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Estimating Height and Weight from Size of Footprints

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ABSTRACT: In the mid 1800s, Topinard proposed a simple formula for estimating a person's height: maximum foot length divided by 0.15 reveals the stature of most individuals. In addition to corroborating Topinard's findings, the author has developed formulas to serve as predictive models for estimating both height and weight when only a subject's footprint dimensions are known. The formulas are presented with a discussion of the data from which they are derived.

KEYWORDS: physical anthropology, footprints, human identification

In the past, physical anthropologists like Paul Topinard [*1*] and Rudolf Martin [*2*] developed a ratio of foot length to stature as a result of measuring numerous subjects. Martin measured both males and females in arriving at his statural estimation. Topinard measured only adult males. Other researchers like Vallois [*3*] used Topinard's formula for estimating stature of prehistoric persons who left their footprints in three caves in France. In his numerous studies of prehistoric human footprints in caves of France and Italy, Pales [*4*] used the Topinard and Martin 15% ratios of foot length to stature in estimating the height of paleolithic Homo sapiens who had occupied the caves. However, Pales had reservations about the 15% ratio value, so he tested its validity by measuring feet. From his work, he accepted the ratio of 15%, but also proposed an equation for determining stature from the right and left feet of adult males:

- For right foot, stature = 3.641 (maximum foot length) + 72.92 ± 4.35.
- For left foot, stature = 4.229 (maximum foot length) + 56.49 ± 3.58.

Pales does not indicate the number of adult males in his study sample.

To my knowledge, the ratio figures arrived at by these earlier researchers have not been tested on subjects in the United States to determine whether or not the 15% foot-length-to-stature ratio also prevails in our society. Furthermore, it seems reasonable to me that there might be a comparable ratio between footprint width and weight. As far as I can determine in surveying the literature, however, researchers have not investigated that possibility.

These are just two of the questions I wanted to investigate when assembling my own data base over the past decade. To develop a data base of footprint/foot outline information, I collected right and left footprints from over 500 subjects. The right and left foot of each subject also was traced around the outer margin to produce foot outlines. The foot outline provides the size parameters of the fleshed bare foot and also represents the boundaries of

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the foot's impression in soft soil, mud, or any other substance that produces a three-dimensional footprint impression. The foot*print*, on the other hand, provides the size dimensions of the foot's plantar surface actually touching the floor or hard surface, which produces a two-dimensional footprint impression.

Preliminary to actually collecting footprints and foot outlines, each subject was assured anonymity of name and confidentiality of age, shoe size, and weight. These turned out to be significant factors for many subjects. Materials were selected for making the footprints and foot outlines that would leave no printing or marking residue on the bottoms or sides of subjects' feet [*5*]. Collecting the footprints and foot outlines from each subject was designed to be done in minimal time, but the time factor was secondary to maintaining procedural accuracy in obtaining the footprint impressions and in tracing the foot outlines. Special care was taken to insure that each footprint and foot outline was collected following the same procedure.

The footprints were made using the Faurot inkless equipment. After the subjects removed shoes and socks, the plantar surface of each bare foot was cleansed with an alcohol-soaked gauze pad to remove any body oils from the foot that could interfere with the special inkless fluid adhering to the bottom of the foot. When the alcohol had evaporated from the foot, the subject stepped onto Faurot sensitized paper, leaving a clear impression of the foot's plantar surface. The foot outline was drawn with a sharp-pointed pencil on the same sheet. The pencil was held perpendicular to the paper as it traced around the margins of the foot. When the outline was completed, the subject lifted the foot from the paper and the procedure was repeated with the other foot.

This collection procedure resulted in a "standing" footprint and foot outline being obtained from the right and left foot of each subject (see Fig. 1). Each subject was weighed and his or her stature measured. Other information obtained from the subject at that time pertained to age, sex, shoe size, shoe width, and ethnic background.

After subjects' footprints and foot outlines were collected, their size dimensions and shape expressions were analyzed by me to minimize observer error. The lengths, widths, and angle measurements of footprints and foot outlines were taken using the Robbins Transparent Metric Grid, a ruler, and a protractor. These measurements were recorded on forms the author designed specifically for that purpose.

