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METRIC METHODS USED TO DETERMINE RACE: CAN THEY IDENTIFY NATIVE MICHIGAN POPULATIONS?

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METRIC METHODS USED TO DETERMINE RACE: CAN THEY IDENTIFY NATIVE MICHIGAN POPULATIONS?

By:

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ABSTRACT

METRIC METHODS USED TO DETERMINE RACE: CAN THEY IDENTIFY NATIVE MICHIGAN POPULATIONS?

By

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The existence and definition of race are debated in modern anthropology, but forensic anthropologists must make racial estimations when creating biological profiles of found skeletons. Researchers must categorize a skeleton as White, Black, or Asian/Native American. The options for distinguishing between White and Native American remains are few and the remains used to create them are biased toward Southwest and Great Plains tribes. This creates the potential for incorrect estimations in other areas of the United States because genetic, temporal, and social differences exist between different tribes.

This study tests the Giles and Elliot (1962), Gill et al. (1988), and Fordisc 2.0 (Jantz and Owsley, 1996) methods for assessing race. Eighty-one Native American crania from the University of Michigan osteological collection were measured for race determination. Fordisc 2.0 was 90% correct, Giles and Elliot was 68% correct, and Gill et al. was 67% correct in race estimation. All three methods produced significant error in race estimation based on z-scores, but Fordisc 2.0 was the most successful. This study has shown that Michigan Native Americans vary significantly from Southwestern and Great Plains Native Americans in their cranial form and these three methods for determining race are not ideal for use in this population.

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Introduction: Race in Anthropology

There is much debate among anthropologists today about the concept and definition of race. Some believe that human beings can be divided into races based on physical characteristics and innate capabilities (Sarich and Miele, 2004). Others argue that this is impossible since physical traits correlate neither with each other nor with innate abilities (Livingstone, 1964; Brace, 1996; Washburn, 1963). Montagu quotes Washburn as saying, "it is impossible to consider each of the two billion persons in the world. Therefore some system of sampling is necessary. It happens that mankind does divide into great groups so that a relatively small number of individuals may substitute for the entire group . . .The racial classification is a simple sample system which allows a student to become familiar with the superficial characters of two billion people in a remarkably short period of time" (Montagu, 1963, pg. 29). This is an example of the position that perhaps "races" exist but more importantly some form of categorization is necessary. This debate has led to the calling of some anthropologists for disuse of the term "race" with all of its hidden meanings and baggage. Sauer (1992) instead suggests using "ancestry" as a term simply denoting a person's likely geographic origins. He says, "No one who argues against the race concept denies that human variation exists or claims that this variation is not systematic. In fact, it is systematic variation that allows anyone to estimate, with varying degrees of specificity a person's place of ancestry from their physical features" (Sauer, 1992, pg 110).

Both sides agree, though, that race is a social construction with massive sway in the public eye (Lieberman et al., 1989). It is therefore understandable why forensic anthropologists regularly deal with race as a part of a biological profile. When presented

with a body to identify, the forensic anthropologist must construct a biological profile including the age, sex, stature, and race of the person. This profile allows police to better match the remains with missing persons reports. When dealing with human remains in the public sector, attention must be paid to identifying race because it is a large part of a person's social identity and to work without it would be to work severely disadvantaged. Since race is such a crucial aspect of a person's social identity, a forensic anthropologist normally offers some information to this regard (Brace, 1995; Kennedy, 1995; Sauer, 1992). Students of forensic anthropology must "appreciate the paradox of how a scientific approach to the study of human evolution and biological diversity co-exists with a non-scientific belief in the existence of human 'races' in the context of determining ancestry in a forensic anthropological investigation and reporting the results of the study in records submitted to clients from medical-legal agencies" (Kennedy, 1995, pg. 800).

To assign a racial category to a skeleton, a forensic anthropologist must first determine the skeleton's region of origin. To this end, the forensic anthropologist may use metric or non-metric means. When using metric means, different aspects of the skeleton are measured. Measurements are entered into functions or plotted on predetermined graphs and the skeleton is categorized into a racial group based on its association with other skeletons. One example of a metric analysis technique used to separate the races is the index. This is the relationship between two measurments. For example, the cranial index is the cranial breadth divided by the length (Downs and Bleibtreu, 1969). Non-metric (or morphological) methods are those that assign regional origin based on examination of the skeletal features. For example, shovel shaped incisors

are often a sign of Asian decent. If they are present in a skull, the skull is likely Asian/Native American (Hinkes, 1990). Both metric and non-metric methods are commonly used in anthropology to estimate the race of individuals in both a forensic and bioarchaeological context.

Metric and non-metric methods of determining race are both susceptible to genetic and environmental influences. Researchers should be aware of the populations with which these methods and equations were tested and created. Using these methods on individuals or groups outside the sample population could introduce unknown error into the estimate. For instance, when working with a native population from the southeastern United States, a researcher should consider the possible problems with using a technique created using Eskimo remains exclusively. Environmental, chronological, and social differences between the two groups could potentially introduce error into ancestry estimates that rely on variable cranial and racial skeletal structure. Regardless of whether metric or non-metric means of evaluation are used to determine race, it is important to understand where and from which populations the techniques were derived.

The three most commonly used racial categories in forensic anthropology in the U.S. today are White/European, Black/African, and Asian, or, in more anachronistic terms, Caucasoid, Negroid, and Mongoloid (Bass, 1995; Brace, 1996; Downs and Bleibtreu, 1969). The goal of the forensic anthropologist is to be able to identify human remains, which includes categorizing them into one of these three races based on the skeleton alone. Most scientific attention has focused on being able to distinguish between White and Black groups, as these are the two primary groups in the American population (75.1% White and 12.3% Black in 2000 according to the United States Census

Bureau). However, limited work has also been done with Asian populations, primarily on Native American remains.

Despite the fact that only 0.9% of the United States' population was comprised of Native Americans in 2000 (United States Census Bureau), there is still much value in research on identifying their remains. It is less surprising when one learns that in some regions of the United States the majority of forensic anthropology cases involve Native American remains. This is because ancient remains are often uncovered during roadwork and construction. Cases such as these are forensic in two ways. First, the remains must be assumed to be modern and of legal import until proven otherwise. Thus, every case is forensic until age or circumstance shows it to be beyond legal significance. Secondly, the Native American Graves and Repatriation Act of 1990 requires that all Native American remains must be repatriated to the appropriate tribe, if possible, and so must be officially associated with a particular tribal entity. A connection between the remains and a modern nationally recognized tribe must be established by physical, historical, and/or cultural means (Native American Graves and Repatriation Act, 1990). This makes Native American remains important to forensic anthropologists because forensic methods of ancestry assessment can be used on these remains to help identify past relationships and population movements among Native groups. They also help identify relationships between groups of the past and groups of the present. These are the two largest reasons for forensic concern with Native American remains. Consequently, sufficient research and diverse means of analysis must be available to distinguish Native American remains from other remains of non-Native origin.

Repatriation is difficult because remains must be associated with a modern tribe by means of comparison with ancient populations. Forensic anthropologists must distinguish between ancestral populations based on the skeleton and associated cultural markers. This is a finer distinction than between races since all Native Americans are considered to belong to the same race. There are countless regional, cultural, and temporal differences between Native American groups. Environmental conditions can affect the bodies of individuals in populations that have lived there for a long time and adapted to the climate (Lahr, 1996; Dolhinow and Sarich, 1971; Downs and Bleibtreu, 1969; Corcos, 1997; Molnar, 1975, 2002; Sarich and Miele, 2004). Environmental factors have been shown to have great influence on bodily form in a variety of studies (Corcos, 1997; Downs and Bleibtreu, 1969; Halloway, 2002; Molnar, 1975, 2002; Sarich and Miele, 2004; Sparks and Jantz, 2002; Steward, 1945). Once environment-specific traits become dominant in a population, the genetic spread of such traits to other populations can be limited by geographic and social filters. Social taboos and marriage customs can be as imposing as physical partitions like mountains and deserts, preventing the free exchange of genes. The frequency of certain traits, then, would vary between even neighboring places (Downs and Bleibtreu, 1969). For instance, the Hopi Indians are on average ten to twelve centimeters taller than the Papago, a tribe living only 200 miles to the south (Molnar, 2002). Brace (1995) argues that not all physical traits are necessarily adaptive and are the product of genetic drift, social and physical restrictions, and other such genetic restrictions. "Regional clusters of populations then owe the similarities in their appearance to the perpetuation of traits that are shared by virtue of kinship but which have no other biological significance" (Brace, 1995, pg 173).

