Original Article

Indian Journal of Forensic Medicine and Pathology
Volume 13 Number 1, January - March 2020
DOI: http://dx.doi.org/10.21088/ijfmp.0974.3383.13120.14

Estimation of Stature from Footprints Measurements by Linear Regression Analysis in South India Population

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How to cite this article:

Gunti Damodar, Nishat Ahmed Sheikh. Estimation of Stature from Footprints measurements by Linear Regression analysis in South India Population. Indian J. Forensic Med Pathol. 2020;13(1):94–101.

Abstract

Background: Human identification using footprint is an emerging biometric technique, and footprints as valuable physical evidence in crime scenes are used to link the crime to the perpetrator. Footprints can be collected from almost all types of crime scenes and the possibility of their recovery at the scenes of sexual offenses and homicide is relatively more. *Aim and Objective:* To estimate stature from footprint length measurements in Telugu people of Nalgonda district at Narketpally State Telangana South India. *Place of Study:* Department of forensic medicine and toxicology on the consenting adult males of Nalgonda District of Telangana State. *Type of Study:* Descriptive cross-sectional study with analytical and comparative components. *Material and method:* The subjects were confirmed to be descent from Nalgonda district and were specifically selected with residence of Nalgonda district only, irrespective of their caste, religion, dietary habits and socioeconomic status. The footprint measurements collected in 150 adult males' volunteers with age of 18 to 40 years. *Observation and Discussion:* In footprint first toe - heel footprint length measurement, i.e. PRT1 and PLT1 was found to be longest, i.e. 24.789 cm and 24.795 cm respectively. In our study it was observed that the footprint length from left foot was larger in comparison to footprints from right foot. In both right and left footprint the first toe length was highest and it was observed that after the great toe length both left and right footprint length measurements from toe 2 to toe 5 till hill length gradually declined, i.e. 24.795 to 20.832 respectively. Simple linear regression equations accuracy in our study verified by comparing the estimated stature with actual stature revealed that both regression equations and scatter graphs indicated the existence of statistically significant positive correlation between footprint lengths and stature of Nalgonda populations. *Conclusion:* The result of this investigation provided regression equations for stature estimation from footprints in Nalgonda populations. The regression equations derived for this pooled sample can be used to estimate stature, as in real crime scenarios.

Keywords: Stature estimation; Footprints; Linear regression.

Introduction

Each and every part of the body in its own way is different, not only within a particular body but also from one body to another. Each part of the body has a relationship with the whole body, nothing exemplifies the very truth that more than the relationship that various parts of the body have to the stature of an individual.[1] Bertillon system was invented by French anthropologist based

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Received on 16.09.2019, **Accepted on** 13.11.2019

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on anthropometry for the purpose of Human identification, various body parts can be used to estimate stature since there is a strong relationship between each part of the body and whole body.[2–6]

With these points it can be considered that an individual's footprint may represent his or her identity, Human identification using footprint is an emerging biometric technique, and footprints as valuable physical evidence in crime scenes are used to link the crime to the perpetrator. Footprints can be collected from almost all types of crime scenes and the possibility of their recovery at the scenes of sexual offenses and homicide is relatively more.[7–8] In various Asian countries like Malaysia, Sri Lanka, Thailand, Indonesia and India people have a habit of walking barefoot, there is a tendency that majority of the rural population walk barefoot, it may be due to socioeconomic and climatic conditions. Foot impressions are found at crime scenes as accused often tend to remove their footwear either to avoid noise or have a better grip while climbing walls, etc., while entering or making an exit.[9–10]

It was Gayer who was probably the first researcher to conduct an in-depth study of footprints while working in united province of India and published his observations in his book. Various other studies were being conducted on the individualization and stature estimation from foot and footprints, and they all suggest different ways of utilization of footprints in forensic examinations.[11–13] Most of the researchers in their studies for stature estimation from foot and footprints were on mixed population and they have specifically cautioned that the people from different regions of a country bear different morphological features based on their different geographical distribution and primary racial characteristics and that is the reason a single formula cannot represent all and various parts of that particular country or world.

