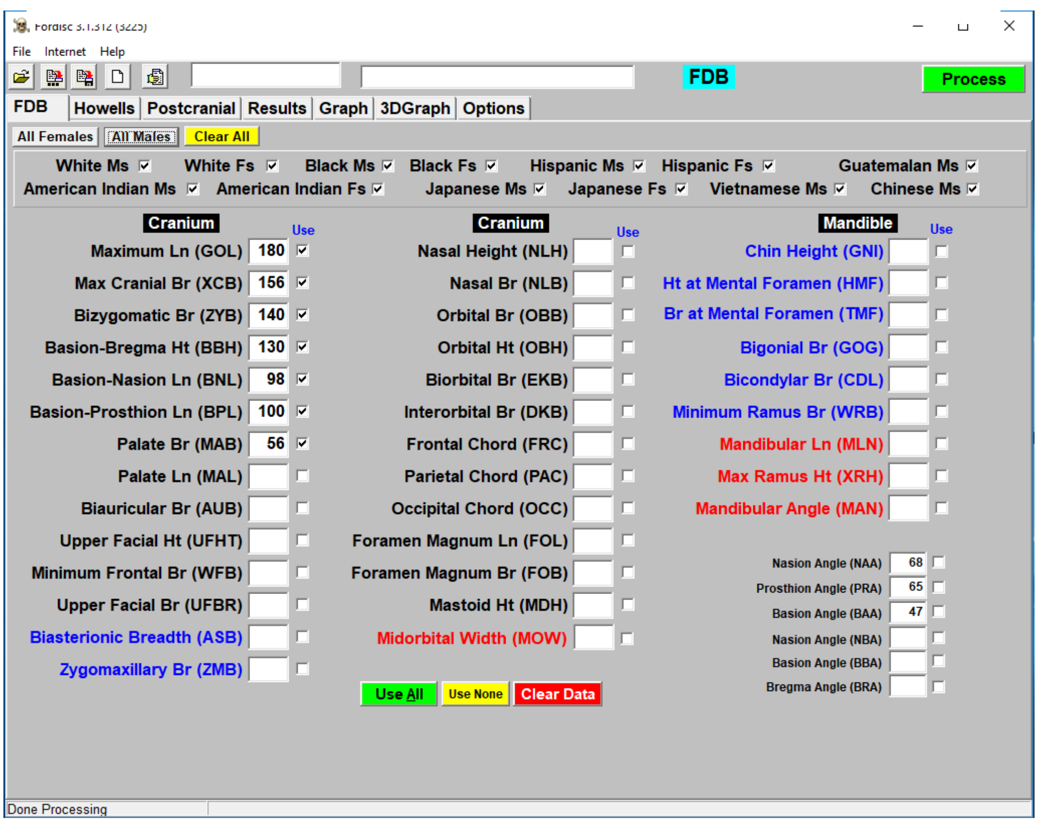

Figure 7: Fordisc - FDB

Appendix E: Results

AncesTrees	**Race – Group #1**	**Race – Group #2**
Correct/n	40/107	44/107
% Correct	37	41.1

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Table 1: Accuracy of AncesTrees for Group One and Two

Fordisc – Howell's	**Race – Group #1**	**Race – Group #2**
Correct/n	39/107	43/107
% Correct	36.1	40.1

Table 2:Accuracy of Fordisc using Howell's Data for the Top Two Groups

Fordisc – FDB	**Race – Group #1**
Correct/n	50/107
% Correct	47.6

Table 3:Accuracy of Fordisc using FDB for the Top Group (Dagdag & Albanese, 2015)

