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TECHNICAL NOTE

CRIMINALISTICS

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Moistened Hands Do Not Necessarily Allude to High Quality Fingerprints: The Relationship Between Palmar Moisture and Fingerprint Donorship

ABSTRACT: We explored the quality distribution of ninhydrin-developed prints on A4 bond paper in two groups of individuals, in Israel and in India. While the quality distributions of the developed marks in both countries had some dissimilarities, both groups showed the expected bell-shape distribution, with the majority of the donors belonging to the central zone, defined as "average" or "good." Attempt was made to correlate between a physiological feature, palmar moisture, and the fingerprint donorship. As a rule, high fingermark quality could be associated with sweating hands, but there were individuals with moist palms whose fingermarks had a low score and vice versa. This finding supports the logical but hitherto unproven assumption that besides the amount of palmar sweat, the other physiological factor governing the prints' quality is the total amount of substrate, amino acids in this case, in the latent deposits, which depends on the substrate concentration in the sweat.

KEYWORDS: forensic science, fingerprints, fingermarks, amino acids, ninhydrin, fingerprint donorship, Corneometer, palmar sweat

The appearance of the first report on the use of ninhydrin for visualizing latent fingermarks on paper (1) marked a new era in fingerprint detection. Over three hundred articles and numerous research reports on latent fingermarks appeared in the scientific literature since that 1954 paper. (This is a crude approximation as many articles were published in journals that are not surveyed by the scientific search tools, such as SciFinder.) The vast majority of these articles dealt with attempts to improve fingermark detectability by applying novel or modified methods or surveyed the scope and limitations of existing techniques. Only a handful dealt with fundamental phenomena, such as the composition of palmar sweat (2–4), the physics of latent fingerprints (5–8), or interaction between fingermarks material and the surface on which they are deposited (9–11). Several useful articles have been published on the chemical composition of eccrine sweat, discussing the subject from physiological rather than forensic standpoint (12–18).

From acquired experience, it is clear that better understanding of some of the fundamental phenomena that are associated with the formation of latent fingermarks can make a significant contribution to the development of more efficient visualization techniques. This study also falls in this category of basic phenomena pertaining to the visualization of latent fingermarks.

Fingerprint experts are occasionally asked in courts of law why they have not been able to develop an individual's latent fingermarks on certain objects. Among the possible explanations: possible use of gloves, long time lapse from contact, problematic surfaces, loose contact, atmospheric conditions, and particularly, "poor fingermark donors." In this work, we conducted a preliminary study whose aim was to examine the "poor donor" element and, particularly, whether moist palms are always associated with high quality latent fingermarks and vice versa.

We defined "fingerprint donorship" as the quality of the developed latent fingermarks of a person. We devised a scale from 1 to 4 to define the fingerprint quality. Grade 1 is given to very weak marks that are hardly noticed and cannot be analyzed, and grade 4, to very good marks that resemble inked prints. In this study, we explored the quality distribution of ninhydrin-developed prints on A4 bond paper in a group of 251 donors, men and women, in Israel. Another group of individuals ($N = 200$), in India, was also tested for donorship distribution. This comparative test had one goal that is to make sure that there are no striking differences between the two ethnic groups, which would strongly limit the value of the final results. A subgroup of 77 individuals in Israel representing all four donorship groups from the Israeli volunteers was subjected also to palmar moisture measurements. The tests were carried out by the Corneometer® CM 825 instrument (CK electronic GmbH, Koln, Germany), a medical tool routinely used by dermatologists to diagnose skin hydration. Measurement is based on the dielectric constant of the water in the superficial

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layers of the stratum corneum, at depths between 18 and 20 μm, to ensure that the measurement is not influenced by capillary blood vessels (19). The readings are in arbitrary units between 0 and 120. Fingermark donorship was plotted against the palmar moisture levels of the 77 individuals.

Experimental

Latent fingermarks were collected 10 min after washing the hands with lukewarm water and soaking with a paper towel. The same procedure was applied to moisture measurements.

Latent Fingermarks Collection and Processing

In Israel, the latent marks were collected indoors, in an air-conditioned environment (temperature 17–22°C, humidity 36–51%), and maintained in a closed drawer until their development. They were processed with ninhydrin 8–35 days after deposition. In India, the mean day temperature during the period of collection was 15–21°C and the relative humidity 64–83%. All the collected latent fingerprint samples were developed on the same day of collection, maximum time lapse until development being 6–8 h.

