iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** X **Month of publication:** October 2019

DOI: http://doi.org/10.22214/ijraset.2019.10041

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue X, Oct 2019- Available at www.ijraset.com

Stature Estimation from Shoe Prints

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Abstract: ***Objective: The forensic anthropometry deals with the measurements of the human body parts. Human body is designed as there is correlation of one body part with the other parts of the body. The present study was conducted to estimate stature using shoe prints of Haryanavi population within confined region of Kurukshetra.***
Method: 50 Haryanavi adults were randomly selected for the purpose of this study. Their height were previously recorded in centimeters. A plain glass plate was cleaned and uniformly smeared with a thin layer of black duplicate ink. Then by using cotton pad uniformly smeared ink is coated on the shoe base of the subject. Then the subject were guided to walk normally on the already spread transparent sheet above the floor. Photos of the prints are taken and then measurements of the prints were taken using pencil and steel scale and all the measurements were noted. Now by applying Jasuja formula stature was estimated.
Result: Student "t" test is applied for the purpose of checking the significance of the observed stature estimation(height measurements) from the left foot measurements(Male and Female) and also from the right foot measurements(Male and Female) either the results are significant or not with respect to that of actual height. In both male and female samples reliability of the calculated height and actual height was found.
Conclusion: The study indicates that there is a strong relationship between body measurement and stature, therefore indicating a linkage between the shoe prints and height of the individual. Consequently this can be very useful in forensic cases to determine height of the perpetrators.
Keywords: Forensic criminal investigation, shoe prints, shoe prints length, stature estimation, forensic anthropology.

I. INTRODUCTION

In the field of Forensics the identification of the suspect is one of the most important tasks that have to be performed by the crime investigator. When little or no information is known about the suspect the forensic investigators have to get the most out of any left evidence. Evidence, left by a suspect, at a crime scene is likely to include shoe prints. Shoe prints have a great forensic value in the estimation of the body height. Shoe prints if present at the scene of crime, may provide clue regarding the stature and the gender of the person. The scope of forensic anthropology is increasing day by day as they not only provide useful information from the dead remains but also from the living being. Anthropometric standards are commonly accepted for the identification purposes. Many parts of the human body have been studied by forensic anthropologists in the progression to formulate biological profile. Parts of body bones and radiographic materials were used to estimate stature and determine sex of the remains from various dimensions. Often the height of a person is one of the identifying variables that have been used by forensic anthropologists (Brenda and Rohren, 2006). Many studies have been performed in order to establish a link between human body parts and the individual's height (Atamturk et al 2008, Jasuja *et* at. 1997, Kanchan *et* al 2008, Krishan 2008). Lower human body extremities have in general a higher correlation with the body stature than their upper extremity counterparts (Sen and Ghosh, 2008). Among the lower extremities, foot dimensions (foot length and foot breadth) are of enormous value in identify of a person's identity (Krishan 2007).Since foot and shoe prints were frequently found at crime scene and because of the ease to analyze them there have been an increasing preference for using foot and shoe (print) dimensions to estimate the body height (Jasuja et al. 1997). In the mid-1800s, Topinard developed a mathematical formula estimating a person's height from a foot print (foot length: stature ratio) and reported be 17% reliability. Foot length has a biological correlation with stature, the latter can be estimated from foot or shoe prints. Any foot/shoe print found at the crime scene, first it is photographed and a cast of the print is made. The photographs and cast are then used for further analysis which may be used for identification and verification purposes. For veritable analysis it is advisable to rely on mathematical formulas to quickly estimate the suspect's height based on the available foot and shoe print measurements.

II. MATERIALS AND METHODS

A. Hypothesis

As every individual has specific bodily features that make him different from others and help in identification. As reported by various Anthropologists, the human body is proportionate and the various osteometric measurements are relatable. Following the same, an attempt has been made to analyze the stature from shoeprints which may prove to be assistive in forensic investigations.

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B. Materials Used

Cellophane (Transparent) sheet (5 ft), Black duplicate ink, Glass plate (24-24 cm), Cotton pad, Cello tape, Scale, Pencil, Methanol.

