Craniofacial variation II:
Head shape prediction from anthropometric measurements and ancestry

K. James Soda[1], Brian Corner[2], Dennis Slice[1]
[1]Department of Scientific Computing
Florida State University
[2]US Army Natick Soldier Research
Development and Engineering Center

Abstract: Over the years a large sample of whole-head surface scans has been collected. These scans could provide valuable information on head shape variation for the design of protective and therapeutic head gear. Unfortunately, in most scans, the vault of the head is obscured by hair or caps. If there were a model to predict this obscured data, then it could leverage existing data for thousands of individuals. Here, we examine the extent to which anthropometric variables and self-reported ancestry can predict a basic measure of head shape, the cranial index, as a first step toward developing more sophisticated models utilizing landmark coordinates, anthropometric variables, ancestry, and other information. Cranial index and seven additional anthropometric measurements were taken from the United States Marine Corps's Anthropometric Survey for Hispanic and White males (N = 61/ancestry). All analyses were made in R ver. 2.15. A significant difference in cephalic indices between White and Hispanic males was examined via ANOVA. Then, linear models were developed to predict cranial index using just the seven anthropometric measurements and then using both the anthropometric measurements and the ancestry data. There was no significant difference in cranial index between ancestries, and the addition of ancestry to linear models of cranial index led to a higher leave-one-out root mean squared error. Although linear models based on anthropometric data are able to predict cranial index, information on ancestry does not always improve the predictive power of such models and therefore ancestry may not play a large role in future models.
This work was funded, in part, by Cooperative Research Agreement W911QY-12-2-0004 between Florida State University and the U.S. Army Natick Soldier Research, Development, and Engineering Center. Approved for public release.

Introduction

- The fit of a helmet on a subject's head depends on the shape of the head. Unfortunately, hair often obscures the vault of the head, thereby preventing an accurate assessment of variability in head shape. Without such an assessment, helmet design becomes challenging. As a result, quantitative methods that predict head shape based on more easily observed qualities, such as post-cranial linear measurments or race, could be an asset to helmet design.
- Cephalic index, that is the ratio between a head's length and its breadth, is one measure of a head's shape (see Boa (1899)).
- Here we attempt to predict the cephalic index of 61 White, male Marines and 61 Hispanic, male Marines based on ancestry and post-cranial data.

Methods

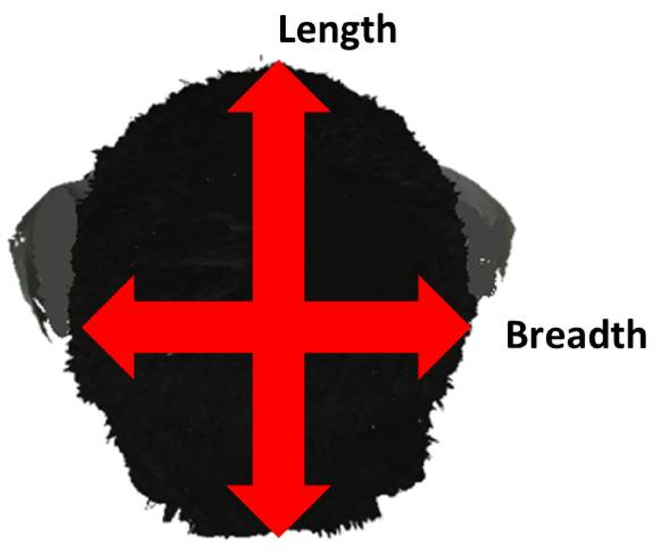

Figure 1. Diagram illustrating the breadth and length of the head. The cephalic index is defined as the ratio between a head's length and a head's breadth.

- 61 White, male subjects and 61 Hispanic, male subjects were randomly selected from the United States Marine Corps's Anthropometric Survey, and each subject's cephalic index was calculated
-The cephalic index of White subject was compared to the cephalic index of Hispanic subjects via a one-way ANOVA test in R (version 2.15).
- There was no evidence for significant interaction terms between race and linear measurements ($F < 3.87$; $p > 0.05$), so two linear models for predicting cephalic index without interaction terms were generated in R. The first incorporated race and seven linear measurements (horizontal foot breadth, foot length, hand breadth, hand length, heel breadth, palm length, and radiale-stylion length), whereas the second only incorporated the linear measurements.
- The accuracy of each linear model was assessed according to the model's leave-one-out root mean squared error.
- To ensure that the results of the ANOVA test were not purely the result of the ancestries chosen, random selection and another one-way ANOVA test compared the cephalic index of 39 White, male subject to 39 Black, male subjects.

