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Using Fingerprints to Reveal the Gender: A Review

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Abstract

The friction ridges and furrows on the pads of the fingers and thumbs produce distinctive patterns known as fingerprints. This friction ridge skin begins to grow in the womb between the ninth and the twenty-fourth weeks of embryonic development. Cuts, burns, and bruises may momentarily impair the quality of a fingerprint. A forensic investigator's top priority when making identification is to determine a person's gender. Effective methods for determining sex include fingerprint ridge density and amino acid profiling of sweat residues found in fingerprints. This article will look at some of the scientific methods used in gender identification through fingerprint analysis.

Keywords: Fingerprint • Ridges • Gender identification • Ridge density • Crime scene • Amino acid residues

Introduction

Fingerprints are distinctive patterns created by friction ridges (raised) and furrows (recessed), which appear on the pads of the fingers and thumbs. Although the prints on the palms, toes, and feet are similarly distinctive, they are less frequently utilised for identification. Between the 9th and 24th weeks of embryonic development, this friction ridge skin starts to form in the womb. No two individuals have the same fingerprints. Even for identical twins, the friction ridge skin pattern develops differently as a result of the differences in growth and pressure that each embryo encounters while in the womb [1]. Owing to their uniqueness, fingerprints can be used for a variety of purposes, such as, background checks, biometric security and authentication, mass disaster victim identification, and, of course, criminal investigations. The random arrangement of friction ridges in fingerprints makes each one unique. The distinct features of friction ridges last from birth until decomposition after death [2]. Fingerprint quality can be momentarily harmed by wounds like cuts, burns, and bruises, but the patterns are recovered once the wounds have entirely healed. Because of these two characteristics, fingerprints have proven to be an extremely valuable tool in identifying perpetrators.

Determining the identity of fingerprint found at a crime scene can have a significant impact on the outcomes of forensic investigations. It can help in elimination of certain prints that are relevant to a crime scene and hence help in establishing a link between the suspect and the crime scene. In the event of accidents, explosions of chemical and nuclear bombs, natural disasters, criminal investigations and ethnic studies, gender identification of a person becomes the first priority in the process of identification by a forensic investigator [3]. While age, size, and race each give points within a wide range of variables, the determination of sex quickly excludes around half the population, making it statistically the most significant criterion of identification [4]. The ease with which they can be collected inherently, the large number of sources (ten fingers) accessible, and the established usage and collection by immigration and law enforcement are all reasons why fingerprint identification is so ubiquitous [5].

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Certain features of the fingerprints, namely fingerprint ridge density and amino acid profiling of sweat residues found in fingerprints can be used efficiently for sex determination of an individual. Numerous characteristics of ridge patterns reflect the biology of individuals. For the purpose of determining gender, ridge characteristics like ridge count, ridge density, ridge thickness to valley thickness ratio, ridge width, and fingerprint pattern variations are used [6]. Sweat and sebum left by fingerprints are frequently overlooked. The amount of metabolites found in sweat varies depending on the body's numerous metabolic processes, which are controlled by a number of hormone-based regulation systems and are influenced by physical characteristics including gender, age, ethnicity, or health state. It has been discovered that individuals in various demographic groupings, such as gender, have varied levels of amino acids (i.e., male and female) [7].

Using fingerprint ridge density and amino acid profiling from the sweat present in fingerprints, this article will examine some of the scientific techniques utilised in fingerprint research to identify gender.

Overview of Fingerprint Ridge Density (FPRD) and composition of sweat

Fingerprint ridge density is defined as the fingerprint ridge count corresponding to a defined fingerprint area. It is determined by two parameters; ridge width and distance between ridges. On the basis of the number of ridges in the fingerprint, it is possible to determine a person's gender by counting the ridges. With a significant standard deviation across subjects of both genders, the average ridge count is marginally higher in males than in females [5].

Single row of pores make up each skin ridge, and perspiration is expelled via these pores and is then left to accumulate on the skin's surface. The human body contains three different kinds of natural secretory glands. Eccrine, sebaceous, and appocrine sweats are produced by each gland, and they are all distinct from one another. Apocrine glands remain dormant until adolescence, but eccrine sweat glands are present at birth and cover the entire body. Apocrine glands are only found in the hairy areas of the axilla, mammary, perineal, and pubic regions [8]. Except for the friction ridge surfaces, sebaceous glands can be found all over the body. These three types of glands produce sweat with different chemical compositions. Composition of eccrine sweat is influenced by diet, hydration, metabolic rate, health status, drug administration, and body region. These substances are mostly made of water, but they also contain trace amounts of unmetabolized pharmaceuticals, lactate, ammonia, calcium, and magnesium, as well as trace amount of minerals like sodium, potassium, calcium, and magnesium. The fluid secreted by the apocrine sweat gland, in contrast, is an oily, odourless material made up of proteins, lipids, and steroids but also contains the same minerals and metabolites [8]. Sebaceous glands secrete sebum, which is primarily composed of saturated fats, waxes, and squalene [1]. Forensic investigations are particularly interested in the composition of these three secretions (Figure 1).

Figure 1. Fingerprints skin impressions.

Table 1. Table showing additional work on FPRD.