C. Sample Collection

In this study 50 samples of shoeprints were taken out of which 25were of males and 25 were of females. The subjects were guided to walk on a cellophane sheet and the prints were taken by inking their footwear soles. Because foot length does not typically stabilize until adulthood only individuals who were 18 years of age or older were invited to participate. Subjects with apparent anomalies, inflammation, trauma, deformities and surgery of foot (if any) were excluded in the present study. The whole process of sample collection is demonstrated as follows-

Demonstrating the process of sample collection

D. Method

The study was conducted in the Department of Zoology, Kurukshetra University, kurukshetra. The aim of this study was properly explained to the subjects and the height of each subject was recorded in centimeters for further comparison with the values so retrieved as the outcome of the study. The method of collection of samples is as follow:-

1) A plain glass plate was cleaned and uniformly smeared with a thin layer of black duplicate ink by using a cotton pad.
2) Then the subject was made to sit on a chair and by using the cotton pad (on which thin and uniformly smeared ink is coated), the shoe sole of the subject is coated with the ink uniformly.
3) Then the subject was guided to stand carefully on glass plate so as to avoid contact with ground in order to avoid prints from getting contaminated and also to check smothering of ink applied on the shoe sole.
4) Then the subject was guided to walk on the cellophane (transparent) sheet already spread on the floor.
5) The pictures of the prints were taken for future reference and then the measurements of the prints were taken using pencil and steel scale and all the measurements were recorded.
6) The cellophane sheet was then cleaned using methanol on cotton so as to prepare the sheet to take prints from the next subject.
7) Following the same procedure, the prints were collected from all the individuals.

Demonstrating the collected shoe prints

E. Analysis

The stature was estimated from blind sample where the source was to reveal in order to check the biasness in analysis. The formula for stature estimation given by Jasuja *et* al. (1997) was applied for stature estimation.

Stature = 3.641 (right shoe length) + 72.29 ±4.35

Stature = 4.229 (left shoe length) + 56.49 ± 3.58

Shoe print length (SPL) is defined as the direct distance between the top of the tip and the lower margin of the heel of the shoe.

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F. Statistical Analysis

1) T-Test: The independent t-test, also called the two sample t-test or student's t-test, is an inferential statistical test that determines whether there is a statistically significant difference in two unrelated groups.

2) Hypothesis for the Independent T-Test: The null hypothesis in the independent t-test is that the population means of the two unrelated groups are equal:

H_0: $u_1 = u_2$

In most cases, we are looking to see if we can show that we can reject the null hypothesis and accept the alternative hypothesis, which is that the population means are not equal:

H_A: $u_1 \neq u_2$

To do this, we need to set a significance level (alpha) that allows us to either reject or accept the alternative hypothesis and its value is set at 0.05.

The *p*-level reported with a *t*-test represents the probability of error involved in accepting the research hypothesis about the existence of a difference. Technically, this is the probability of error associated with rejecting the hypothesis of no difference between the two categories of observations (corresponding to the groups) in the population when, in fact, the hypothesis is true. (Statistical 7.0 help guide)

III. RESULTS AND DISCUSSION

The details of the shoe print length for both the right and left feet in males and females were recorded separately. The details of the same are shown in Table-1 and 2 respectively.

Serial No.	Right shoe length (cm)	Left shoe Length (cm)
1	28.3	28.1
2	27.2	27.3
3	28.4	28.6
4	25.2	25
5	27.6	27.9
6	25.0	25.0
7	26.8	26.9
8	26.5	26.6
9	25.6	25.5
10	26.6	26.7
11	28.3	28.5
12	29.3	29.5
13	28.0	28.3
14	30.1	30.3
15	30.7	30.5
16	28.8	28.6
17	26.6	26.7
18	28.5	28.3
19	26.8	26.8
20	29.1	28.9
21	25.6	25.5
22	27.4	27.6
23	26.0	26.0
24	27.3	27.4
25	28.1	28.0

Serial No.	Right shoe Length (cm)	Left shoe Length (cm)
1	23.1	23.2
2	25.0	26.0
3	24.0	24.0
4	26.0	25.0
5	24.0	24.2
6	24.8	25.0
7	25.4	25.1
8	24.8	24.9
9	25.5	25.0
10	24.3	24.0
11	24.5	24.0
12	25.0	24.9
13	23.9	24.2
14	24.8	24.6
15	25.0	25.0
16	23.9	23.7
17	26.1	26.0
18	21.0	21.4
19	27.0	27.0
20	22.4	22.0
21	25.0	25.3
22	25.8	26.0
23	22.8	22.8
24	21.4	21.6
25	21.4	21.2

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
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A demonstration of the stature estimation from shoe prints applying the standard formula reported by Jasuja *et* al. is as follow:-

1) Formula: Stature = 3.641 (right shoe length) + 72.29 ±4.35
Stature = 4.229 (left shoe length) + 56.49 ± 3.58

2) Sample-1 (Male)

Length of right shoe measured = 28.3 cm
Length of left shoe measured = 28.1cm
Stature from right
Foot = 3.641(28.3) +72.29=174.60
Stature from left foot = 4.229(28.1) +56.49 = 176.17

So, following this method, the values for stature were estimated from both left and right feet. The same formula was applied on rest of the samples and the details of the final outcome for males and females are given in **Table-3 and 4** respectively.