Foot outline and footprint length measurements were taken from the mid-rear heel point of reference (pterion) that had been designated by Martin (see Figs. 2 and 3). The point of reference at the front of the foot outline or footprint was the most anterior point of each toe. In taking foot-length measurements, Martin and Topinard measured from the mid-rear heel site to the anterior tip of Toe 1 or in some cases Toe 2 when Toe 2 was the longest toe. Other researchers (Meredith [*6*]) used Hrdlicka's [*7*] rear-heel-to-Toe 1 alignment. Some of the earlier studies had given the impression that only Toes 1 and 2 were the longest. However, in gathering data, I discovered that Toe 3 can occasionally be the longest toe. Therefore, the foot measurement I used was maximum length from heel (pte) to the front of whichever toe was anterior. My measuring foot outline and footprint length to each toe was in part a result of my being interested in other questions than simply the one of verifying the foot-length-to-stature ratio. Width measurements across the ball portion of the footprint and foot outline were taken from the medial and lateral metatarsal landmark sites designated by Martin (see Fig. 4).

The data collected from footprint and foot outline measurements were then entered into the University of North Carolina/Greensboro computer. Preliminary to examining the correlation of footprint and foot outline lengths with stature, tests were run to examine the correlation between right and left footprint measurements and right and left foot outline measurements. The 0.95 to 0.99 length correlations between right and left footprints (Table 1) and between right and left foot outlines make it apparent that either foot can be used for statural estimation. The scattergram illustrating correlation of right and left footprint length from

FIG. 1—*Right and left plantar footprints with boundaries of bare feet shown in the outline around the footprints.*

heel to Toe 1 in parallel alignment (Fig. 5) visually confirms the unusually high correlation.

The subjects are males and females, ranging in age from 3 to 79. Correlation of ball width from Metatarsal 1 to Metatarsal 5 between right and left footprints and right and left foot outlines are nearly as high as they are for the lengths: 0.92 to 0.93 range.

We look first at the foot outline and its relationship to stature for males and females from 3 to 79 years of age. In Table 2, we find a 14.928% ratio of right foot outline length-to-stature (standard deviation [S.D.] 0.664, $N = 536$). For the left foot outline, nearly the same ratio is derived: 14.976% (S.D. 0.707, $N = 535$). Hence, we see that for all subjects—both sexes and all ages—the ratio between maximum foot length and stature is comparable to the 15% suggested by Topinard and Martin.

If we select males and females over 14 years of age (Table 2), we find that for males the ratio for the right foot outline is 15.128% (S.D. 0.951, $N = 224$). For the left foot outline, it is 15.199% (S.D. 0.638, $N = 223$). For females over age 14, the right foot outline ratio is 14.726% (S.D. 0.636, $N = 284$), and for the left foot outline the ratio is 14.750% (S.D. 0.666, $N = 284$). These figures also confirm the 15% ratio proposed by Topinard and Martin. Therefore, the foot outline is indeed an accurate representation of the fleshed foot.

In looking at the footprint ratios (Table 3), we find that for all subjects, the ratio is 14.098% (S.D. 0.652, $N = 546$) for the right footprint and 14.160% (S.D. 0.650, $N = 546$) for the left footprint. Thus, the plantar surface footprint shows a 1% difference in its relationship to stature over what was found in the fleshed foot.

The 14% footprint length-to-stature ratio holds true for both males and females. In looking at males over the age of 14, the ratio of foot length to stature is 14.312% (S.D. 0.596,