S. No	Author	Mean for FPRD	
		Males	Females
1.	Krishan et al. - 2012 - Kangra, India (16)	15.51	17.11
2.	Gutierrez-Redomero et al. - 2013 - Puna-Quebrada, Argentina (17)	14.33	16.13
3.	Ahmed and Osman – 2016 – Khartoum, Sudan (18)	9.75	10.80
4.	Sanchez-Andres et al. - 2018 - Madrid, Spain (19)	12.25	13.27

Literature Survey

Accrue conducted a study in 1999 to test the idea that women have more dense ridges due to their finer epidermal ridge detail than men. The study employed 400 ten-print cards representing 400 people who were chosen at random. The sample population's demographic breakdown includes 100 Caucasian males, 100 African American males, 100 Caucasian females, and 100 African American females, all of whom are between the ages of 18 to 67. All different forms of finger print pattern show a comparable ridge flow at the upper portion of the radial side of the central core region of the prints, hence this area was chosen for analysis by him. This technique helps to segregate ridges within a clearly defined area, which makes the ridge counting procedure easier. The findings of the study indicate that women typically have a substantially higher ridge density than men, and that this trend holds true for both Caucasian and African American respondents. After the application of Bayes theorem, it was concluded that a given fingerprint with a ridge density of 11 ridges/25mm^2 or fewer is likely to be male in origin and a fingerprint with a ridge density of 12 ridges/25 mm^2 or above is more likely to be of female origin, regardless of ethnicity [9].

Nayak et al. conducted a research in 2010 to examine how the density of fingerprint ridges varies by gender in the Chinese and Malaysian populations. The study involved 200 subjects (100 men and 100 women) of Chinese descent and 100 subjects (50 men and 50 women) of Malaysian descent. The ridge density in Chinese participants ranged from 9.3 to 14.9 ridges/25 mm^2 for males, with a mean of 11.73 ridges/25 mm^2, and from 11.1 to 16.4 ridges/25 mm^2 for females, with a mean of 14.15 ridges/25 mm^2. Among Malaysians, the range of ridge density was 9.4 to 14.4 ridges/25 mm^2 for males (mean: 11.44 ridges/25 mm^2) and 11.4 to 15.3 ridges/25 mm^2 for females (mean: 13.63 ridges/mm^2). The difference in mean ridge density between females and males is 2.42 ridges/25 mm^2 in Chinese subjects and 2.19 ridges/25 mm^2 in Malaysian subjects [10].

Similar study was conducted by Nayak et al. to study the difference in ridge density among Indian population. 100 healthy male and 100 healthy female Indian subjects between the ages of 18 and 25 were chosen at random. This study revealed a statistically significant difference between the ridge density of male and female fingerprints in individuals of Indian descent. It has been discovered that fingerprints with a mean ridge density of 12 ridges/25 mm^2 or less are more likely to be those of males, whereas those with a mean ridge count of more than 12 ridges/25 mm^2 are more likely to be those of females [11].

A research was carried out by Pattanawit et al. to examine the topological, age-grouping, and sexual variations in fingerprint ridge density (RD) among native north-eastern Thais aged 14 to 24 who are descended from north-eastern Thai ancestry. 353 unrelated volunteers, including 191 men and 162 women, provided their fingerprints, which were then divided into three groups: group A (all subjects), group B (people aged 14 to 18), and group C (people aged 18 to 24). Two topological regions-ulnar and radial-were evaluated for ridge density. After assessment of ridge density in both the regions, there were significant variations between the sexes and age groups. Higher ridge density, or narrower ridges, is present in females than in males. A decline in ridge density values with ageing was also noted during the study [12].

In a study of 200 subjects (100 men and 100 females) from a Spanish-Caucasian population, Gutiérrez-Redomero et al. examined the variability of FPRD and its use in sex determination. Males are most likely to have the FPRD of 16 ridges/25 mm^2 or less, whereas females are more likely to have the FPRD of 17 ridges/25 mm^2. They discovered that women have finer ridges and a higher ridge density than men. Another notable finding was the inter-digital ridge density, which showed that the thumb and index finger had lower ridge densities than the other three fingers [13].

In another study by Gutiérrez-Redomero et al. Fingerprint ridge density variation by sex, age, and topology in the Mataco-Mataguayo and Spanish populations were analysed on 209 participants (99 men and 110 women), and the degree of sexual dimorphism in ridge density and the age at which it appears were determined. The findings showed that ridge breadth is sexually dimorphic at the start of adolescence, after the age of 12, with females having higher ridge density [14].

In order to examine sex estimation by finger ridge count, Nithin et al. analysed 550 people (275 males and 275 women) from the South Indian population who ranged in age from 18 to 65. According to this study, a fingerprint with a ridge density of less than 13 ridges per 25 mm^2 is likely to be male, while a fingerprint with a ridge count of more than 14 ridges per 25 mm^2 is likely to be female [15] (Table 1).

Crystal et al. employed a bioaffinity-based sensing system that can distinguish between male and female fingerprint samples based on the amounts of amino acids in fingerprint material. The explanation for this determination is based on the fact that females have different amino acid concentrations in their systems than males. The L-AAO enzyme may bind to a wide variety of L-amino acids with various degrees of affinity, allowing it to utilise them as substrates and convert oxygen to peroxide. The secondary component of the cascade, HRP, uses the peroxide as a substrate and oxidises a dye functioning as a co-substrate to provide a signal at a certain wavelength. The L-AAO/HRP bioassay has proven to be accurate and repeatable for the purpose of differentiating between fingerprint samples acquired from both males and females. The results of the ROC analysis, which was performed on 50 samples of imitated fingerprints, showed that it is possible to identify the gender of the fingerprint originator using this technique. The results of preliminary statistical analyses using replicated fingerprint samples showed that there was a 99% possibility of correctly identifying the gender of the fingerprint originator [7].

Conclusion

In the forensic community, fingerprints have been the de facto method of identifying people for more than a century. Fingerprints are frequently employed to decipher a person's individuality. The hands are a person's primary physical part, and they are typically indispensable to the commission of any crime. Since fingerprints are permanent, they remain constant over the course of an individual's life. The hands are a person's primary physical part, and they are typically necessary to the commission of any crime. Since fingerprints

are permanent, they remain constant over the course of an individual's life. All the methods reviewed in this paper have proved to be useful for gender identification using fingerprints.

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