Results

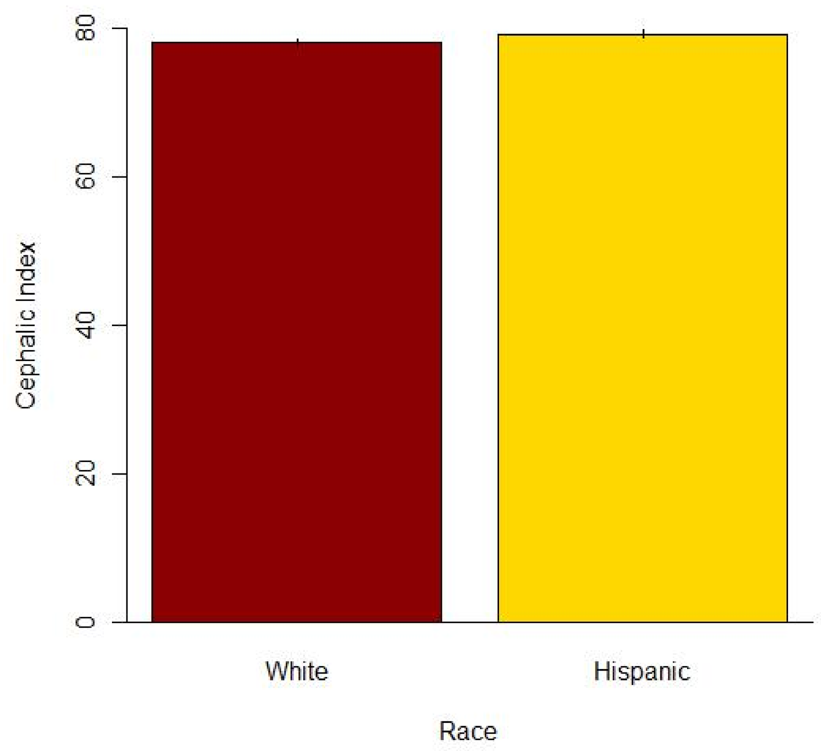

Figure 2. A bar chart comparing the mean cephalic index of White data points to the mean cephalic index of Hispanic data points. The error bars represent plus or minus one standard error. There is no significant difference between the two values ($F_{1,120} = 2.454$; p = 0.1199).

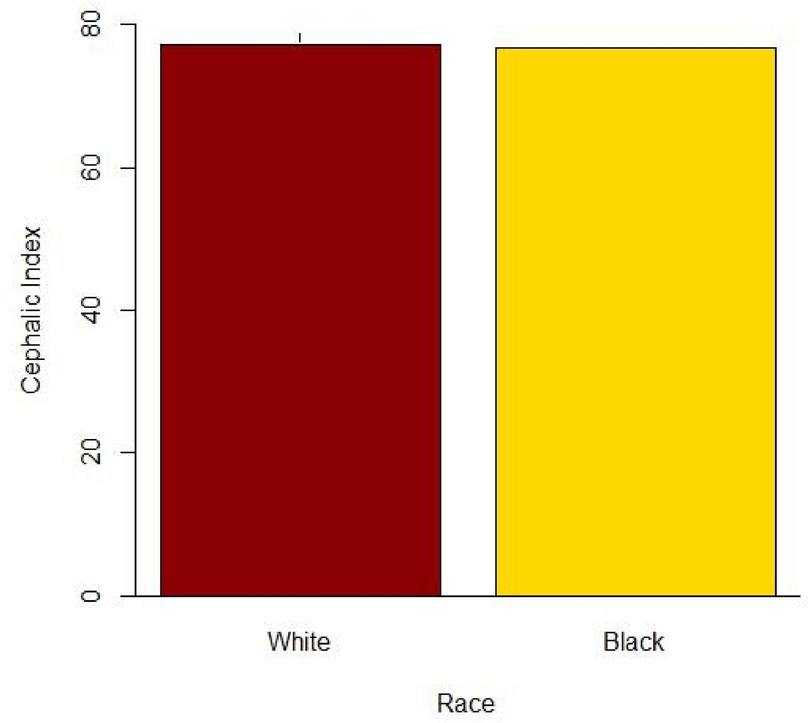

Figure 3. A bar chart comparing the mean cephalic index of White data points to the mean cephalic index of Black data points. The error bars represent plus or minus one standard error. There is no significant difference between the two values ($F_{1,76} = 0.6053$; p = 0.439).

