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Can ancestry be consistently determined from the skeleton?

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Abstract: Although the concept of race has been thoroughly criticised in biological anthropology, forensic anthropology still uses a number of methods to determine the 'race' of a skeleton. The methods must be evaluated to see how effective they are given large individual variation. This study used 20 cases of skeletons of varied provenance to test whether the nine published methods of 'race' determination, using a range of various approaches, were able to consistently identify the ethnic origin. No one individual was identified as belonging to just one 'major racial class', e.g. European, meaning that complete consistency across all nine methods was not observed. In 14 cases (70%), various methods identified the same individual as belonging to all three racial classes. This suggests that the existing methods for the determination of 'race' are compromised. The very concept of 'race' is inapplicable to variation that occurs between populations only in small ways and the methods are limited by the geographic population from which their discriminant functions or observations of morphological traits were derived. Methods of multivariate linear discriminant analysis, e.g. CRANID, are supposed to allocate an individual skull to a specific population rather than a 'major race'. In our analysis CRANID did not produce convincing allocations of individual skeletons to specific populations. The findings of this study show that great caution must be taken when attempting to ascertain the 'race' of a skeleton, as the outcome is not only dependent on which skeletal sites are available for assessment, but also the degree to which the unknown skeleton's population of origin has been investigated.

Key words: human skeletal identification; race; discriminant function analysis; non-metric variation

Introduction

The concept of assigning skeletal remains into a defined 'race' is problematic due to the nature of human variability (Kaszycka et al. 2009). Some elements of variability can be attributed to genetic drift in small populations (Henneberg

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2006; Rhine 1993) or to natural selection in antecedent populations, however, with the increasing levels of migration and the resultant gene flow, levels of variability of specific racial identifiers are increasing within local populations. In general, the concept of 'race' is ill suited to the study of human variation because this variation is quasi-continuous and most of it occurs among individuals in the same populations while only about a quarter is attributable to geographic distribution of people (Brace 2005; Henneberg 2010; Lewontin 1976). Anthropological methods available to identify a race are derived from specific skeletal samples representing particular geographic groups. Thus, discriminant functions or morphological categories recommended by a method may not be adequate to identify the racial affinity of a skeleton of unknown provenance (Iscan 1983; Iscan & Steyn 1999; Patriquin et al. 2002). Some members of a particular 'race' may share some features within a population, such as the presence of a wide nasal aperture in African Americans; however, individual variability can often cause an overlap of such features with other 'races'. The discrimination ability of available methods should be investigated in skeletal samples from outside the geographic populations, for which the original methods were derived, to be able to assess their general usability. In the literature there is a wide variety of methods used to ascertain the ancestry of skeletal samples. These methods used craniometric (Giles & Elliot 1962; Gill 1984; Wright 2008) and morphologic (Bass 1995; Brues 1990; Gill 1998; Rhine 1993) assessments of the skull and metric assessment of the pelvis (Iscan 1983; Patriquin et al. 2002). These skeletal elements are commonly accepted as the gold standard for determining 'race' from skeletal remains. Other such studies exist, however their methods are comparatively similar to those mentioned previously. In this study nine methods of 'race' determination, chosen to represent their common types, have been applied to 20 cases of skeletons requiring racial identification as if they were a subject of forensic investigation. Thus each of the skeletons is to be considered a separate case. The ability of the nine methods to consistently determine the 'race' of a skeleton was evaluated.

Method

The nine methods (Table 1) were applied to 20 skeletons held by The Ray Last Laboratory at The University of Adelaide. The origin of these skeletons is unknown, however, they are most likely to come from two sources; (1) donated skeletons of Australians of European descent with a slight possibility of Australian Aboriginal admixture, and (2) teaching skeletons bought by the University from India early in the 20th century.