The marks were processed with the ninhydrin working solutions that are routinely used in both countries. Each group applied the technique with which they were most experienced (which was not identical). The developed marks were scored by senior fingerprint examiners, one in each research group, on a 4-grade scale: 1—"weak donors" (color was hardly observed, and no meaningful mark was noticed), 2—"average donors" (weak prints developed, but only a few minutiae could be characterized), 3—"good donors" (good prints, with sufficient characteristics, to be compared also by Automated Fingerprints Identification System), and 4—"excellent donors" (inked print quality).

Ninhydrin Reagent and Development Procedure

India—Ninhydrin (Qualigens Fine Chemicals Pvt. Ltd., Mumbai, India) was used without any further purification. A 1.5% solution of ninhydrin was prepared in acetone, followed by the addition of 3–4 drops of acetic acid to the solution.

Processing for the development of latent fingerprints was carried out by immersion of the paper item in the ninhydrin solution in a Petri dish for 2–3 sec, followed by air-drying. Development was accelerated by heating the sample in an oven maintained at 100–110°C, with 80–85% relative humidity for 3–4 min. Developed prints were photographed using a digital camera (Canon IXUS 700; Canon Inc. Headquarters, Tokyo, Japan) and were stored in a jpeg format.

Israel—The working solution was composed of 0.5% ninhydrin in HFE7100 containing 1% acetic acid. Paper was immersed in the reagent in a glass tray for 2–3 sec, dried in the fume hood, and kept in a paper envelope.

Palmar Sweat Measurements

Palmar moisture levels were measured with a Corneometer® CM 825. This is an analytical device which is used experimentally and clinically for measuring the moisture on the upper 18–20 m layer of the skin, mainly the stratum corneum (Fig. 1). It measures the electric capacitance of the sample, which depends on the dielectric constant of the medium between its tracks. As the capacitance of the skin depends on its water content, a capacitance measurement

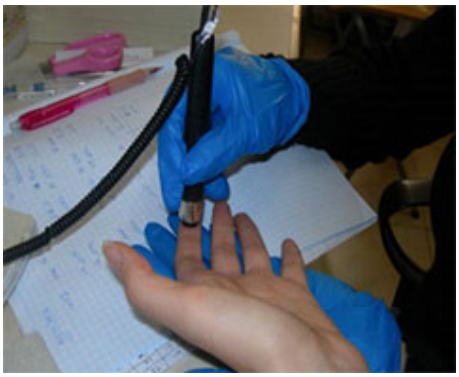

FIG. 1—*Palmar moisture measurement with Corneometer® CM 825.*

can determine the amount of moisture on the skin surface. The influence of ground capacitance and other sweat components on the measured capacitance is insignificant, because of the fact that the dielectric constant of water ($\varepsilon = 81$) differs greatly from that of most other substances ($\varepsilon < 7$; [20–22]). The readings are in arbitrary units and can vary between 0 and 120. This instrument was reported in the past for another forensic study involving sweat; the correlation between palmar moisture and the amounts of iron which are transferred to the hand from holding a weapon (23).

Results and Discussion

Donorship distribution in both groups is shown in Fig. 2. As can be seen, each group contains all four types of donors: excellent, good, average, and weak, but their division is not identical. While most subjects fall in the middle of the scale (*c*. 79% in the Indian group and 66% in the Israeli group), the internal distribution is quite different, with a larger portion of Israeli subjects in the "good" and "excellent" groups. The differences between the two ethnic groups are not surprising. They may arise from, e.g., genetic differences (3), but also from the subjective nature of the scoring. It is less likely to stem from the slight differences in the development conditions because both formulations employ ninhydrin, both target the same substrate, amino acids, and are carried out under optimal conditions for each group. Surprisingly, dietary differences, if at all, play only a marginal role in controlling the amino acid distribution in sweat, as was shown by Hier et al. (24). It must be emphasized that the exact distribution is not so important and only the general shape matters. To reduce the subjectivity within each group, one and the same observer recorded and scored the observations. Another way of reducing the subjective nature of the split study was by letting each group of researchers carry out the latent fingermark processing by its own best procedure, which should provide each party with the best results. As can be noticed, the differences between the two ethnic groups were most noticeable in the two middle groups of donors, "average" and "good" (Fig. 2). This is obviously the region that is most susceptible to subjective decisions. When the "average" and "good" groups were united, the two diagrams became very similar (Fig. 3). It is noteworthy that we did not notice any abnormal statistical behavior in the two groups that would greatly limit the value of the study. Only at this point, after realizing that the Israeli donors sufficiently resemble the donors from India and that they have no unique traits that would limit the study to Israel only, did we start measuring the palmar moisture of the Israeli volunteers.

