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Study of fingerprints in Argentina population for application in personal identification

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ABSTRACT

The fingerprints of the Buenos Aires and Chubut provinces in Argentina have been studied, with the aim of knowing and quantifying the variability of these features, which are used in the identification process. The data studied for this research was obtained from 330 individuals, of both sexes, from two Argentinian population samples (170 individuals from Buenos Aires and 160 from Chubut), which amounts to a total of 3300 fingerprints. The different types of minutiae were located, identified, and visually quantified in four areas on the fingerprint. Two perpendicular axes were drawn whose intersection was located in the center of fingerprint. In addition, a circle was defined on these quadrants whose radius cut fifteen ridges. This method divides the fingerprints into four quadrants with two sectors apiece. The results obtained for both populations were compared statistically with those published previously for an Argentinian population sample, which had been collected using the same methodology. Therefore, Argentina becomes the country with the most information in this matter.

For both populations, the highest frequencies were of ridge endings, followed by bifurcations and convergences. In this study of minutiae, statistically significant differences were found between the area of the fingerprint (inside and outside the circle), males and females, and types of main pattern for both samples. However, although the results show common patterns in the distribution of minutiae, there are also significant differences between populations. This reveals a significant ancestral and frequency effect of the minutiae, which would indicate that the minutiae are more genetically dependent than has been suspected so far. Furthermore, the non-equiprobability found for the frequency of the types of minutiae indicates that the weight provided by these characteristics is not the same when applied in identification processes, whether used quantitatively (numerical standard) or qualitatively (holistic method).

1. Introduction

Dermatoglyphics show great variability at both the individual and population level, allowing these to be used as an identifying tool in forensic sciences. Lophoscopy, a discipline based on personal identification from papillary ridges, has been the mainstay of forensic science for more than a century; it is one of the fastest methods to identify an individual reliably. In order to establish one identification, it is necessary that a great deal of information of a suitable quality must be available for the purposes of comparing between a fingerprint of an unknown donor and another known identity.

When examining the structure of the papillary ridges, it is observed that there are flows of ridges in variable directions that are not continuous, presenting frequent interruptions in the flow of each ridge as well as variations in its length. The small distinguishing features found along each individual ridge were defined as minutiae [1], and are also known as characteristic points [2]. The Level-1 detail of comparison in the process fingerprint identification is established between the ridge flows of both fingerprints, in relation to the type of pattern match. The Level-2 detail corresponds to the match in type and location of the minutiae, which, given its great variability, is the fundamental basis of identification from fingerprints. The Level-3 detail would be in relation to the size and shape of ridges and pores.

Four stages are followed to perform a complete examination between two images containing papillary ridges: analysis, comparison, evaluation, and verification (ACE-V). The approach of the ACE-V protocol was suggested for the first time by the Mounted Police of Canada in

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the middle of the last century [3], but it was not until the late 1990s that its use spread. In the current practice of examining fingerprints, experts have issued a categorical opinion of identification or exclusion, as a result of the implementation of the ACE-V protocol. Nevertheless, there are two different ways to reach this conclusion, either by applying the method of numerical standard or the holistic method [4].

Most countries use the numerical standard method, which consists of reaching a minimum number of points in correspondence between two prints to provide a positive identification. However, the threshold may vary from country to country; South Africa and Turkey use a numerical standard of 7 points, for example, compared to others with 16 points, such as France and Italy, and in most countries the numerical standard is set to 12 points [5,6]. This disparity of opinion is due to the fact that the minimum number of minutiae necessary to prove an identity has not been rigorously established [6–11]. Regarding the holistic approach, the expert will conclude with an opinion of individualization (or exclusion) when personally convinced that there is sufficient detail in the correspondence of the minutiae (or enough discordance, in the case of exclusion) between the images compared. This sufficiency threshold is reached on the basis of training, experience, and expert knowledge. The expert evaluates the quality, quantity, and specificity of the features presented by the papillary ridges, using three levels of detail and any casual features that may be present (e.g., scars, secondary ridges, creases, wrinkles, etc.) [12]. Although the importance of expert experience in the identification process cannot be denied, this opinion is completely subjective, and is not based on any statistical calculation between the matching characteristics of the compared images.

The field of forensic science has been undergoing a process of change since 2009, when the National Academy of Sciences (NAS) [13] published a research paper that recognizes that most of the techniques used in forensic science do not have a sound scientific basis. Furthermore, it showed that many tools used to solve crimes have not been subjected to rigorous experimental analysis, and there are no protocols or standards to ensure that their results are valid and reliable. Important forensic institutions such as the International Association for Identification (IAI) [12] or the European Fingerprint Working Group (EFP-WG) of the European Network of Forensic Science Institutes (ENFSI) [14] issued resolutions which advocated for the development of statistical models through research, so as to improve the methods which are used to value the weight of evidence in each particular case.