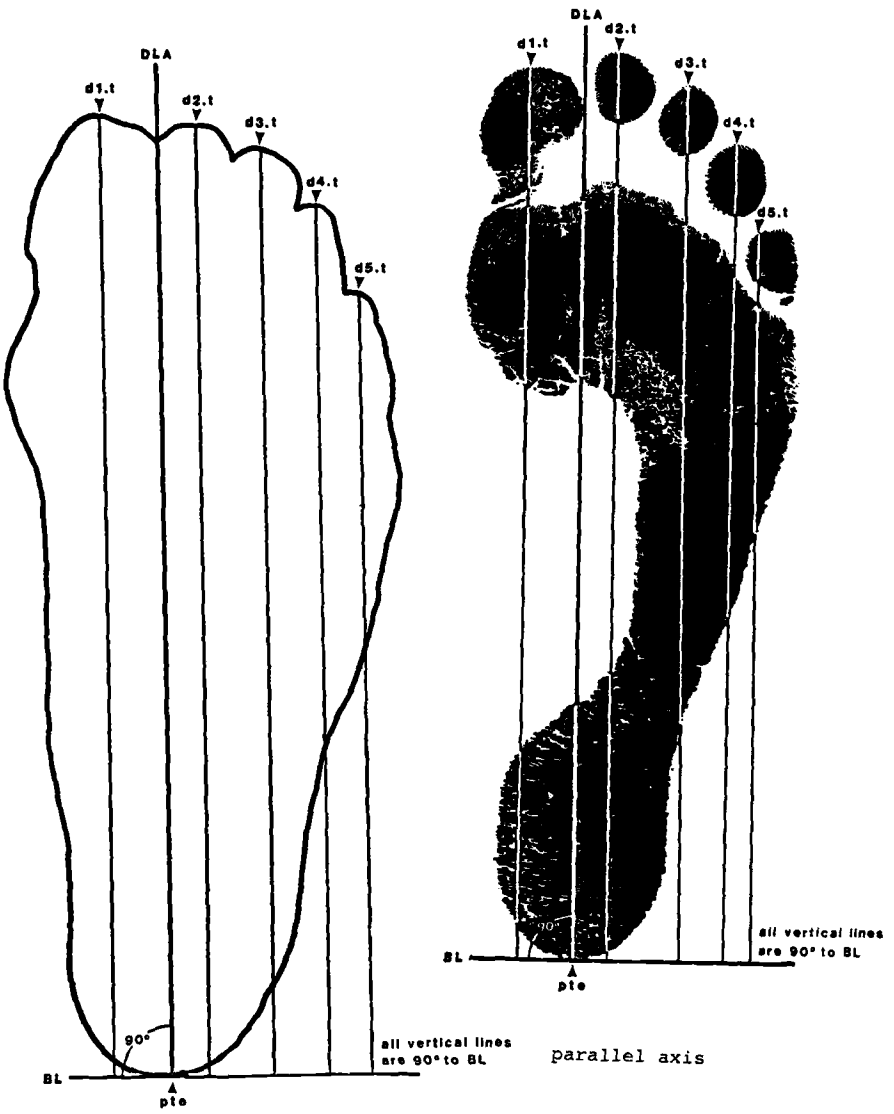

FIG. 2—*Footprint and foot oulitne measurements in the parallel (to pte) axes. (Reprinted from Robbins, L. M.*, Footprints: Collection, Analysis, and Interpretation, *Charles C Thomas, Springfield, IL, 1985 [8].)*

$N = 225$) for the right footprint and 14.387% (S.D. 0.572, $N = 226$) for the left footprint. For females over age 14, the ratio is 13.903% (S.D. 0.614, $N = 292$) for the right footprint and is 13.951% (S.D. 0.622, $N = 291$) for the left footprint. Once again, we find that separating out the subjects by sex does not change percent ratio of footprint length to stature. Therefore, we can say that footprint length represents 14% of a person's stature, but cautiously provide a margin of variation of ± 25.4 mm (1 in.).

A similar caution should apply in using the formula of 15% when calculating the ratio of foot outline or fleshed foot length to stature.

In addition to calculating the ratio of footprint and foot outline length to stature, correla-