Corneometer results that were compared with the donorship levels (Figs 4 and 5) truly elucidated the subject. At first glance,

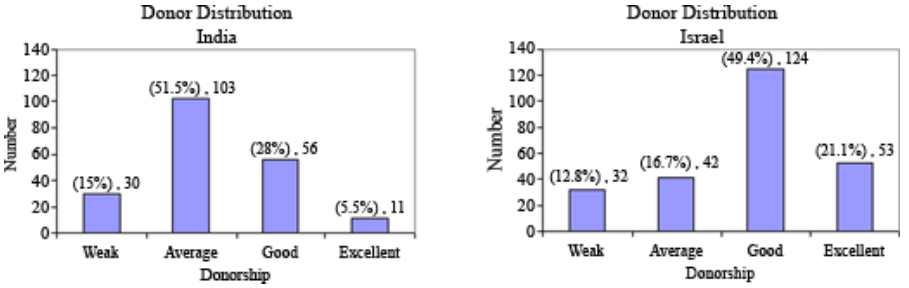

FIG. 2—*Donorship distribution—Israel (251 subjects) and India (200 subjects).*

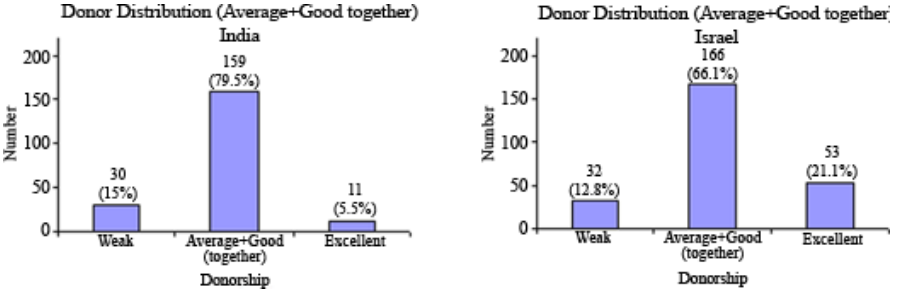

FIG. 3—*Donorship distribution Israel and India (two middle groups together).*

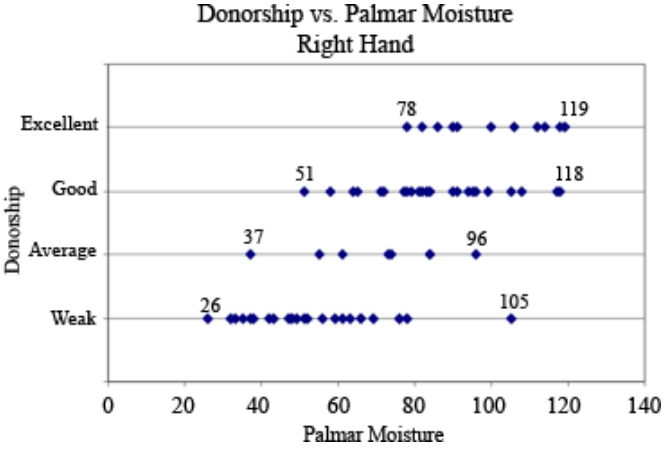

FIG. 4—*Donor quality versus palmar moisture, right hand (77 subjects).*

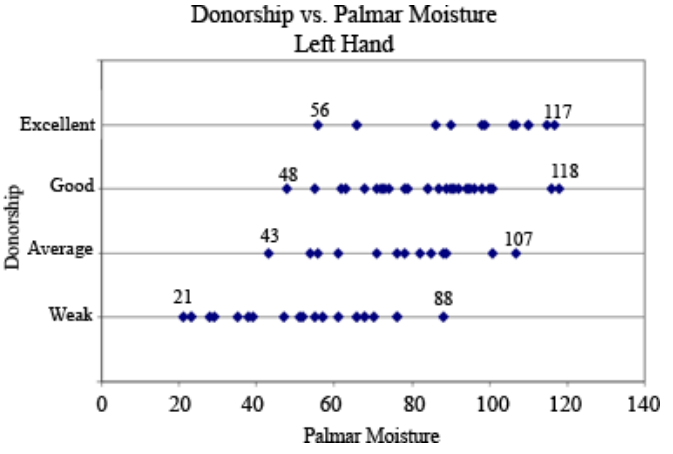

FIG. 5—*Donor quality versus palmar moisture, left hand (77 subjects).*

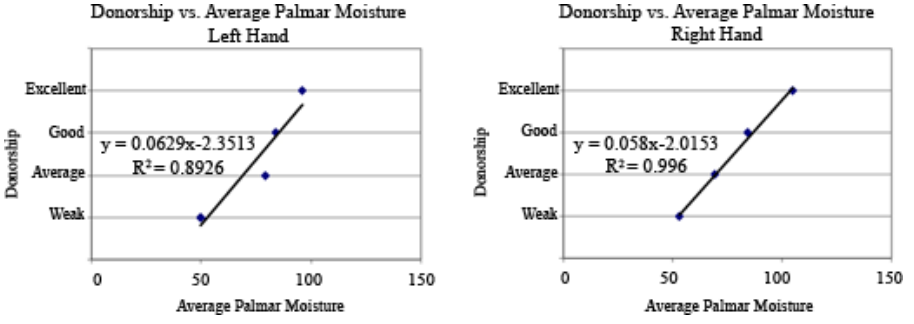

FIG. 6—*Donor quality versus average palmar moisture, both hands (77 subjects).*

they looked somewhat surprising. Good fingermarks are normally associated with moist palms, and hence, we expected the fingermark donorship to correlate well with the moisture level. While this was the general trend (Fig. 6), the range of moisture levels in each one of the four groups was quite wide, with a considerable overlap between the groups. For instance, the "weak group"

stretched between moisture levels 21 and 88 (with one donor measuring 105! in the 0–120 scale), whereas the ''good group,'' which lays two grades above, stretched between 48 and 118 (Fig. 4). Overlapping is particularly noticeable between every two adjacent groups, but considerable overlapping is also noticed between the remote groups, ''weak'' and ''good'' or ''average'' and ''excellent.'' (There were donors whose palms were quite moist, but their donorship grade was relatively low. On the other hand, one ''excellent'' donor had a moisture level of only 56!). This apparent paradox may be reconciled with the perception that moisture is not the only physiological factor governing the prints' quality. As our visualization technique is based on color formation between a fingermark reagent (ninhydrin) and amino acids, it is clear that the spatial distribution of amino acids in the latent mark is the most important factor which governs the fingermark quality. If the amino acid concentrations in the sweat of all