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TECHNICAL NOTE

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Chemical Composition of Fingerprints for Gender Determination*

ABSTRACT: This work investigates the chemical nature of fingerprints to ascertain whether differences in chemical composition or the existence of chemical markers can be used to determine personal traits, such as age, gender, and personal habits. This type of information could be useful for reducing the pool of potential suspects in criminal investigations when latent fingerprints are unsuitable for comparison by traditional methods. Fingertip residue that has been deposited onto a bead was extracted with a solvent such as chloroform. Samples were analyzed by gas chromatography/mass spectrometry (GC/MS). The chemical components identified include fatty acids, long chain fatty acid esters, cholesterol and squalene. The area ratios of ten selected components relative to squalene were calculated for a small preliminary experiment that showed a slight gender difference for three of these components. However, when the experiment was repeated with a larger, statistically designed experiment no significant differences between genders were detected for any of the component ratios. The multivariate Hotelling's T^2 test that tested all ten-component ratios simultaneously also showed no gender differences at the 5% significance level.

KEYWORDS: forensic science, fingerprints, chemical characterization, gas chromatography/mass spectrometry

Fingerprints at crime scenes are crucial in identifying suspects. However, if the fingerprints are smudged or are only partial prints, they may not be suitable for Automated Fingerprint Identification System (AFIS) processing. If there were a way to characterize the individual who left the fingerprint, such as age, gender, ethnic background or personal habit, the list of suspects might be reduced. Whether such information, specifically gender determination, can be extracted from fingerprint residue is the basis of this report. It should be noted that these experiments were performed on unprocessed fingerprint residue to determine whether any differences could be detected before studying what effects visualization processing might have on these results.

Lipids on the skin surface originate from the sebaceous gland and the epidermis. The palm and fingertips primarily have eccrine glands, although the material found on these areas is usually contaminated with sebaceous gland secretions due to frequent contact with regions rich in this gland, such as the face (1). The eccrine glands produce inorganic components (chlorides, metal, phosphate) and amino acids. Sebaceous glands produce components such as squalene, fatty acids, and alcohols. It is believed that slight variations in the composition of the sebaceous fatty acid mixtures give individuals a unique scent (2). It is this compositional variation that is believed to provide trained dogs the ability to track an individual. We hypothesized that if this were true, then there is a possibility that general differences in chemical residue from fingertips could be used to distinguish between males and females and various age groups.

Initial experiments in this area were studying the chemical composition of children and adults' fingerprints. This study showed children's fingerprints (pre-pubescent) had less non-volatile components, such as long chain fatty acid esters, than adult fingerprints due primarily to inactive sebaceous glands. The chemical composition of adults' prints sampled in this study showed some compositional differences that raised the possibility of characterizing individuals based on their fingerprint residue. A preliminary experiment was conducted to study the sources of variations of the chemical components in fingertip residue that was sampled on four different days, for three individual subjects at two different times of the day (morning and afternoon). The results from this study showed little variation due to the different sampling days and replicate measurements. The majority of the variation for the chemicals measured arose due to the three different subjects. These data showed that variations in three components, specifically palmitic acid (C16 acid), palmitoleic acid (C16:1 acid), and oleic acid (C18:1 acid), could be gender dependent. This led to new experiments with a larger sampling group to determine whether this observation still would be statistically valid.

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Experimental

Subjects

All approvals required by the Department of Energy to perform research with human volunteers were acquired before actual work proceeded. All necessary steps to protect the volunteers' privacy and confidentiality were taken and the entire sample collection and analysis processes were conducted in accordance with the protocols approved by the Oak Ridge Associated Universities/Oak Ridge National Laboratory (ORAU/ORNL) Human Studies Institutional Review Board (IRB). For these preliminary experiments, volunteers were not asked to provide a fingerprint containing distinct ridgelines or any other information that could serve to breach the confidentiality of this study. The volunteers were required to read and sign an informed consent form before providing a sample.

Sample Collection

Sample collection consisted of using a glass bead (purchased at local hobby store) and jars with Teflon-lined caps that were both washed prior to collection. The use of the glass bead was adopted from Bernier et al. who demonstrated that material from skin can be collected by handling glass beads (3). Samples were obtained from volunteers in a manner that did not expose the volunteers or sampling personnel to chemicals. The volunteer simply rubbed his/her fingertips across his/her forehead, removed the glass bead from the sampling jar and rubbed the bead between his/her fingertips for about 15 seconds. The volunteer then placed the bead back into the jar and screwed on the Teflon-lined cap. Each sample was labeled with a code number to insure privacy.

