

# BILATERAL VARIATIONS IN THE FOOT ANATOMY: MORPHOMETRIC ANALYSIS OF YOUNG HARYANVI MALES

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**Abstract:** Present study is undertaken to study the bilateral variations in the Anatomy of foot. The study is conducted on 400 young Haryanvi males belonging to age group 5.00 – 20.99 years, residing in Haryana region. The foot index is derived from foot length and foot width dimensions of male subjects and quantitatively analyzed to assess bilateral asymmetry. The sample size for present study is comprised of a total of 400 male subjects divided into eight age groups, i.e. i) (5.00-6.99 years), ii) (7.00- 8.99 years), iii) (9.00-10.99 years), iv) (11.00-12.99 years) v) (13.00- 14.99) vi) 15.00-16.99 vii) 17.00- 18.99 viii) 19.00-20.99. Foot length and foot breadth of the male subjects is measured using standard anthropometric techniques. Foot length is measured using measuring steel tape and sliding caliper is used for measuring the foot width. Relative index of asymmetry (RIA) i.e. Percentage distribution of asymmetry in the different parts of body is calculated of foot length, foot breadth and foot index dimensions. Applying Student's t-test reveals statistically highly significant bilateral asymmetry in foot length of all the age groups whereas bilateral asymmetry for foot breadth is not significant for one group i.e. 7.00-8.99 years. Most statistically significant value for foot breadth is 4.11\*\*\* is found in the age group i.e. 19.00-20.99 years followed by age group 13.00-14.99 years with the value 3.35\*\*. Most statistically significant value i.e. 11.59\*\*\* among all the age groups is found for foot length and is present in the age group 13.00-14.99 years. Least significant value for foot length is 3.66\* and foot breadth is 1.99\* found in age group 5.00-6.99 and 15.00-16.99 respectively.

**Keywords:** Foot Length, Foot Width, Foot Index, Foot Anthropometry, Bilateral variations.

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## 1. INTRODUCTION

Various dimensions of each foot of an individual often differ from one another – thus one particular size of a shoe might fit one foot but not the other (Rys & Konz, 1989). Foot dynamic anthropometry has a vital role in medical rehabilitation, sport science, and footwear design among others (Deisinger et. al. 2000). There is wide diversity in human foot size and shape depending upon race, age, sex etc. It is known that one's foot size changes with age. Children and teenagers grow one to three foot sizes each year (Rout et al. 2010). Ideally, foot measurements should be taken separately for each size to allow the proper shoe fit across all sizes (Krauss et al. 2008). For proper designing of footwear, foot size and proportion is of great importance for proper fit and comfort of foot within the shoe. Generally it is also proved that adult male foot dimensions are larger than the adult female foot dimensions. Ewunonu et al. (2014) have shown significantly higher mean values of foot length and foot breadth in males than females. The study further indicated that in both males and females, right foot is longer and wider than left foot. In majority of the elderly people, the feet are considerably broader than the footwear available (Chantelau & Gede, 2002). Manna et al. (2001) found no significant difference in foot dimensions between the right and left foot of Bengalee (Indian) female subjects except the foot breadth. For 18 years

and above, Nigerian feet are longer and broader in males than in females. Both Nigerian males and females feet had higher mean foot length than that of Cucassians (**Bob-Manuel and Didia, 2008**). Similar observation was made by **Oladipo et al. (2008)** who found right foot 2 to 3 mm longer and wider, and suggested that the left and right shoe shape should not be symmetrical while designing footwear. Contributing studies on foot size and proportions are useful in forensic, designing shoe and orthopedic applications.

#### AIMS AND OBJECTIVES

- Present study aims to analyze the foot length, foot breadth and foot index of the left and right feet and report bilateral differences.
- To find if there are any ages related changes in these measurements.

## 2. MATERIALS AND METHOD

### Materials and Methods

Present cross-sectional study has been conducted on a total of 400 males ranging in age from 5.00 years to 20.99 years. Subjects were measured for anthropometrical measurements (foot length and foot breadth) with a view to assess their bilateral asymmetry. Data is collected from various districts of Haryana state of India. Subjects were measured with their prior consent in their free hours of work. Present study has already been approved by institutional clinical ethical committee (ICEC), DeshBhagat University, MandiGobindgarh, Punjab, India.

#### 1. Inclusion Criteria:-

- Subject should be born and resident of Haryana state of India.
- Age of the subjects should be from 5.00years to 20.99years.

#### 2. Exclusion Criteria:-

- Subjects below 5.00 years and above 20.99 years of age.
- Subjects with congenital malformation, apparent anomalies, inflammation, trauma, deformities and surgery (if any) will be excluded as that may have affected their foot anatomy and morphometry.
- Subjects migrated to Haryana India.

