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ORIGINAL ARTICLE

Arch Index: An Easier Approach for Arch Height (A Regression Analysis)

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Abstract: *Background:* Arch-height estimation though practiced usually in supine posture; is neither correct nor scientific as referred in literature, which favour for standing x-rays or arch-index as yardstick. In fact the standing x-rays can be excused for being troublesome in busy OPD, but an ink-footprint on simple graph-sheet can be documented, as it is easier, cheaper and requires almost no machineries and expertisation. *Objective:* So this study aimed to redefine the inter-relationship of the radiological standing arch-heights with the arch-index for correlation and regression so that from the later we can derive the radiographical standing arch-height values indirectly, avoiding the actual maneuver. *Methods:* The study involved 103 adult subjects attending at a tertiary care hospital of North Bengal. From the standing x-rays of foot, the standing navicular, talar heights were measured, and 'normalised' with the foot length. In parallel foot-prints also been obtained for arch-index. Finally variables analysed by SPSS software. *Result:* The arch-index showed significant negative correlations and simple linear regressions with standing navicular height, standing talar height as well as standing normalised navicular and talar heights analysed in both sexes separately with supporting mathematical equations. *Conclusion:* To measure the standing arch-height in a busy OPD, it is wise to have the foot-print first. Arch-index once get known, can be put in the equations as derived here, to predict the preferred standing arch-heights in either sex.
Key words: Arch-Index, Arch of Foot, Arch-height

Introduction

Measurement of the height of the arch of foot deserves immense importance so far its clinical aspects are concerned and for this purpose since middle of the past century several methods were used by pioneer researchers. Practically the height of the medial longitudinal arch provides acceptable outlook of the arch-height. Some researchers have classified the foot arch type by only visual impression, which was quite practiced till the end of last century [1-3]. On the other hand a few of them carried on such a classification based on palpation of the navicular tuberosity [4]. In late nineties researchers approached with the help of radiography in parallel with footprint. Radiographically parameters like the 'talar height' , 'navicular height' and recently the 'normalised navicular height' obtained from standing weight bearing lateral view x-ray of foot, were accepted as yardsticks to predict the arch height [5-8].

Procurement of, and processing the footprint being easier and cheaper, is more acceptable for the patient than radiography. Hence, in spite of the fact that radiography is still important in establishing the arch height, footprint procedures are preferred to it [9-10]. It was previously disclosed that the foot-print obtained on a graph sheet by conventional ink is better that the electronic foot-print obtained by special soft-ware system, so far determination of the sole contact area was concerned [11].

This can be conveniently taken on a graph paper and the Arch Index can be calculated thereafter to ascertain the height of the arch of foot. The concept of Arch Index was first described by Cavanagah *et al.* (1987) as the ratio of the area of the middle third of the foot to the entire foot area excluding the toes. An arch index of less than 0.21 has been said to be indicative of a cavus foot, while it greater than 0.26 is indicative of planus foot whereas Arch Index between 0.21~0.26 corroborates normal arch height. Importance of "arch-index" as a sensitive podographic indicator was later on confirmed in different studies. [12] Later it has been established the Arch Index, derived from footprint to show a significant negative correlation with the navicular height [8, 13-15]. But unfortunately almost no studies have inter-related mathematically the foot-print derived arch-index values with the radiographically evaluated standing arch-height measurements with an acceptable equation, by which one can interpret directly the standing navicular or talar height with the help of arch index without proceeding through actual maneuver. Especially such information lacks in pertinent literature so far in Indian population is concerned.

Objective: This study is based on the question that whether the value of the arch-index, once determined; can predict the standing navicular height, standing talar height as well as their respective 'normalised' values of an individual?

