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Functional Anatomy of the Human Foot in Relation to Dimensions of the Sesamoid Bones

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ABSTRACT

The sesamoid bones in relation to the first metatarsal are subject to directional forces exerted by surrounding muscles. Dimensions of human hallux correspond to anthropometric parameters which are determined by functional demand and laterality. The present study on 20 embalmed male human feet (10 from each side) was undertaken to determine various anthropometric parameters in relation to the first metatarsal and the sesamoid bones associated with it and correlate them with the laterality and functional demand of the foot. Linear measurements of the articular facets of the sesamoid bones and those on the first metatarsal were recorded and analysed statistically and it was observed that majority of cases showed lateral asymmetry in favour of left feet.

Key words: Human foot, sesamoid bones, functional anatomy

INTRODUCTION

Human foot is a unique endowment of the Homo sapiens. It is not shared with any other animal unlike the hand which is shared by some of the higher animals. Only human being has a bipedal orthograde gait and the credit for the same goes to high development of the foot in addition to innumerable modifications in many parts of the body. Since feet bear body weight throughout life, carry us from one place to another and maintain balance, is not it strange that the two of them do not share equal weight? According to morphometric study of medical malleolus and greater trochanter on the two sides, there is 60: 40 ratio of dominance between left and right lower limbs in right handed individuals (1).

In the foot, maximum weight is borne by first metatarsal alone followed by the fifth. In the first metatarsophalangeal joint there are two sesamoid bones which help in weight bearing. With each step of a normal gait, most of the body weight is distributed over the big toe and its sesamoid bones (2).

Sesamoid Bones

The sesamoid bones of the first metatarsophalangeal joint are constant. They are

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lenticular and elongated with a cartilaginous dorsal surface that slides in the grooves on the plantar surface of the head of the first metatarsal bone (3).

The sesamoid bones are firmly attached to each other by a stout and thick intersesamoid ligament. Proximally they are attached by the plantar portion of metatarsophalangeal capsule to the neck of the first metatarsal.

The medial sesamoid bone receives the attachments of the medial head of flexor hallucis brevis and the abductor hallucis. Medially it is attached to the medial joint capsule. Distally the combined tendons extend from the distal extremity of the medial sesamoid into a thick strong tendinous band attaching to the plantar medial aspect of the base of the proximal phalanx. The medial portion of the plantar fascia blends in to the plantar non-articular surface of the sesamoid (4).

The lateral sesamoid receives the attachments of the lateral head of the flexor hallucis brevis and the oblique and transverse heads of the abductor hallucis under cover of the intermetatarsal ligament along its margins. The lateral conjoined tendon extends from the distal extremity of the lateral sesamoid to the plantar lateral aspect of the base of the proximal phalanx. The lateral sesamoid is also attached on its plantar surface to the plantar fascia and to the medial aspect of the neck of second metatarsal by the strong deep portion of the intermetatarsal ligament (4).

First Metatarsal

This is distinctly shorter and more stocky than the second metatarsal. Its base is opposite the medial cuneiform with a marked vertical development and is more slender transversely. It is invested with cartilage, presenting a concave cupulate aspect, particularly transversely.

The head is very large and slightly flattened vertically. Its cartilagenous cover extends well beyond its plantar surface. A prominent ridge divides the head into two regions represented by two sagittal grooves in which the sesamoids slide (3).

MATERIAL AND METHODS

The first metatarsophalangeal joint from 20 embalmed male human feet [10 of left and 10 of right side] was dissected out. The sesamoid bones [SB] were carefully removed from the joint and marked medial and lateral. The first metatarsal [MT] was cleaned and then with a planimeter gauge, following dimensions, both on sesamoid bones [SB] and first metatarsal [MT] were measured and tabulated after taking each reading thrice and noting the mean [Figure 1].

dsm = diameter of medial SB in sagittal axis
dtm = diameter of medial SB in transverse axis
am = area of medial SB
Dsm = diameter of corresponding medial articular facet on 1st MT in sagittal axis
Dtm = diameter of corresponding medial articular facet on 1st MT in transverse axis
Am = area of corresponding medial articular facet on 1st MT
dsl = diameter of lateral SB in sagittal axis
dt = diameter of lateral SB in transverse axis
al = area of lateral SB
Dsl = diameter of corresponding lateral articular facet on 1st MT in sagittal axis