Considering these views on the spread of genetically defined variation, it is not difficult to accept that the skeletal morphology of different tribes and populations could be different from area to area within the United States.

Ancestry Assessment in Native American Remains: A Review

Since research on determining Native American identity is rarer than the other forms of ancestry research, there are few methods available. The methods that have been developed to identify Native American remains are frequently only successful when performed by the developers and then only when tested on certain populations. These methods have not been widely tested and few forensic anthropologists have validated them on their local populations. It is important to make certain that environmental and genetic differences have not changed a local population in such a way as to make predictive methods developed elsewhere useless. Thus, forensic anthropologists should test their common methodologies on a local population prior to a career of usage.

There are two major collections that are used frequently to develop the analytical methods for determining race. These are the Hamann-Todd Collection, located in Cleveland, Ohio, and the Terry Collection, located at the Smithsonian in Washington D.C. Both were begun in the late 1800s and represent adults who lived from the late 1800s to the mid 1900s. These collections are large (over 1,000 skeletons in each) and information about age, sex, ancestry, and stature is known for most individuals (Cleveland Museum of Natural History, 2002; Hunt, 2004). The Hamann-Todd and Terry collections are some of the best resources for developing and testing ancestry methods because they offer a large selection of remains often of known life histories.

The remains in the Hamann-Todd and Terry collections are the foundation for many metric and non-metric techniques for determining ancestry as well as other aspects of a biological profile. However, most ancestry techniques derived from these populations are heavily biased toward White and Black populations. There is a Native

American component in the Hamann-Todd collection but it is very small since the remains for this collection were taken primarily from the unclaimed bodies at the city morgue. Techniques for ancestral identification based on or tested only on the Terry Collection are not representative of, and cannot properly assess, Native American remains. Nevertheless, many of the different methods for assessing the race of human remains have been developed from these collections.

Based on work from both collections, the most widely known and used metric analysis for distinguishing between populations based on ancestry was authored by Giles and Elliot (1962). Its popularity stems from its claim to distinguish between Whites, Blacks, and Native Americans (as well as the sexes) while requiring only eight measurements. It was developed using the Terry collection, the Todd collection, and a Native American sample drawn exclusively from the Archaic Indian Knoll site in Kentucky. Giles and Elliot used 408 specimens composed of 108 White males, 79 White females, 113 Black males, and 108 Black females. The number of Native American specimens used was not published. This method requires that the eight measurements be entered into a series of formulae, creating a discriminant function, which will produce a figure representing a racial affinity. Each measurement is weighted with predetermined weights to produce an affinity score.

The Giles and Elliot (1962) discriminant functions were tested by Fisher and Gill (1990) on a mixed Northwestern Plains Indian sample from the University of Wyoming skeletal collection. Twenty-seven skeletons of whose sex and ancestry had already been determined by anthroposcopic methods and archaeological context were analyzed using the Giles-Elliot system. The results suggested that the Giles and Elliot system was only

25% accurate in race estimation. The authors performing the comparison claimed that there was more morphological variation among Native American groups than the Giles-Elliot analyses allow. Only a small percentage of all Native American variation was represented by those remains found at Indian Knoll. Fisher and Gill concluded that metric analyses should not extend beyond the population used to derive them.

This conclusion is also supported by Ayers et al. (1990). Ayers et al. tested the Giles-Elliot functions using 191 forensic cases, 11 of which were Native American, where sex and ancestry could be accurately ascertained from soft tissues. They found similar results as Fisher and Gill (1990). Many of the Native American remains were improperly classified. The authors conclude that the Giles and Elliot (1962) discriminant function analyses are only useful within the population used to create them. When Iscan (1990) tested the Hamann-Todd collection and the Terry collection, he found Giles and Elliot to be around 95% successful, though this test was primarily done only between White and Black crania. It was also a test of the same collections used to create the function. Iscan (1990) warns against using these formulae outside the originating population.

A series of indices was developed for distinguishing between Black, White, and Amerindian remains by Gill et al. (1988). The authors developed this method using 125 white crania from the Terry Collection, Smithsonian Institution, and forensic cases, as well as 173 Native American remains from the Arikara, Pawnee, Dakota, northwestern Plains, Omaha, Minnesota, and Mimbres tribes. A modified coordinate caliper called a simometer was used to test the utility of 14 measurements. In the end, three indices were created from six measurements that separated white from Native American skulls. They

were the maxillofrontal index, zygoorbital index, and alpha index. For each, a measurement called the subtense (basically, the projection of the nasal bones at a given breadth) was divided by the breadth, then multiplied by 100 for a percentage relationship between the subtense and breadth. Sectioning points were set at 40-38-60 for the three indices respectively meaning that scores below these numbers were considered Native American. Gill et al. had more than 90% accuracy classifying Native Americans and Whites regardless of bone condition and found that this method could be more accurate than visual methods alone. The authors claimed features of the mid-face are under strong genetic control and are little affected by the environment (Gill et al, 1988).

In 1990, Gill and Gilbert tested the method outlined by Gill et al (1988). The fourteen measurements were taken of the skulls of 398 of individuals. The sample consisted of 125 Whites, 100 Blacks, and 173 Native Americans. The number of measurements used was again dropped to 6, forming the same three indices. Using these indices, the authors were able to correctly assess the ancestry of the skulls between 87.0% and 88.8% of the time. Gill et al.'s 1988 method seems to be a promising method for distinguishing between the remains of Whites from Blacks and Native Americans, but not between Blacks and Native Americans, based on the accuracy of the original study and subsequent tests (Gill et al., 1988; Gill and Gilbert, 1990).

Dr. Richard L. Jantz and Dr. Stephen D. Ousley (1996) of the University of Tennessee, Knoxville (UTK) designed a software program that classifies skeletons into ancestry groups. A forensic skeletal sample called the Forensic Data Bank was created using skeletal measurements from forensic cases at UTK and from other forensic cases around the country whose measurements were submitted to UTK. Using the Forensic

Data Bank, they created Fordisc 2.0, a computer program that uses discriminant function analysis on cranial and post-cranial measurements to determine ancestry and sex. Between 1 and 34 measurements are required to allot a cranium to one of several different ancestry groups. The Native American sample is composed mostly of Southwest and Great Plains tribes though there has been input from other places as well. The accuracy rates offered by the creators are 95% correct ancestral differentiation between Black and White remains and 96% between Black, White, Native American, and Chinese (Owsly and Jantz, 1996). This program is used by many forensic anthropologists because of its versatility, ease of use, and accuracy (Ubelaker, 1998).

In 2002, Ubelaker et al. reported on an application of Fordisc 2.0 to a sample of Spanish crania. They found that 44% were classified as White, 35% as Black, 9% Hispanic, 4% American Indian. The remaining were classified as Chinese or Vietnamese. The authors explain these results in two ways. First, the crania were noticeably small and could therefore have "fooled" the computer. Second, and most importantly, Fordisc 2.0 does not have a category that would have been a perfect fit for a Spanish sample. The remains used to create the system were American forensic cases meaning that samples from elsewhere in the world could not be classified correctly. The program simply lacks the appropriate database from which to draw a conclusion. In their final words, however, the authors suggest that a global database would only improve "an already useful forensic tool" (Ubelaker et al., 2002, pg 4).

Fordisc 2.0 was tested again in 2005 by Williams et al. This time the sample was from ancient Nubia and the program did not perform well. The results ranged through all of the available categories leading the authors to argue that Fordisc 2.0 is based on a poor

database. Further, they claim it perpetuates the improper methods for separating groups of people into races based on stereotypical features while disregarding subtleties in variation (Williams et al., 2005).

As this short review demonstrates, there has been little research on differentiating between Native Americans and other racial groups. In fact, there are only a few metric analyses available that examine Native American remains and these are biased toward the Southwest and Plains Indian tribes. Of those choices, it is also obvious that the success rates for these are not exceptional, Giles and Elliot being found to be only 25% accurate in one instance (Fisher and Gill, 1990). Many authors of validation studies regarding these metric methods believe that the poor success rates are due to the differences in Native American sample populations (Fisher and Gill, 1990; Ayers et al., 1990; Ubelaker et al., 2002). Samples tested from collections outside the home range of the method rarely work well.