Serial No.	Calculated Height From Right shoe Length (cm)	Calculated Height From Left shoe Length (cm)	Actual Height (cm)
1	174.60	176.17	175.26
2	175.67	175.52	177.80
3	175.69	177.43	177.80
4	164.04	165.79	167.64
5	172.78	170.83	170.18
6	158.96	158.63	157.48
7	174.21	170.25	172.72
8	168.77	168.98	167.64
9	165.49	164.32	165.1
10	169.14	169.40	170.18
11	171.95	173.74	172.72
12	178.26	177.29	177.86
13	174.23	175.32	173.72
14	181.88	184.62	182.88
15	184.33	185.47	185.42
16	181.13	180.89	182.88
17	169.86	169.86	170.18
18	178.24	178.70	177.80
19	180.62	180.62	182.88
20	178.60	179.32	177.80
21	172.05	173.21	165.10
22	165.49	164.32	172.72
23	166.95	166.44	167.64
24	171.68	172.36	172.72
25	174.60	174.90	175.26

Serial No.	Observed Height From Right shoe Length(cm)	Observed Height From Left shoe Length(cm)	Actual Height(cm)
1	156.12	154.60	154.39
2	163.31	166.44	165.1
3	159.67	157.98	157.48
4	166.44	166.95	165.10
5	159.67	158.83	156.20
6	162.58	162.21	165.1
7	164.77	155.73	167.64
8	162.58	161.79	159.75
9	165.1	155.79	167.64
10	156.41	157.98	157.48
11	157.23	157.99	157.48
12	163.32	161.79	164.73
13	159.31	158.83	157.48
14	162.59	160.52	162.56
15	163.32	162.22	160.2
16	159.31	156.72	157.48
17	167.32	166.44	167.64
18	148.75	146.99	144.78
19	170.60	170.67	172.72
20	153.85	153.87	154.94
21	163.32	163.48	162.56
22	162.23	166.44	162.56
23	155.31	152.91	154.94
24	150.21	147.84	144.78
25	150.21	150.73	144.78

Student "t" test was applied to check the significance of the estimated stature (height measurements) from the left and right foot measurements in males and females. The following results were obtained:

a) In the males where the stature was estimated from the right shoeprints, t-test was applied to check if there is statistically significant difference between the two groups. The p value came out to be 0.1 which indicates that there is no significant difference between the two groups and hence the verifying the methodology so adopted for stature estimation.

b) Similarly, when the stature was estimated from the left shoeprints, t-test was applied to check if there is statistically significant difference between the two groups. The p value came out 0.1 and hence also verifying the methodology so adopted for stature estimation.

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c) In the females where the stature was estimated from the right shoe prints, t- test was applied to check if there are statistically significant differences between the two groups. The p value came out 0.2 hence also verifying the methodology so adopted for stature estimation provided positive result.

d) Similarly, in the females where the stature was estimated from the left shoe prints, t-test was applied to check if there are statistically significant differences between the two groups. The p value came out 0.2 hence also verifying the methodology so adopted for stature estimation provided positive result.

The results showed no significant differences in the values calculated for stature and the available records of stature as in all the sets, the p value was found to be less than 0.05 (p> 0.05) indicating the two values to be same thus verifying the methodology adopted and the research findings. First and foremost question when this work was started is that whether the formula used provides positive results or not. Topinard was the first researcher to report his findings on the estimation of stature from shoe and foot prints where the ratio of the shoe prints/ stature came out 17%. The work done by Jasuja *et* al. reported this ratio to be 14.73%. A similar study in 2002 conducted by Burke (22 subjects) indicated the shoe prints: stature ratio of 15.2%.Another study performed among 200 adult Gujjars (a people in North India) reported that age had no significant correlation with stature (p>0.05) (Kanchan *et* al., 2008). In the present study when ratio was calculated for both the genders, ratio of right shoe print/stature came out to be10.84% for the males and for the left shoe prints, the value was found to be 11.76%. In females, the ratio of right shoe print/stature was found to be 9.81% and for left shoe print/stature it was found to be 11.34%. The results of this study show that there is a strong relationship between the measured variables and the individual's stature.

IV. CONCLUSION

In this study, samples of shoe prints were collected randomly from the individuals belonging to Haryana region. The method implied is simple and repeatable. After taking measurements and calculating the stature, statistical analysis was done applying the student t- test. The results obtained showed that there is no statistically significant difference between the calculated values and the available data, indicating a reliable association. The p values so obtained verify that methodology adopted provides positive results.