Foot and footprints parameters used for stature estimation, various investigators concluded that toes to heel length measurements from foot and footprints are more reliable and had more accuracy in comparison to other measurements of foot. In this present cross-sectional prospective study we aim to estimate stature from footprint length measurements in Telugu people of Nalgonda district at Narketpally State Telangana South India.

Materials and Methods

In the present study was conducted at Kamineni Institute of Medical Sciences and Research Center, at Narketpally District Nalgonda by the Department of forensic medicine and Toxicology on the consenting adult males of Nalgonda District of Telangana State. The research was with the aim of estimation of stature from foot print measurements collected in 150 adult males' volunteers with age of 18 to 40.

The subjects were confirmed to be descent from Nalgonda district and were specifically selected with residence of Nalgonda district only, irrespective of their caste, religion, dietary habits and socioeconomic status. The study was a predominantly descriptive cross-sectional study with analytical and comparative components. Sufficient permissions and consents are procured before the measurements of the volunteers are taken and clearance from the Institutional Ethical committee is obtained in advance.

During data collection, volunteers were advised to clean their feet with water, Kores quick drying blue/black duplicating ink was used with the help of a footprint roller. Left foot was inked first with minimal pressure and volunteers was asked to place his foot on A4 size plain white paper on a uniform surface, anatomical landmarks of the feet was marked on the paper at mid-rear heel point, anterior point of all toes. Designated longitudinal axis (DLA) and the base line (BL) were made on the footprints. 90° on the footprint placed on the DLA and the midpoint of the protractor base at Pternion, perpendicular baseline by drawing a line through Pternion along the base of protractor, five diagonal footprint length measurements were taken from mid - rear heel point to most anterior point of each left toe. Same procedure was repeated for right footprint length measurements. Stature; using the stadiometer, the subject was made to stand barefoot in the standard standing position on its baseboard. Both feet are in close contact with each other and head oriented in Frankfurt's plane. The height was then recorded in centimeter from the standing surface to the vertex in the weight-bearing position of foot.

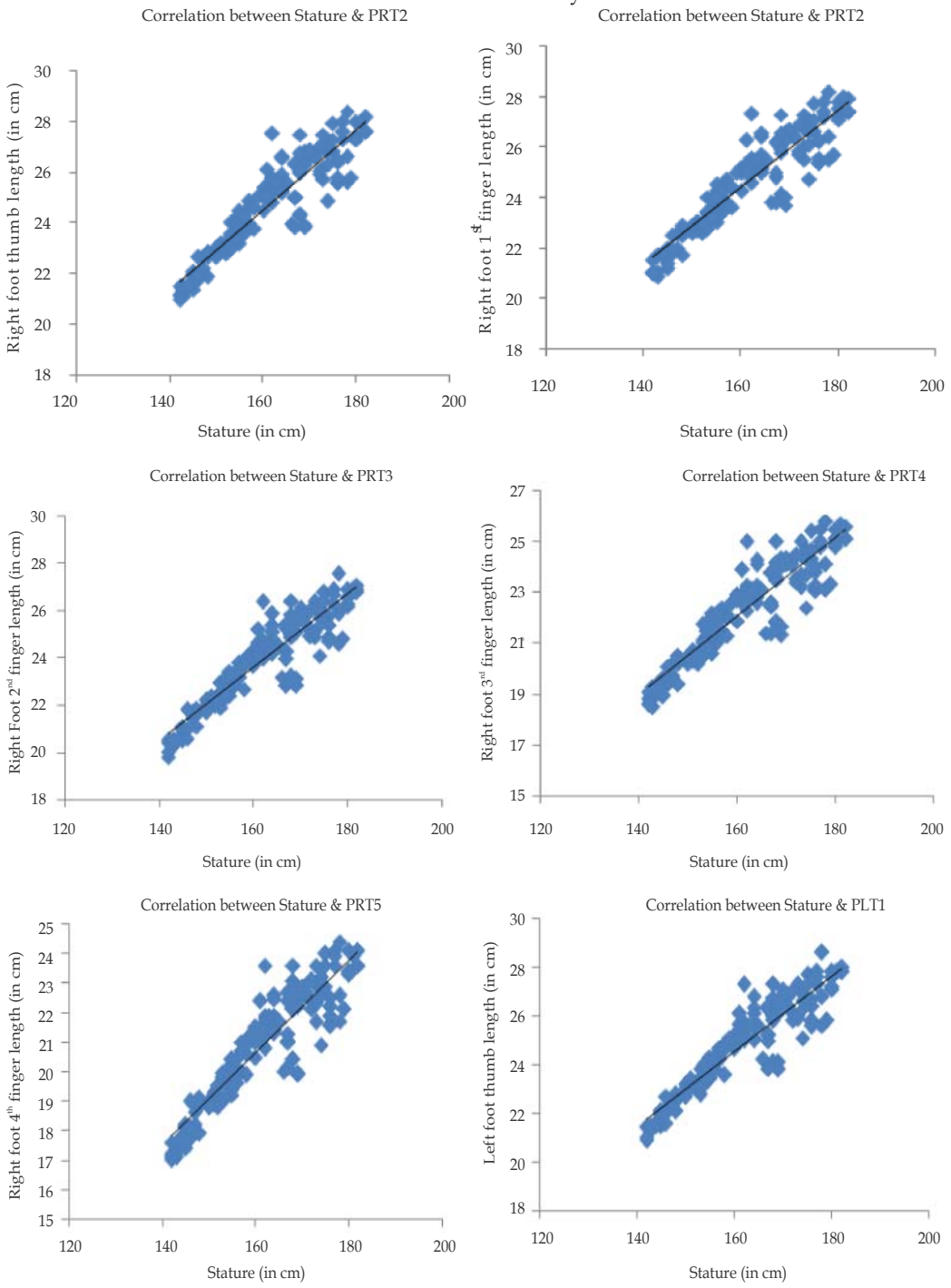
Footprint length measurements: PLT: Pternion to the most anterior point of Left Toe 1 on footprint of left leg and similarly for PRT: Pternion to the most anterior point of Right Toe 1 on footprint of Right leg and so on for every toe on right and left footprints.