If the commonly held methods for distinguishing Native American from White and Black remains have not been shown to be very successful outside of the original sample population, their utility in other areas of the country ought to be examined. Each area could have its own unique skeletal adaptations to the environment and history of ancestry. Trait frequencies could be unaccounted for in methods developed in other areas. Hence, areas beyond the bounds of the original sampling of a technique should be tested before use and reliance. Without such testing, there is the potential for inaccuracy in forensic evaluations.

This study proposes to assess the utility of three methods for distinguishing between White and Native American populations from the Great Lakes region,

specifically Michigan. This study will address the Giles and Elliot (1962), Gill et al. (1988), and Fordisc 2.0 metric methods for utility in distinguishing between Native American and White populations. This is important because the Great Lakes sample was not one used to formulate any of these methods and could thus prove problematic. There could be physical and/or genetic differences between the populations used to create the methods and the Great Lakes population. I believe that Fordisc 2.0 program will work well at determining the race of my sample. I do not think the Giles and Elliot (1962) or Gill et al. (1988) methods will be successful because of the restricted samples used to create them.

Materials and Methods

The 81 crania used for this study are housed in the human osteology collections held at the University of Michigan in Ann Arbor, Michigan. All of the remains used were recovered from archaeological excavations conducted in Lapeer (10 skulls), Clinton (3), Macomb (1), Cass (1), Menominee (6), Braunch (2), Benzie (2), Missaukee (6), Bay (1), Marquette (2), Antrim (1), Leelanau (1), Alcona (1), Lake (1), Saginaw (4), Oakland (3), St. Clair (1), Jackson (1), Tuscola (4), Isabella (1), Sanilac (1), Huron (1), Presque Isle (2), Gratiot (1), Montmorency (1), Washtenaw (13), Ottawa (1), Wayne (5), Otsego (1), and Emmet (1) counties of Michigan. Based on contextual and scientific evidence, all remains were judged to be prehistoric, varying from Early to Late Woodland, and therefore of Native American descent. The skulls varied in completeness though only those with most osteological landmarks available were used. They were measured by the author in the spring of 2005.

For the Giles and Elliot and Fordisc 2.0 techniques, measurements were taken with standard sliding and spreading calipers. These measurements can be found in Table 1. All measurement definitions were taken from Buikstra and Ubelaker (1994) and all point definitions were taken from Bass (1995) and White (2000). The measurements for the Gill technique were taken from the Gill et al. (1988) and Gill and Gilbert (1990) articles and were performed using a simometer. These are also listed in Table 1. Point definitions were again taken from Bass (1995) and White (2000).

Table 1. Measurements and Definitions

maximum cranial length	glabella to opisthocranion	G&E, Fordisc
maximum cranial breadth	eurion to eruion	G&E, Fordisc
bizygomatic diameter	greatest distance between zygomatic arches	G&E, Fordisc
basion-bregma height	basion to bregma	G&E, Fordisc
cranial base length	basion to nasion	G&E, Fordisc
basion-prosthion length	basion to prosthion	G&E, Fordisc
maxillo-alveolar breadth	ectomolare to ectomolare	Fordisc
maxillo-alveolar length	prosthion to alveolon	Fordisc
biauricular breadth	auriculare to auriculare	Fordisc
upper facial height	nasion to prosthion	G&E, Fordisc
minimum frontal breadth	frontotemporale to frontotemporale	Fordisc
upper facial breadth	frontomalare temporale to frontomalare temporale	Fordisc
nasal height	nasion to nasospinale	Fordisc
nasal breadth	maximum breadth of nasal aperture	G&E, Fordisc
orbital breadth	dacryon to ectoconcion	Fordisc
orbital height	distance from most superior and inferior points on orbital margin	Fordisc
biorbital breadth	ectoconchion to ectoconchion	Fordisc
interorbital breadth	dacryon to dacryon	Fordisc
frontal chord	nasion to bregma	Fordisc
parietal chord	bregma to lambda	Fordisc
occipital chord	lambda to opisthion	Fordisc
foramen magnum length	basion to opisthion	Fordisc
foramen magnum breadth	distance between most lateral margins of foramen magnum	Fordisc
mastoid length	vertical projection of mastoid process	Fordisc
maxillofrontal breadth	maxillofrontale to maxillofrontale	Gill et al.
naso-maxillofrontal subtense	depth from maxillofrontal breadth to nasal bridge	Gill et al.
mid-orbital breadth	zygoorbitale to zygoorbitale	Gill et al.
naso-zygoorbitale subtense	distance from zygoorbitale breadth to nasal bridge	Gill et al.
alpha chord	breadth from points left and right along a line from zygoorbitale to the point where the naso-maxillary suture meets the nasal aperture	Gill et al.

Table 1. Measurements and Definitions (cont.)

naso-alpha subtense	projection from the apha points ot the deepest point on the nasal bridge	Gill et al.

To test Fordisc 2.0, the measurements were entered into the computer program that performed all necessary calculations. The results were displayed as a series of probability scores and a graph of the proximity of the skull in question to the average scores of each of the target groups. The posterior probability score was of use here because it is the score that estimates the likelihood that the crania fit into the categories being tested. The posterior probabilities for all of the categories total to 1.000. The highest score is the most likely category for the skull. The typicality probability is also offered by Fordisc 2.0 but was not used in this analysis because it predicts the likelihood that the skull actually belongs to any of the categories being tested. Since all of the skulls are known to be Native American, the typicality score is unnecessary.

The Giles and Elliot discriminant functions were carried out using a calculator. In order to evaluate the race of a skull using the Giles and Elliot technique, the sex of the crania must be known. Giles and Elliot (1963) provide formulae for determining sex. Once the sex has been determined, the appropriate race formula can be chosen. The formulae can be found in Table 2.

Table 2. Giles and Elliot Formulae

Sex	1.16(maximum cranial length) + 1.66(cranial base length) + 3.98(bizygomatic diameter) - 1.00(basion-prosthion) + 1.54(upper facial height)	A score below 891.12 is female.
Male: White vs. Native American	0.10(basion-prosthion) - 0.25(maximum cranial length) - 1.56(maximum cranial breadth) + 0.73(basion-bregma) - 0.29(cranial base length) + 1.75(bizygomatic diameter) - 0.16(upper facial height) - 0.84(nasal breadth)	A score below 22.28 is White.
Female: White vs. Native American	3.05(basion-prosthion) - 1.04(maximum cranial length) - 5.41(maximum cranial breadth) +4.29(basion-bregma) - 4.02(cranial base length) + 5.62(bizygomatic diameter) - 1.00(upper facial height) - 2.19(nasal breadth)	A score below 130.1 is White.

Therefore, if a skull was determined to be male the following would be the procedure for determining the race. The basion-prosthion length would be multiplied by 0.10. From this would be taken 0.25 multiplied by the maximum cranial length. From this would be subtracted 1.56 times the maximum cranial breadth. To this would be added 0.73 times the basion-bregma length. From this would be subtracted 0.29 times the cranial base length. To this would be added 1.75 times the bizygomatic diameter. From this would be taken 0.16 times the upper facial height. Finally, 0.84 times the nasal breadth would be subtracted from this. If the total score fell below 22.28, the skull should be considered White.

The Gill et al. (1988) method consists of three indices briefly outlined previously. The first index, maxillofrontal, is determined by dividing the naso-maxillofrontal subtense by the maxillofrontal breadth and multiplying by 100. If the result is less than 40, the skull is Native American. The zygoorbital index is the naso-zygoorbital subtense divided by the zygoorbital breadth and multiplied by 100. A score of less than 38 is Native American. Finally, the alpha index is the naso-alpha subtense divided by the

alpha cord and multiplied by 100. Results less than 60 are considered to be Native American. The ancestry would be the average of the three indices. Thus, if a skull received two Native American scores and a White score, it would be considered Native American.

Fordisc 2.0 classifies a skul based on the input of certain measurements into discriminant functions. The person using the program inputs the measurements and selects the races he/she thinks the skull may be. The program then produces two scores for each racial category chosen. The scores are the posterior probability and the typicality probability. For this research, the hightest posterior probability score indicates the rae. For example, if a skull scored .750 for American Indian male and .250 for American Indian female, I would record the skull as an American Indian male.