Material and Methods

This descriptive epidemiological study was carried out in the Out-patient Department of Radio-diagnosis (Radio-diagnosis OPD) of North Bengal Medical College, within the period of one year with the proper permission from (a) the institutional Ethical Committee; (b) Principal of the medical college and (c) the Heads of the concerned departments. The Radiology OPD was visited twice a week. Patients and their attendants, waiting there, who were found having no obvious vivid deformity of lower-limb and apparently not seriously sick; were approached randomly and thus initially 140 adult persons were approached. Detailed history was taken to exclude any previous operations, injuries or diseases of lower limb, vertebral column as well as in sole and thus 125 were short listed. Among them finally 103 subjects have put their informed consent to be included in the study.

X-rays of their left foot were obtained in standing position with both legs straight keeping aside to bear the body weight equally, as referred in literature [16-17]. From each set of X-ray film 'height of the talar dome' (henceforth mentioned as Talar Height); 'height of the navicular tuberosity' (henceforth mentioned as Navicular Height) and the 'truncated foot length' (henceforth mentioned as Foot length) were measured.

Fig-1: The below skiagram of foot depicts the measurement of navicular height (NH), Talar height (TH) and truncated foot length (FL) in standing posture.

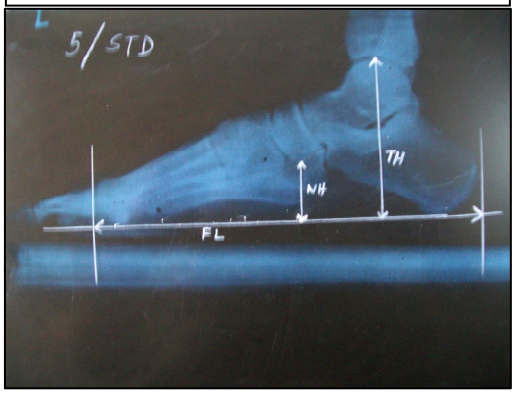
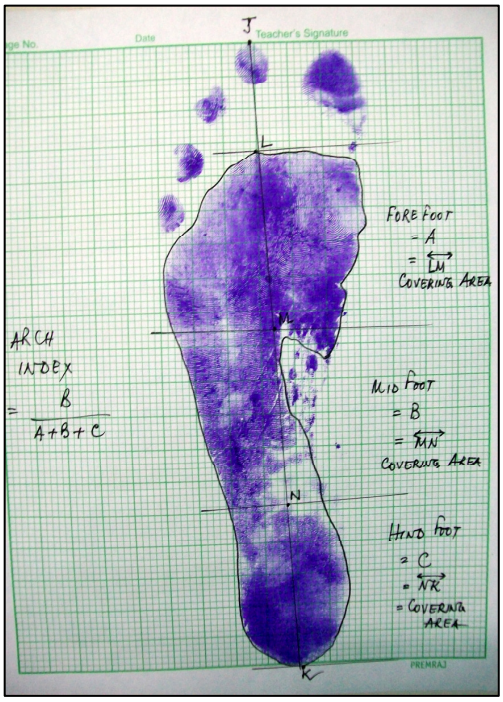


Fig-2: The below photograph of left foot-print illustrates the estimation of the arch index from a footprint of an individual



The 'truncated foot length' (FL) was determined by the distance of posterior calcanean tuberosity to the head of the first metatarsal excluding the phalanges. (Fig.1)

After that, a washable inkpad was rubbed on the plantar aspect of the subject's left foot and he/she was instructed to stand in same posture followed during x-ray, on a cm-calibrated graph-sheet provided; so that it totally covers his/her left foot. Thus the standard imprint of the weight-bearing left foot was taken, which was considered to be the foot-print of a 50% body-weight bearing foot (the other 50% of the body weight was borne by the right foot, whose print was not taken).

Following the description in literature in the footprint, the linear distance of the centre of the heel (say the point K) and the tip of the second toe (axis of the foot) (say the point J) was measured. Next perpendicular line was drawn tangential to most anterior point of the main body of the foot print. Their point of intersection was marked (say the point L). Next the line LK was divided in equal three parts. Ultimately the main body of the footprint was divided in three areas from those points with the perpendiculars from the foot axis. The anterior, middle and posterior areas were marked as A, B, C respectively. Their areas were determined (in sq.cm). Arch Index = B ÷ [A+B+C]. (Fig.2) [12]

Values were put for statistical analysis in SPSS version 12.0 software for required analysis. Prediction of significant relationship amongst the pair of variables was determined by the "Correlation coefficient" i.e. Pearson's 'r' or Spearman's rank 'rho' depending on their distribution [18].

