Journal of Forensic and Legal Medicine 42 (2016) 25–32

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Research Paper

Topological variability and sex differences in fingerprint ridge density in a sample of the Sudanese population

Altayeb Abdalla Ahmed [a, b, *], Samah Osman [a]

[a] Anatomy Department, Faculty of Medicine, University of Khartoum, P.O. Box 102, Khartoum, Sudan

[b] Department of Basic Medical Sciences, College of Medicine, King Saud bin Abdulaziz University for Health Sciences, Mail Code: 3127, P.O. Box 3660, Riyadh 11481, Saudi Arabia

ARTICLE INFO

Article history:
Received 2 December 2015
Received in revised form
4 February 2016
Accepted 4 May 2016
Available online 12 May 2016

Keywords:
Dermatoglyphics
Fingerprint ridge density
Sex identification
Sudanese population
Forensic anthropology

ABSTRACT

Fingerprints are important biometric variables that show manifold utilities in human biology, human morphology, anthropology, and genetics. Their role in forensics as a legally admissible tool of identification is well recognized and is based on their stability following full development, individualistic characteristics, easy classification of their patterns, and uniqueness. Nevertheless, fingerprint ridge density and its variability have not been previously studied in the Sudanese population. Hence, this study was conducted to analyze the topological variability in epidermal ridge density and to assess the possibility of its application in determining sex of Sudanese Arabs. The data used for this study were prints of all 10 fingers of 200 Sudanese Arab individuals (100 men and 100 women) aged between 18 and 28 years. Fingerprint ridge density was assessed for three different areas (radial, ulnar and proximal) for all 10 fingers of each subject. Significant variability was found between the areas ($p < 0.01$). Women showed significantly higher ridge density in the three areas for all and each fingers. Men and women showed similar patterns of densities with distal areas being denser than proximal ones. Side asymmetry was more evident in distal areas. Ridge density thresholds for discrimination of sexes were developed. Hence, fingerprints found in forensic examinations/crime scenes can be useful to determine sex of Sudanese individuals based on fingerprint ridge density; furthermore, ridge density can be considered a morphological trait for individual variation in forensic anthropology.

1. Introduction

Dermatoglyphics is discipline that involves studying and analyzing the epidermal ridges in the anterior aspect of the palm and sole, including the fingers and toes.[1] Dermatoglyphics has manifold utilities in genetics, biological anthropology, morphology and anatomy, and human biology to diagnose genetic and medical diseases, to explore ancestral affiliations, to understand evolution of subdivided populations, to analyze intra- and interindividual variation, and for explication of population and human variability.[2–10]

The epidermal ridges are a reflection of the dermal papillae that develop very early in the prenatal period, between the 10th and 16th weeks of estimated gestational age, nevertheless, they are considered fully developed by the 24th week of development.[11] The factors controlling these ridges have received much attention; however, while some authors suggest that these ridges are polygenic traits, i.e., they are under the control of a series of independent additive genes of equal effect, without dominance, others indicate that these ridges are regulated by a major gene during development with its effect following Mendelian or non-Mendelian expectations.[12–15] These traits have been shown to differ in the extent of genetic determination, with ridge counts showing a high degree of hereditability compared to the pattern intensity index, which is largely determined by environment during the prenatal development.[14] Hence, the ridges development and expression, in terms of organization and quantity, is an end result of a complex interaction of mainly genetic factors that may be influenced by environmental factors during the first few months of intraembryonic development. There is a general consensus that in

* Corresponding author. Department of Basic Medical Sciences, College of Medicine, King Saud bin Abdulaziz University for Health Sciences, Mail Code: 3127, P.O. Box 3660, Riyadh 11481, Saudi Arabia. Tel.: +966 11 4295269 (office); fax: +966 11 4299999x95262; +966 558962147 (mobile).

E-mail addresses: drahmedal@gmail.com, ahmedal@ksau-hs.edu.sa (A.A. Ahmed).

http://dx.doi.org/10.1016/j.jflm.2016.05.005
1752-928X/

the absence of external modifications/factors e.g., scars, lesions, after the ridges are formed, they are considered as stable structures that remain essentially unchanged throughout the life of the individual.[12] To this end, it should be emphasized that although the ridge count is independent of age, ridge size increases with the somatic growth of autopods.[12,16]

Exploration of sexual dimorphism and variations between populations forms two important pillars in physical anthropology that have been assessed by different morphological, molecular, and biochemical markers. Nevertheless, among the various morphological markers, the dermatoglyphics, e.g., fingerprint, palm print, or footprint, have become very popular for studying these pillars. The fingerprint recognition systems are increasingly being used as a tool for personal identification and documentation. The increased probability of retaining only latent fingerprints from crime scenes or weapons used in offenses and the possibility of finding dismembered hands/fingers in mass disasters/criminal mutilation necessitate exploration of the potential use of different fingerprint parameters for inferring sex and ethnicity.[17,18] Assessment of the existence of sexual differences in fingerprints has previously focused on the variation of qualitative and quantitative traits among different populations.[19–22]

