UTILITY OF 95% CONFIDENCE INTERVALS IN ESTIMATION OF HEIGHT WITH GROWING DIMENSIONS OF HUMAN BODY SEGMENTS
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ABSTRACT: BACKGROUND: Height is the major parameter of personal identification. In any kind of mishap, forensic scientists require to estimate stature from body part(s). Confidence intervals or confidence limits provide basis for such identification. OBJECTIVE: To determine 95% confidence intervals for mean heights on the basis of body segment. MATERIAL & METHODS: The study consisted of 100 males and 100 females. Their stature and hand length, hand breadth, foot length & foot breadth on the right and left side was recorded. Logistic regression analysis was carried out to know the body segment(s) identifying gender. 95% confidence intervals of mean height for identified body segment were determined. RESULTS: Logistic regression analysis revealed Right Hand Width and Right Foot Length could determine correct gender. Thus 95% confidence intervals for mean heights for each observed value of Right Hand Width and Right Foot Length of male and female were generated. Validity revealed that 75% and 40% heights lie in 95% confidence interval according to Right Hand Width while 100% and 67% lie in 95% confidence interval according to Right Foot Length of males and females, respectively. CONCLUSION: 95% confidence intervals provide the range of height within which the individual may have his/her height instead of single value. This gives good approximation to actual value (height). KEYWORDS: Logistic regression, 95% CI, height identification, human remains.

INTRODUCTION: Anthropometry is a series of systematized measuring techniques that express quantitatively the dimensions of human body and skeleton. Use of anthropometry in forensic science helps the law enforcement agencies in achieving personal identity in case of unknown human remains as anthropometric characteristics have direct relationship with sex and shape1. Height is considered as one of the parameters of personal identification. Its estimation is considered to be an important assessment in the identification of unknown human remains. For better accuracy, height estimation may be attempted only after attainment of maturity. The mass disaster, homicide, plane crashes, train and road accidents etc. require the forensic scientists to estimate stature from different body parts. There is always need for such studies which help in identifying the deceased from fragmentary and dismembered human remains. Confidence intervals or confidence limits provide a method of stating the precision or closeness of the sample statistic2. Thus the present study was undertaken to estimate height from 95% confidence intervals for mean heights determined on the basis of growing size of body segment.

MATERIAL AND METHODS: The present study consisted of 100 males and 100 females above 25 years of age from western Maharashtra. Only right handed subjects were included in the study. Stature and other four anthropometric measurements viz. hand length, hand breadth, foot length and
foot breadth were taken on the right and left side of each individual. All measurements were taken by one observer in order to void inter-observer error, in a well-lighted room. The measurements were taken using standard instruments in centimeters to the nearest millimeter according to the techniques described by Vallois\(^3\). The subjects included in the study were healthy and free from any apparent symptomatic deformity.

Of these 100 males and 100 females 90 from each were selected randomly for determination of 95% confidence intervals. Remaining 10 were kept for validation of stature from 95% confidence intervals developed from 90. Initially data of 180 randomly selected subjects was analyzed for identification of sex by applying binary logistic regression technique to know the most appropriate body segments. 95% confidence intervals of the mean height were determined using the measurements of these body segments. These intervals were generated for each observed body segment value. Further, heights of remaining 10 males and females were compared with 95% intervals of heights, for assessment of validity.

**RESULTS:** The difference in measurements of all study variables between male and female study subjects was significant. Over all these measurements were significantly higher in male study subjects (Table 1).

The logistic regression analysis was carried out to detect the variable i.e. body segment that classify gender of the respective individual most correctly. It was carried out by entering each variable independently. This analysis revealed that Right Hand Width and Right Foot Length could determine 83.9% and 84.4% correct gender, respectively (Table 2).

Gender wise 95% confidence intervals for mean height of these two variables were determined (Table 3, 4, 5 & 6).

In the set of 90 Right Hand Width values of male subjects; two Right Hand Width values, amongst data set of 10 males kept for validity assessment of 95% confidence intervals, were not observed. Of remaining 8 males, heights of 6 (75%) males with various Right Hand Width values found to be laying in corresponding 95% Confidence Limits. While heights of less proportion of females (40%), found lying in respective 95% Confidence Limits of height. In the set of 90 Right Foot Length values of male subjects three Right Foot Length values amongst values of 10 males were not observed. Of remaining 7 males, heights of all i.e. 100% were found to be laying in respective 95% Confidence Limits of heights. Similarly 4 observations in female subjects were not found in the set of 90 Right Foot Length values of females. For remaining 6 Right Foot Length values, heights of 4(67%) females were found to be laying in respective 95% Confidence Limits (Table 7).