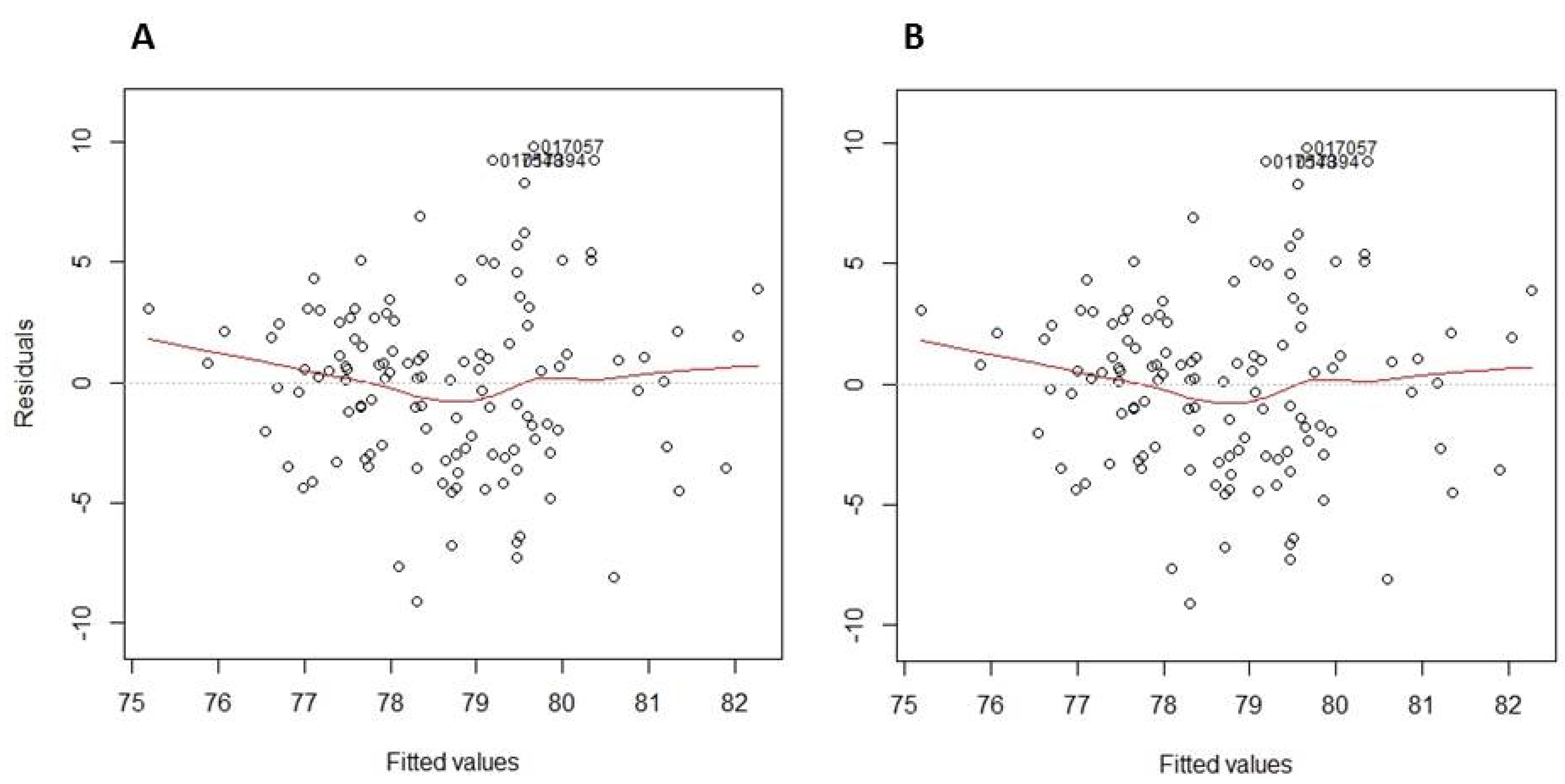

Figure 4. A) Residuals from the linear model incorporating ancestry plotted against the predicted value. B) Residuals from the linear model not incorporating ancestry plotted against the predicted value. In both figures, the three largest residuals are indicated by their specimen number. The red line represents a generalized additive model to predict the residual based on the predicted value. Ideally, the generalized additive model should be a horizontal line at Residual = 0. The addition of race does not significantly improve the fit of the model ($F_{1,117} = 0.3986$; p = 0.529).

Analysis and Conclusions

- The leave-one-out root mean squared error was 3.94 units for the model incorporating ancestry, but only 3.91 units for the model excluding ancestry. This implies that the model that does not incorporate ancestry generates slightly more accurate predictions.
- Given that models incorporating ancestry do not have increased accuracy and that there is no evidence to believe that Hispanic and White subjects have different cephalic indices on average, ancestry may not always be useful for predicting head shape. The abscence of a significant difference in cephalic index between Black and White subjects further supports this claim.

References

- Boas, F. (1899). The cephalic index. American Anthropologist 1: 448-461.
- R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.ISBN 3-900051-07-0, URL http://www.R-project.org/.