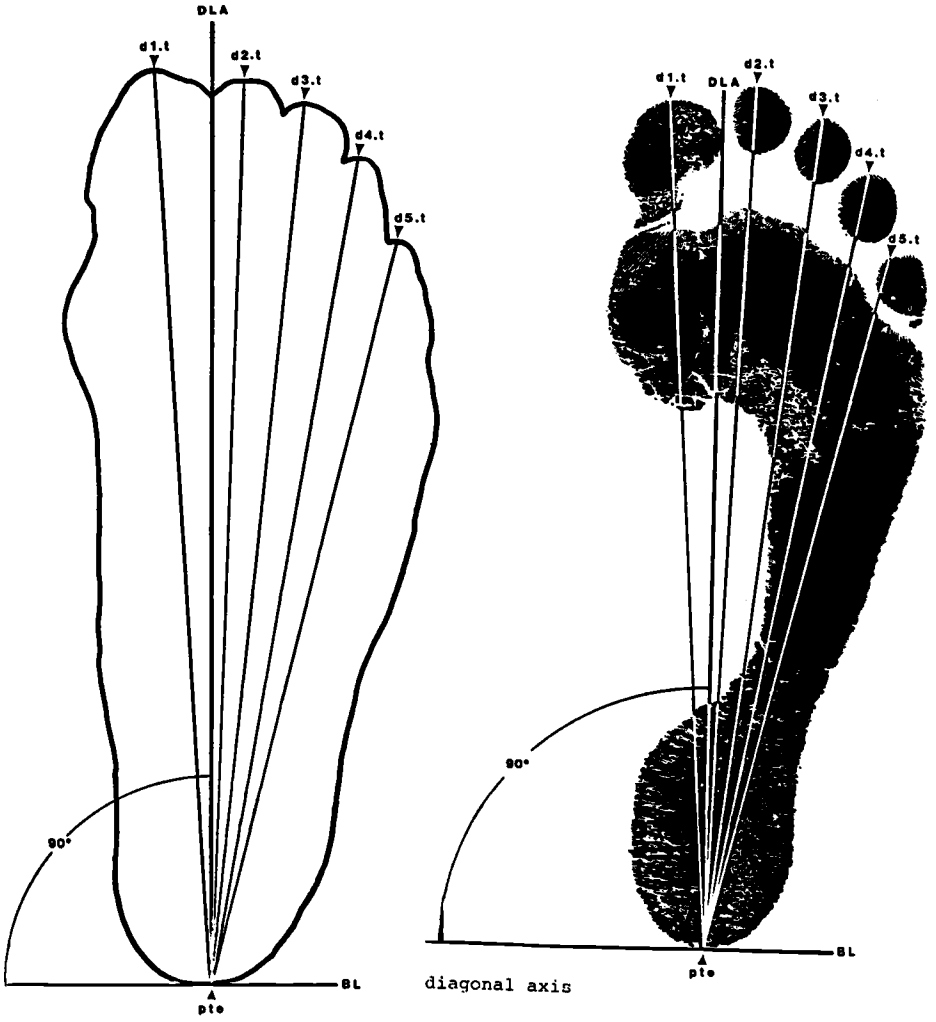

FIG. 3—*Footprint and foot outline measurements in the diagonal (to pte) axes. (Reprinted from Robbins, L. M.,* Footprints: Collection, Analysis, and Interpretation, *Charles C Thomas, Springfield, IL, 1985 [8].)*

tion tests were also run. Correlations of 0.80 and higher were obtained in those tests on all subjects (Table 4).

An attempt was also made to develop an equation that could predict an individual's height if specific measurement variables were known. An equation was produced but it is unduly complicated when one recognizes that all one has to do is use the appropriate percentage formula with the length measurement from the rear heel point of reference to the most anterior toe tip on that foot. (As a footnote, the exercise involved in obtaining the equation was a good lesson to me in how one can generate superfluous information simply because the technology is available to do so.) One can make the simple very complex if one so desires.

To the best of my knowledge, an attempt has not been made to relate foot measurements to body weight. Given the ease with which body weight may fluctuate in some individuals, it is understandable that this feature has not been examined. I selected width of the ball of the