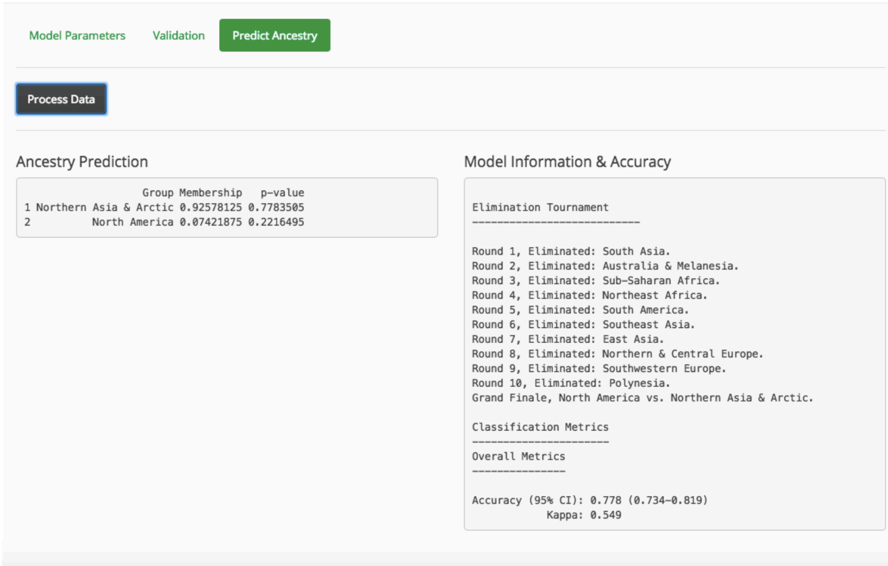

Figure 8: AncesTrees Results page

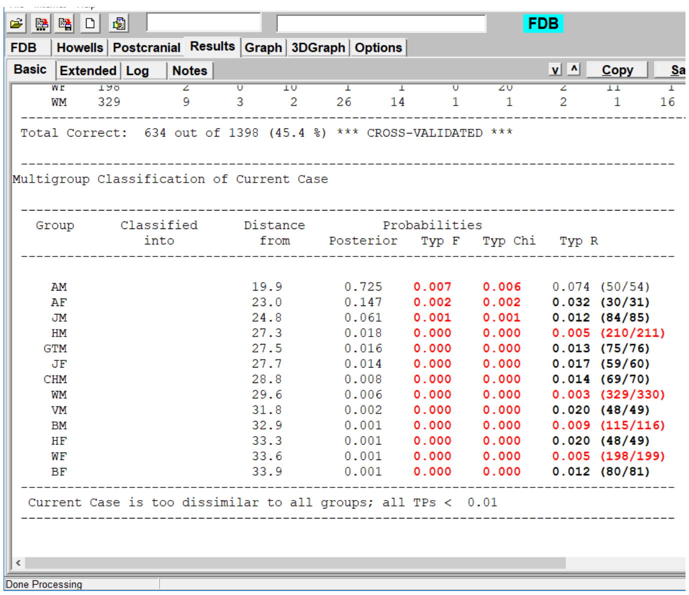

Figure 9: Fordisc - Howell's Databank Results page

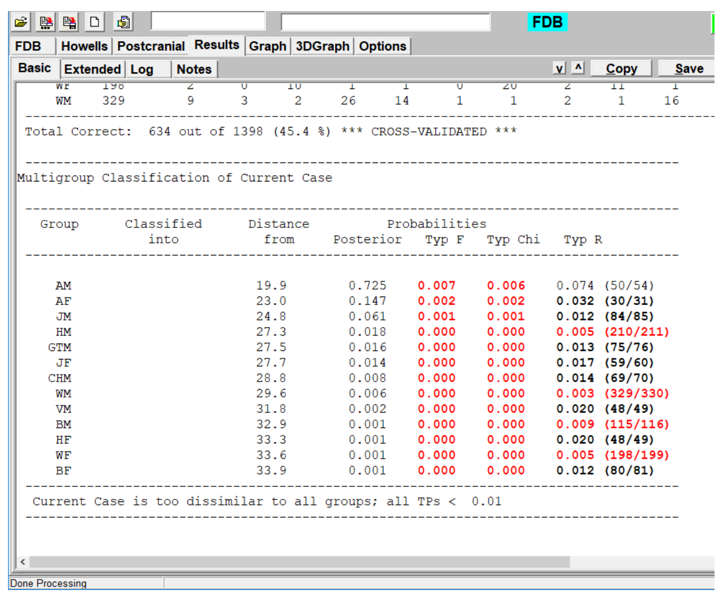

Figure 10: Fordisc - FDB Results page

Appendix F: Tables of Populations in Fordisc

Population	Number of Males	Number of Females
American Blacks	156	96
American Whites	518	340
American Indians	59	32
Chinese	79	0
Guatemalan	83	0
Hispanics	227	62
Japanese	84	58
Vietnamese	51	0

Table 4: Maximum number of cases in Forensic Data Bank Groups. Actual samples varied due to missing data.

Name	Abbreviation	Area
AINU	AIN	Hokkaido, Japan
ANDAMAN ISLAND	AND	Andaman Islands
ANYANG	ANY	China
ARIKARA	ARI	South Dakota, USA
ATAYAL	ATA	Taiwan
AUSTRALIA	AUS	Lower Murray River
BERG	BER	Austria
BURIAT	BUR	Siberia, Russia
BUSHMAN	BUS	South Africa
DOGON	DOG	Mali
EASTER ISLAND	EAS	Easter Island
EGYPT	EGY	Gizah
ESKIMO	ESK	Greenland
GUAM	GUA	Guam
HAINAN	HAI	China
MOKAPU	MOK	Hawaii
MORIORI	MOR	Chatham Islands
NORSE	NOR	Oslo, Norway
NORTH JAPAN	NJA	Hokkaido, Japan
PERU	PER	Peru
PHILLIPINES	PHI	Phillipines
SANTA CRUZ	SAN	California, USA
SOUTH JAPAN	SJA	Kyushu, Japan
TASMANIA	TAS	Tasmania
TEITA	TEI	Kenya
TOLAI	TOL	New Britain
ZALAVAR	ZAL	Hungary
ZULU	ZUL	South Africa

Table 5: Table of Howell's Groups in Fordisc (Fordisc Help, 2015)

Vita Auctoris

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