Relation of changes of a dependent variable (say, y) with an independent variable (say, x) was ascertained by simple linear regression, with the "Regression coefficient (say, b)" and "Regression constant (say a)"; where the model of the regression equation was y = a + bx .Again as in every equation; 95% confidence interval (≡ 1.96 standard deviation) was accepted and "standard error of regression (STE)" was considered, Then the final equation model becomes y = (a+ bx) ± (1.96 x STE) [18].

Results

Among 103 adult subjects, we could include 90 (87.4%) male and 13 (12.6%) females. Since the foot-architecture of a man and woman are not same anatomically and gait of a man differs from that of a woman, so all the results have been grouped sex-wise for further prediction. The mean-values of the standing navicular and talar heights were found as 3.52 ±0.79 cm and 7.74 ±0.60 cm in males and the same for females as 3.07 ±0.34 cm and 7.31 ±0.27 cm respectively. Later those parameters were normalised to the standing foot length of individual to obtain their 'standing normalised' navicular and talar heights, which were documented with mean of 3.52 ±0.79 in males and 3.07± 0.34 in females.

Values of Arch Indices in respective sex-group were also calculated out to be finalized with mean of 0.22 ±0.04 and 0.23 ±0.03 among males and females. Following the classification-system as described by McCroy *et al.*(1997) [14] based on the arch index, in the present population 59.8% had normal arch, whereas 35.3% and 4.9% had high and flat arches respectively.

In both the groups the arch-index noted to bear significant negative correlation (Correlation coefficient -0.74 with p=0.000, and -0.75 with p=0.000) with the absolute value of standing navicular height (NHSTD).So naturally, regression was continued in each group an resultant equations could be derived as follow-
In males: NHSTD = [6.98 – 15.97 x Arch Index] ± 1.04
In females: NHSTD = [5.1 – 8.99 x Arch Index] ± 0.49 (Table -1, Fig. 3)

Table-1: Estimation of standing navicular height (NHSTD) from Arch Index in both sexes

	Male n =90		**Female n= 13**	
	Arch Index	NHSTD	Arch Index	NHSTD
Mean	0.22	3.52	0.23	3.07
Std. Devn.	0.04	0.79	0.03	0.34
Correlation coefficient	- 0.74 (p= 0.000)		-0.75 (p= 0.006)	
Regression coefficient	-15.97 (p= 0.000)		-8.99 (p= 0.006)	
Regression constant	6.98		5.1	
Std. Error of Estimate	0.53		0.25	
Wald statistics (F value)	106.88 (p=0.000)		11.51 (p= 0.006)	

Independent variable: Arch Index
Dependent variable: Standing navicular height (NHSTD)
The above table represents the correlation and regression of Arch Index to NHSTD in both the sexes

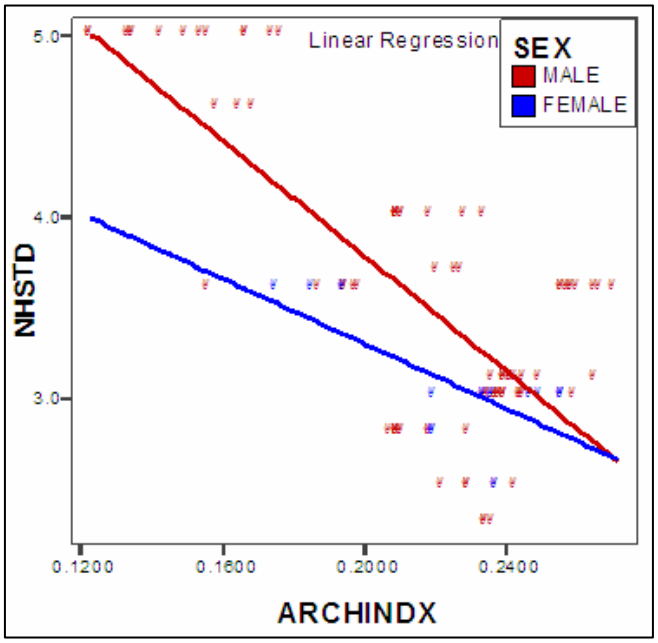


Fig-3: Scatter plot showing regression amongst Arch Index and NHSTD in either sex.

