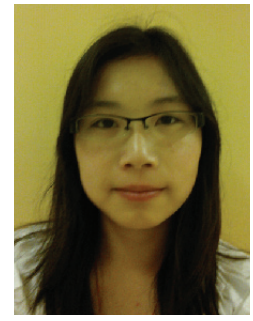
Bioanalysis

Is it possible to identify gender and ethnicity via hair elements?

"For this approach, no quantitative analysis is required, as the relative concentrations of the elements in the hair can be used to infer gender and ethnicity."

Keywords: electrothermal vaporization • forensic analysis • hair analysis • inductively coupled plasma optical emission spectrometry • trace element analysis



Lily Huang
Queen's University, Department of Chemistry, 90 Bader Lane, Kingston, ON K7L 3N6, Canada

Diane Beauchemin
Author for correspondence:
Queen's University, Department of Chemistry, 90 Bader Lane, Kingston, ON K7L 3N6, Canada
diane.beauchemin@chem.queensu.ca

Introduction & goal

Anthropology and ethics researchers often argue as to whether individuals should be categorized according to race [1]. Nonetheless, certain distinguishing features have been established in some races based on distinct bone structures, particularly in the cranial area [2]. However, the use of qualitative features, referred to as non-metric traits, can be subject to bias, which may jeopardize the accuracy of the conclusion [3,4]. Thus, statistical methods based on measurable data, such as DNA (deoxyribonucleic acid) profiling, have been introduced to reduce human error while attempting to categorize through discrimination [5,6]. This editorial aims to introduce a promising alternative method, which involves trace multi-elemental analysis of hair by solid sampling electrothermal vaporization coupled to inductively coupled plasma optical emission spectrometry (ETV-ICP-OES), for the differentiation of both gender and general ethnicity [7].

Conventional methods

Principles

Currently, a victim's gender and ethnicity are mainly inferred through bone and dental analyses. Identification of ethnicity or ancestry is often based on cranial and dental variations between large generalized groups of ethnicities, such as more retracted mandibles in caucasian Europeans in comparison to Asians and Africans [2]. Other features, such as nose or nasal cavity, chin shape, palate and teeth profiles can also be used to differentiate those three general ethnic groups [8]. It is widely known that the hips, humerus and femurs of individuals are great indicators of gender differences [9,10]. And DNA profiling has been used for both gender and ethnic background differentiations [6].

Features & limitations

As each individual's DNA is unique, DNA analysis is a powerful method of identification, if the unknown sample can be matched to one contained in a database. Teeth profiles can similarly be used for identification of an individual if they can be matched to known profiles in a repository. On the other hand, most methods of bone structure analysis are mainly qualitative, thus subject to bias and human error, and may fail to properly identify the individual [5], even more so in the case of mixed races, where individuals can adopt certain bone features from either their mother or their father [1,3]. Furthermore, such sort of analysis is useless when bones are not available, such as in missing person cases, and cannot assist in finding living victims. Finally, several sources of DNA found at crime scenes, such as blood and urine, can be adulterated or have a short life span.

Relationship between trace elements in hair & gender or ethnicity

Hair is a stable substance that, depending on its length, is capable of retaining years

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of information. Trace elements become available for endogenous binding in hair mainly through sweat glands (eccrine, apocrine, sebaceous and epidermis) in hair follicles [11]. Therefore, which elements are present in hair depends on which elements are excreted by the body into sweat fluids. Certain trace elements can also displace common minerals in proteins and bones, such as Ce replacing some Ca [12].

Elements vs gender

Males have more active and larger sweat glands than females, which can lead to large concentrations of certain easily excreted elements [13]. Indeed, lower concentrations of Ag, Sr and Mg, and higher concentrations M, Mo, Sn, K and Pb have been reported in males compared with females [14].

Elements vs ethnicity

Many anthropologists argue about the definition of ethnicity, i.e. whether it pertains to nationality/geographical location or a more genetic base. Most observations of non-metric traits consider ancestry and refer to the family background [1–3]. However, dietary habits as well as environmental factors can affect the Al, Ni, S, Hg and Pb levels in hair. Hence, chemists try to look at ethnicity in terms of both the family background and the nationality/geographical location of the individual, as this can help to eliminate environmental factors [7,15]. Genetic differences also play a large role in determining the levels of trace elements that are excreted by sweat glands.

ETV-ICP-OES

Principles

The ICP is a high-temperature (up to 10,000 °K), 1.2-kW electrodeless discharge of partially ionized argon. When an aerosol of the sample is introduced into the heart of the plasma, atomization, ionization and excitation of atoms and ions takes place, emission then resulting from their relaxation to the ground state, which is detected by a spectrometer. When coupled to an ETV unit, which consists in a small graphite furnace into which 5 mg of sample is placed on a graphite boat, direct solid sampling can be carried out. This minimizes contamination, as no digestion, dilution, etc. is then required. On the other hand, in order to get reproducible results, the 5-mg aliquot should be representative; therefore, the hair is ground up into a powder prior to analysis. The ETV furnace is resistively heated in steps in order to ash as much of the matrix as possible before vaporizing the elements. Vaporization of the latter can be facilitated using 4 ml/min of CCl_2F_2 to transform elements into more volatile chlorides and fluorides [7].

