JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, May 2011, Vol. 56, No. 3
doi: 10.1111/j.1556-4029.2011.01710.x
Available online at: onlinelibrary.wiley.com

TECHNICAL NOTE

ANTHROPOLOGY

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Estimation of Stature from Hand Impression: A Nonconventional Approach*

ABSTRACT: Stature is used for constructing a biological profile that assists with the identification of an individual. So far, little attention has been paid to the fact that stature can be estimated from hand impressions left at scene of crime. The present study based on practical observations adopted a new methodology of measuring hand length from the depressed area between hypothenar and thenar region on the proximal surface of the palm. Stature and bilateral hand impressions were obtained from 503 men of central India. Seventeen dimensions of hand were measured on the impression. Linear regression equations derived showed hand length followed by palm length are best estimates of stature. Testing the practical utility of the suggested method on latent prints of 137 subjects, a statistically insignificant result was obtained when known and estimated stature derived from latent prints was compared. The suggested approach points to a strong possibility of its usage in crime scene investigation, albeit the fact that validation studies in real-life scenarios are performed.

KEYWORDS: forensic science, forensic anthropology, estimation of stature, scene of crime, hand impression, nonconventional method

Personal identification plays a vital role in medico-legal and crime scene investigation. In this context, stature is considered as one of the "Big Four" parameters required to assist with the identification of an individual when other lines of evidence are corroborative (1). The knowledge of definite relationship between various body dimensions can be useful in estimating stature of an unknown person.

Often, the only evidence that may be available at the scene of a crime is in the form of latent impressions from hands and feet. In such cases, the impression can be used to estimate stature of the unknown person. Very few studies (2–4) have been reported so far on this aspect.

Various landmarks for measuring hand length have been adopted by different workers. Ozaslan et al. (5) and Krishan and Sharma (6) have measured it as the distance between midpoint of the line joining the ulnar and radial stylions and dactylion. Stylion is the deepest point on the styloid process while dactylion is the lowest point on the anterior margin of the middle finger when the arm is hanging by the side of the subject. Atallah and Marshall (7) measured it from radial stylion to dactylion, while Sanli et al. (8) and Habib and Kamal (9) measured it from center of bracelet crease of wrist. Although Jasuja and Singh (4) do define the measurement as distance between "metacarpo-phalangeal wrist crease" and most forwardly projecting point on the middle finger, it seems they probably meant it from bracelet crease. The above-mentioned methods of measurement are useful for estimating stature from fleshed hand retrieved in cases of accident, mass disaster, or homicide where landmarks are distinctly visible. So far, the traditional method of measuring hand length from center of bracelet crease to dactylion has been used on impressions also (2,4).

Before taking up the present study, a small exercise was undertaken on 53 individuals to check as to what kind of imprints can be found in a real-life scene of crime. After applying black ink on their hands up to bracelet crease, subjects were requested to enact/simulate actions like holding an object, unintentionally putting their hand on a table or wall, breaking a lock with a hammer, etc. When the impressions left were analyzed, it was observed that none of the hand impressions showed bracelet crease. Impressions were of proximal surface of palm from the depressed area between hypothenar and thenar region. Hence, in crime scene investigation if such impressions are lifted, measured and stature is estimated using regression formula derived from hand length measured from bracelet crease, the estimated stature will be much less than actual one. To eliminate such practical anomalies, the present study is devised keeping in mind real-life scene of crime by verging on the practical aspects that an investigator may find at his disposal and his limitations.

Based on our observations, a new method has been adopted for measuring hand length on impressions, from the depressed area between hypothenar and thenar region to most forwarding point found on the middle finger (dactylion). Second, unlike traditional method, finger length has been measured in three segments: distal part, distal and middle parts, and total finger, i.e., distal, middle, and proximal parts of finger together. All fingers were measured in three segments except thumb where distal and total thumb lengths were considered. Generally, when one holds something or inadvertently places his hand on any surface, one tends to leave behind impression of one or two segments (more frequently distal one) rather than finger as a whole. Jasuja and Singh (4) conducted a study on Jat Sikh where they have ignored impression of thumb because of its "variable flexibility." The present study has included thumb keeping in mind its important role while holding objects in power or precision grip. Thumb may not leave impression of its

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*Presented at the 18th Triennial Meeting of the International Association of Forensic Sciences, July 21–26, 2008, in New Orleans, LA.

Received 17 June 2009; and in revised form 6 April 2010; accepted 17 April 2010.

complete palmar (ventral) surface but inter-phalangeal crease depicted in the impression distinctly separate the two finger segments.