The ability of the methods to consistently determine the 'race' of an individual was evaluated in three different ways. (1) Counting in how many cases the majority of methods gave the same result, i.e. at least five of the nine methods consistently identified the skeleton as belonging to the same 'race'. (2) Counting in how many cases results were fully ambiguous, i.e. the skeleton was identified as belonging to one 'race' by the same number of methods as belonging to the other 'race'. (3) Counting in how many cases methods identify the skeleton as belonging at the same time to all three of the 'racial classes', with at least one method in each class. The above categories are not mu-

Table 1. Methods used for the determination of ancestry in this study

Method Number	Description of method	Possible Results	Collection Used	Author & Date
1	3× craniofacial indices	White or Black/ Indian/Eskimo	Terry collection, Smithsonian Institution as well as secondary sources	Gill 1984
2	2× cranial discriminant functions	White, Black or American Indian	Terry collection, St. Louis Todd collection, Cleveland	Giles & Elliot 1962
3	11× morphological traits of skull	Caucasoid, Mongoloid or Negroid	Meta-analysis of previous studies	Bass 1995
4	20× morphological traits of skull	Caucasoid, Mongoloid or Negroid	Meta-analysis of previous studies	Rhine 1993
5	12× morphological traits of skull	White, Black or East Asian/American Indian/Polynesian	Meta-analysis of previous studies	Gill 1998
6	Morphological study of the nasal root	Caucasoid, Mongoloid or Negroid	Peabody Museum Collection	Brues 1990
7	4× Pelvic discriminant functions	White or Black	Terry collection, Smithsonian Institution	Iscan 1983
8	4× Pelvic discriminant functions	White or Black	Dissection specimens, University of Pretoria Raymond Dart collection, Johannesburg	Patriquin et al. 2002
9	Multivariate statistics on cranial dimensions	Many populations	Howells' public data set	CRANID by Wright 2008

tually exclusive except for (1) and (2). Authors of each method gave somewhat different names for the 'racial categories' into which their method is supposed to classify and individual. For purposes of comparing the methods we have grouped their results into three general classes; Black, White and Other. 'Black' includes any determination pertaining to Sub-Saharan African ancestry, 'White' includes any determination pertaining to European ancestry, while 'Other' includes any determination that is pertaining to Asian, Amerindian, Indigenous Australian and Oceanian ancestry.

Outcomes of 'racial' determination were transformed into numerical values for the purposes of statistical analysis. An outcome of 'Black' was given the value '1'; an outcome of 'White' was given the value '2'; to increase precision of analysis, the 'Other' class was divided into an outcome of 'Mongoloid' that was given the value '3' and all other outcomes were given the value '4'. Consistency of the nine methods was then analysed using a non-parametric One-way ANOVA (Kruskal-Wallis test). Inter-correlation between the nine methods was also analysed using the non-parametric Spearman test.

Results

Table 2 shows that no one individual was identified as belonging to only one 'racial class'. Twelve individuals fall under the 'majority' category (see 'consistency'

Table 2. Results of determination of 'race' of a series of male skeletons, of different provenance, by a number of methods recommended by forensic anthropology texts. Numbers 1) 2) etc. in columns indicate results of different discriminant function equations by the same authors