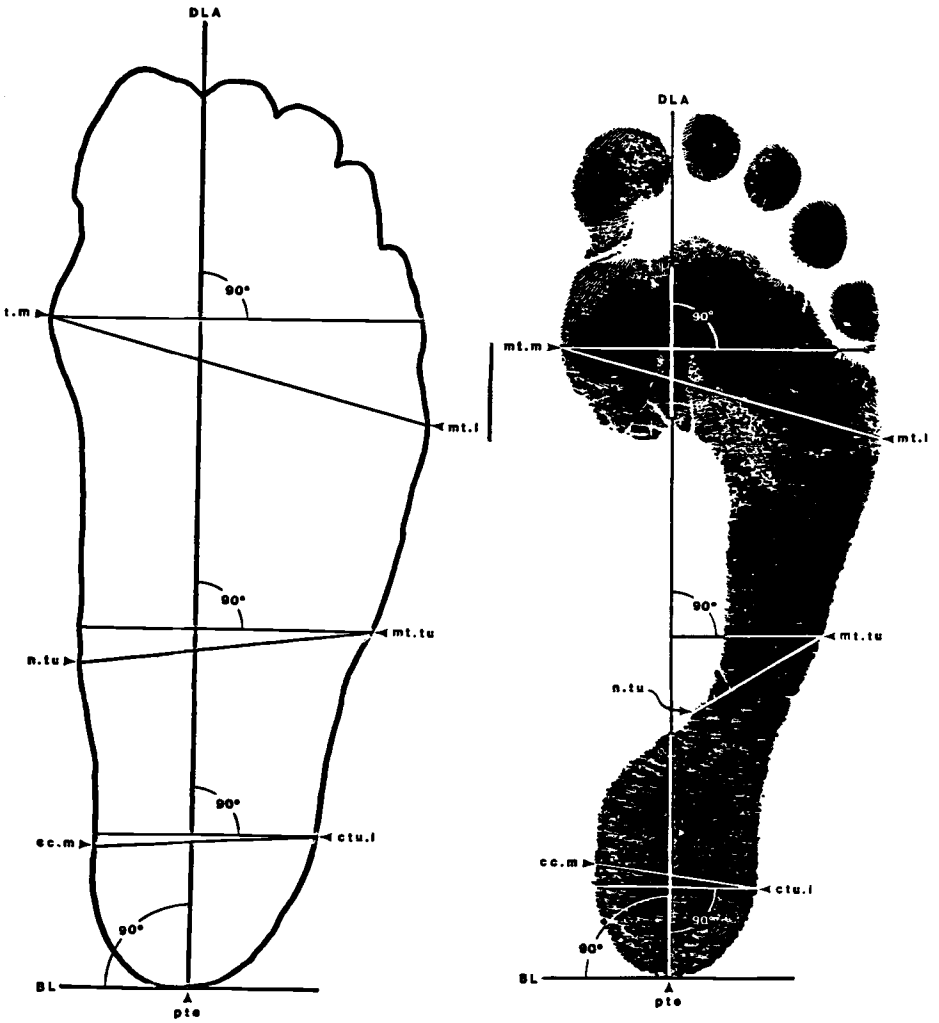

FIG. 4— *Width measurement lines across footprint and foot outline ball, arch, and heel in horizontal and diagonal axes. (Reprinted from Robbins, L. M.,* Footprints: Collection, Analysis, and Interpretation, *Charles C Thomas, Springfield, IL, 1985 [8].)*

foot from the medial to lateral metatarsal in generating the ratio of footprint and foot outline width to body weight (Table 5).

For the right foot outline of all subjects, the ratio is 73.443% (S.D. 16.343, $N = 542$). The ratio is 73.628% (S.D. 16.594, $N = 542$) for the left foot outline. In looking at both males and females, we find that for males over age 14, the ratio is 66.591% (S.D. 9.692, $N = 216$) for the right foot outline and 66.507% (S.D. 9.883, $N = 216$) for the left foot outline. For females over age 14, we do note a difference in the ratio between the right and left foot outlines. For the right foot outline, the ratio is 70.637% (S.D. 9.132, $N = 293$) and for the left foot the ratio is 73.411% (S.D. 9.535, $N = 287$). Repeated tests did not alter these figures. Thus, the ratio of foot outline ball width to weight ranges from 67% in males to 71% in females. When both sexes and all ages are combined, the ratio is 73% for the right foot

TABLE 1—*Correlations of bare footprints to foot outlines;* N = *number of subjects. (Reprinted from Robbins, L. M.,* Footprints: Collection, Analysis, and Interpretation, *Charles C Thomas, Springfield, IL, 1985 [8].)*

Toe	Right to Left Footprint	*N*	Right to Left Foot Outline	*N*
	LENGTHS: PARALLEL AXIS			
1	0.98	549	0.98	541
2	0.98	531	0.98	541
3	0.98	541	0.98	541
4	0.98	543	0.98	541
5	0.97	495	0.97	541
	LENGTHS: DIAGONAL AXIS			
1	0.98	545	0.95	531
2	0.98	527	0.98	530
3	0.98	537	0.98	530
4	0.95	539	0.98	530
5	0.97	491	0.97	530
Ball width	0.93	550	0.92	541