The third part of the study is measuring length of only the palmar surface excluding fingers in the impression. The measurement is particularly useful in cases where phalangeal crease is either not visible or absent. This type of impression is left when one is lifting or pushing heavy objects and also by workers engaged in manual labor whose metacarpo-phalangeal and proximal creases are poorly developed or obscured because of callous formation.

The present study statistically analyzes the relationship between various dimensions of hand impression with stature and derives regression equations to estimate stature from them. The study also proposes to test the efficacy of the suggested method by applying its regression equation on latent prints that are usually found at crime scenes.

Materials and Methods

The study was conducted in Saugor district of Madhya Pradesh located in the central part of India. Stature of an individual is determined by both genetic and environmental factors like nutrition, climate, etc. To maintain genetic homogeneity of the sample, an attempt has been made to include subjects from intermarrying caste groups.

Subjects included in the study ranged in age from 18 to 35 years, were healthy, free from any orthopedic or dermatological abnormalities, and right-handed. After application of ink on both hands of the subject, bilateral impressions were collected on a clean sheet of paper. Prints where either metacarpo-phalangeal or phalangeal creases were not visible have not been included in the study. After excluding the incomplete ones, prints of 503 men formed the database for the present study.

Stature was measured with an anthropometer as a vertical distance from horizontal floor to vertex (highest point on the head) when subject is standing in erect posture with head in Frankfurt horizontal plane.

The following measurements have been taken on impression of hand:

- Hand length: It is measured between the most forwarding point on curvature of depression between hypothenar and thenar area (Fig. 1, Point A) to the most distal point on middle finger (Fig. 4, Point B).
- Hand breadth: It is measured between metacarpal radiale (most medially projecting point on head of second metacarpal, Fig. 1, Point C) and metacarpal ulnar (most laterally projecting point on head of fifth metacarpal, Fig. 1, Point D).
- Palm length: It is measured proximally from the depression between hypothenar and thenar area (Fig. 1, Point A) to center of metacarpo-phalangeal crease of middle finger (Fig. 1, Point E).
- Complete finger length: It is measured from center of metacarpo-phalangeal crease of finger to most distal point on finger (Fig. 1, Point E–B in middle finger).
- Distal and Middle finger length: It is measured between the center of proximal phalangeal crease to the most distal point on finger (Fig. 1, Point F–B in middle finger).
- Distal finger length: It is measured between the center of distal phalangeal crease to the most distal point on finger (Fig. 1, Point G–B in middle finger).

All the dimensions have been measured with sliding caliper (Dial caliper manufactured by Mitutoyo Corporation in Japan, accuracy 0.01 mm). Data were subjected to statistical analysis using statistical package for social science SPSS version 11.0 (SPSS Inc., Chicago, IL), and linear regression formulae were calculated for various combinations to reach the best estimation possible.

To test the utility of the suggested method to aid crime scene investigation, an additional exercise was undertaken on 137 subjects. Inked impressions of hand were obtained following the suggested method. Regression equation for hand length was derived. An additional set of latent impressions of hand was obtained from subjects by asking them to place their hand on a paper as one may do inadvertently. Latent prints were developed using ninhydrin solution. Ninhydrin reacts with amino acids present in sweat of the latent impression and makes it visible; 1.5% ninhydrin solution was prepared in acetone. A few drops of glacial acetic acid were added to bring pH of the solution to 4. Paper containing latent print was sprayed with the above solution and kept for 2–3 min at 100–105°C in an oven. Impression becoming visible almost immediately was photographed for record. Length of hand was measured following the suggested technique on developed latent prints, and regression equation derived from inked impressions was used to estimate stature.

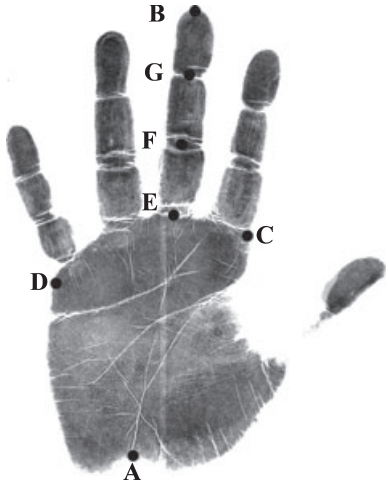

FIG. 1—*Impression of hand depicting landmarks for various dimensions.*

Results

Table 1 shows descriptive statistics for stature and various dimensions of hand including palm and finger segments. It is observed that there is no statistical significant bilateral difference in measurements of impression except for hand width, distal segment of thumb, and distal and middle segments of little finger. The observation is in concordance with the studies conducted by Krishan and Sharma (6) among Rajputs of Himachal Pradesh and Habib and Kamal (9) among Egyptians. The observed asymmetry in the above dimensions may be because of muscular dominance in right-handed subjects and variable pressure applied by them while giving impression. For further analysis, except for the above-mentioned dimensions, measurements pertaining to right side are considered.