Exclusion criterion: Those with any apparent disease, orthopedic deformity, morphologically showing the congenital malformations, dwarfism/ achondroplasia, features of nutritional deficiencies and injuries to extremities, using medication thought to alter growth, neuromuscular weakness

or abnormal tone or with any other major medical illnesses or growth disturbance were excluded from the study.

Results

Descriptive statistics like minimum, maximum mean and SD, etc. of stature and all footprint length of right and left foot was done. Association between stature and footprint length including great toe was present by scatter diagram. All association positively exists. All toes including great toe are positively correlated with stature. So, on the basis of that we calculate the simple and multiple regression equations on both footprints length, by using this equation we can predict the stature value by using footprint lengths. The whole statistics was done by MS-Excel.



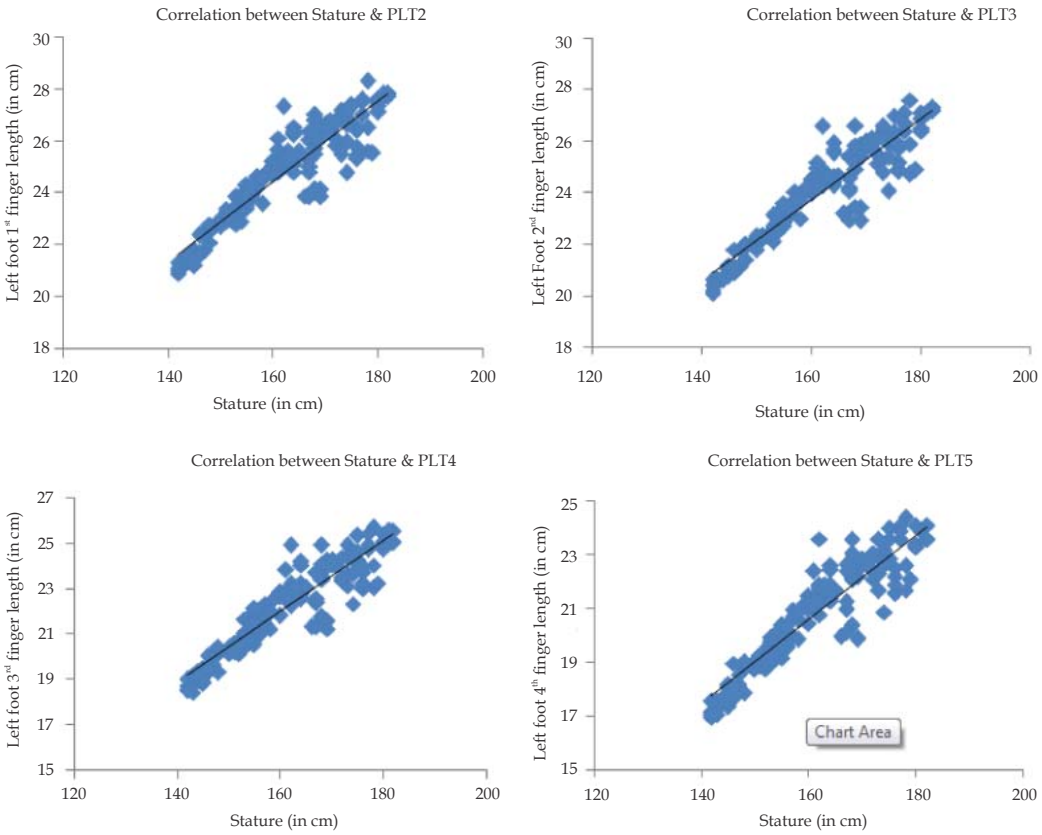


Fig. 1: Positive correlation reflected by scatter graph between footprints length measurements PRT1-5 and PLT1-PLT5 and stature.

Table 1: Basic statistics of all footprint length

Variables	N	Min (CM)	Max (CM)	Range Max-Min (CM)	Mean (CM)	SD
Stature	150	142	182	40	161.61	11.06
PLT1	150	20.9	28.6	7.7	24.789	1.858
PLT2	150	20.9	28.3	7.4	24.674	1.85
PLT3	150	20.1	27.6	7.5	23.984	1.876
PLT4	150	18.44	25.74	7.3	22.249	1.866
PLT5	143	16.96	24.36	7.4	20.832	1.887
PRT1	150	21	28.5	7.5	24.795	1.87
PRT2	150	20.9	28.2	7.3	24.658	1.857
PRT3	150	19.8	27.6	7.8	23.839	1.869
PRT4	150	18.5	25.8	7.3	22.31	1.865
PRT5	144	17	24.4	7.4	20.872	1.847

As per our observation in Table 1 the descriptive basic statistics of stature and both right and left footprints length measurements is being highlighted. In our study stature ranges from 142 cm to 182 cm (mean 161.61 cm). In foot print first toe- heel footprint length measurement i.e. PRT1 and PLT1 was found to be longest, i.e. 24.789 cm and 24.795 cm respectively. In our study it was observed that the footprint length from left foot was larger in comparison to footprints from right foot. In both right and left foot