**DISCUSSION:** In practice, it is not logical to predict single value of height; which has less chances of matching with actual height. 95% confidence intervals provide the range of values (heights) within which the 95% values (of heights) will lie. This gives good approximation to actual value (height) and avoids barriers in the search/study. The concept of 95% confidence interval is widely used in health studies viz. in developing reference ranges\(^2\) as well as cutoff values\(^4\) to identify healthy and diseased individuals.

It was preferred to carry binary logistic regression analysis with only one independent variable. This was with assumption that in any kind of mishap the single body segment may obtain.
present study only two measurements that were highly classifying subjects’ gender were considered. But as measurements of hands and feet provide good approximation about the height of the person, on all measurements 95% confidence intervals can be determined as nobody knows which body segment may found. These confidence intervals contain the population value with probability 0.95. It provides a formal expression of the uncertainty which must be attached to the point estimate on account of sampling errors alone. Also in present study 95% confidence intervals are generated on the basis of only 90 observations. If the number of observations is increased it will facilitate to give enough large number of observations viz. heights, for each single value of the predictor variable like Rt. Hand Width & Rt. Foot Length, and generate very highly diagnostic 95% confidence intervals according to growing value of the predictor variable.

CONCLUSION: The 95% confidence intervals provide the range of height within which the individual may have his/her height instead of single value. This gives good approximation to actual value (height).

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| Gender | Statistic | Height | Right Hand Length | Left Hand Length | Right Hand Width | Left Hand Width | Right Foot Length | Left Foot Length | Right Foot Width | Left Foot Width |
|--------|-----------|--------|-------------------|------------------|------------------|-----------------|-------------------|-----------------|-----------------|----------------|
| Male   | N         | 90     | 90                | 90               | 90               | 90              | 90                | 90              | 90              | 90             |
|        | Minimum   | 136.00 | 15.30             | 15.10            | 7.30             | 7.00            | 22.20             | 22.00           | 22.10           | 8.50           |
|        | Maximum   | 178.00 | 21.00             | 21.00            | 9.10             | 9.10            | 28.40             | 28.30           | 24.78           | 10.70          |
|        | Mean      | 165.32 | 18.29             | 18.17            | 8.18             | 7.97            | 24.85             | 24.78           | 24.65           | 9.73           |
|        | SD        | 165    | 0.95              | 0.96             | 0.45             | 0.49            | 1.25              | 1.26            | 0.51            | 0.53           |
| Female | N         | 90     | 90                | 90               | 90               | 90              | 90                | 90              | 90              | 90             |
|        | Minimum   | 140.00 | 14.70             | 14.70            | 6.70             | 6.50            | 20.00             | 19.50           | 19.50           | 7.30           |
|        | Maximum   | 165.00 | 18.30             | 18.20            | 8.30             | 8.30            | 24.50             | 24.40           | 24.50           | 10.00          |
|        | Mean      | 151.44 | 16.64             | 16.55            | 7.43             | 7.28            | 22.57             | 22.42           | 22.42           | 8.79           |
|        | SD        | 152.00 | 16.70             | 16.5             | 7.40             | 7.30            | 22.55             | 22.50           | 22.50           | 8.80           |

| Unpaired ‘t’ test value | P value |
|-------------------------|---------|
| 14.396                  | <0.001  |
| 12.270                  | <0.001  |
| 12.425                  | <0.001  |
| 12.612                  | <0.001  |
| 11.160                  | <0.001  |
| 13.568                  | <0.001  |
| 13.575                  | <0.001  |
| 11.620                  | <0.001  |
| 12.165                  | <0.001  |

Table 1: Descriptive statistics of study variables
### Table 2: Logistic Regression analysis predicting gender

| Independent Variable | β coefficient | Constant | Prediction | Male (90) | Female (90) | % correct |
|----------------------|---------------|----------|------------|-----------|-------------|-----------|
| Rt. Hand Length      | -2.188        | 38.179   |            | 71        | 70          | 78.3      |
| Lt. Hand Length      | -2.260        | 39.169   |            | 74        | 72          | 81.1      |
| Rt. Hand Width       | -4.868        | 37.793   |            | 75        | 76          | 83.9      |
| Lt. Hand Width       | -4.069        | 30.859   |            | 70        | 75          | 80.6      |
| Rt. Foot Length      | -2.157        | 50.980   | 76         | 76        | 84.4        |
| Lt. Foot Length      | -2.086        | 49.099   | 74         | 78        | 84.4        |
| Rt. Foot Width       | -3.099        | 27.909   | 74         | 67        | 78.3        |
| Lt. Foot Width       | -3.177        | 29.052   | 75         | 72        | 81.7        |