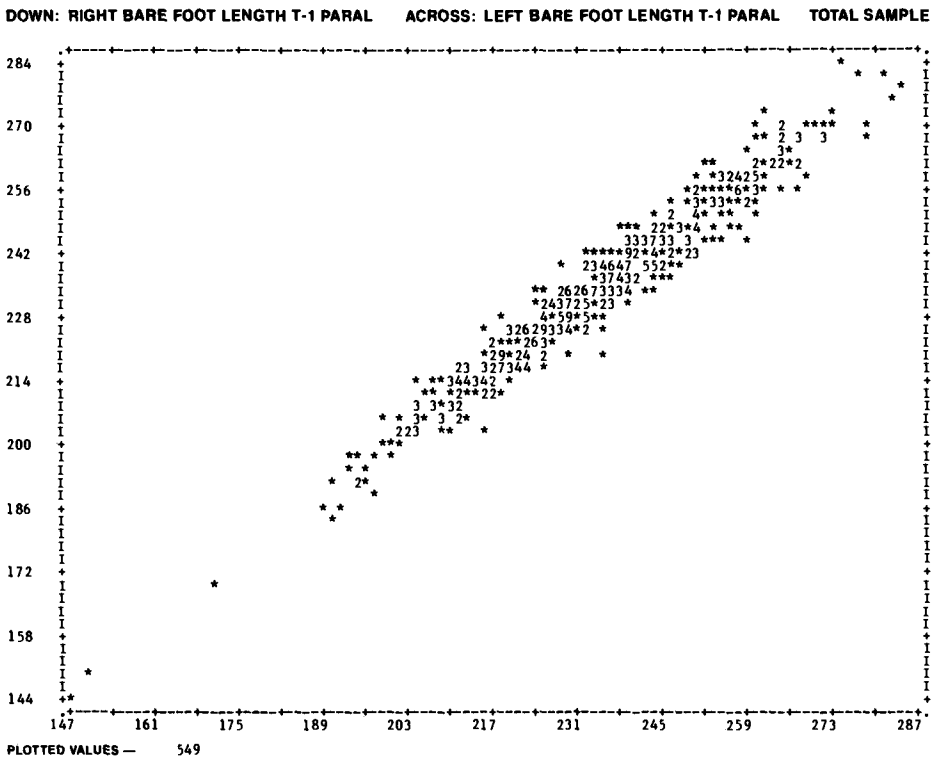

FIG. 5—*Correlation of right to left footprint length from heel (pte) to Toe 1.*

TABLE 2—*Foot outline length-stature ratio.*

Subjects	Right			Left		
	Mean, %	Std. Dev.	*N*	Mean, %	Std. Dev.	*N*
Total subjects (males/females 3 to 79 years)	14.928	0.664	536	14.976	0.707	535
Males over 14 yrs.	15.128	0.591	224	15.199	0.638	223
Females over 14 yrs.	14.726	0.636	284	14.750	0.666	284

TABLE 3—*Footprint length-stature ratio.*

Subjects	Right			Left		
	Mean, %	Std. Dev.	*N*	Mean, %	Std. Dev.	*N*
Total subjects (males/females 3 to 79 years)	14.098	0.652	546	14.160	0.650	546
Males over 14 yrs.	14.312	0.596	225	14.387	0.572	226
Females over 14 yrs.	13.903	0.614	292	13.951	0.622	291

TABLE 4—*Correlations of right bare footprint and right foot outline measurements with stature.* N = *total subjects. (Reprinted from Robbins, L. M.*. Footprints: Collection, Analysis and Interpretation, *Charles C Thomas, Springfield, IL, 1985 [8].)*

Toe	Footprint/Stature	*N*	Foot Outline/Stature	*N*
	LENGTHS: PARALLEL AXIS			
1	0.84	548	0.84	541
2	0.84	537	0.84	541
3	0.83	542	0.84	541
4	0.83	544	0.84	541
5	0.83	512	0.84	541
	LENGTHS: DIAGONAL AXIS			
1	0.84	545	0.85	536
2	0.84	534	0.84	535
3	0.84	539	0.84	535
4	0.80	541	0.84	535
5	0.84	509	0.84	535

outline. For the left foot outline, we find that females have the same ratio as the ratio for all subjects combined; males have a ratio of 66%.