## 3. METHODS

### Sampling:

- A total of 400 subjects examined on the simple random basis. To observe age related changes in foot size and proportion the sample is further divided into eight age groups (table 3.1).
- Prior informed consent was taken from the subjects (if adult) otherwise from their parents before their participation in the study. Date of birth of each subject was confirmed and noted from detailed mark sheets of previous classes or from birth certificates, identity proof whichever available for calculating the decimal age.
- Ethical approval was taken from the university ethical committee before the commencement of study.

**Table 3.1: Age group wise distribution of subjects**

Age Group (years)	Males (N=400)
5.00-6.99	50
7.00 - 8.99	50
9.00 - 10.99	50
11.00- 12.99	50
13.00-14.99	50
15.00-16.99	50
17.00-18.99	50
19.00-20.99	50
<b>Total</b>	<b>400</b>

\*N is total number of subjects

### Anthropometric Measurements

The following anthropometric measurements i.e. Foot Length (cm) and Foot Breadth (cm) were taken on each subject following the techniques given by **Lohman et al. (1988)**. Foot index of both right and left feet is computed for each individual.

#### ARMANTARIUM

1. Spreading caliper
2. Measuring tape

Foot length is measured using measuring steel tape and Sliding caliper is used for measuring the foot width. The data is analyzed to find mean, standard deviation and RIA i.e. Relative index of asymmetry. Subjects with apparent foot anomalies, inflammation, trauma, deformities and surgery (if any) are excluded because of their unsuitability for the investigation.

#### SOMATOMETRIC MEASUREMENTS

**Foot Length :-** It is distance measured from acropodian (it is the most forwardly projecting point on the head of the first or second toe whichever is larger when the subject stands erect) to pternion (it is the most backwardly projecting point on the heel) (Witana et al. 2006).

**Foot Breadth :-** The foot breadth is measured as the distance between medial margin of the head of the first metatarsal and lateral margin of the head of the fifth metatarsal (Witana et al. 2006).

**Foot index (FI):-** is calculated as foot width divided by foot length and multiplied by 100 (Jung et al.2001).

#### Foot Indices:

$$\text{Foot index} = \frac{\text{Foot breadth} \times 100}{\text{Foot length}}$$

#### RELATIVE INDEX OF ASYMMETRY (RIA)

Percentage distribution of asymmetry in the foot dimensions i.e. foot length, foot breadth and foot index is calculated using the formula of Relative Index of Asymmetry (RIA) given by **Wolanski (1965)**.

$$\text{RIA} = \frac{2(D)}{X_R + X_L} \cdot 100$$

Where D is the mean difference between right and left side measurement of the body. Individual differences are calculated as higher value minus lower value.

$X_R$  is the mean for right side of the body.

$X_L$  is the mean for the left side of the body.

### 4. RESULTS

Within sample variation occurs more for foot length in both right and left feet as compared to foot width. Percentage distribution of asymmetry in the foot dimensions is calculated and is resulting in the significant values for foot dimensions. RIA values of foot length are significant for all age groups except for the age group.

Similarly RIA values for foot breadth dimensions are significant for all age groups except for the age group 9.00-10.99 years. The t-values listed in table 4 shows that there is statistically significant bilateral difference in the above mentioned foot measurements. Maximum bilateral difference (D) for foot length is present among the males of age group 9.00-10.99 years. Applying Student's t-test reveals statistically significant bilateral asymmetry in foot length of all the age groups whereas bilateral asymmetry for foot breadth is not significant for one group i.e. 7.00-8.99 years. Most statistically significant value for foot length is 11.59\*\*\* and is found in the age group 13.00-14.99 years whereas most statistically significant value for foot breadth is 4.11\*\*\* is found in the age group i.e. 19.00-20.99 years followed by age group 13.00-14.99 years with the value 3.35\*\*. Least significant value for foot length is 3.66\* and foot breadth is 1.99\* found in age group 5.00-6.99 and 15.00-16.99 years respectively.

**Table 1: Right Foot length and foot breadth of Haryanvi males with age**

Age Group (years)	N (number of Subjects)	Foot Length (cm)	Foot Breadth (cm)	Right Foot Index
		Males		
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
5.00-6.99	50	16.77 $\pm$ 0.45	3.98 $\pm$ 0.37	23.71 $\pm$ 1.84
7.00-8.99	50	21.57 $\pm$ 0.81	4.06 $\pm$ 0.58	18.75 $\pm$ 2.04
9.00-10.99	50	22.17 $\pm$ 1.10	4.83 $\pm$ 0.60	21.75 $\pm$ 2.01
11.00-12.99	50	23.28 $\pm$ 1.24	5.40 $\pm$ 0.61	23.17 $\pm$ 1.66
13.00-14.99	50	24.07 $\pm$ 0.85	6.64 $\pm$ 0.45	27.60 $\pm$ 1.63
15.00-16.99	50	25.39 $\pm$ 0.87	6.89 $\pm$ 0.57	27.15 $\pm$ 2.37
17.00-18.99	50	26.32 $\pm$ 0.83	7.67 $\pm$ 0.71	29.18 $\pm$ 2.86
19.00-20.99	50	26.71 $\pm$ 1.16	8.21 $\pm$ 0.75	30.74 $\pm$ 2.44