Methods		1	2	3	4	5	6	7	8	9	Consistency
Specimen		CDF[1]	CDF	Cranial descriptive (morphological) traits	Cranial descriptive (morphological) traits	Cranial descriptive (morphological) traits	Nasal root	PDF[2]	PDF	CRANID Cranial Dimensions	White/black/other
No	Label										
1	2	3	4	5	6	7	8	9	10	11	12
1	A	White	1) Black 2) American Indian	–7/9* traits indicate Caucasoid –1/9* traits indicate Negroid –1/9* traits indicate Mongoloid	–12/19* traits indicate Caucasoid –2/19* traits indicate Negroid –5/19* traits indicate Mongoloid	–10/12 traits indicate White –2/2 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) White 2) White 3) White 4) White	1) White 2) White 3) White 4) White	Zalavar Hungarian medieval	7/1/1
2	B	White	1) Black 2) American Indian	–6/9* traits indicate Caucasoid –2/9* traits indicate Negroid –1/9* traits indicate Mongoloid	–14/19* traits indicate Caucasoid –4/19* traits indicate Negroid –1/19* traits indicate Mongoloid	–9/12 traits indicate White –1/12 traits indicate Black –2/12 traits indicate East Asian, American Indian or Polynesian	Caucasoid	1) White 2) White 3) White 4) White	1) White 2) White 3) White 4) White	Berg Austria medieval	8/1/0
3	1	White	1) White 2) American Indian	–7/11 traits indicate Caucasoid –2/11 traits indicate Negroid –2/11 traits indicate Mongoloid	–8/20 traits indicate Caucasoid –5/20 traits indicate Negroid –7/20 traits indicate Mongoloid	–3/12 traits indicate White –4/12 traits indicate Black –5/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	South Australian Indigenous	4/2/3
4	2	White	1) Black 2) American Indian	–8/11 traits indicate Caucasoid –1/11 traits indicate Negroid –2/11 traits indicate Mongoloid	–10/20 traits indicate Caucasoid –6/20 traits indicate Negroid –4/20 traits indicate Mongoloid	–7/12 traits indicate White –4/12 traits indicate Black –1/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) Black 2) Black 3) Black 4) Black	1) Black 2) Black 3) Black 4) Black	Patagonian	4/3/2
5	3	White	1) Black 2) American Indian	–11/11 traits indicate Caucasoid	–14/20 traits indicate Caucasoid –3/20 traits indicate Negroid –3/20 traits indicate Mongoloid	–6/12 traits indicate White –1/12 traits indicate Black –5/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) White 2) White 3) White 4) White	1) White 2) White 3) White 4) White	North Japan Hokkaido	6/1/2

1	2	3	4	5	6	7	8	9	10	11	12
6	4	White	1) Black 2) American Indian	–8/8* traits indicate Caucasoid	–9/15* traits indicate Caucasoid –2/15* traits indicate Negroid –4/15* traits indicate Mongoloid	–6/10* traits indicate White –4/10* traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) White 2) White 3) White 4) White	1) White 2) White 3) White 4) White	London medieval	7/1/1
7	5	White	1) Black 2) American Indian	–8/11 traits indicate Caucasoid –2/11 traits indicate Negroid –1/11 traits indicate Mongoloid	–11/20 traits indicate Caucasoid –5/20 traits indicate Negroid –4/20 traits indicate Mongoloid	–4/12 traits indicate White –2/12 traits indicate Black –6/12 traits indicate East Asian, American Indian or Polynesian	Negroid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Egypt 26–30 dynasty	4/4/1
8	6	White	1) Black 2) American Indian	–7/11 traits indicate Caucasoid –2/11 traits indicate Negroid –2/11 traits indicate Mongoloid	–7/20 traits indicate Caucasoid –8/20 traits indicate Negroid –5/20 traits indicate Mongoloid	–8/12 traits indicate White –3/12 traits indicate Black –1/12 traits indicate East Asian, American Indian or Polynesian	Caucasoid	1) Black 2) Black 3) Black 4) Black	1) Black 2) Black 3) Black 4) Black	Punjab	4/4/1
9	7	White	1) Black 2) American Indian	–8/11 traits indicate Caucasoid –1/11 traits indicate Negroid –2/11 traits indicate Mongoloid	–9/20 traits indicate Caucasoid –7/20 traits indicate Negroid –4/20 traits indicate Mongoloid	–6/12 traits indicate White –2/12 traits indicate Black –4/12 traits indicate East Asian, American Indian or Polynesian	Negroid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Teita East African	4/5/0
10	AM1	White	1) White 2) American Indian	–8/11 traits indicate Caucasoid –2/11 traits indicate Negroid –1/11 traits indicate Mongoloid	–13/20 traits indicate Caucasoid –5/20 traits indicate Negroid –2/20 traits indicate Mongoloid	–7/12 traits indicate White –2/12 traits indicate Black –3/12 traits indicate East Asian, American Indian or Polynesian	Negroid	1) Black 2) White 3) White 4) White	1) White 2) Black 3) Black 4) Black	Sydney Aboriginal	6/2/1