For this reason, and although at first the use of the likelihood ratio was rejected by many experts, this theory is currently advocated as an objective way to evaluate the weight of evidence provided by the dermatoglyphic information [15–22]. In any case, it is necessary to increase general knowledge about the major fingerprint features to perform a probabilistic calculation; specifically, more studies on the distribution and variability of the minutiae are necessary, because these aforementioned features are the mainstay of identification. It is particularly striking that, despite the use of dactyloscopy for more than a century, articles that have provided information on the variability of the minutiae are so few. In addition, most of them study fingerprint samples from males, and vary considerably both in the sample size (such as the fingers selected for analysis) and the types of minutiae valued [23–35].

In recent years, there have been some studies in which fingerprint samples from females were also analyzed, which also evaluated sexual differences, topological differences within the same finger, the differences between fingers and types of pattern, and population differences [36–41]. In this regard, significant differences for the frequency of the types of minutiae between populations were brought to light for the first time between Argentinean and Spanish samples [40], and in 2015, it also found such differences in the North American population between individuals of European and African origin [41].

Therefore, this document is presented in order to increase the amount of research that covers the study of the minutiae; the aim was to study different aspects of the variability of the minutiae of the ten fingers in two samples of Argentinean populations, and to provide scientific data that support the identification process of Criminalistics Services from different countries, as well as to increase the knowledge of the variability of these traits in human populations.

2. Material and methods

The samples were collected at the Instituto Universitario de la Policía Federal Argentina (IUPFA) in the City of Buenos Aires, and in the Police Academy at Rawson in the province of Chubut, with the informed consent of the individuals studied. The sample size was 330 adults, of whom 170 individuals were native to Buenos Aires (80 males and 90 females) and 160 to Chubut (80 males and 80 females). The fingerprints of the ten fingers were obtained, and a total of 3300 fingerprints were studied.

Regarding the sample from Buenos Aires, those individuals whose parents and at least three grandparents also were born in this province were determined to be autochthonous. In cases where only three grandparents were born in Buenos Aires, the fourth grandparent needed to have been born in a province bordering Buenos Aires. Regarding the Chubut sample, people of the province of Chubut whose parents and grandparents were also born in Chubut were identified as autochthonous.

All participants in this study were adults; the average age in the sample from Buenos Aires was 23.69 years (27.33 years for males and 20.46 for females), and in Chubut's sample it was 30.53 years (29.92 years for males and 31.13 for females).

The technique used to collect fingerprint impressions was a variation on the adhesive paper and graphite method [39,40,42,43]. Fingertip papillae ridges were stained homogeneously with graphite powder and then rolled (from ulnar to radial) over the sticky side of an appropriately sized label. Next, these labels were stuck to transparent acetate sheets which had been designed so that each sheet had ten separate areas for depositing each of the ten fingerprint impressions obtained from a single individual. With this technique, a mirror image of the fingertip surface is obtained, similar to that achieved with the classic ink method.

Subsequently, the fingerprints were digitalized on the premises of the Commissary of Scientific Police at Alcalá de Henares (Madrid), and the fingers were assigned the numbers 1–10, starting from the right thumb, or finger 1 (F1), and ending with the left little finger, or finger 10 (F10). The classification used for identification of types of patterns was described by Galton [1], which is based on the number of triradius or deltas to classify types of patterns into four groups: arches, loops (ulnar and radial), and whorls. For localization and quantification of minutiae (Level-2 detail), eight areas were designed, using a standardization method [39,40] which consists of drawing two perpendicular axes on the fingerprint whose intersection is located in the center of fingerprint. Thus four quadrants, two distal or top (ulnar and radial) and two proximal or bottom (ulnar and radial) are obtained. In addition, a circle was defined on these quadrants whose radius cut fifteen ridges perpendicularly in one of the distal quadrants, starting from the center cut of the previous axes. In this way, the fingerprint is divided into four quadrants and these in turn into two sectors (inside and outside the circle), which can be assessed independently. The establishment of a constant diameter in the circle of 15 ridges allows a better comparison between fingers and between sexes, as it eliminates the differences caused by the effects of finger size (as that of the papillary ridges).

Afterward, we proceeded to the identification and location of the minutiae. The classification used for this study was based on a modified version of the classification system used by the Spanish Scientific Police in which a total of 20 types of minutiae are identified, and that has already been used in two previous papers [39,40], allowing for a direct comparison of the results of the three papers (Fig. 1). All characteristic points were located, identified, and manually counted on the eight topological areas. This allowed the individualization of 26,400 ridge count areas for analysis.

A log sheet for each finger was used for counting the minutiae by sectors. The coding of the fingerprints allowed us to build a database consisting of 330 individuals and 1727 variables. This in turn made it