print the first toe length was highest and it was observed that after the great toe length both left and right foot print length measurements from toe 2 to toe 5 till hill length gradually declined i.e. 24.795 to 20.832 respectively. There had been a significant degree of decrease between T4 and T5 of both foot print length compared to the difference from T1 to T3. The reason attributed to this significant decrease was due to T5 of around 13 prints did not make a contact with the ground during the process of imparting of footprints.

In our observation as per Table 2 and 3, it was observed that all length measurements were statistically significant asymmetry and T1 and T2 lengths were found to be significantly more asymmetric in our study. The Table 2 and 3 reflects means, bilateral differences in footprints, standard deviations, *p* - value, *t* – values. The highest *t* - value was found for T4 (0.8616) and the lowest t value for T3 (0.6698). In the Table 5 our study represents the simple linear regression equations to estimate stature from footprint length measurements in both right and left footprints. Table 4 represents the correlation coefficient with stature and shows that there is positive relationship and statistically significant correlation and all are highly significant. The coefficient of determination R^2 the predictive accuracy in our study was found to be statistically highly significant for estimation of stature. Fig 1 represents the regression line, it is crossing through the center of the data in the scatter diagram. The standard error of estimate predicts the deviations of the estimated stature from the actual stature, it is considered that if the SEE is zero then there is no variation about the regression line and correlation is perfect, as shown in Table 5 in our observation. Standard error estimate ranged in between from 18.12 to 19.68 cm in our study. PLT1 shows the least SEE and PRT2 exhibits the highest SEE in our study. Scatter diagram as shown in Fig 1 reflects an elliptical pattern of distribution of values and its analysis strongly indicated the positive correlation between footprint length measurements and the stature.