The graph represents the prediction of NHSTD from Arch Index in male and female subjects.

Similar trend also noted for 'standing normalised navicular height (NNHSTD)', with which arch-index maintained correlation -0.62 (p=0.000) and -0.81(p=0.001) in male and female groups respectively. Further analysis here also produced equations for simple linear regression as:

In males: NNHSTD = [0.29 – 0.55 x Arch Index] ± 0.06
In females: NNHSTD = [0.34 – 0.82 x Arch Index] ± 0.04 (Table -2, Fig. 4)

Table-2: Estimation of standing normalised navicular height (NNHSTD) from Arch Index in both sexes

	Male n =90		**Female n= 13**	
	Arch Index	NNHSTD	Arch Index	NNHSTD
Mean	0.22	0.17	0.23	0.16
Std. Devn.	0.04	0.03	0.03	0.03
Correlation coefficient	- 0.62 (p= 0.000)		- 0.81 (p= 0.001)	
Regression coefficient	- 0.55 (p= 0.000)		- 0.82 (p= 0.003)	
Regression constant	0.29		0.34	
Std. Error of Estimate	0.03		0.02	
Wald statistics (F value)	54.13 (p=0.000)		20.49 (p= 0.001)	

Independent variable: Arch Index
Dependent variable: Standing normalised navicular height (NNHSTD)
The above table represents the correlation and regression of Arch Index to NNHSTD in both the sexes

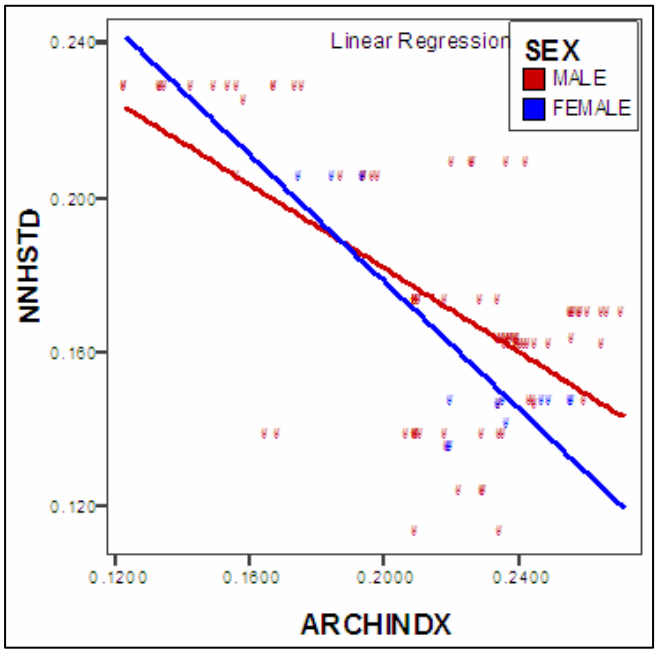


Fig-4: Scatter plot of regression amongst Arch Index and NNHSTD either sex.

The graph represents the regression between the arch-index and standing normalised navicular height in both males and females.

The graph represents the prediction of NHSTD from Arch Index female subjects.

