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Forensic Anthropology Population Data

# A study of limb asymmetry and its effect on estimation of stature in forensic case work

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ABSTRACT

Estimation of stature is an important parameter in identification of commingled, mutilated and skeletal remains in forensic examinations. Bilateral asymmetry is defined as the difference between the measurements of the left and right sides of the human body. While estimating stature from skeletal material as well as from body parts in forensic anthropology case work, asymmetry of the human body may result in erroneous estimates due to bilateral variations present in dimensions of the human body and bones. The purpose of the present study was to evaluate asymmetry in upper and lower extremity dimensions in a north Indian population and to see its effect on the estimation of stature from these dimensions. The study was based on a sample of right-handed 967 adult male Gujjars, an endogamous group of North India. Bilateral asymmetry was assessed in six limb dimensions i.e. total upper extremity length, upper arm length, forearm length, hand length, total lower extremity length and lower leg length using a paired *t*-test. The results indicated that statistical significant bilateral asymmetry exists in total upper extremity length, upper arm length, forearm length, total lower extremity length and lower leg length ($p < 0.01$). Correlation coefficients of various dimensions of upper and lower extremities with stature were found to be highly significant ($p < 0.001$). Regression equations were calculated for estimation of stature from these limb dimensions using both left and right sides. The study concludes that there is a higher possibility of obtaining erroneous results while estimating stature from those body dimensions which show statistically significant bilateral asymmetry when formula developed from one side is used on the other side. Although, there seems to be a little possibility of obtaining erroneous results while estimating stature from those body dimensions which showed statistically insignificant asymmetry, it is strongly recommended that the examiner must first identify the side to which the limb part or bone belongs to, and then apply the appropriate formula derived for that particular side.


## 1. Introduction

A forensic examiner is often asked to opine on the identification of the deceased whenever case material such as skeletal remains and body parts are brought for examination. The need for identification may arise in cases of homicide, suicide, bomb blasts, terrorist's attacks, wars, air plane crashes, road and train accidents, as well as natural mass disasters like tsunami, floods, and earth quakes. The main aim of the examiner is to identify the deceased with respect to sex, stature, race/ethnicity and age. Stature estimation is considered as an important part of the identification process as it narrows down the investigation by focusing on victims.

Although human body appears to be bilaterally symmetric, researchers have noticed the presence of skeletal and morphological asymmetries in human body for long time. Bilateral asymmetry is defined as the difference between the measurements of the left and right side of the human body. Most of the studies focusing on bilateral asymmetry have been conducted on the long bones of the extremities using specimens prepared from cadavers [1–8], a few others have been conducted on the living [9–22] as well as on radiographic and photonabsorptionmetric measurements of the living [23–28]. These studies demonstrated the existence of bilateral asymmetry in the anthropometric dimensions, bones, teeth, dermatoglyphic patterns, rate of maturation or growth of the skeletal components, and various characters of the skull bone, face, etc. These variations have been demonstrated in embryos, fetuses, infants, children, adolescents, and in adults.

Bilateral variations in upper and lower limb bones are attributable to difference in mechanical stress and strain over different bones during its growth, and referred to as directional asymmetry [29]. Genetic factors, availability of minerals and vitamins and hormonal regulation also play a vital role in the

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development of asymmetries in the body. A study has confirmed that in the majority of people (nearly 90%), the right arm is more developed than the left. In the legs however, the pattern is just the reverse. Although less marked, 55–75% of people have a stronger left leg [30]. This contra lateral dominance in upper and lower limbs is known as cross-symmetry pattern.

Stature is a useful parameter of identification in forensic anthropology case work and has been the focus of many researchers in the past. The established relationship between various body parts and stature of a person allows forensic anthropologists to estimate stature from different parts of the body and bones. While some researchers worked on the estimation of stature from isolated bones [31–45] others worked on radiographic material [46–51], and percutaneous body measurements [52–59].

The purpose of the present study is to evaluate bilateral asymmetry in the upper and lower limbs of the body in an endogamous population of North India and observe the effect of asymmetry on estimation of stature.

## 2. Materials and methods

### 2.1. Subjects

The present study was conducted on a sample of 967 adult male Gujjars aged between 18 and 30 years (mean age 24.26 years; SD 3.23). Gujjars are one of the major endogamous caste groups inhabiting the Siwalik Hills and adjoining plains of the Sub-Himalayan region near Chandigarh city of North India. These Gujjars are sedentary and agriculturist having husbandry as a secondary population. The data for the present study was collected from sixteen villages in the Siwalik range. This study is a part of a large investigation conducted on Gujjars of North India by the principal author [60–65].

### 2.2. Methodology

Besides stature, seven anthropometric measurements i.e. height acromion, height radiale, height stylion, height dactylion, height iliocristale, height tibiale and height spherion were taken independently on left and right sides of the individuals. All the measurements were taken using an anthropometric rod to the nearest 0.1 cm, following standard procedures and landmarks defined by Weiner and Lourie [66].