1	2	3	4	5	6	7	8	9	10	11	12
11	AM2	White	1) White 2) American Indian	–6/11 traits indicate Caucasoid –2/11 traits indicate Negroid –3/11 traits indicate Mongoloid	–8/20 traits indicate Caucasoid –3/20 traits indicate Negroid –9/20 traits indicate Mongoloid	–4/12 traits indicate White –3/12 traits indicate Black –5/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) Black 2) Black 3) Black 4) Black	1) White 2) White 3) Black 4) Black	Eskimo Greenland	3.5/1.5/4
12	AM3	White	1) Black 2) American Indian	–9/11 traits indicate Caucasoid –1/11 traits indicate Negroid –1/11 traits indicate Mongoloid	–14/20 traits indicate Caucasoid –3/20 traits indicate Negroid –3/20 traits indicate Mongoloid	–7/12 traits indicate White –4/12 traits indicate Black –1/12 traits indicate East Asian, American Indian or Polynesian	Caucasoid	1) White 2) White 3)White 4) White	1) White 2) White 3) Black 4) Black	Italian Post-Medieval	7.5/1.5/0
13	AM4	White	1) White 2) American Indian	–6/11 traits indicate Caucasoid –4/11 traits indicate Negroid –1/11 traits indicate Mongoloid	–8/20 traits indicate Caucasoid –8/20 traits indicate Negroid –4/20 traits indicate Mongoloid	–3/12 traits indicate White –7/12 traits indicate Black –2/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) Black 2) Black 3) Black 4) Black	1) Black 2) Black 3) Black 4) Black	Egypt 26–30 dynasty	3.5/3.5/2
14	AM5	White	1) White 2) American Indian	–10/11 traits indicate Caucasoid –1/11 traits indicate Mongoloid	–12/20 traits indicate Caucasoid –5/20 traits indicate Negroid –3/20 traits indicate Mongoloid	–8/12 traits indicate White –1/12 traits indicate Black –3/12 traits indicate East Asian, American Indian or Polynesian	Negroid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) White 4) Black	Poundbury UK	6.5/2.5/0
15	HS-041	White	1) Black 2) American Indian	–9/11 traits indicate Caucasoid –2/11 traits indicate Mongoloid	–12/20 traits indicate Caucasoid –5/20 traits indicate Negroid –3/20 traits indicate Mongoloid	–7/12 traits indicate White –1/12 traits indicate Black –4/12 traits indicate East Asian, American Indian or Polynesian	Negroid	1) White 2) Black 3) Black 4) Black	1) Black 2) Black 3) Black 4) Black	Zulu South African	4/5/0

1	2	3	4	5	6	7	8	9	10	11	12
16	HS-038	White	1) Black 2) American Indian	–8/11 traits indicate Caucasoid –3/11 traits indicate Mongoloid	–17/20 traits indicate Caucasoid –1/20 traits indicate Negroid –2/20 traits indicate Mongoloid	–6/12 traits indicate White –2/12 traits indicate Black –4/12 traits indicate East Asian, American Indian or Polynesian	Caucasoid	1) White 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Italian Post-Medieval	6/3/0
17	HS-039	White	1) Black 2) American Indian	–7/11 traits indicate Caucasoid –4/11 traits indicate Mongoloid	–12/20 traits indicate Caucasoid –2/20 traits indicate Negroid –6/20 traits indicate Mongoloid	–5/12 traits indicate White –3/12 traits indicate Black –4/12 traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) White 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Tolai New Britain	4/3/2
18	HS-012	White	1) Black 2) American Indian	–7/8* traits indicate Caucasoid –1/8* traits indicate Mongoloid	–12/15* traits indicate Caucasoid –3/15* traits indicate Mongoloid	–3/10* traits indicate White –7/10* traits indicate East Asian, American Indian or Polynesian	Mongoloid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Berg Austria Medieval	4/3/2
19	SC-002	White	1) Black 2) American Indian	–8/10* traits indicate Caucasoid –2/10* traits indicate Mongoloid	–10/19* traits indicate Caucasoid –5/19* traits indicate Negroid –4/19* traits indicate Mongoloid	–9/11* traits indicate White –2/11* traits indicate Black	Caucasoid	1) Black 2) Black 3) Black 4) Black	1) Black 2) Black 3) Black 4) Black	Punjab	5/3/1
20	SC-003	White	1) Black 2) American Indian	–10/11 traits indicate Caucasoid –1/11 traits indicate Mongoloid	–14/20 traits indicate Caucasoid –1/20 traits indicate Negroid –5/20 traits indicate Mongoloid	–7/12 traits indicate White –2/12 traits indicate Black –3/12 traits indicate East Asian, American Indian or Polynesian	Caucasoid	1) Black 2) Black 3) Black 4) Black	1) White 2) Black 3) Black 4) Black	Punjab	5/3/1