Alike that significant negative correlation also could be documented for the dependence of standing talar height (THSTD) on arch-index of an individual, as studied in both the sex-groups (Coefficients as -0.82 with p=0.000 and -0.61 with p=0.028 in males and females respectively). Simple linear regression later on again revealed the equations as follows:

In males: THSTD = [10.63 – 13.35 x Arch Index] ± 0.67

In females: THSTD = [9.09 – 9.14 x Arch Index] ± 0.65 (Table -3, Fig. 5)

Table-3: Estimation of standing talar height (THSTD) from Arch Index in both sexes

	Male n =90		**Female n= 13**	
	Arch Index	THSTD	Arch Index	THSTD
Mean	0.22	7.74	0.23	7.02
Std. Devn.	0.04	0.59	0.03	0.40
Correlation coefficient	-0.82 (p= 0.000)		-0.61 (p= 0.028)	
Regression coefficient	-13.35 (p= 0.000)		-9.14 (p= 0.028)	
Regression constant	10.63		9.09	
Std. Error of Estimate	0.34		0.33	
Wald statistics (F value)	186.76 (p=0.000)		6.45 (p= 0.028)	

Independent variable: Arch Index
Dependent variable: Standing talar height (THSTD)
The above table represents the correlation and regression of Arch Index to THSTD in both the sexes

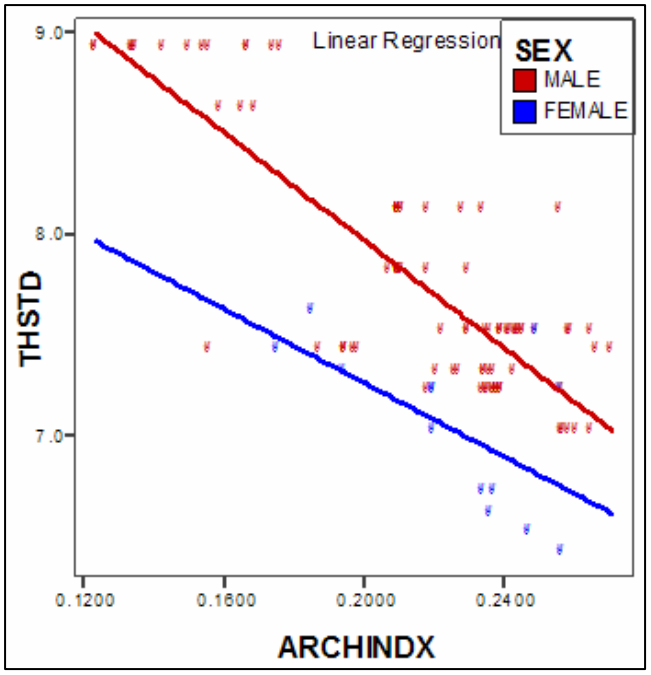


Fig-5: Scatter plot of correlation of Arch Index and THSTD both sexes.

The graph represents the prediction of THSTD from Arch Index in both male and females.

Dependency of the 'normalised talar height in standing (NTHSTD)' was also confirmed with the arch-index as studied group-wise with correlation coefficient -0.38/p=0.000 and -0.81/p=0.001 in males and females respectively. Like before, here also regression study has affirmed the equations of simple linear model as:
In males: NTHSTD = [0.43 – 0.21 x Arch Index] ± 0.37
In females: NTHSTD = [0.65 – 1.27 x Arch Index] ± 0.04 (Table -4, Fig. 6)

Table-4: Estimation of standing normalised talar height (NTHSTD) from Arch Index in both sexes

	Male n =90		**Female n= 13**	
	Arch Index	NTHSTD	Arch Index	NTHSTD
Mean	0.22	0.39	0.23	0.36
Std. Devn.	0.04	0.02	0.03	0.04
Correlation coefficient	- 0.38 (p= 0.000)		-0.81 (p= 0.001)	
Regression coefficient	- 0.21 (p= 0.009)		-1.27 (p= 0.001)	
Regression constant	0.43		0.65	
Std. Error of Estimate	0.19		0.02	
Wald statistics (F value)	14.13 (p=0.000)		20.92 (p= 0.001)	

Independent variable: Arch Index
Dependent variable: Standing normalised talar height (NTHSTD)
The above table represents the correlation and regression of Arch Index to NTHSTD in both the sexes