Multiple regression equation of stature on left & right foot thumb and all fingers.

1. Stature = 39.37 – 1.83* PRT1 – 2.54* PRT2 + 6.81* PRT3 + 3.38* PRT4 – 0.36* PRT5
2. Stature = 24.07 + 2.93* PLT1 + 0.89* PLT2 + 2.98* PLT3 – 0.85* PLT4 – 0.46* PLT5

Table 2: Descriptive statistics of footprints length

Variables	N	Mean diff.	SD	*t* - value	*p* - Value
T-1 (PLT1-PRT1)	150	0.1367	0.092	0.6936	0.489
T-2 (PLT2-PRT2)	150	0.1804	0.1364	0.7227	0.471
T-3 (PLT3-PRT3)	150	0.1625	0.1084	0.6698	0.504
T-4 (PLT4-PRT4)	150	0.061	0.1754	0.8616	0.3903
T-5 (PLT5-PRT5)	143	0.039	0.1271	0.7965	0.427

Table 3: Descriptive statistics and comparison of footprint length of both foot

Variables	Left Foot (in cm)		Right Foot (in cm)	
	Mean	Mean ± S.D.	Mean	Mean ± S.D.
T1	24.789	24.789 ± 1.858	24.795	24.795 ± 1.87
T2	24.674	24.674 ± 1.85	24.658	24.658 ± 1.857
T3	23.984	23.984 ± 1.876	23.839	23.839 ± 1.869
T4	22.249	22.249 ± 1.866	22.31	22.31 ± 1.865
T5	20.832	20.832 ± 1.887	20.872	20.872 ± 1.847

Table 4: Correlation between stature (in cm) and all footPrint length (in cm)

Variables	Correlation with Stature	*Z* - test	*p* - Value	Significance
PRT1	0.902	25.4167	0.0000	All are highly significant
PRT2	0.91	26.7014	0.0000	
PRT3	0.8946	24.3546	0.0000	
PRT4	0.8671	21.1765	0.0000	
PRT5	0.8838	22.9808	0.0000	
PLT1	0.9	25.1187	0.0000	
PLT2	0.9008	25.2369	0.0000	
PLT3	0.8846	23.0763	0.0000	
PLT4	0.8734	21.8178	0.0000	
PLT5	0.8691	21.3754	0.0000	

Table 5: Simple Linear regression equation of stature on different footprint length of both foot.

Variables	Linear Regression line of stature on different foot print Length	R2	SEE	*p* - Value	Significance
PRT1	Stature = 27.03 + 5.43 * PRT1	0.845	18.98	0.0000	All are highly significant
PRT2	Stature = 26.963 + 5.46 * PRT2	0.84	19.68	0.0000	
PRT3	Stature = 31.308 + 5.466 * PRT3	0.853	18.04	0.0000	
PRT4	Stature = 40.316 + 5.437 * PRT4	0.841	19.59	0.0000	
PRT5	Stature = 49.36 + 5.378 * PRT5	0.848	19.62	0.0000	
PLT1	Stature = 25.216 + 5.502 * PLT1	0.854	18.12	0.0000	
PLT2	Stature = 25.517 + 5.516 * PLT2	0.852	18.13	0.0000	
PLT3	Stature = 30.897 + 5.45 * PLT3	0.855	18.17	0.0000	
PLT4	Stature = 40.643 + 5.437 * PLT4	0.846	19.59	0.0000	
PLT5	Stature = 49.58 + 5.378 * PLT5	0.851	18.24	0.0000	