Ridge density, which implies counting of ridge numbers in specific area, has recently received considerable interest. The reported findings indicate the existence of ethnic and sexual differences in ridge densities that have been attributed to two main determinants: ridge breadth and the distance between the ridges.[18,23,24] Moreover, reports show that there is inter-individual variability in these densities, and that women have finer ridges than do men.[18,25] The fingerprint ridge density has significant sexual dimorphism in various populations, e.g., Spanish, Chinese and Malaysian, Indian, and Turkish.[17,23,26,27] Nevertheless, the degree of sexual dimorphism expression has been shown to be variable between populations.[18,23] Moreover, within the same sex, there can differences between populations within the same geographical area.[28] One study showed that the fingerprint densities of Sub-Saharan Africans are lower than those of Spanish Caucasians.[29] Moreover, it was found that Sub-Saharan men have different patterns of fingerprints on each hand.[10] These differences between populations necessitate population-specific studies to assess fingerprint densities using different areas and both hands. However, few studies have evaluated fingerprint ridge density in Africans.[29] In addition, to our knowledge there is a lack of studies using ridge densities of Arab-African individuals.

Sudan is one of the largest African countries and is located in the northeastern part of Africa. Its population comprises of different ethnicities, with Sudanese Arabs forming the majority of the contemporary population. The need to assess different methods of establishing identity among Sudanese individuals is increasing due to the existing civil war, tribal conflicts, and escalation of crimes. In addition, economic constraints limit the application of definitive DNA methods of identification. The main parameters for identification have been explored using different body parts e.g., stature and sex.[30–35] However, there is no study about the use of dermatoglyphics in the Sudanese population. Therefore, for the aforementioned reasons this study was conducted to analyze the topological variability and differences between hands (right vs. left), and to explore the extent of sexual dimorphism in epidermal ridge density among Sudanese Arabs.

2. Material and methods

The data used for this study were obtained from fingerprints collected from 200 participants (100 men and 100 women). Subjects were aged between 18- and 28-years-old, and were from different faculties at the University of Khartoum. Adult individuals were selected to ensure the cessation of growth, which may affect ridge widths.[36] Individuals were right-handed Sudanese Arabs who had mixed genes of Arabs and local Africans, e.g., Nubians. They came originally from different localities and were living in Khartoum, hence, were representative of contemporary Sudanese Arabs. Each subject was asked to complete the study questionnaire, including basic demographic data and was required to sign a consent form. All participants were students or staff and they were not involved in manual work, which could affect the morphological analysis of dermal ridges. Moreover, all fingers were examined to exclude any evidence of disturbed skin integrity e.g., scar or trauma that might affect the fingerprint The mean age of the included individuals was 21.42 ± 2.55 years for men and 20.60 ± 2.53 years for women. The study protocol was approved by the ethical committee of the Faculty of Medicine, University of Khartoum.

Fingerprints were obtained from the subjects using rolled print (inked) method. Initially, participants were asked to clean and dry their hands. Then a total of 2000 fingerprints were obtained from the ten digits of the 200 subjects, which were labeled as R I, R II, R III, R IV, and R V for the right hand and L I, L II, L III, LIV, and L V for the left hand. Then, the areas of the fingerprints to be used were located on the basis of the method proposed by Gutiérrez-Redomero.[29] Therefore, to locate the three counting area, each fingerprint was divided into four sectors via two perpendicular axes crossing two ridges above the center of the type pattern, then a horizontal line was placed parallel to the interphalangeal joint. Furthermore, in case of the presence of arches lacking a defined nucleus, the axes were positioned to intersect at the center of the dactylogram at the top of the arch (Fig. 1).[5] Then, with the aid of a magnifier ($\times 10$) the ridges occupying a defined area (radial, ulnar, or proximal) were counted diagonally on a 5 mm $\times$ 5 mm square on a ruler to establish fingerprint ridge density values based on the method described by Acree.[24]

The samples were statistically analyzed using IBM SPSS Statistics v21.0 software and Microsoft Office 365 ProPlus Excel program. Prior to analyzing all fingerprints, the ridge counts for the three studied areas of 15 fingerprints were determined by the second author on two different evaluations days to check for an intra-observer error. Same fingerprints were evaluated by the first author once and tested for inter-observer error. Intra- and inter-observer errors were tested using paired t-test and showed no significant difference ($p > 0.05$). Ridge counts for the three studied areas of all 10 fingers of each participant were obtained by the second author, allowing an estimate of the mean for each area (radial, ulnar and proximal) and each finger for each subject. For each sex, descriptive statistics of the sample data were obtained for each area by digit. Differences between the sexes were analyzed for the three areas, using all digits and the individual digits using independent t-tests and Mann–Whitney U tests. The side asymmetry in ridge densities in the three areas (radial, ulnar, and proximal) were compared by digit, for each sex using Wilcoxon signed ranks tests.

The mean ridge density for each area on all 10 fingers for each subject and the distribution frequency were used to calculate the likelihood ratio (LR) in order to obtain the probability of inference of sex from ridge density values, where RD is ridge density, C the male donor, and C′ the female donor.[27,37]

LR = probability of observing a given ridge density if the donor was male (C)/probability of observing a given ridge density if the donor was female (C′) = P(RD/C)/P(RD/C′). The LR value provides the strength of support for one of the hypotheses: C (male) or C′ (female). The posterior probabilities P(C|RD) and P(C′|RD) were then calculated using Bayes' theorem.[37] Next, the favored odds for the support of most likely sex were obtained using the LR and the