[1]CDF – Cranial Discriminant Function; [2]PDF – Pelvic Discriminant Function; [A]A skeleton of an adult from the Abbie Museum of Anatomy, University of Adelaide; [B]A skeleton of known sex, age and race from a donated cadaver – white Australian male who died at age XX years; [1–5]Actual skeletons of individuals of unknown sex, age and race used as teaching aids in dissection rooms; [AM#]Skeletons of individuals of unknown sex, age and race from the Abbie Museum of Anatomy, University of Adelaide; [HS–0##/SC–0##]Boxed half-skeletons of unknown sex, age and race from the University of Adelaide; *Some traits were excluded due to their absence on the skeleton.

column for specimen numbers 1, 2, 5, 6, 9, 10, 12, 14, 15, 16, 19, 20), where in most cases skeletons were identified as being White (specimens 9 and 16 were identified as black). Three individuals fall under the 'ambiguous' category (specimen numbers 7, 8, 13), where in all cases skeletons were identified as being equally White and Black. Fourteen individuals were identified as belonging to all three of the racial classes by at least one method in each group (specimen numbers 1, 3, 4, 5, 6, 7, 8, 10, 11, 13, 17, 18, 19, 20).

A non-parametric analysis of the transformed data found a significant difference between the results of the nine different methods ($p<0.0001$). Non-parametric analysis of the inter-correlation between the nine methods found that only two methods (methods 7 and 8) displayed significant correlation ($r=0.56$, $p=0.01$).

Discussion

The combination of the nine methods used in this study failed to produce fully consistent identification of the ancestry of even a single skeleton. Although, with a larger sample size, or with yet another method, it may have been possible to find an individual who belonged only to one 'racial group'; such an event would still be a small portion of all cases. Were any of the skeletons studied here an actual forensic case, the fact that in none of the instances a fully consistent result has been achieved is disturbing. It indicates that the reliability of the methods is below 5% level while in criminal cases the proof required is that "beyond reasonable doubt". The ethnic origins of the skeletons used in this study where not precisely known, with one exception (specimen 2), however, this is of little importance when no combination of the nine methods was able to consistently identify a single skeleton as belonging to just one and the same 'racial group'.

The ability of methods of forensic anthropology to determine 'race' from the skeleton has been questioned by Brues (1992). She states that paradoxical diagnoses of 'race' from the skull may be due to the use of a subset of a single population to represent a large geographic area. She does, however, commend the work of Giles and Elliot (1962) describing their method as the 'standard' of racial determination. Contrarily, Snow et al. (1979) found that in a collection of 42 skulls from White, Black and Indian Americans, the racial origin of only 30 skulls was identified correctly using the Giles and Elliot (1962) method. They concluded that the geographically limited crania used to develop the discriminant functions were not representative of the crania of present-day Americans. This concept can be applied to all the methods used in this study, as the origin of the 20 skeletons may not have matched with the populations used to derive the methods. Multivariate discriminant function approaches, such as that of Wright (2008), proposed to improve precision of identification of ancestry, however, they do not seem to perform significantly better as evidenced by our results and those of Kallenberger and Pilbrow (2012) who found that the CRANID program was only able to accurately assign 39% of specimens to geographically closest matching reference samples.

No single individual was identified as belonging to only one 'racial group'. It is concerning that nine methods of forensic anthropology, whose sole purpose is to ascertain the 'race' of an individual, did not yield consistent results. In 14 cases

(70%), individuals were identified as belonging to all three racial classes. Specimen 18 was identified as White by four methods (Bass 1995; Gill 1984; Rhine 1993; Wright 2008), Black by three methods (Giles & Elliot 1962; Iscan 1983; Patriquin et al. 2002) and either Asian, Amerindian, Indigenous Australian or Oceanian by two methods (Brues 1990; Gill 1998). Specimen 10 was found to be majority White (six of the nine methods) however the CRANID software (Wright 2008) identified this individual as being a Sydney Aboriginal. Results such as these show that the range of inconsistencies found in assignment of 'race' does not improve using more sophisticated software.