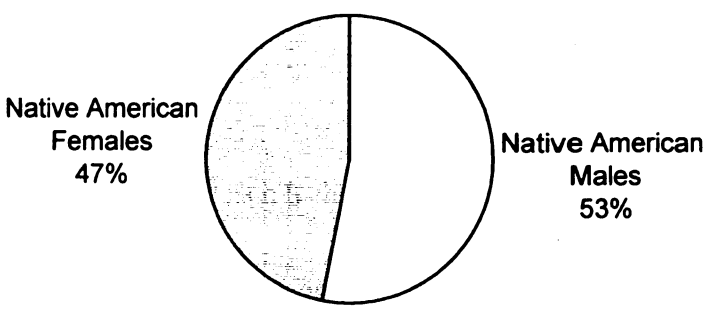
Each method is evaluated by its success rate. Since all of the crania are Native American, a positive Native American identification is considered a success for that method. The total number of correct racial determinations is divided by the number of skulls analyzed by each method for a percentage representation of success. An ideal method of analysis would have a success rate of 100%, meaning that it would correctly assign Native American race to all 81 skulls.

Results

All of the measurements recorded for this study can be found in Appendix A. The worksheets for each method can be found in Appendices B and C. The numerical data were entered into a spreadsheet program where they were then manipulated according to the requirements of each technique to produce a racial affiliation.

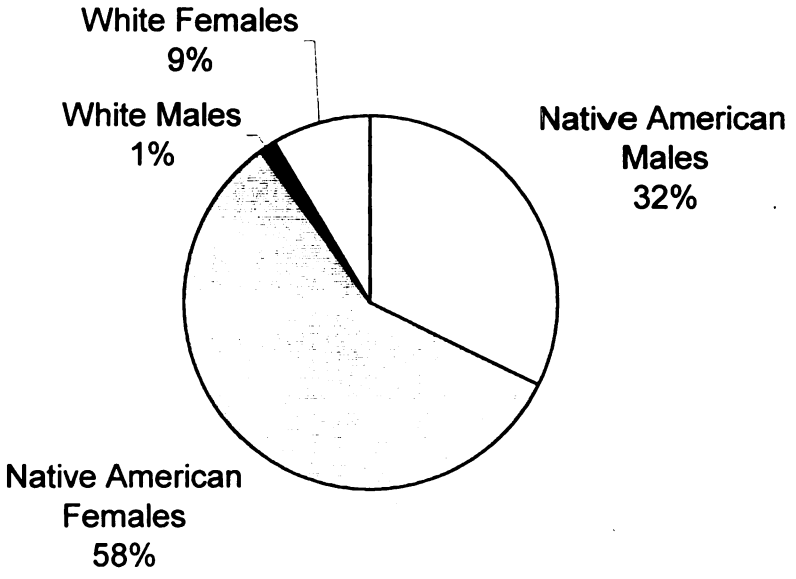
Of the 81 crania, 43 were judged by the author to be male and 38 were female.

Figure 1. Actual Sexes of the Sample



Due to the flexible, accommodating nature of Fordisc 2.0, even those samples lacking several measurements could be analyzed. Therefore, all 81 samples were run through Fordisc 2.0. Seventy-three were considered Native American (26 males and 47 females) and 8 were White (1 male and 7 females). The posterior probabilities ranged from 1.000 (a perfect score) to .445, with an average score of .845. Most scores were between .800 and 1.000, a strong indication of category.

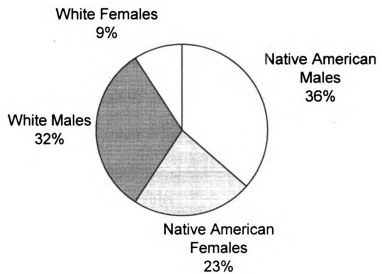
Figure 2. Fordisc 2.0 Results



Of the 81 specimens, 45 were complete enough to be analyzed for sex by the Giles and Elliot (1963) formula. The rest of the skulls were too fragmentary for analysis.

Fifteen were determined to be female and 33 were male. Of those, 44 were able to be analyzed by the Giles and Elliot formulae for race. Sixteen males were determined to be Native American, 14 males were White, 10 females were Native American, and 4 females were White.

Figure 3. Giles and Elliot Results



Fifty-eight of the original 81 skulls were usable for the Gill et al. (1988) indices. Thirty-nine were considered Native American and 19 were considered White.

Giles and Elliot properly assigned the sex of 15 of 24 females (63%) and 24 of 24 (100%) males. This is an overall success rate of 81%. Fordisc 2.0 properly assigned 35 of 38 (92%) females and 23 of 43 (53%) males for a success rate of 72%.

The results of each test were recorded as positive or negative with a 1 indicating a race of Native American and 0 White. If insufficient data was available, the field was left blank. The results of this system can be found in Appendix D.

The mean score for Fordisc 2.0 was 0.90 or 90% (73 of 81), Giles and Elliot was 0.68 or 68% (30 of 44), and Gill was 0.67 or 67% (39 of 58). These are the percentages of correct racial affiliation.

A z-score test for difference in proportions was conducted to determine the significance of the difference between the proportion of crania classified as Native American in the sample, using each different method and the actual proportion of Native Americans in the sample (1.0). The null hypotheses I am testing is that the proportion correctly classified using each method is equal to the actual proportion of Native Americans. The alternative hypothesis is that the proportion correctly classified using each method is not equal to the actual proportion of Native Americans in the sample. The calculated z-score using Fordisc 2.0 to determine race is –2.96; the z-score using Giles and Elliot for classification is –6.08; and the z-score using Gill for classification is –6.23. This means that the proportion correctly classified using each of these methods differed from the known proportion of Native Americans in the sample. Using the common alpha level of .05, a calculated z-score between –1.96 and 1.96 indicates that the method being tested properly predicted the race of the skull samples. All three methods tested resulted in z-scores that were outside the +/- 1.96 range, indicating that none of the methods were acceptable for determining race in a sample of Native Americans remains found in Michigan. Fordisc 2.0 resulted in the lowest z-score (2.96), but this score still indicates that this method is not reliable when using remains from the Michigan sample.

Of interest with the Gill et al. method was the actual range of scores for the samples. Though the overall results of the testing showed that the method was not very effective at separating White from Native American remains in the Michigan sample (67% accurate), it is interesting to note that the scores were generally close to the cut off marks assigned by the authors. Many were within 5 points of the sectioning points leaving the possibility that the Michigan sample is simply less distinctive based on this technique and an adjustment of the sectioning points would prove more successful. This further suggests that the Michigan population has some kind of genetic or environmental difference from the other populations tested. This could be coincidental and a product of sampling error but it could also be a sign of a larger trend.

A similar statement could not be made of the Giles and Elliot data. Those scores generally fell far above or below the sectioning point of 22.28, ranging from a low of −12 to a high of 48 for males. For females, the sectioning point was 130.1 with a range of 47 to 190.

Discussion

Though not the focus of this work, it is important to note how well Giles and Elliot and Fordisc 2.0 sexed the samples since the racial assignment in both cases was based on the determined sex. The skulls were sexed as they were examined by the author based on morphological features characteristic of males and females as described in Bass (1995) and White (2000). There were no postcranial remains associated with the crania. The sex assigned by this visual method was compared to that assigned by each method. Giles and Elliot properly assigned 15 of 24 females (63%) and 24 of 24 (100%) males. This is an overall success rate of 81%. Fordisc 2.0 properly assigned 35 of 38 (92%) females and 23 of 43 (53%) males for a success rate of 72%. Of note here is that Fordisc 2.0 was just as likely to correctly classify a male skull as male as it was to incorrectly classify it as female. However, this tendency did not seem to have a great effect on the racial determination since Fordisc 2.0 outperformed the Giles and Elliot method in the end.

The basic data relating to racial assignment is relatively easily deciphered. The first and most important point is that the means are contrasting. Fordisc 2.0 classifies 90% of the skulls correctly while the other two methods only correctly assign 67% (Gill et al.) and 68% (Giles and Elliot). The reason for this difference is most likely the samples used to create the individual methods. Fordisc 2.0 was created using a variety of skeletal samples from across the continent, though admittedly focused on Southwestern and Great Plains tribes, whereas the others were created using more restricted sampling. Giles and Elliot (1962) used only one collection from one archaeological site (Indian Knoll). The Gill et al. (1988) method was developed using an assortment of Great Plains

samples and was tested (Gill and Gilbert, 1990) on samples from other regions. However, it was not tested in the northern Midwest particularly.