**Table 2: Left Foot length and foot breadth of Haryanvi males with age**

Age Group (years)	N (number of Subjects)	Foot Length (cm)	Foot Breadth (cm)	Foot Index
		Males		
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
5.00-6.99	50	16.63 $\pm$ 0.40	3.94 $\pm$ 0.42	23.66 $\pm$ 2.29
7.00-8.99	50	21.10 $\pm$ 0.52	4.19 $\pm$ 0.54	19.85 $\pm$ 2.44
9.00-10.99	50	21.71 $\pm$ 1.00	5.01 $\pm$ 0.50	23.12 $\pm$ 2.23
11.00-12.99	50	22.90 $\pm$ 1.19	5.65 $\pm$ 0.59	24.65 $\pm$ 1.73
13.00-14.99	50	23.69 $\pm$ 0.83	6.88 $\pm$ 0.43	29.07 $\pm$ 1.69
15.00-16.99	50	24.89 $\pm$ 0.89	6.96 $\pm$ 0.54	27.98 $\pm$ 2.23
17.00-18.99	50	25.91 $\pm$ 0.83	7.99 $\pm$ 0.72	30.88 $\pm$ 2.84
19.00-20.99	50	26.64 $\pm$ 0.77	8.5 $\pm$ 0.43	31.91 $\pm$ 1.58

**Table 3: Relative Index of Asymmetry (RIA) and D Values of foot length and foot breadth of Haryanvi males.**

Age Group (In Years)	Foot Length		Foot Breadth	
	D	RIA	D	RIA
5.00-6.99	0.22	1.34	0.18	4.59
7.00-8.99	0.76	3.57	0.19	4.74
9.00-10.99	0.55	2.53	0.35	7.10
11.00-12.99	0.44	2.00	0.28	5.20
13.00-14.99	0.41	1.72	0.29	4.40
15.00-16.99	0.50	2.02	0.22	3.23
17.00-18.99	0.45	1.74	0.34	4.33
19.00-20.99	0.48	2.00	0.51	6.10

**Table 4: Test of Significance (t-Value): Comparison between right and left side body breadths of upper and lower limbs of males with age**

Age Group (Years)	Foot length	Foot Breadth
5.00-6.99	3.66***	2.28*
7.00-8.99	4.36***	1.72
9.00-10.99	5.40***	3.14**
11.00-12.99	5.36***	2.38*
13.00-14.99	11.59***	3.35**
15.00-16.99	5.71***	1.99*
17.00-18.99	5.67***	2.36*
19.00-20.99	4.41***	4.11***

\*p&lt;0.05, \*\*p&lt;0.01, \*\*\*p&lt;0.001

## 5. DISCUSSION

It has been found that only few studies are available comparing the bilateral asymmetry of foot dimensions. There is wide diversity in human foot size and shape depending upon race, age, sex etc. It is known that one's foot size changes with age. Children and teenagers grow one to three foot sizes each year (Rout 2010). Manna et al. (2001) found no significant difference in foot dimensions between the right and left foot of Bengalee (Indian) female subjects except the foot breadth. For 18 years and above, Nigerian feet are longer and broader in males than in females. Both Nigerian males and females feet had higher mean foot length than that of foot width (Bob-Manuel and Didia, 2008). Similar observation was made by Oladipo et al. (2008) who found right foot 2 to 3 mm longer and wider, and suggested that the left and right shoe shape should not be symmetrical while designing footwear. Findings from the present studies did not confirm all the results of earlier findings completely, however present study found longer right foot like earlier studies but found left foot broader than the right foot. Maximum intra sample variability is found in foot length in all the age groups.

Body proportion differences between populations and ethnic group are well known and are often use to exemplify the concept of genetic potential. The largest the differences in the ethnic group, when all are growing up in good environments are those of shape rather than size (Norgan, 1998). According to Bhatnagar et. al. (1984) hand and foot dimensions are helpful in the determination of sex, age and height of an individual which further helps in the stature reconstruction as it provides forensic anthropological estimation of height of a person in the living state. Bilateral variations for body breadths in the present study may be genetic or weight bearing functions.

## 6. CONCLUSION

The study concludes that foot length, foot width (foot size) and foot index (foot shape) of Haryanvi males shows statistically significant bilateral differences. Present observation can be used as base line data for the use of forensic science and foot shape is essential for the properly designing of the shoe shape. There are considerable variations for the patterns of growth within human population. Causes of these variations can be understood by conducting such growth studies.

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