Table 3: Right hand width wise 95% confidence intervals for mean height of males

| Rt. Hand Width (cm) | n   | Minimum | Maximum | Median | Mean | S.D. | 95% Confidence Limit |
|---------------------|-----|---------|---------|-------|------|------|-----------------------|
|                     |     |         |         |       |      |      | Lower Limit | Upper Limit |
| 7.30                | 1   | 163     | 163     | 163   | -    | -    | -         | -          |
| 7.40                | 6   | 151     | 165     | 157.5 | 157.5| 5.36 | 151.88    | 163.22     |
| 7.50                | 1   | 161     | 161     | 161   | -    | -    | -         | -          |
| 7.60                | 5   | 157     | 164     | 161   | 160.8| 2.59 | 157.59    | 164.01     |
| 7.70                | 2   | 153     | 159     | 156   | 156  | 4.24 | 117.88    | 194.12     |
| 7.80                | 7   | 156     | 172     | 167   | 163.9| 6.91 | 157.46    | 170.25     |
| 7.90                | 7   | 157     | 177     | 165   | 165.1| 6.36 | 159.26    | 171.03     |
| 8.00                | 13  | 136     | 174     | 163   | 161.2| 9.5  | 155.41    | 166.90     |
| 8.10                | 2   | 160     | 162     | 161   | 161  | 1.41 | 148.29    | 173.71     |
| 8.20                | 6   | 160     | 178     | 170.5 | 170.2| 6.91 | 162.91    | 177.42     |
| 8.30                | 4   | 165     | 171     | 167.5 | 167.8| 2.5  | 163.77    | 171.73     |
| 8.40                | 12  | 160     | 176     | 167.5 | 167.9| 4.48 | 165.07    | 170.76     |
| 8.50                | 3   | 169     | 173     | 170   | 170.7| 2.08 | 165.50    | 175.84     |
| 8.60                | 6   | 169     | 178     | 170.5 | 172.5| 4.32 | 167.96    | 177.04     |
| 8.70                | 4   | 158     | 168     | 163   | 163  | 4.4  | 156.00    | 169.99     |
| 8.80                | 3   | 163     | 170     | 164   | 165.7| 3.79 | 156.26    | 175.07     |
| 8.90                | 3   | 165     | 174     | 172   | 170.3| 1.73 | 158.59    | 182.07     |
| 9.00                | 4   | 162     | 177     | 171.5 | 170.5| 6.35 | 160.39    | 180.61     |
| 9.10                | 1   | 178     | 178     | 178   | 178  | -    | -         | -          |

Table 3: Right hand width wise 95% confidence intervals for mean height of males.
### Table 4: Right hand width wise 95% confidence intervals for mean height of females

| Rt. Hand Width (cm) | n | Minimum | Maximum | Median | Mean | S.D. | 95% Confidence Limit Lower Limit | 95% Confidence Limit Upper Limit |
|---------------------|---|---------|---------|--------|------|------|----------------------------------|----------------------------------|
| 6.70                | 1 | 140     | 140     | 140    | 140  | -    | -                                | -                                |
| 6.80                | 2 | 146     | 157     | 151.5  | 151.5| 7.78 | 81.62                            | 221.38                           |
| 7.00                | 10| 142     | 160     | 149    | 148.9| 6.47 | 144.27                           | 153.53                           |
| 7.10                | 6 | 140     | 153     | 148.5  | 147.8| 4.87 | 142.72                           | 152.95                           |
| 7.20                | 12| 142     | 153     | 150    | 148.9| 3.96 | 146.40                           | 151.44                           |
| 7.30                | 5 | 140     | 162     | 152    | 152  | 8.92 | 140.93                           | 163.07                           |
| 7.40                | 10| 150     | 165     | 154.5  | 155.3| 4.97 | 151.75                           | 158.85                           |
| 7.50                | 10| 145     | 165     | 152    | 152.4| 6.53 | 147.72                           | 157.08                           |
| 7.60                | 12| 145     | 162     | 152.5  | 151.6| 4.76 | 148.56                           | 154.61                           |
| 7.70                | 8 | 146     | 155     | 152    | 151.3| 2.82 | 148.90                           | 153.60                           |
| 7.80                | 4 | 145     | 153     | 149    | 149  | 4.62 | 141.65                           | 156.35                           |
| 7.90                | 5 | 153     | 158     | 154    | 154.8| 2.17 | 152.11                           | 157.49                           |
| 8.00                | 2 | 159     | 161     | 160    | 160  | 1.41 | 147.29                           | 172.71                           |
| 8.10                | 1 | 154     | 154     | 154    | 154  | -    | -                                | -                                |
| 8.20                | 1 | 155     | 155     | 155    | 155  | -    | -                                | -                                |
| 8.30                | 1 | 159     | 159     | 159    | 159  | -    | -                                | -                                |