Features & limitations

With ICP-OES, over 70 elements can be measured at sub-parts-per-billion detection level [16]. All the elements are determined simultaneously. The temperature program of the ETV can vaporize the whole sample in only 85 seconds [7]. On the other hand, the hair needs to be washed to get rid of exogenously absorbed elements, dried and grinded prior to analysis.

Application to hair analysis for identification of gender & ethnicities by multivariate analysis

For this approach, no quantitative analysis is required, as the relative concentrations of the elements in the hair can be used to infer gender and ethnicity. Discrimination is achieved with the aid of a multivariate statistical method called linear discriminant analysis (LDA), which uses recognition pattern of linear combination of the elemental signal peak areas generated by ETV-ICP-OES [17]. For instance, the relative proportions of magnesium, sulfur, strontium and zinc were sufficient to correctly predict gender in 15 samples, while nine elements were required to infer general ethnicity (caucasian, south Asian or east Asian). This correct prediction also included two samples from a completely different geographical location (hundreds of kilometers away) than from where the hair samples used to train the model were obtained [7].

Conclusion

Although this approach is in its infancy and much work remains to be done to refine the model so that it can identify more specific ethnicities, it nonetheless remains a promising method for forensics analysis. Preliminary results have even indicated that, in contrast to conventional methods of identification for ethnicity, when mixed races are involved, ETV-ICP-OES in combination with LDA indicates that an individual is a mixture of two races, along with the proportions of the mixture and which race predominates. Furthermore, ETV-ICP-OES is much faster than conventional DNA analysis and uses a smaller sample amount than cranial analysis.

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References

1 Sauer NJ. Forensic Anthropology and the concept of race: if races don't exist, why are forensic anthropologists so good at identifying them? *Soc. Sci. Med.* 34(2), 107–111 (1992).

2 Rosas A, Bastir M, Alarcon JA, Kuroe K. Thin-plate spline analysis of the cranial base in African, Asian and European populations and its relationship with different malocclusions. *Arch. Oral Biol.* 53(9), 826–834 (2008).

3 Schmitt A, Cunha E, Pinheiro J. *Forensic Anthropology and Medicine: Complementary Sciences From Recovery to Cause of Death.* Humana Press, NJ, USA, 281–316 (2007).

4 Ossenberg N. Within and between race distances in population studies based on discrete traits of the human skull. *Am. J. Phys. Anthrop.* 45(3), 701–715 (1976).

5 Parr NML. Determination of ancestry from discrete traits of the mandible (thesis). University of Indianapolis, IN, USA (2005).

6 Foreman LA, Lambert JA. Genetic differentiation within and between four UK ethnic groups. *Forensic Sci. Int.* 114(1), 7–20 (2000).

7 Huang L, Beauchemin D. Ethnic background and gender identification using electrothermal vaporization coupled to inductively coupled plasma optical emission spectrometry for forensic analysis of human hair. *J. Anal. At. Spectrom.* 29, 1228–1232 (2014).

8 Blumenfeld J. Racial identification in the skull and teeth. *Totem* 8(1), 20–23 (2011).

9 Iscan MY, Shihai D. Sexual dimorphism in the Chinese femur. *Forensic Sci. Int.* 74(1), 79–87 (1995).

10 Steyn M, Iscan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. *Forensic Sci. Int.* 106(2), 77–85 (1999).

11 Chittleborough G. A chemist's view of the analysis of human hair for trace elements. *Sci. Total Environ.* 14(1), 53–75 (1980).

12 Chojnacka H, Górecka H, Górecki H. The influence of living habits and family relationships in element concentrations in human hair. *Sci. Total Environ.* 366(2), 612–620 (1980).

13 Waller MF, Haymes EM. The effects of heat and exercise on sweat iron loss. *Med. Sci. Sports Exerc.* 28(2), 197–203 (1996).

14 Chojnacka K, Michalak I, Zielinska A, Górecka H, Górecki H. Inter-relationship between elements in human hair: the effect of gender. *Ecotoxicol. Environ. Saf.* 73(8), 2022–2028 (2010).

15 Kiado A. Factors affecting the trace-metal content of human hair. *J. Radioanal. Nucl. Chem.* 15(1), 229–243 (1973).

16 Hou X, Jones BT. Inductively coupled plasma/optical emission spectrometry. In: *Encyclopedia of Analytical Chemistry.* Meyers RA (Ed.) John Wiley & Sons Ltd, Chichester, England, 9468–9485 (2000).

17 Asfaw A, Wibetoe G, Beauchemin D. Solid sampling electrothermal vaporization inductively coupled plasma optical emission spectrometry for discrimination of automotive paint samples in forensic analysis. *J. Anal. At. Spectrom.* 27(11), 1928–1934 (2012).