Conclusion

Eighty-one crania from the Upper and Lower Peninsulas of Michigan were measured. Based on contextual and scientific evidence, they were all considered prehistoric and therefore Native American. Three methods for determining race were tested. The first was authored by Giles and Elliot in 1962. It is a series of discriminant functions into which measurements are input to receive a sex and race for the remains. This method was created using the Hamman-Todd collection, Terry collection, and a Native American sample from the Indian Knoll stie in Kentucky. The second method was authored by Gill et al. in 1988. This is a series of indices based on measurements of the skull. It was created using the Terry collection and a Native American sample of various Great Plains tribes. The last, Fordisc 2.0, is a computer program developed by Ousley and Jantz in 1996. It is also a series of discriminant functions that discriminates between certain races. It was developed using forensic cases compiled in the Forensic Databank and various Native American samples from the southwest and Great Plains.

Of the three, Fordisc 2.0 performed the best with a success rate of 90%. A higher success rate means that the method is more reliable. The Giles and Elliot method and Gill et al. method were unable to properly determine the race of the samples (68% and 67% accuracy respectively) and should not therefore be used in the Great Lakes region. This is most likely caused by the lack of extensive testing of these methods around the Great Lakes region. Their sample populations were simply too restricted and not widely enough tested to allow for a great amount of genetic and environmentally created variation in the human skull. Fordisc 2.0, probably because it was created using a

continually expanding database of site and forensic data, is best equipped to make an educated prediction about the race of the Michigan sample of crania.

I had originally hypothesized that Fordisc 2.0 would work well for my Michigan population, meaning it would have little significant error. I further hypothesized that the Gill et al. and Giles and Elliot methods would not perform well. My expectations were proven wrong by my research. Though Fordisc 2.0 worked the best of the three methods, it still produced significant error. Therefore, all three techniques for determining race produced significant error.

This study suggests that the native peoples of Michigan were physically similar but significantly different from their counterparts in other parts of the country, particularly those of the central mid-west and the northern plains. If true, this could mean that more work is necessary to determine exactly what kind of relationship native peoples of Michigan had with people elsewhere on the continent and the consequences of these relationships on the genetic makeup of the population. It is possible that the Michigan populations developed more localized physical features as a result of genetic drift and social and physical barriers. These should be explored more fully by further studies of physical and genetic variation among and between populations of the Michigan area and other areas. It is also possible that the Michigan sample is merely representative of a point in a continuum of trait manifestations. The other areas of the United States could simply be on a different part of the continuum. This continuum, however, has not yet been documented. These kinds of studies would allow forensic anthropologists to make better predictions about race when presented with Native American skulls. Further tests should be conducted nationally to validate these and other methods for determining race

of Native American remains before use and reliance, as this study has shown that there could be significant variation among populations. Such methods, including those tested here, could be improved by the inclusion of a greater variety of broader data sets. Forensic anthropologists need to be sure that the methods they are using are accurate and reliable in their area.

APPENDICES

Appendix A: Measurements Taken

Crania Number	1	2	3	4	5	6	7	8	9	10	11
cranial length	182	182	174	182	191	181	180	185	185	176	165
cranial breadth	133	130	141	129	130	135	134	140	143	140	130
bizygomatic		103	148		146	117	128	141		127	
basion-bregma	131	128	137	133	141	130	134	138	144	127	129
cranial base lt.	99	101	104	107	109	101	99	109	109	104	96
basion-prosth.	108	97	90	104	97	98	96	110	106	102	94
maxillo-alv. Br.	62	51	65	68	68	65	65	65			58
maxillo-alv. Lt		52		52	53	54	52	60	55	57	50
biauricular	126	119	131	124	134	123	125	130	133	130	116
upper facial ht	51	63	54	77	72	62	63	71	71	71	58
min. frontal br.	102	98	95	90	99	91	92	95	102	94	85
upper facial br.	117	103	109	103	115	103	103	108		107	95
nasal ht.		49	45	56	52	46	44	50	53	49	47
nasal br.		27	34	32	32	27	25	31	32	26	23
ortibal br.	43	38	39	38	42	41	38	42	45	44	35
orbital ht.	31	32	32	35	34	35	32	33	38	33	32
biorbital br.	112	99	105		110	99	98	101		101	87
interorbital br.	31	27	26	25	32	22	22	22	28	22	19
frontal chord	109	109	110	103	114	106	112	111	121	109	110
parietal chord	115	103	108	103	110	110	109	116	109	105	101
occipital chord	98	99	101	100	96	101	97	96	100	94	90
for. Mag. Lt.	40	37	36	35	38	34	41	39	36	35	34
for. Mag. Br.	31	32	29	31	34	30	31	35	30	31	29
mastoid lt.	32	26	29	26	36	29	26	31	34	31	18

Crania Number	12	13	14	15	16	17	18	19	20	21	22
cranial length	187	179	183	187	166	167	166	176	178	179	186
cranial breadth	140	146	159	160	121	140	140		135	137	
bizygomatic	139	151				126	130	134	132	130	148
basion-bregma	135	135	134	144	134	128	127	125	131	129	140
cranial base lt.	109	106	106	111	101	98	97	104	103	94	112
basion-prosth.	105	102	106	97	94	92	99	101		93	110
maxillo-alv. Br.	70	65	68	66	91	68	60	62	66	64	66
maxillo-alv. Lt	58	53	64	49	45	50	53	53		52	60
biauricular	137	137	147	144	105	128	121	124	128	126	139
upper facial ht	75	75	73	69	67	63	68	67		65	78
min. frontal br.	96	99	99	107	87	94	90	94	89	95	103
upper facial br.	111	112	112	112	92	107	102	103	99	104	116
nasal ht.	54	50	50	52	52	51	50	54	52	51	51
nasal br.	28	28	29	30	22	34	25	27	26	27	24
ortibal br.	42	41	42	45	38	41	43	37	39	41	43
orbital ht.	35	37	35	35	35	34	32	34	32	35	36
biorbital br.	105	102		101	86	99	92	95	99	98	106
interorbital br.	23	17		20	19	26	22	20	21	20	22
frontal chord	113	121	118	123	104	109	105	105	110	116	130
parietal chord	110	104	112	114	103	101	103	102	107	107	104
occipital chord	93	91	98	102	91	92	96	93	99	94	104
for. Mag. Lt.	35	40	41	35	38	37	30	33	35	34	36
for. Mag. Br.	29	35	36	34	28	32	26	31	30	29	31
mastoid lt.	33	31	35	24	19	28	26	39	26	26	34

Crania Number	23	24	25	26	27	28	29	30	31	32	33
cranial length	160	170	171	178	193	180	177	166	187	174	185
cranial breadth		151	135	135	147	135	138	130	146	133	136
bizygomatic	120		133		125	129	140		133		131
basion-bregma	125	137	121	134	135	135	133	123	137	135	130
cranial base lt.	90	105	96	100	102	104	96	93	95	100	103
basion-prosth.	91	100	99	97	98	95	94	100	91	98	105
maxillo-alv. Br.	62	64	59	59	61	61	67	60	59	66	61
maxillo-alv. Lt	56	52	53	49	53	51	54	55	54	53	58
biauricular	117	135	123	124	123	124	128	118	123	119	120
upper facial ht	63	69	66	64	75	64	66	65	73	68	65
min. frontal br.	85	96	99		101	96	96	90	106	92	91
upper facial br.	93	105	108		106	106	109	100	110	96	103
nasal ht.	98	55	47	48	57	52	49	45	54	49	46
nasal br.	25	27	25	29	24	30	27	25	25	27	24
ortibal br.	36	40	42	42	42	45	42	39	41	34	40
orbital ht.	30	33	35	34	36	37	36	32	37	36	33
biorbital br.	87	96	100		97	100	104	95	100	87	94
interorbital br.	18	26	22	21	16	19	24	21	21	23	19
frontal chord	102	116	111	107	119	112	110	108	114	109	111
parietal chord	101	101	102	117	113	115	106	100	120	108	116
occipital chord	87	93	90	98	109	95	95	94	108		91
for. Mag. Lt.	29	35	35	35	42	37	36	34	36		38
for. Mag. Br.	24	32	28	28	34	33	26	28	31		30
mastoid lt.	23	25	22	26	35	28	30	22	33	29	29