| Rt. Foot length (cm) | n | Minimum | Maximum | Median | Mean | S.D. | 95% Confidence Limit Lower Limit | 95% Confidence Limit Upper Limit |
|----------------------|---|---------|---------|--------|------|------|----------------------------------|----------------------------------|
| 22.20                | 1 | 153     | 153     | 153    | 153  | -    | -                                | -                                |
| 22.40                | 1 | 164     | 164     | 164    | 164  | -    | -                                | -                                |
| 22.80                | 1 | 153     | 153     | 153    | 153  | -    | -                                | -                                |
| 23.00                | 2 | 158     | 166     | 162    | 162  | 5.66 | 111.18                           | 212.82                           |
| 23.10                | 1 | 151     | 151     | 151    | 151  | -    | -                                | -                                |
| 23.30                | 3 | 155     | 160     | 160    | 158.3| 2.89 | 151.16                           | 165.50                           |
| 23.40                | 2 | 159     | 160     | 159    | 159.5| 0.71 | 153.15                           | 165.85                           |
| 23.50                | 2 | 160     | 161     | 160    | 160.5| 0.71 | 154.15                           | 166.85                           |
| 23.60                | 1 | 157     | 157     | 157    | 157  | -    | -                                | -                                |
| 23.70                | 6 | 155     | 169     | 161    | 161.3| 5.32 | 155.75                           | 166.91                           |
| 23.90                | 2 | 161     | 169     | 165    | 165  | 5.66 | 114.17                           | 215.62                           |
| 24.00                | 4 | 157     | 168     | 160    | 161.5| 4.65 | 154.09                           | 168.91                           |
| 24.10                | 1 | 171     | 171     | 171    | 171  | -    | -                                | -                                |
Table 5: Right foot length wise 95% confidence intervals for mean height of males.

| Rt. Foot length (cm) | n  | Minimum | Maximum | Median | Mean | S.D. | 95% Confidence Limit | Lower Limit | Upper Limit |
|----------------------|----|---------|---------|-------|------|------|----------------------|-------------|-------------|
| 20.00                | 1  | 144     | 144     | 144   | 144  | -    | -                   | -           | -           |
| 20.40                | 1  | 142     | 142     | 142   | 142  | -    | -                   | -           | -           |
| 20.50                | 1  | 142     | 142     | 142   | 142  | -    | -                   | -           | -           |
| 20.80                | 2  | 140     | 149     | 144.5 | 144.5| 6.36 | 87.32               | 201.68      |             |
| 21.00                | 2  | 142     | 148     | 145   | 145  | 4.24 | 106.88              | 183.12      |             |
| 21.20                | 2  | 142     | 145     | 143.5 | 143.5| 2.12 | 124.44              | 162.56      |             |
| 21.30                | 2  | 140     | 157     | 148.5 | 148.5| 12.02| 40.50               | 256.50      |             |
| 21.40                | 1  | 152     | 152     | 152   | 152  | -    | -                   | -           | -           |
### Table 6: Right foot length wise 95% confidence intervals for mean height of females

| Height | MALES | FEMALES |
|--------|-------|---------|
|        | Rt. Hand Width | Estimation | Rt. Foot Length | Estimation | Height | Rt. Hand Width | Estimation | Rt. Foot Length | Estimation |
| 154    | 7.5     | --       | 23.6        | --       | 155    | 7.2        | ×          | 21.4        | --         |
| 154    | 7.9     | ×        | 22.3        | --       | 157    | 7.1        | ×          | 23.8        | √          |
| 163    | 8.2     | √        | 24.5        | √        | 165    | 7.7        | ×          | 23.5        | ×          |
| 184    | 9.4     | --       | 27.4        | --       | 163    | 7.8        | ×          | 23.8        | √          |
| 175    | 8.6     | √        | 25.5        | √        | 140    | 7.4        | ×          | 20.5        | --         |
| 172    | 8.4     | ×        | 25.3        | √        | 155    | 7.3        | √          | 22.6        | ×          |
| 165    | 8.0     | √        | 24.2        | √        | 148    | 7.3        | √          | 22.2        | --         |
| 169    | 8.3     | √        | 24.9        | √        | 149    | 7.5        | √          | 22.5        | √          |
### Table 7: Estimation of height from 95% confidence intervals

|   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|
| 165 | 8.3 | √ | 23.7 | √ | 155 | 7.4 | √ | 22.3 | √ |
| 175 | 8.8 | √ | 25.7 | √ | 147 | 7.4 | × | 21.5 | -- |

--: No respective variable value (Rt Hand Width / Rt Foot Length) in processed (90 subjects) data set.
×: Height doesn’t lie in 95% Confidence Interval
√: Height lies in 95% Confidence Interval

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