individuals were the same, the amount of sweat (palmar moisture) would be the only important factor. It is known that the composition of latent print residue may vary significantly between individuals. For instance, amino acid levels as low as 0.3 mg/L and as high as 2.59 mg/L have been measured in eccrine sweat (3,4,12–18). Thus, high moisture levels may not be sufficient to produce good prints, if they are associated with low concentration of amino acids; and good fingermarks may be obtained even with low moisture levels, if the content of amino acids in the sweat is relatively high. The other physiological factor, which controls the fingermark quality, is perhaps the density of the sweat pores, which should affect the continuity of the sweat impressions along the ridges. This feature, too, is known to show considerable diversity with regard to pores' size, shape, and density. Another, nonphysiological factor is the pressure with which the latent print is impinged with respect to donor variations. Two other fingerprint reagents, which are known to react with amino acids, DFO and 1,2-indanedione, have also been tried in this study, albeit on a smaller scale. The results were in very close agreement with the ninhydrin findings. Obviously, fingerprint techniques that are based on different substrates, such as Ag-PD, which develops the lipid fraction, or fingerprint powders, which adhere to the entire sweat matrix, may show a different distribution of donorship levels, but we assume a similar relationship pattern between the moisture levels and the fingermark quality.

Conclusions

While fingerprint donorship, as judged by amino acid reagents, is closely correlated with the moisture levels on the palms, this is not always the case, as there are meaningful deviations in both directions. The other factor that dictates the quality of the developed prints is the amino acid concentration in the sweat (or other relevant substrates, for different fingerprint reagents).

Conflict of interest: The authors have no relevant conflicts of interest to declare.

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