Crania Number	34	35	36	37	38	39	40	41	42	43	44
cranial length	188	170	182	175	184	154	185	193	176	172	170
cranial breadth	136	144	134	125	139	137	133	141	134	135	135
bizygomatic		136	137		125	119		121	129	138	
basion-bregma	142	135	127	132	123	120	137	135	130	133	124
cranial base lt.	106	95	103	101	98	88	108	103	100	95	98
basion-prosth.	95	94	93	93	90	87		90	97	94	96
maxillo-alv. Br.	70	51	54	61	59	61	52	46	58		65
maxillo-alv. Lt	54	49	49	47	53	45		47	53	54	47
biauricular	126	126	129	122	118	120	127	119.	122	122	129
upper facial ht	82	71	63	64	66	59		70	67	78	60
min. frontal br.	95	97	87	87	99	86	97	98	91	90	91
upper facial br.	110	103	107	104	107	98	106	99	103	106	99
nasal ht.	55	50	52	49	52	45	53	53	51	58	45
nasal br.	31	30	26	26	25	28	26	23	23	27	25
ortibal br.	43	41	44	37	42	35	44	42	42	43	39
orbital ht.	35	37	35	32	35	34	34	38	35	37	35
biorbital br.		96	102	93	102	89	97	92	93	98	95
interorbital br.	27	22	23	19	25	20	17	17	19	21	17
frontal chord	112	110	109	107	100	105	118	114	112	113	107
parietal chord	114	103	104	103	114	101	113	119	106	105	107
occipital chord	108	101	100	105	106	83	102	101	97	93	86
for. Mag. Lt.	35	30	38	37	37	31	35	39	36	36	37
for. Mag. Br.	30	28	29	30	32	27	31	30	31	27	34
mastoid lt.	28	25	29	31	25	21	30	25	22	27	25

Crania Number	45	46	47	48	49	50	51	52	53	54	55
cranial length		178	183	174	184	170	177	179	170	179	172
cranial breadth	135	128	140	134	145	136	139	140	133	132	130
bizygomatic		128	133		147		130	140			
basion-bregma	145	135	128	131	133	131	130	133	129	133	126
cranial base lt.	103	104	104	102	104	96	102	101	96	102	94
basion-prosth.	110	98	104	103	96	89	103	98	97	97	88
maxillo-alv. Br.	69	48	64	63	63	61	67	68	64	66	57
maxillo-alv. Lt	63	49	57	57	55	44	57	54	51	55	49
biauricular	125	120	127	123	136	121	125	131	116	121	
upper facial ht	71	61	72	74	70	66	67	50	67	71	60
min. frontal br.	96	88	98	93	92	87	91	96	87	93	90
upper facial br.	109		113	105	108	102	101	109	94	108	97
nasal ht.	52	53	52	52	54	50	52	50	52	53	47
nasal br.	27	23	27	25	28	28	27	27	28	29	28
ortibal br.	43	40	44	42	42	42	40	43	38	43	40
orbital ht.	33	33	35	34	33	33	33	32	33	35	35
biorbital br.	98	95	100	94	99	92	91	95	88	102	89
interorbital br.	22	20	20	21	19	17	20	17	19	21	20
frontal chord	117	110	111	110	116	109	112	109	105	114	107
parietal chord		112	108	106	107	109	106	108	105	107	102
occipital chord		96	95	88	98	91	92	99	92	99	99
for. Mag. Lt.	33	33	33	37	33	35	37	34	39	41	35
for. Mag. Br.	31	27	29	28	26	28	30	30	27	31	28
mastoid lt.	30	26	31	27	25	24	27	29	29	26	

Crania Number	56	57	58	59	60	61	62	63	64	65	66
cranial length	175	172	176	173	188	174	191	166	173	186	179
cranial breadth	139	128	129	140	146	134	135	134	150	140	132
bizygomatic	144				154		136	127	152	145	131
basion-bregma	134	124	130	132	137	135	138	122	132	141	129
cranial base lt.	105	99	103	108	112	102	109	96	100	108	100
basion-prosth.	105	94	99	104	113	100	96	99	104	108	100
maxillo-alv. Br.	69	64	68	106	74	56	64	58	74	67	63
maxillo-alv. Lt	60	52	52	52	62	56	50	54	61	56	52
biauricular	129	123	125	133	141	126	128	122	142	134	121
upper facial ht	74	61	72	63	78	70	75	65	80	75	64
min. frontal br.	95	90	86	94	97	92	97		94	97	89
upper facial br.	113	98	105	109	116	104	106	101	113	112	101
nasal ht.	56	49	54	51	55	53	56	47	57	56	46
nasal br.	32	26	31	29	30	25	26	23	28	27	25
ortibal br.	47	40	43	43	45	43	41	36	45	43	40
orbital ht.	36	34	34	32	34	36	37	36	36	38	32
biorbital br.	102	91	98	100	111	101	94	88	98	97	91
interorbital br.	22	16	23	19	23	23	22	23	20	18	19
frontal chord	108	107	106	106	116	113	119	99	114	113	102
parietal chord	114	109	110	100	106	97	110	106	99	104	118
occipital chord	102	92	90	106	102	98	104	85	101		92
for. Mag. Lt.	35	38	41	33	39	35	36	37	35		37
for. Mag. Br.	31	31	33	27	33	30	27	31	40		30
mastoid lt.	31	21	30	26	32	28	31	26	27	23	27

Crania Number	67	68	69	70	71	72	73	74	75	76	77
cranial length	187	172	175	180	179	167	170	184	176	174	184
cranial breadth	138	145	138		134	130	134	135	140	135	132
bizygomatic		130		135		128	133		136	134	
basion-bregma	140	132	127	120	132	131	123	131	137	135	136
cranial base lt.	110	103	90	100	103	101	95	102	100	105	104
basion-prosth.	107	102	90	100	107	100	91	98	97	92	96
maxillo-alv. Br.	67	65	62	62	66	62	61	66	62		63
maxillo-alv. Lt	58	54	46	57	58	57	46	54	53		48
biauricular	127	127	121	123	123	124	126	126	126	122	117
upper facial ht	78	73	64	76	68	70	57	81	71	67	69
min. frontal br.	93	92	92	86	90	88	96	89	95	93	97
upper facial br.	111	103	98	103	107	97	104		103	104	103
nasal ht.	56	55	47	55	49	49	46	54	51	54	49
nasal br.	27	26	26	28	27	27	25	24	29	28	24
ortibal br.	41	45	37	42	44	37	42	38	41	40	42
orbital ht.	37	35	32	39	33	37	32	36	37	33	37
biorbital br.	101	92	90	95	98	91	96		96	96	92
interorbital br.	24	18	18	20	21	21	20	19	21	24	23
frontal chord	117	107	111		106	107	112	111	113	111	114
parietal chord	111	111	112		100	107	104	117	101		122
occipital chord	98	93	92	102	104	88	95	92	106		
for. Mag. Lt.	36	37	34	38	37	32	30	37	39	35	
for. Mag. Br.	30	29	27	33	28	27	29	31	30	30	29
mastoid lt.	32	28	21	24	23	27	20	29	25	28	25

Crania Number	78	79	80	81
cranial length	167	186	180	176
cranial breadth		145	133	131
bizygomatic			139	127
basion-bregma	126	138	127	131
cranial base lt.	98	109	104	100
basion-prosth.	97	101	103	100
maxillo-alv. Br.	62	71	60	66
maxillo-alv. Lt	54	52	56	56
biauricular	115	140	127	121
upper facial ht	68	69	67	69
min. frontal br.	85	98	89	90
upper facial br.		114	107	102
nasal ht.	51	55	45	50
nasal br.	23	29	28	24
ortibal br.	39	43	40	49
orbital ht.	36	35	35	33
biorbital br.		103	96	96
interorbital br.	20	25	21	22
frontal chord	104	117	106	108
parietal chord	99	115	108	105
occipital chord	92	91	103	91
for. Mag. Lt.	33	37	38	35
for. Mag. Br.	31		28	31
mastoid lt.	26	30	24	23