Table 2 depicts the correlation coefficient values between stature and different dimensions of hand impression. All dimensions exhibit statistically significant correlation with stature. Except for complete index finger, hand, and palm lengths showing

TABLE 1—*Descriptive statistics for stature and dimensions of hands in men.*

Parameters	Mean (mm)		Standard Deviation (mm)		Standard Error of Mean (mm)		Bilateral Difference "*t*"-value	Significance Level
	Right	Left	Right	Left	Right	Left		
Stature	1678		55.8		2.56		–	–
Hand length	177.06	177.19	7.47	7.47	0.40	0.40	0.305	0.761
Hand width	83.12	82.04	5.38	5.51	0.29	0.29	−3.074	0.002*
Palm length	98.80	98.53	5.47	5.11	0.29	0.27	0.778	0.437
Thumb distal	31.36	30.81	3.25	2.81	0.17	0.15	−2.122	0.035*
Complete thumb	64.56	64.38	4.77	4.34	0.25	0.23	−0.519	0.604
Index distal	23.19	23.02	2.03	1.87	0.11	0.99	−1.190	0.235
Index distal + middle	47.05	47.13	3.39	3.29	0.18	0.18	0.264	0.792
Complete index	70.69	71.01	4.28	4.08	0.23	0.22	1.318	0.188
Middle distal	24.01	24.07	2.19	2.07	0.12	0.11	0.449	0.653
Middle distal + middle	52.02	52.27	3.65	3.59	0.19	0.19	0.973	0.331
Complete middle	78.29	78.61	4.56	4.39	0.24	0.23	1.374	0.170
Ring distal	24.39	24.46	2.09	2.21	0.11	0.12	0.480	0.632
Ring distal + middle	50.29	50.61	3.49	3.56	0.18	0.19	1.628	0.104
Complete ring	73.28	73.54	4.48	4.57	0.24	0.24	0.925	0.356
Little distal	22.54	22.47	1.78	1.86	0.95	0.99	−0.530	0.596
Little distal + middle	40.86	41.54	3.19	3.20	0.17	0.17	3.013	0.003*
Complete little	60.08	60.01	3.77	40.07	0.2	0.21	0.394	0.694

*Bilateral difference is statistically significant at $p < 0.05$.

TABLE 2—*Correlation between the stature and various dimensions of hand impression.*

Parameters	Value of Pearson's Correlation "*r*"*
Hand length	0.558
Hand width (Right)	0.284
Hand width (Left)	0.233
Palm length	0.465
Thumb distal (Right)	0.261
Thumb distal (Left)	0.222
Complete thumb	0.276
Index distal	0.233
Index distal + middle	0.304
Index	0.402
Middle distal	0.243
Middle distal + middle	0.356
Complete middle	0.358
Ring distal	0.267
Ring distal + middle	0.390
Complete ring	0.356
Little distal	0.252
Little distal + middle (Right)	0.331
Little distal + middle (Left)	0.354
Complete little	0.364

*All parameters exhibit significant correlation with stature at $p < 0.05$.

substantial correlation, all other dimensions are weakly related with stature (10).

Table 3 illustrates coefficient of determination (*R* square), standard error of estimate, and possible linear regression equations for estimating stature from dimensions of hand. Independent variables (hand dimensions) are incorporated into a regression formula to give best estimation of stature (dependent variables). Regression formula is written as S = a + bx, where "a" is constant and "b" is regression coefficient of independent variable. Best model/regression formula is chosen according to value of coefficient of determination "*R* square" (8). "*R* square" is proportion of variation in dependent variable (stature) explained by independent variables (hand dimensions). Model with highest value of coefficient of determination "*R* square" is the best model for determining stature. In the above table, linear regression model for hand length is found to be the best model with highest value for "*R* square" as 0.312. The table also reports the standard error of the estimate which predicts the deviation of estimated stature from known stature. It ranges from 46.35 to 54.95 mm. A low value indicates greater accuracy in estimated stature. Hand length followed by palm length gives best estimate.

Table 4 depicts application of the suggested approach on latent prints. Regression formula derived from inked impression was applied on developed latent impression of each subject to estimate stature from his latent hand length. Difference between known stature and one estimated from latent print is found to be statistically insignificant at 95% confidence limit.