Sample Analysis

The residue left on the glass bead was extracted with chloroform (Burdick and Jackson) and evaporated to dryness. The sample was reconstituted with chloroform to a final volume of 150 μL. One microliter was injected onto a Thermo Finnigan Voyager GC/MS (San Jose, CA). The GC parameters were as follows: 30 m DB-5MS capillary column (J&W Scientific). The initial oven temperature of 50°C was held for 1 min and then ramped at 10°C/min to a final temperature of 310°C and held for 20 min. All samples were processed within 90 min of collection to prevent any sample loss or degradation due to aging of the print.

Experimental Design

This fingerprint study was designed as a nested experiment (4) with four sources of uncertainty or variation. The four sources of variation are designated as day-to-day variation, periods within a day (am and pm), gender within a period, and experimental error due to replicate measurements.

Ten females and ten males volunteered to examine the differences between female and male fingerprint chemical components that were sampled on five different days. Two replicate measurements on each subject were made (one in the morning and one in the afternoon) for a total of eight measurements per day. Two dif-

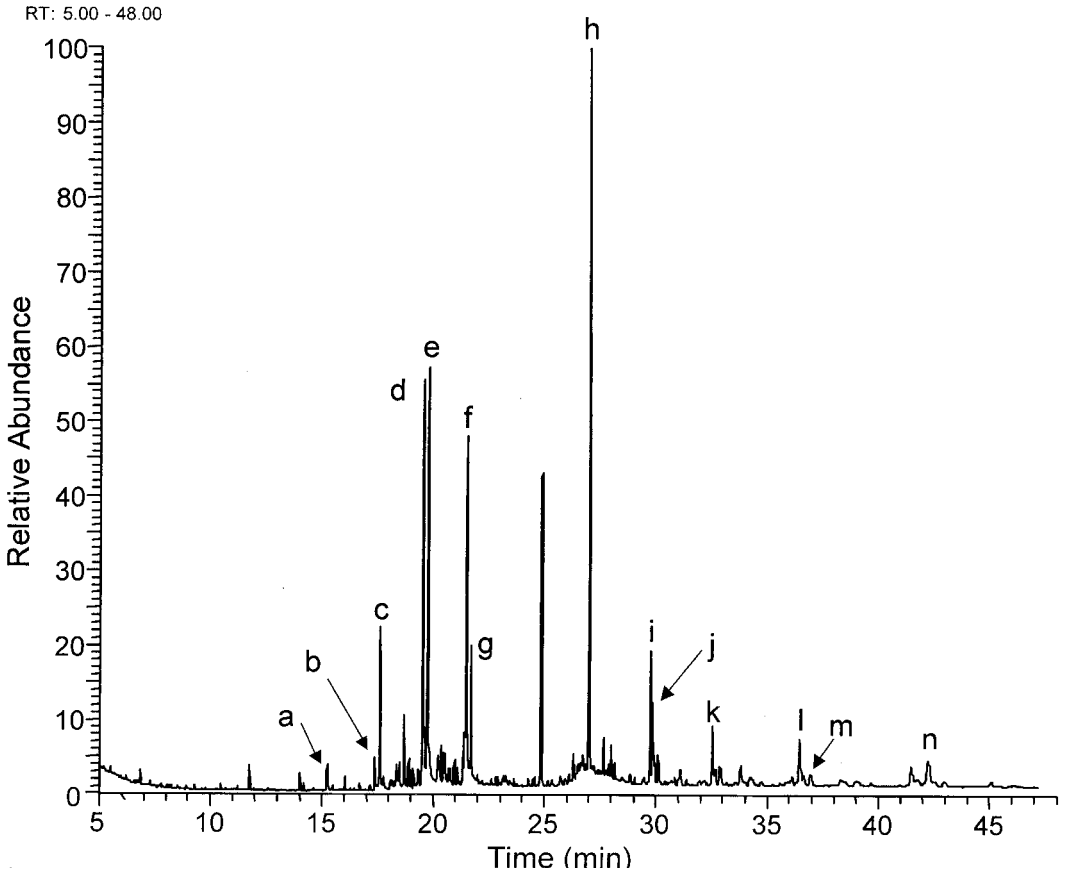

FIG. 1—*Typical gas chromatogram obtained from chloroform extraction of fingertip residue off glass bead with selected components identified—*(a) *dodecanoic acid,* (b) *tetradecenoic acid,* (c) *myristic acid (C14),* (d) *palmitioleic acid (C16:1),* (e) *palmitic acid (C16),* (f) *oleic acid (C18:1),* (g) *stearic acid (C18),* (h) *squalene,* (i) *cholesterol,* (j) *9-hexadecenoic acid tetradecyl ester,* (k) *9-hexadecenoic acid hexadecyl ester,* (l) *9-hexadecenoic acid octadecyl ester,* (m) *9-hexadecanoic acid octadecyl ester,and* (n) *9-hexadecenoic acid eicosyl ester.*