Only right-handed individuals were included in the study. Maximum care was taken regarding the accuracy of measurements while measuring the subjects for stature, upper and lower limb dimensions. The instruments were regularly checked for accuracy and precision while collecting data. All the measurements were taken by the principal author (KK) to avoid any inter-observer error inherent in measuring the individuals.

The anthropometric measurements are defined as follows:

*Stature*: The subject should stand on a horizontal platform with his heels together, stretching upward to the fullest extent, aided by gentle traction by the measurer on the mastoid processes. The subject's back should be as straight as possible, which may be achieved by rounding or relaxing the shoulders and manipulating the posture. The marked Frankfurt plane must be horizontal (Frankfurt Horizontal i.e. FH plane). Either the horizontal arm of an anthropometer, or a counter weighted board, is brought down on to the subject's head. If an anthropometer is used, one measurer should hold the instrument vertical with the horizontal arm in contact with the subject's head i.e. the point vertex (the highest point on the head when the head is held in FH plane), while another applies the gentle traction. The subject's heels must be watched to make sure they do not leave the ground.

*Height acromion*: This is the vertical distance between the ground and the point acromion (the most laterally situated point on the acromion process of scapula and is located when the body is in upright position and the arms are hanging down).

*Height radiale*: This is the vertical distance between the point radiale (the point on the upper edge of capitulum when the subject stands with arms hanging down and palms turn towards thigh) and the ground.

*Height stylion*: This is the vertical distance between the point stylion on radius ('stylion radiale', the most distal point on the stylion process of radius bone) and the ground.

*Height dactylion*: This is the vertical distance between the point dactylion (the most distal point on the middle finger of the hand) and the ground.

*Height iliocristale*: This is the straight distance between the point iliocristale (the point most laterally projected on the iliac crest upwards, i.e. the point where the lateral margin passes over the upper margin) and the ground.

*Height tibiale*: This is the straight distance between the point tibiale (the highest point on the medial edge of tibia) and the ground.

*Height spherion*: This is the straight distance between the point spherion (the most distal point on the tibia lying on the medial malleolus) and the ground.

All the measurements were taken on the subject in the same position and posture as that for the stature measurement. From the seven anthropometric measurements, six limb dimensions were calculated as follows:

Total upper extremity length = height acromion − height dactylion
Upper arm length = height acromion − height radiale
Forearm length = height radiale − height stylion
Hand length = height stylion − height dactylion
Lower extremity length = height iliocristale (HI) − 7.50% of HI
(Martin and Saller [67])
Lower leg length = height tibiale − height spherion

In any forensic study based on anthropometry, the technical error of measurement is of utmost important. Therefore, following Schell et al. [13], technical error of measurement was calculated by measuring an individual twice but at different times for all the anthropometric measurements taken on subjects (30 subjects). The technical error of measurement is defined as the square root of the sum of the squared deviations divided by twice the sample size ($S^2 = \sqrt{\sum d^2/2n}$). The same formula was applied to the left–right differences. The value of '*F*' statistics (*F*-ratio) was calculated. For judging the statistical significance of the *F*-score, the value of 0.05 was taken as the level of significance.

### 2.3. Statistical analysis

The data obtained were computed and analyzed using SPSS (Statistical Package for Social Sciences, version 11.0) computer software and results were drawn. Descriptive statistics were obtained for stature and various limb dimensions. Differences between the right and left sides were evaluated using the paired *t*-test. Karl Pearson's correlation coefficient is derived to find the relation between various limb measurements and stature. Linear regression equations are derived for estimation of stature from various limb dimensions. '*p*' value of less than 0.01 was considered as significant.

## 3. Results

Descriptive statistics of stature and limb measurements in adult Gujjar males of North India are shown in Table 1. Limb measurements for both left and right sides are presented. The Gujjar males have an average stature of 172.54 cm in the study sample of 967 adults.

Bilateral differences (left–right) in the limb dimensions are presented in Table 2. Maximum bilateral asymmetry is shown by

**Table 1**
Descriptive statistics for stature and limb measurements in adult male Gujjars ($n = 967$).

| Limb dimension (in cm) | Mean | | SD | | Minimum | | Maximum | |
|---|---|---|---|---|---|---|---|---|
| | Left | Right | Left | Right | Left | Right | Left | Right |
| Total upper extremity length | 76.91 | 77.58 | 2.56 | 3.01 | 60.71 | 60.08 | 87.70 | 88.97 |
| Upper arm length | 31.92 | 32.49 | 1.54 | 1.59 | 23.42 | 24.58 | 40.75 | 42.05 |
| Forearm length | 26.52 | 27.06 | 1.11 | 1.14 | 19.38 | 19.19 | 35.71 | 34.97 |
| Hand length | 18.53 | 18.06 | 0.97 | 0.94 | 13.72 | 13.96 | 22.78 | 22.89 |
| Total lower extremity length | 96.09 | 95.98 | 1.53 | 1.50 | 84.90 | 84.38 | 105.90 | 105.34 |
| Lower leg length | 39.80 | 39.14 | 1.18 | 2.06 | 32.83 | 31.75 | 44.60 | 44.23 |
| Stature | 172.54 | | 6.68 | | 151.2 | | 186.5 | |