Appendix B: Giles and Elliot Data

Sex by G & E Number	MCL	CBL	Bizyg	Ba-Pr	UFH	product	891.12?
1	182	99		108	51	346	n/a
2	182	101	130	97	63	896.2	male
3	174	104	148	90	54	956.68	male
4	182	107		104	77	403.32	n/a
5	191	109	146	97	72	997.46	male
6	181	101	117	98	62	840.76	female
7	180	99	128	96	63	883.6	female
8	185	107	141	110	71	952.74	male
9	185	109		106	71	398.88	n/a
10	176	104	128	102	71	893.58	male
11	165	96		94	58	346.08	n/a
12	187	109	139	105	75	961.58	male
13	179	106	151	102	75	998.08	male
14	183	106		106	73	394.66	n/a
15	187	111		97	69	410.44	n/a
16	166	101		94	67	369.4	n/a
17	167	98	126	92	63	862.9	female
18	166	97	130	99	68	876.7	female
19	176	104	134	101	67	912.3	male
20	178	103	132		99	1055.3	n/a
21	179	94	130	93	65	888.18	female
22	186	112	148	110	78	1000.8	male
23	160	90	120	91	63	818.62	female
24	170	105		100	69	377.76	n/a
25	171	96	133	99	66	889.7	female
26	178	100		97	64	374.04	n/a
27	193	102	125	98	75	908.2	male
28	180	104	129	95	64	898.42	male
29	177	96	140	94	66	929.52	male
30	166	93		100	65	347.04	n/a
31	187	95	133	91	72	923.84	male
32	174	100		98	68	374.56	n/a
33	185	103	131	105	65	902.06	male
34	188	106		95	82	425.32	n/a
35	170	95	136	94	71	911.52	male
36	182	103	137	93	63	931.38	male

37	175	101		93	64	376.22	n/a
38	184	98	125	90	66	885.26	female
39	154	88	119	87	59	802.2	female
40	185	108				393.88	n/a
41	193	103	121	90	70	894.24	male
42	176	100	129	97	67	889.76	female
43	172	95	138	94	78	932.58	male
44	170	98		96	60	356.28	n/a
45		103		110	71	170.32	n/a
46	178	104	128	98	61	884.5	female
47	183	104	133	104	72	921.14	male
48	174	102		103	74	382.12	n/a
49	184	104	147	96	70	982.94	male
50	170	96		89	66	369.2	n/a
51	177	102	130	103	67	892.22	male
52	179	101	140	98	50	911.5	male
53	170	96		97	67	362.74	n/a
54	179	102		97	108	446.28	n/a
55	172	94		88	60	359.96	n/a
56	175	105	144	105	74	959.38	male
57	172	99		94	61	363.8	n/a
58	176	103		99	72	387.02	n/a
59	173	108		104	63	372.98	n/a
60	188	112	154	113	78	1024	male
61	174	102		100	70	378.96	n/a
62	191	109	136	96	74	961.74	male
63	166	96	127	99	65	858.48	female
64	173	100	152	104	80	990.84	male
65	186	108	145	108	75	979.64	male
66	179	100	131	100	64	893.58	male
67	187	110		107	111	463.46	n/a
68	172	103	130	102	73	898.32	male
69	175	90		90	64	360.96	n/a
70	180	100	135	100	76	929.14	male
71	179	103		107	68	376.34	n/a
72	167	101	128	100	70	878.62	female
73	170	95	133	91	57	881.02	female
74	184	102		98	81	409.5	n/a
75	176	100	136	97	71	923.78	male
76	174	105	134	92	67	920.64	male
77	184	104		96	69	396.34	n/a

78	167	98		97	68	364.12	n/a
79	186	109		101	98	446.62	n/a
80	180	104	139	103	67	934.84	male
81	176	100	127	100	69	881.88	female

Male Race by G & E Number	Ba-Pr	MCL	MCB	Ba-B	CBL	Bizyg	UFH	NB	product	22.28?
1										
2	97	182	130	128	101	130	63	27	20	white
3	90	174	141	137	104	148	54	34	37	A.I.
4										
5	97	191	130	141	109	146	72	32	48	A.I.
6										
7										
8	110	185	140	138	107	141	71	31	25	A.I.
9										
10	102	176	140	127	104	128	71	26	1.2	white
11										
12	105	187	140	135	109	139	75	28	20	white
13	102	179	146	135	106	151	75	28	34	A.I.
14										
15										
16										
17										
18										
19	101	176		125	104	134	67	27		n/a
20										
21										
22	110	186		140	112	148	78	24		n/a
23										
24										
25										
26										
27	98	193	147	135	102	125	75	24	-12	white
28	95	180	135	135	104	129	64	30	13	white
29	94	177	138	133	96	140	66	27	31	A.I.
30										
31	91	187	146	137	95	133	73	25	7.1	white

32										
33	105	185	136	130	103	131	65	24	16	white
34										
35	94	170	144	135	95	136	71	30	15	white
36	93	182	134	127	103	137	63	26	25	A.I.
37										
38										
39										
40										
41	90	193	141	135	103	121	70	23	-9.3	white
42										
43	94	172	135	133	95	138	78	27	32	A.I.
44										
45										
46										
47	104	183	140	128	104	133	72	27	8.1	white
48										
49	96	184	145	133	104	147	108	28	21	white
50										
51	103	177	139	130	102	130	67	27	8.6	white
52	98	179	140	133	101	140	50	27	29	A.I.
53										
54										
55										
56	105	175	139	134	105	144	74	32	31	A.I.
57										
58										
59										
60	113	188	146	137	112	154	78	30	36	A.I.
61										
62	96	191	135	138	109	136	75	26	25	A.I.
63										
64	104	173	150	132	100	152	113	28	25	A.I.
65	108	186	140	141	108	145	75	27	37	A.I.
66	100	179	132	129	100	131	64	25	23	A.I.
67										
68	102	172	145	132	103	130	73	26	1.5	white
69										
70	100	180		120	100	135	76	28		n/a
71										
72										

73										
74										
75	97	176	140	137	100	136	71	29	21	white
76	92	174	135	135	105	134	67	28	23	A.I.
77										
78										
79										
80	103	180	133	127	104	139	67	28	29	A.I.
81										

Female Race by G&E Number	Ba-P	MCL	MCB	Ba-B	CBL	Bizyg	UFH	NB	product	130.1?
1										
2										
3										
4										
5										
6	98	181	135	130	101	117	62	27	68	white
7	96	180	134	134	99	128	63	25	159	A.I.
8										
9										
10										
11										
12										
13										
14										
15										
16										
17	92	167	140	128	98	126	63	34	75	white
18	99	166	140	127	97	130	68	25	135	A.I.
19										
20										
21	93	179	137	129	94	130	65	27	138	A.I.
22										
23	91	160		125	90	120	63	25		n/a
24										
25	99	171	135	121	96	133	66	25	154	A.I.
26										

27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38	90	184	139	123	98	125	66	25	47	white
39	87	154	137	120	88	119	59	28	74	white
40										
41										
42	97	176	134	130	100	129	67	23	151	A.I.
43										
44										
45										
46	98	178	128	135	104	128	61	23	190	A.I.
47										
48										
49										
50										
51										
52										
53										
54										
55										
56										
57										
58										
59										
60										
61										
62										
63	99	166	134	122	96	127	65	23	140	A.I.
64										
65										
66										
67										

68										
69										
70										
71										
72	100	167	130	131	101	128	70	27	174	A.I.
73	91	170	134	123	95	133	57	24	159	A.I.
74										
75										
76										
77										
78										
79										
80										
81	100	176	131	131	100	127	69	24	165	A.I.