The footprint width-body ratio (see Table 6) for all subjects is 66.751% (S.D. 15.105, $N = 550$) for the right foot and 66.920% (S.D. 15.420, $N = 550$) for the left foot.

The ratio of footprint width to weight for males over age 14 is 60.479% (S.D. 8.957, $N = 217$) for the right footprint and for the left footprint it is 60.493% (S.D. 9.196, $N = 217$). The ratio for females over age 14 is 66.877% (S.D. 8.506, $N = 293$) for the right footprint

TABLE 5—*Foot outline diagonal ball width as percent of weight.*

Subjects	Right			Left		
	Mean, %	Std. Dev.	*N*	Mean, %	Std. Dev.	*N*
Total subjects (males/females 3 to 79 years)	73.443	16.343	542	73.268	16.594	542
Males over 14 yrs.	66.591	9.692	216	66.507	9.883	216
Females over 14 yrs.	70.637	9.132	293	73.411	9.535	287

TABLE 6—*Bare footprint diagonal ball width as percent of weight.*

Subjects	Right			Left		
	Mean, %	Std. Dev.	*N*	Mean, %	Std. Dev.	*N*
Total subjects (males/females 3 to 79 years)	66.751	15.105	550	66.920	15.420	550
Males over 14 yrs.	60.479	8.957	217	60.493	9.196	217
Females over 14 yrs.	66.877	8.506	293	67.143	8.615	293

and 67.143% (S.D. 8.615, $N = 293$) for the left one. Once again we can see that males and females differ in the width of their footprint or foot outline relationship to weight. And females again have the same ratio as for all subjects combined.

This ratio method develops an index figure from which to calculate weight if the width of the ball of the foot is known. For example, if an adult male has a width across the ball of his right footprint of 100 mm, the index figure of 60.479% should be used in calculating weight. In this case, it would be 75 kg (165 lbs).

Again caution dictates against using an absolute number. It is appropriate to supplement this with a range of at least ± 4.5 kg (10 lbs).

Correlation tests were run on the data to examine the relationship of footprint and foot outline size to body weight. The 0.72 correlation of footprint ball width to weight for all subjects (total of 550) gives additional support to using the percentage ratio in estimating a person's weight. The 0.75 correlation of foot outline ball width to weight also illustrates the strong relationship between one's foot breadth and body weight. I have not developed an equation for estimating a person's weight from known foot or footprint width or length variables. That exercise remains to be done.

It should come as no surprise that there is a strong positive correlation between one's stature and footprint or foot outline maximum length and between one's body weight and width across the ball section of the footprint or foot outline. One's vertical height must have an adequate support base, both in length and in width. Increasing the distance between the right and left foot does not provide a functionally efficient base. Increasing the length and width of the foot does. The same principle operates in the relationship of footprint and foot outline width across the ball section and one's weight. Right and left foot positions may accommodate some portion of the weight, but a broader foot structure increases the size of the support base. We cannot escape the fact that our bodies exhibit a unity of parts. Our task is to study how that unity is achieved and how it functions.

References

[1] Topinard, P., *L'Anthropologie*, Vol. 1, 2nd ed., Reinwald, Ed., Paris, 1877.
[2] Martin R., *Lehrbuch der Anthropologie*, Vol. 1 (of 3), Gustav Fischer, Jena, 1928.
[3] Begouen, C. and Vallois, H., *Les Empreintes Prehistoriques*, Institut International d'Anthropologie III° Session, Amsterdam, 1928.
[4] Pales, L., *Les Emprientes de Pieds Humains dans les Cavernes*, Memoir 36, Archives de l'Institut de Paleontologie Humaine (Fondation Albert Ier, Prince de Monaco), Masson, 1976.
[5] Robbins, L. M., "The Individuality of Human Footprints," *Journal of Forensic Sciences*, Vol. 23, No. 4, Oct. 1978, pp. 778-785.
[6] Meredith, H. V., "Human Foot Length from Embryo to Adult," *Human Biology*, Vol. 16, No. 4, 1944, pp. 207-282.
[7] Hrdlicka, A., *Anthropometry*, The Wistar Institute of Anatomy and Biology, Philadelphia, PA, 1920.
[8] Robbins, L. M., *Footprints: Collection, Analysis and Interpretation*, Charles C Thomas, Springfield, IL, 1985.

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