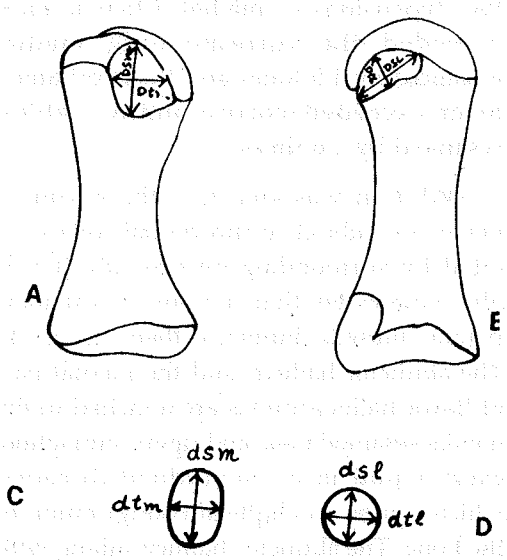

Figure 1. Medial (a) and lateral (b) aspect of first metatarsal bone. Medial (c) and lateral (d) sesamoid bones

Dtl = diameter of corresponding lateral articular facet on 1st MT in transverse axis

Al = area of corresponding lateral articular facet on 1st MT

The area of articular facets of SB [am, al] and the corresponding articular facets on head of 1st MT [Am, Al] was calculated using the formula of Pretterklieber (5) as follows:

$$\text{Area am [or Am] and al [or Al]} = \frac{\text{ds (or Ds) dt (or Dt) } \pi}{4}$$

The value of π was taken as 3.14.

RESULTS

From the analysis of the data, it has been observed that both sesamoid bones are elliptical in shape. Medial sesamoid bones [n = 20] were measured in terms of dsm, dtm and area [am]. Similar readings [dsl, dtl and al] were taken for the lateral sesamoid bones [Table 1]. It was observed that the areas of both sesamoid bones was more in the left feet, especially that of the medial sesamoids. The area of medial sesamoid in left feet was 76.150 ± 11.380 and in the right feet, it was 62.800 ± 8.400. The difference was quite significant. Similarly, values of areas of lateral sesamoids in left and right feet were also more in favour of left feet but the difference was not significant. The dsm and dtm of medial sesamoids of left feet was 10.9 ± 1.45 and 8.0 ± 0.74 respectively whereas in the right feet, the same were 10.0 ± 1.06 and 8.0 ± 0.53 respectively. These differences were significant.

Corresponding dimensions of articular facets for medial sesamoid bones [Dsm, Dtm and Am] as well as lateral sesamoids [Dsl, Dtl and Al] on the first metatarsal head were also recorded [Table 2]. The ratio of the surface area on first metatarsal to the area of sesamoid bone in the left feet was 1.5:1 for both the sesamoids. On the right side, this ratio was 1.6:1 for both sesamoids.

Table 1. *Sesamoid bones*

Variable	Left		Right		
	Mean	SD	Mean	SD	t
dsm	10.900	1.450	10.000	1.060	1.503
dtm	8.90	0.740	8.000	0.530	2.966
am	76.150	11.380	62.800	8.400	2.831
dsl	10.800	1.910	10.100	1.640	0.834
dtl	7.700	0.640	7.400	1.510	0.549
al	66.100	9.020	60.88	19.400	0.732

Reference: t95% = 1.734, t99% = 2.552

Table 2. *1st Metatarsal bones*

Variable	Left		Right		
	Mean	sd	Mean	SD	t
Dsm	14.300	1.180	14.000	1.310	0.510
Dtm	10.180	2.790	9.280	3.070	0.651
Am	114.270	11.970	101.980	14.670	1.947
dsl	13.400	1.020	12.400	12.000	1.336
Dtl	9.800	0.830	9.110	1.370	1.292
Al	103.080	8.600	98.670	27.060	0.466

Reference: t95% = 1.734, t99% = 2.552

The area of articular facet for medial sesamoid on the head of first metatarsal was significantly higher on the left side while, that for lateral sesamoid, though higher on the left side, was not significantly so.

DISCUSSION

Lateral asymmetry in the anthropometric dimensions of sesamoid bones of human hallux is obvious from the present study. Lateral asymmetry in favour of left foot has also been demonstrated (6,7). Values of all dimensions are more in the left foot as compared to the right in the present study.