Discussion

The four main attributes of biological identity that forensic investigators try to determine are sex, age, ancestry, and stature. Currently, estimation of stature is performed from fleshed and skeletal remains. There has been little attempt to use complete or partial hand impressions left at scene of crime for estimating stature.

It is observed that hand impressions left varied with type of activities the person is engaged in. Usually, partial impressions of hand are left. Hence, linear regression equations have been developed for all possible types of impressions that are usually left. Moreover, impressions left inadvertently do not include bracelet crease traditionally used to estimate stature from hand impressions. When this was investigated, it was found that hand and the distal part of forearm where bracelet crease is situated are not in the same plane. An impression containing bracelet crease can only be obtained when the subject first brings his forearm in contact with surface/paper and subsequently presses his palm thereby automatically lifting his forearm upward. This means that one needs active cooperation of the subject for obtaining an impression from bracelet crease. Hence, probability that a person leaves behind hand impression inadvertently from bracelet crease at scene of crime is most unlikely and rare. Technique suggested in the present study uses landmark in the proximal part of palm which was visible in every impression taken.

TABLE 3—*Linear regression equation,* R *square, and standard error of estimate of various dimensions of hand impression.*

Parameters	Regression Equation	*R* Square	Standard Error of Estimate (mm)
Hand length	S = 940.29 + 4.169 (HL)	0.312	46.35
Hand width (Right)	S = 1433.53 + 2.946 (HW)	0.081	53.57
Hand width (Left)	S = 1483.85 + 2.366 (HW)	0.054	54.81
Palm length	S = 1210.16 + 4.740 (PL)	0.216	49.47
Thumb distal (Right)	S = 1470.12 + 3.226 (Td)	0.076	53.71
Thumb distal (Left)	S = 1540.42 + 4.454 (Td)	0.045	54.95
Complete thumb	S = 1538.16 + 4.473 (Tc)	0.068	53.94
Index distal	S = 1307.81 + 5.246 (Id)	0.162	51.15
Index distal + middle	S = 1443.37 + 4.996 (I.dm)	0.093	53.23
Complete index	S = 1530.26 + 6.389 (Ic)	0.054	54.34
Middle distal	S = 1336.04 + 4.375 (Md)	0.128	52.18
Middle distal + middle	S = 1395.86 + 5.431 (Mdm)	0.127	52.22
Complete middle	S = 1530.42 + 6.163 (Mc)	0.059	54.21
Ring distal	S = 1353.87 + 4.429 (Rd)	0.126	52.22
Ring distal + middle	S = 1366.07 + 6.214 (Rdm)	0.152	51.46
Complete ring	S = 1504.90 + 7.113 (Rc)	0.071	53.85
Little distal	S = 1356.71 + 5.359 (Ld)	0.132	51.93
Little distal + middle (Right)	S = 1442.35 + 5.783 (Ldm)	0.110	52.60
Little distal + middle (Left)	S = 1420.97 + 6.190 (Ldm)	0.125	52.71
Complete little	S = 1500.81 + 7.878 (Lc)	0.063	54.08

S, Stature; HL, Hand length; HW, Hand width; PL, Palm length; T, Thumb; I, Index finger; M, Middle finger; R, Ring finger; L, Little finger; d, Distal segment of finger; c, Complete finger; dm, Distal and middle segments of finger.

TABLE 4—*Estimation of stature from latent prints using regression equation of suggested method (N = 137).*

Known Stature Mean (mm)	Mean Stature Estimated from Latent Prints (mm)*	Mean Difference Between Known & Estimated Stature (mm)
1674.1 ± 40.9	1673.9 ± 27.31	32.5 ± 21.6 $t = 0.019^{\dagger}$

*Regression formula used to estimate stature from latent print. S = 1104.7 + 3.22 HL, SEE 3.83.

†Significance 0.985, $p > 0.05$.

While testing forensic utility of the suggested technique, regression equation derived from inked prints was applied on latent impressions, the usual form of evidence left at the crime scene. It was found that difference between known stature and stature estimated from latent impressions is negligible and statistically insignificant. As one may not always find complete hand impression at the scene of crime, the test may be applied on partial latent impressions too. When inked and latent impressions of hand were compared, landmarks used in the suggested method were distinctly visible in latent form although the details of metacarpo-phalangeal and inter-phalangeal creases of few fingers were sometimes absent.

Although the approach suggested in the present study is successful in reconstructing stature from hand impressions, validation studies in real-life scenarios are suggested for the method to be standardized. It is expected that in future, it can be used to assist crime scene investigation if undertaken as a standard operating procedure.

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