Appendix C: Gill et al. Data

No.	Max Sub.	MFB	NZ Sub	ZOB	NA Sub	Alpha	Max Index	40	Zygo Index	38	Alpha Index	60	total
1	10	31					32.26	A.I.					n/a
2	10	27	19	53		34	37.04	A.I.	35.85	A.I.	0.00		n/a
3	12	26		7			46.15	W	0.00				n/a
4	10	25				33	40.00	either			0.00		n/a
5	11	32		65		37	34.38	A.I.	0.00		0.00		n/a
6	6	18	17	53	12	28	33.33	A.I.	32.08	A.I.	42.86	A.I.	A.I.
7	10	20	20	62	14	27	50.00	W	32.26	A.I.	51.85	A.I.	A.I.
8	11	21	21	53	14	32	52.38	W	39.62	W	43.75	A.I.	W
9	13	28				35	46.43	W			0.00		n/a
10	8	19	22	52	16	27	42.11	W	42.31	W	59.26	A.I.	W
11	4	14	20	50	16	25	28.57	A.I.	40.00		64.00	W	n/a
12	8	20	20	54	13	25	40.00	either	37.04	A.I.	52.00	A.I.	A.I.
13	9	16	23	53	17	28	56.25	W	43.40	W	60.71	W	W
14				54		33			0.00		0.00		n/a
15	8	20	22	58	16	33	40.00	either	37.93	A.I.	48.48	A.I.	A.I.
16	7	17	17	47	11	18	41.18	W	36.17	A.I.	61.11	W	W
17	16	26		68			61.54	W	0.00				n/a
18	11	22		51			50.00	W	0.00				n/a
19	12	20	21	50	14	20	60.00	W	42.00	W	70.00	W	W
20	12	19	18	47	9	14	63.16	W	38.30	W	64.29	W	W
21	8	19	19	54	13	23	42.11	W	35.19	A.I.	56.52	A.I.	A.I.
22	9	21	20	56	11	22	42.86	W	35.71	A.I.	50.00	A.I.	A.I.
23	6	13	17	53	13	22	46.15	W	32.08	A.I.	59.09	A.I.	A.I.
24	7	19	16	48	13	25	36.84	A.I.	33.33	A.I.	52.00	A.I.	A.I.
25	7	19	20	60	15	29	36.84	A.I.	33.33	A.I.	51.72	A.I.	A.I.
26	6	20	20	49	11	22	30.00	A.I.	40.82	W	50.00	A.I.	A.I.
27	9	16	23	48	19	22	56.25	W	47.92		86.36	W	n/a
28	9	18	21	50	13	23	50.00	W	42.00	W	56.52	A.I.	W
29	9	24		58			37.50	A.I.	0.00				n/a
30	7	21	16	51		24	33.33	A.I.	31.37	A.I.	0.00		n/a
31	8	18	23	48	18	23	44.44	W	47.92	W	78.26	W	W
32	7	19	22	48	15	27	36.84	A.I.	45.83	W	55.56	A.I.	A.I.
33	5	17	17	52	12	24	29.41	A.I.	32.69	A.I.	50.00	A.I.	A.I.
34	5	17	20	55	10	23	29.41	A.I.	36.36	A.I.	43.48	A.I.	A.I.
35	14	22		53		27	63.64	W	0.00		0.00		n/a

36	7	16	24	57	17	26	43.75	W	42.11	W	65.38	W	W
37	9	19					47.37	W					n/a
38	9	17	21	55	14	23	52.94	W	38.18	W	60.87	W	W
39	11	20		52		27	55.00	W	0.00		0.00		
40	9	14	21	49	13	20	64.29	W	42.86	W	65.00	W	W
41	8	15	22	49	17	22	53.33	W	44.90	W	77.27	W	W
42	7	18	22	54	13	22	38.89	A.I.	40.74	W	59.09	A.I.	A.I.
43	7	19	21	54	11	19	36.84	A.I.	38.89	W	57.89	A.I.	A.I.
44	6	17	21	50	9	25	35.29	A.I.	42.00	W	36.00	A.I.	A.I.
45	5	18	17	62	10	19	27.78	A.I.	27.42	A.I.	52.63	A.I.	A.I.
46	6	17	19	56	11	21	35.29	A.I.	33.93	A.I.	52.38	A.I.	A.I.
47	6	18	19	62	9	20	33.33	A.I.	30.65	A.I.	45.00	A.I.	A.I.
48	7	20	23	60	9	18	35.00	A.I.	38.33	W	50.00	A.I.	A.I.
49	8	17	23	57	16	22	47.06	W	40.35	W	72.73	W	W
50	5	16	16	52	7	15	31.25	A.I.	30.77	A.I.	46.67	A.I.	A.I.
51	8	18	22	54	11	16	44.44	W	40.74	W	68.75	W	W
52	7	19	17	55	9	18	36.84	A.I.	30.91	A.I.	50.00	A.I.	A.I.
53	7	18	16	53	9	19	38.89	A.I.	30.19	A.I.	47.37	A.I.	A.I.
54	9	21					42.86	W					n/a
55	8	20		56		26	40.00	W	0.00		0.00		n/a
56	9	18	21	60	13	24	50.00	W	35.00	A.I.	54.17	A.I.	A.I.
57	7	16	21	57	11	21	43.75	W	36.84	A.I.	52.38	A.I.	A.I.
58	5	18	18	54	11	25	27.78	A.I.	33.33	A.I.	44.00	A.I.	A.I.
59	6	20	19	57	8	20	30.00	A.I.	33.33	A.I.	40.00	A.I.	A.I.
60	9	20	21	56	12	24	45.00	W	37.50	A.I.	50.00	A.I.	A.I.
61	7	18	21	66	14	26	38.89	A.I.	31.82	A.I.	53.85	A.I.	A.I.
62	9	19	21	54	13	24	47.37	W	38.89	W	54.17	A.I.	W
63	6	19	10	55	12	22	31.58	A.I.	18.18	A.I.	54.55	A.I.	A.I.
64	7	15	20	59	16	25	46.67	W	33.90	A.I.	64.00	W	W
65	7	16	19	58	12	25	43.75	W	32.76	A.I.	48.00	A.I.	A.I.
66	5	15	19	52	13	23	33.33	A.I.	36.54	A.I.	56.52	A.I.	A.I.
67	10	19	21	55	15	24	52.63	W	38.18	W	62.50	W	W
68	7	14	26	55	19	24	50.00	W	47.27	W	79.17	W	W
69	7	17	18	51	10	24	41.18	W	35.29	A.I.	41.67	A.I.	A.I.
70	8	19	22	59	13	21	42.11	W	37.29	A.I.	61.90	W	W
71	11	21		65			52.38	W	0.00				n/a
72	7	18	17	48	13	26	38.89	A.I.	35.42	A.I.	50.00	A.I.	A.I.
73	6	15	18	53	13	25	40.00	either	33.96	A.I.	52.00	A.I.	A.I.
74	8	19					42.11	W					n/a
75	6	16	21	59	11	24	37.50	A.I.	35.59	A.I.	45.83	A.I.	A.I.
76	6	19	19	55	14	27	31.58	A.I.	34.55	A.I.	51.85	A.I.	A.I.

77	8	23		58		26	34.78	A.I.	0.00		0.00		n/a
78	8	20				21	40.00	A.I.			0.00		n/a
79	15	25			14	25	60.00	W			56.00	A.I.	n/a
80	6	18	20	60	15	29	33.33	A.I.	33.33	A.I.	51.72	A.I.	A.I.
81	6	17	17	61	11	25	35.29	A.I.	27.87	A.I.	44.00	A.I.	A.I.

Appendix D: Results

Sample #	Fordisc 2.0 race 0 white 1 N.A.	Giles & Elliot race 0 white 1 N.A.	Gill race 0 white 1 N.A.
1	1		
2	1	0	
3	1	1	
4	1		
5	1	1	
6	1	1	1
7	1	1	1
8	1	1	0
9	1		
10	1	0	0
11	0		
12	1	0	1
13	1	1	0
14	1		
15	1		1
16	1		0
17	1	1	
18	1	1	
19	1		0
20	1		0
21	1	1	1
22	1		1
23	1		1
24	1		1
25	1	1	1
26	1		1
27	0	0	
28	1	0	0
29	1	1	
30	1		
31	0	0	0
32	1		1
33	1	0	1
34	1		1

35	1	0	
36	1	1	0
37	1		
38	0	1	0
39	1	1	
40	0		0
41	0	0	0
42	1	1	1
43	1	1	1
44	1		1
45	1		1
46	0	1	1
47	1	0	1
48	1		1
49	1	0	0
50	1		1
51	1	0	0
52	1	1	1
53	1		1
54	1		
55	1		
56	1	1	1
57	1		1
58	1		1
59	1		1
60	1	1	1
61	1		1
62	1	1	0
63	1	1	1
64	1	1	0
65	1	1	1
66	1	1	1
67	1		0
68	1	0	0
69	1		1
70	1		0
71	1		
72	1	1	1
73	1	1	1
74	1		
75	1	0	1

76	1	1	1
77	0		
78	1		
79	1		
80	1	1	1
81	1	1	1
Mean	0.90	0.68	0.67
stand. dev.	0.30	0.47	0.47

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