The study indicates that there is a strong relationship between body measurement and stature, especially between the foot parameter and the stature, therefore indicating a linkage between the shoe prints and height of the individual. The results indicate that an accurate estimation of body height can be realized from shoe prints. Consequently this can be very useful in forensic cases to determine the body height of possible perpetrators.

Moreover this study should be carefully applied for stature estimation for each population as body measurements can and will be influenced by environmental factors like nutrition, diseases.

The two major conclusions that were drawn from the present study are-

The values obtained from left shoe prints provide better results in terms of association than those of right shoe prints.

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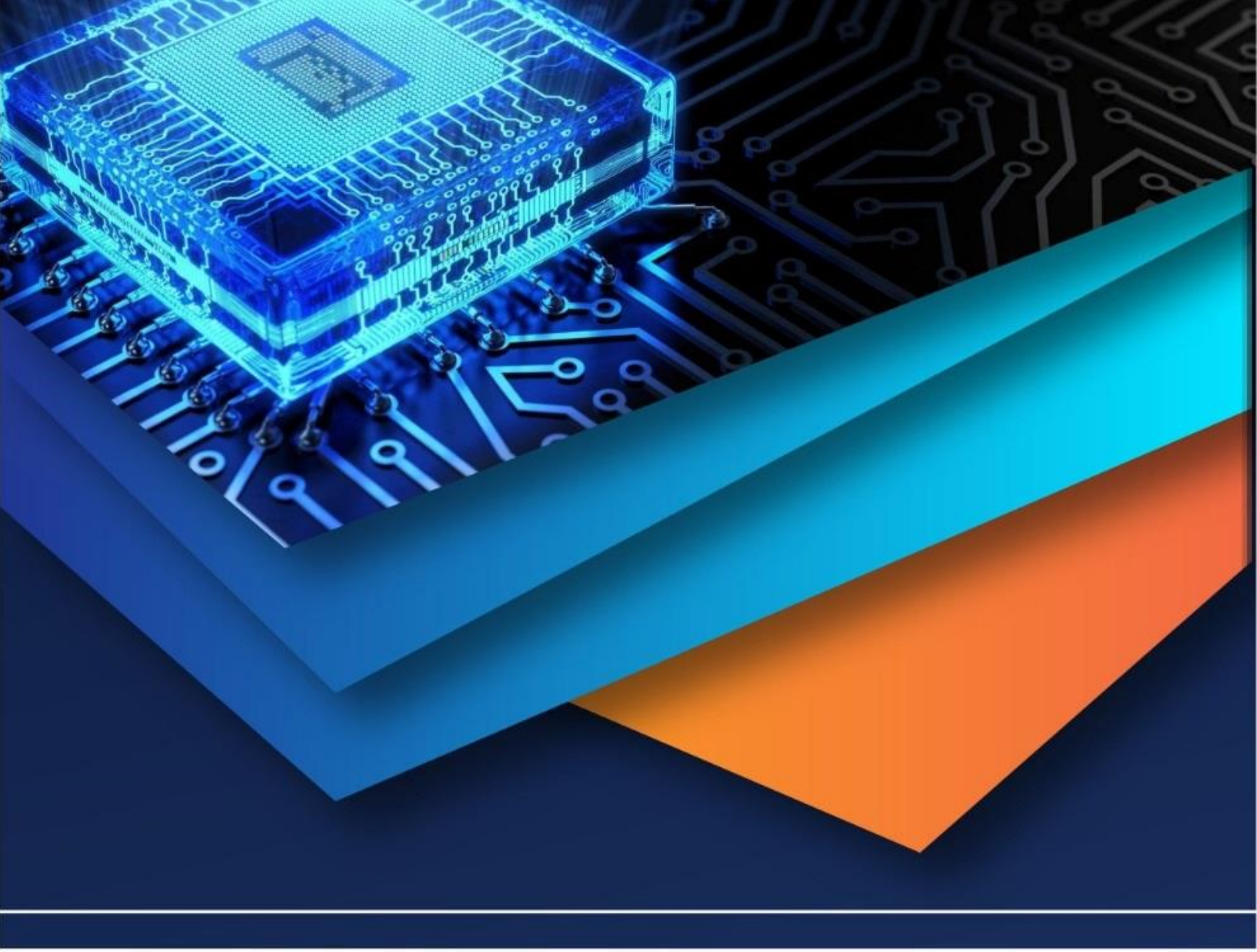

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