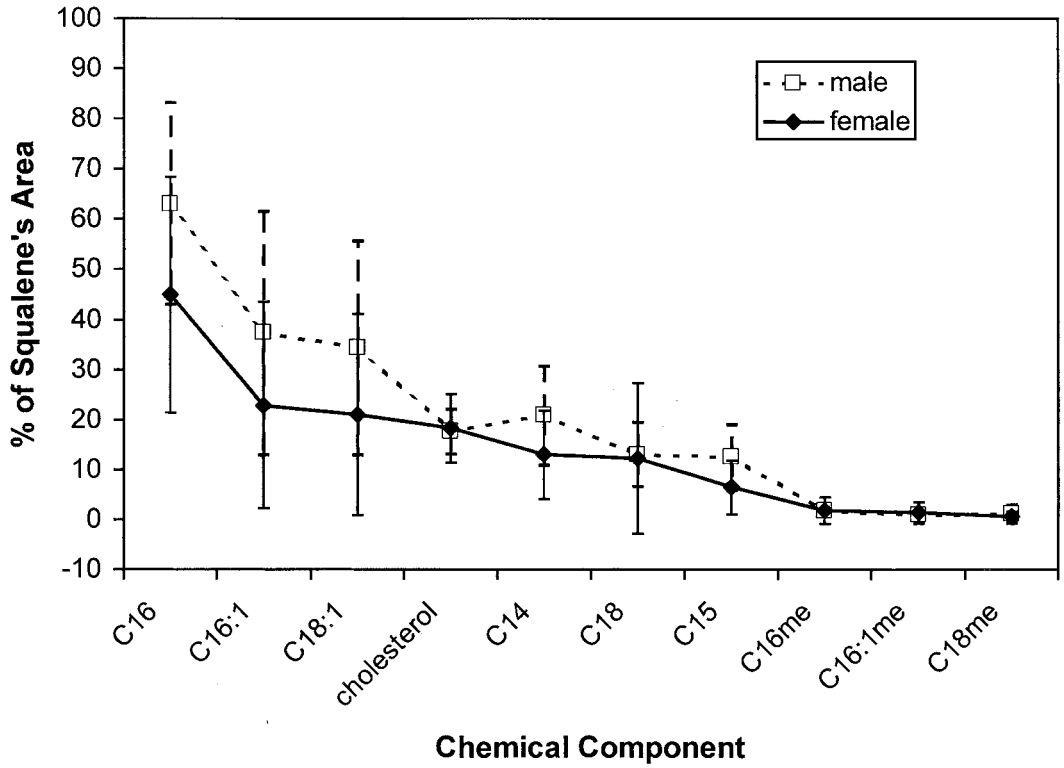

FIG. 2—*Comparison of female and male average percentages of squalene's area plotted with +/− one standard deviation of error.*

ferent females and two different males were sampled each day for the five-day sample period. The subjects were randomly allocated over the five days and the measurements were taken in random order within each morning and afternoon time period.

Results And Discussion

Figure 1 shows a typical chromatogram obtained from a fingerprint sample. The base peak in most fingerprint samples was squalene (peak h; t_r=27.00 min). The other components identified include unsaturated fatty acids of various carbon length, monounsaturated fatty acids, and cholesterol. Long chain fatty acid esters were also observed, but usually at lower abundance than the previously mentioned components. Using the results from our preliminary experiments, ten components were chosen as possible indicators for gender differentiation. These components were myristic acid (C14), pentadecanoic acid (C15), palmitic acid (C16), palmitoleic acid (C16:1), methyl palmitate (C16me), methyl palmitoleate (C16:1me), methyl stearate (C18me), oleic acid (C18:1), stearic acid (C18), and cholesterol. For each subject, the peak area for these components was divided by the squalene peak area, the largest peak in each fingertip residue chromatogram. As previously noted, samples were processed within 90 min of collection to avoid sample loss or degradation due to aging of the prints. Earlier studies (not reported) showed that peak area ratios were constant for up to six hours at room temperature. Figure 2 shows the average value for each component-to-squalene ratio for males and females and their standard deviations. Although the averages for palmitic acid, palmitoleic acid, and oleic acid, are slightly higher in males than females, incorporating standard deviations negates any statistically significant difference.

For each chemical component, the sources of variation were statistically evaluated using the method of analysis of variance. An F-test was used to test whether each variation source made a significant contribution to the total uncertainty. No source of variation due to day-to-day, period-within-day, and gender-within-period gave a 5% significant test for any of the chemical measurements. This means that all of the variation can be attributed to experimental random variation. No statistically significant gender effects were detected. An additional statistical test was performed considering all ten components simultaneously using the Hotelling's T^2 test (5). This also showed no gender differences at the 5% significance level.

The chemical composition of fingerprints holds much information that could be useful in criminal investigations. Although this work did not find compositional variations that could be used to distinguish between genders, it is possible that there are other distinguishing components in fingerprints.

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