Discussion

India is a multi-racial, multi-ethnic and multicultural land of great diversity. The stature estimation is considered as important parameters in identification of a person, the human body parts has biological correlation with stature and this very fact had been utilized by many investigators and had used body parts or skeletal remains to determine stature. Stature estimation by measuring various long bones has been attempted by several researchers with variable degree of success in past. Each investigator has derived their own formula for determining the stature from long bones, while few had used body parts like, forearm length, head length, etc.[14,15]

Limited investigators had conducted studies on footprint to determine stature in India, the observation of our study had provided linear regression equations to determine stature from various bilateral footprint length measurements among Nalgonda district of Telangana state south India when footprints found at scene of crimes to determine the identity of suspects. In our study the sample size of the volunteers taking part in this study was 150, with the age in a range of 18 to 40. Stature at around 18 years is usually accepted as adult even though there are small increments in stature even after this age.[16] Few researchers highlighted that foot in males grows to its adult size by 16 years of age.[17] So the volunteers were preferred with minimum age of 18 to conduct the study. Even though, loss of stature seen with the increase in age is not accompanied by diminution of foot size and it is not possible to see how much variability could be incorporated into predictive calculation in the study.[18] Investigator Friedlaender et al.[19] in his study suggested that a decline in stature does not commence until the fifth decade of life.

The study reveals that the left footprint length measurements found to be larger than the right footprint length and this indicate the existence of statistically significant bilateral asymmetry and such bilateral asymmetry in lower limbs of Nalgonda population of Telangana state is in consistent with the study made by Irene's on Egyptian population.[20] Krishan in his study found asymmetry in T2, T4 and T5 in Indian population on Gujjars of North India.[21] While Kanchan found asymmetry in T1-T3 in Indian population. Similarly Philip and Robbins also did not find significant bilateral asymmetry in their study on footprints and various measurements of feet in south Indian population and U.S. population respectively. Both the investigators commented that measurements of most variables in person's left and right bare footprints are similar enough to permit either right or left foot being used for height and weight analysis. The mean footprint length measurements of Nalgonda population showed an appreciable size of variation, it can be compared to the mean footprint length of other studies from North of India population.

Sarah[22], Kanchan[23] and Nataraja Moorthy et al.[24] all in their research study highlighted an important observation during the development process of footprint, fifth toe of few subjects was found to be missing that is it did not made any contact with the ground and was reflected as missing toe in prints of foot. In our study 4.76% of the subjects T5 did not made the contact while producing the footprints. The comparative percentage of non contact of T5 is considerable low in Nalgonda population, Kanchan et al. 8%, Natraja Moorthy et al. 8.8% and Sarah et al. with the highest 16.1%. This non contact of fifth toe comes out to be an important and valuable clue in crime scene investigation and perpetrator identification could be possible in this scientific way. In our study also we found the observation in similar pattern unlike with other researchers.

Simple linear regression equations accuracy in our study verified by comparing the estimated stature with actual stature revealed that both regression equations and scatter graphs indicated the existence of statistically significant positive correlation between footprint lengths and stature of Nalgonda populations. In the regular trend in crime scene investigation wherein most of the crime scenes are disturbed by the general public and team members by imparting footprints at the scene of crime, hence it is the duty of the investigating officer to recognize and locate the appropriate footprints for stature estimation and so as to link effectively the crime scene and the perpetrator forensically.

Conclusion

The present study concludes that footprint length measurements have a strong relationship to stature of adult male in Nalgonda population of south India. This investigation revealed that the footprints of Nalgonda populations are different from other populations in India and outside India. It is clear evident that people from different regions of a country and world have different morphological features which depend upon geographical distribution and racial characteristics. The result of this investigation provided regression equations for stature estimation from footprints in Nalgonda populations. The regression equations derived for this pooled sample can be used to estimate stature, as in real crime scenarios. It is improper to utilize these population specific equations to estimate stature from footprints for any other populations either in India or elsewhere in the world. It is also suggested that similar study with larger subjects living in various other parts of India and the world need to be conducted for the meaningful forensic investigation.

Acknowledgments

Authors acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript. The authors are also grateful to authors/editors/ publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

Source of funding: Nil

Competing interests: Authors have declared that no competing interests exist.

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