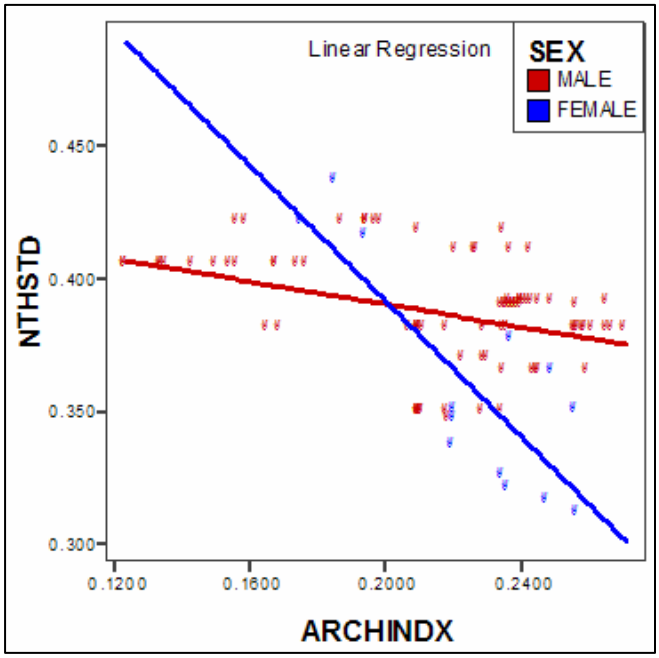


Fig-6: Scatter plot of regression amongst Arch Index and NTHSTD in both sexes.

The graph represents the regression between Arch Index and NTHSTD in both males and females.

Discussion

Essence of this study was to reveal an easier way to derive the standing arch-height of an individual usable in day-to-day clinical practice bypassing the so called troublesome maneuvers; so that it becomes feasible for a clinician to get the idea of actual standing arch-height indirectly from the method adoptable OPD, which has been successfully achieved by the regression equations enlisted above. Foot being a bilateral structure of our body, throughout this study all x-rays have been taken for the left-foot of the subjects for universal representation. As a byproduct, this study could interpret the arch-height parameters in both the sex groups and establish the regression equations separately. Though this study had a considerable number of male participants, but it is true that this it could not include sufficient female subjects, which is essentially for the lack of awareness, privacy and female technicians in the limited infrastructure; but still it gives an impression of arch-height parameters in both the sex groups strengthening the result and outcome.

The values of the absolute standing navicular height, standing talar height as well as those of 'normalised' standing navicular and talar heights and even the arch-index, as studied here no doubt corroborate earlier studies [6-8, 19-25]. But documentation of 'standing normalised talar height' was not found in any literature as searched for. In addition this study also documented slight gender preponderance of the standing arch-heights values in male than in females. In this issue earlier studies could not reach any common conclusion definitely [26-29]. So far the values of arch-indices are concerned, though almost 60% of the study population has normal arch, but nearly 36% has higher arches, which might be for their habitat in foothill areas.

The standing navicular height (NHSTD), talar height (THSTD) and normalised navicular height (NNHSTD) along with normalised talar height (NTHSTD) individually has been correlated with the arch-index at the margin of statistical significance. Findings of majorities of previous studies were same with the present one [8, 12, 14, 15, and 21]. But it is very much unfortunate that derivation of regression equations enlightening the dependence of each factors on arch-index, which has been vividly discussed in this study, found nowhere in persistent literature as searched for. So naturally it would be the first attempt for doing such.

Conclusion

Since arch-index is a time-tested reliable parameter for estimation of arch height so itself can be used regularly for measuring such. Radiographical arch-height estimation though preferred by clinicians, but usually approached in a wrong way to measure it in supine posture in stead of measuring it in standing posture because of heavy crowd with limited radiological machineries and expertisation. This study confirms with the fact that without going in the unnecessary time-taking radiological procedures, it is better to have the foot-print of the subject to analyse the arch-index, from which standing arch-height values easily can be calculated.

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