Both SB were larger in the right than in the left feet (5) and it was also found that SB of left foot have better arterial supply and accordingly, the left foot is dominant (5). These findings suggest that footedness determines the vascularization of the ossa sesamoidea in the adults. According to the author (5), the predominance of left foot (7) may be the explanation for better vascularization of the left sesamoid bones. It was also observed (5) that the dimensions of articular surfaces on the head of the first metatarsal exceeded the corresponding sesamoiid bone 1.4 times [medial bone] and 1.5 times [lateral bone]. In the present study, the dimensions of medial articular facet exceeded the corresponding medial sesamoid by 1.5 times and those of lateral facet exceeded corresponding lateral sesamoid by 1.6 times.

While it was seen that the sesamoid bones are subject to directional forces exerted by surrounding muscles (8), it was also suggested that actions of intrinsic plantar muscles influence their shape (9). The abductor hallucis and the medial part of flexor hallucis brevis are attached to the medial sesamod bone and upon contraction, exert a pull in a longitudinal direction which causes an elliptical configuration of the bone. The abductor hallucis, along with the lateral part of flexor hallucis brevis are attached to the lateral sesamoid and these exert their pull in a transverse direction giving the sesamoid bone a somewhat circular shape. In the present study, however, both the sesamoids were observed to be elliptical, the medial being more or so.

Studies on the walking mechanisms (4) show that in the stance phase, the weight is first transmitted along the lateral border of the foot and then to all the metatarsal heads. It has been found that the first and the fifth metarsal share maximum weight, with the first metatarsal accounting for about one third of total weight. In the swing phase, however, the weight is transmitted along the medial side of the foot and is again borne maximally by the first metatarsal. The direction of force is longitudinal and is borne maximally by the medial sesamoid bone [Figure 2). Besides this, the medial sesamoid is fractured more often than the lateral, which again suggests that it bears more weight than the lateral (4). The

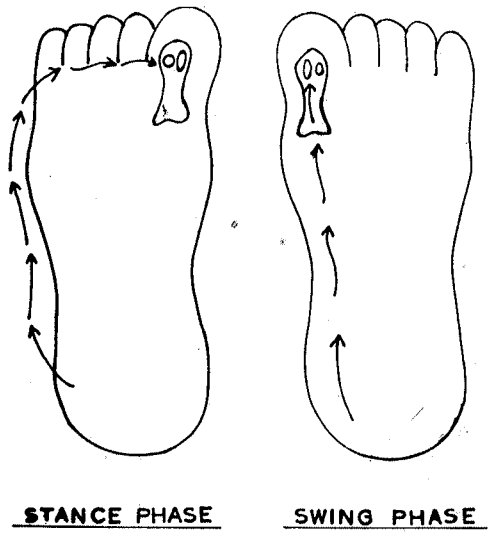

Figure 2. Direction of forces during walking

present study also shows a better developed medial sesamoid.

(1) carried out morphometric study of greater trochanter and medial malleolus of lower limb and found a 60:40 ratio in left and right limbs respectively. Present study shows a lateral asymmetry of medial sesamoid in favour of left side in a ratio of 67:33 and of lateral sesamoid in a ratio of 60:40.

The proportion, as observed by Gupta and Anand (1) shows a preference in favour of left foot.

It is is speculated that the differences in the two feet depend on the total stress imposed on a particular bone, i.e., not only quantitative but also qualitative differences have their effect on the bones (10).

It can thus be concluded that dimensions of sesamoid bones of human hallux correspond to functional demand and laterality.

REFERENCES

1. Gupta C and Anand C (1983). Asymmetry of limb bones (Personal Communication).
2. Stokes IAP, Hutton WC and Scott JRR (1979). Forces acting on the metatarsals during normal walking. *J Anat* **129**:579-590.
3. Faure C (1981). The skeleton of the anterior foot. *Anat Clin* **3**:49-65.
4. Melvin JH (1981). The sesamoids of the hallux. *Clin Orthop Rel Res* **157**:192-198.
5. Pretterklieber ML (1990) Dimensions and arterial vascular supply of the sesamoid bones of the human hallux. *Acta Anat* **139**:86-90.
6. Latimer HB and Lowteasce EW (1965). Bilateral asymmetry in weight and in length of human bones. *Anat Rec* **152**:217-224.
7. Singh I (1970). Functional asymmetry in the lower limbs. *Acta Anat* **77**:131-138.
8. Preischoft M (1969). Statistic untersuchungen an Fussder Primaten. I Statik der Zehen und: des Mittelfusses. *Z Anat Fntw Gesch* **129**:285-345.
9. Carter DR (1987). Mechanical loading history and skeletal biology. *J Biomech* **20**: 1095-1109.
10. Dhall U (1984). Bilateral asymmetry in the area of articular surfaces of human ankle joint *J Anat Soc India* **33**:15-18.