The accurate determination of 'race' is virtually impossible with distribution of human variation within and between populations. For this reason, no-matter how sophisticated the method, there is no way to consistently identify an individual as belonging to one specific 'race'. In court cases it is advisable to abstain from stating the 'race' of a skeleton, even if desired by the court, because a mistake in assignment is likely and it will compromise the proceedings. If an 'ethnic' identification is required, it is better to base it on the evidence of lifestyle, such as tooth wear or limb characteristics than on any 'racial' characters.

According to the discriminant function of Gill (1984) all 20 specimens in this study were White. This is questionable as only 12 specimens were consistently found to be White by a majority of the methods. In addition to this, specimen 13 displayed morphological features congruent with an African American or Australian Aboriginal person. These features included a wide nasal aperture, significant prognathism and a heavy supraorbital ridge. Despite this, the ability of the methods to determine the 'race' of this individual was ambiguous at best, with results showing that three and a half methods indicated White; three and a half indicated Black, and two indicated either Asian, Amerindian, Indigenous Australian or Oceanian. This suggests that determination of 'race' through individual morphological features of the skull (Bass 1995; Gill 1998; Rhine 1993) is limited by the specific sites available for examination. If, in the case of specimen 13, remains were fragmented and the mid-facial region was absent, the individual may have been identified as being White; a conclusion that would not be accepted had the skull been fully intact.

Multivariate metric methods based on linear discriminant analysis (LDA) such like FORDISC (Ousley et al. 2009) or CRANID (Wright 2008) also have their fallacies. If even one anthropometric point (out of the 29 necessary) is missing, say due to a fractured skull, CRANID will not work. When less than 21 measures, available in FORDISC are used, results are not convincing, too (Williams et al. 2005). Wright (2008) states that results of the distributable version of CRANID can only be taken as reliable if the most likely sample population has a high probability and if the sample populations that immediately follow are consistently from contiguous geographical areas. In our analysis of 20 skulls, CRANID returned a result 'poorly catered for' for eleven of our specimens (Specimens 1, 2, 3, 5, 7, 11, 13, 15, 16, 17, 18). Wright (2008) states that this lack of fit may be due to measurements being wrongly made or entered, the geographical area from which these individuals came is poorly catered for in the database, the individuals being morpho-

logically atypical, or the individuals are of mixed ancestry. This however, does not help to understand what specifically caused an ambiguous result for each of our 11 abovementioned specimens. In the present day forensic applications it is likely that increased number of mixed ancestry individuals may appear due to an increase in migration, thus limiting the applicability of metric methods.

Statistical analysis found a significant difference between the results of the nine methods. This indicates that, statistically, the methods are not consistent. In a practical sense, this means that forensic investigators using one, or even a few of these methods, will be obtaining results different from investigators who may be using a different combination of methods.

A number of methods of forensic anthropology were unable to consistently determine the 'race' of any of the 20 skeletons. Racial determination is an identifier of an individual's uniqueness, regularly sought after by law enforcement in cases of discovery of skeletal remains. We have shown that even with 20 non-fragmented sets of skeletal remains none could be consistently placed into a single racial category. Individual variability may have played a significant role leading to inconsistency of the results found in this study, which further confirms the ideas of Brace and Ryan (1980), Henneberg (2010) and Lewontin (1976); that most human variation occurs between individuals of the same population rather than being attributable to geographic distribution. Since the majority of the biological variation in the human species occurs among individuals with the minority being due to geographic differences (Brace 2005; Henneberg 2010; Lewontin 1976), it seems impossible to construct a precise method of 'racial' identification. Instances of such identification may be successful in particular local populations created by recent migrations.

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Authors' contributions

IS and MH were responsible for project design. IS made measurements and determined ancestry. IS and MH conducted statistical analysis, made conceptual contributions and wrote the manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

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