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**ORIGINAL ARTICLE**

# Arch Height: A Regression Analysis of Different Measuring Parameters

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**Abstract:** *Rationale*: For measuring the height of the arch of foot either standing navicular height or talar height of the medial longitudinal arch was accepted in earlier days, where as the 'standing normalised navicular height' is taken by modern day by authors as a yardstick. But being troublesome and time consuming, we practically not opt for them in busy OPD schedule; rather go for measuring the arch-height in supine posture. *Objectives*: So this study was aimed to derive the regression between the standing arch-height values with the supine counterparts, so that former can be predicted easily from later. *Methodology*: It was carried out among 103 adult subjects in the purview of North Bengal Medical College & Hospital. From the x-ray films of their feet in supine and standing posture the navicular and talar heights were determined and the records were analysed. *Result*: Statistically significant correlation followed by regression analysis could reveal simple linear regression-equations for predicting the standing arch-height values from the supine values; derived separately in both males and females. *Conclusion*: Thus, from a known supine arch-height value, we can derive the respective standing arch- height, as well as the 'standing normalised navicular height' indirectly avoiding the entire troublesome maneuver in regular practice. So the present study recommends this method in clinical fields as because this is more rational and ideal approach to estimate arch height.
**Keywords:** Arch-height, standing arch-height, supine arch-height, navicular height, talar height, standing normalised navicular height.

## Introduction

For determination of the height of the arch of foot we usually refer to the height of the highest arch of foot i.e. the medial longitudinal arch (MLA).Variation of opinions was noted in accepting a universal standard regarding the 'reference parameter' for calculating the height of the MLA radiographically. Earlier researchers used *Talar height* i.e. the height of the 'apex of the talar dome' as the guideline because they considered talar height as the highest point of the medial longitudinal arch [1-2]. Later on, majority had approved the *Navicular height* i.e. the height of the navicular tuberosity as the 'reference parameter' in view of the fact that it could depict how much the foot is clear from ground [3-4].

In recent years researchers modified their view in favour of *Standing Normalised Navicular Height*, as an 'universal reference parameter' which; along with the absolute navicular height, also considers the foot length (specifically 'truncated foot length' i.e. excluding the phalanges, for their variable length), representing more accuracy for foot architecture [3-4].

Though the recommended procedure to measure the height of the arch of foot is done in standing weight bearing posture [5], it is often not feasible in the busy and crowded out patient department in the limited infrastructure available. Usual practice is to deal maximum cases radiologically and the arch height is assessed with the patient supine. In this context, the present study is a humble attempt to redefine the correlation as well as regression among the different arch height estimation-parameters obtained from radiography, so that by simple equation we can predict the more scientific standing arch-height values from the supine ones. Such an endeavor which seems to be previously almost undisclosed (so far as the latest journal reviews are concerned) is carried out in the purview of a tertiary care hospital in Northern part of West Bengal.

*Objective:* The present study was built up on following questions as

1. Whether the standing arch-height (navicular or talar) can be determined from respective supine values?
   and
2. Whether the "standing normalised navicular height" of an individual can be predicted from the supine navicular and supine talar heights?

## 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 twice a week. Patients and their attendants, 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 or injuries of lower limb and vertebral column 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 both in supine as well as in standing weight bearing position. 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. The 'truncated foot length' (FL) was determined by the distance of posterior calcanean tuberosity to the head of the first metatarsal excluding the phalanges [1]. (Fig. no. 1 & 2)

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

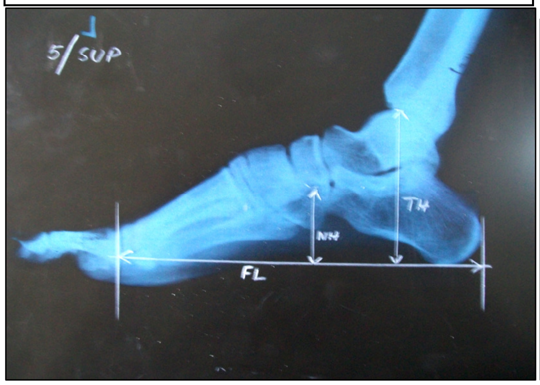
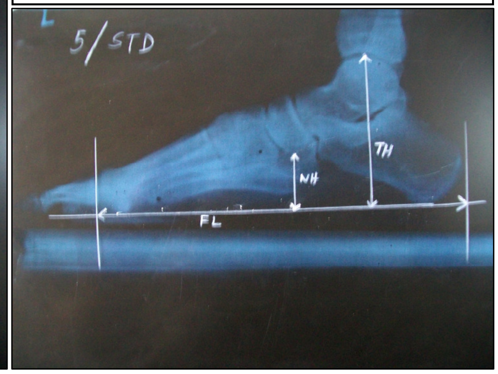



Fig.-2: The above skiagram of foot depicts the measurement of navicular height (NH), Talar height (TH) and truncated foot length (FL) in standing posture.




Thus for each subject six sets of values were obtained namely (i) supine navicular height (NHSUP), (ii) supine talar height (THSUP), (iii) supine foot length (FLSUP), (iv) standing navicular height (NHSTD), (v) standing talar height (THSTD) and (vi) standing foot-length (FLSTD). The 'standing normalised navicular height' (NNHSTD) was calculated as a ratio (so unit less) of standing navicular height (NHSTD) to standing foot length (FLSTD).

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 in normal scale. 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 $y = (a+ bx) \pm (1.96 \times STE)$ [6].

## 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 and supine navicular height were found as 3.52 ±0.79 cm, 4.07 ±0.67 cm in males and 3.07 ±0.34 cm, 3.77 ±0.47 cm in females respectively with an eventual navicular drop (difference between standing navicular height and supine navicular height) as 0.56 ±0.42 cm and 0.61 ±0.37 in both the groups.

Values of the standing and supine talar heights were 7.74 ±0.60 cm, 8.07 ±0.64 cm in males and 7.31 ±0.27 cm, 7.71 ±0.29 cm in females respectively with the mean talar drop (difference between standing talar height and supine talar height) 0.33 ±0.23 cm and 0.37 ±0.23 cm in both the groups. Similarly group-wise the mean foot length was also measured in both the postures and found to be 17.99 ±1.17 cm (supine), 20.31 ±1.72 cm (standing) in males and 16.03 ±1.72 cm, 19.72 ±1.44 cm respectively in supine and standing posture in females; depicting a change (difference between standing foot-length and supine foot-length) of 2.29 ±1.14 cm and 3.22 ±0.58 cm respectively in males and females.

The standing normalised navicular height (NNHSTD) was found to be 0.17±0.32 and 0.16±0.03 in males and females respectively. In both the groups supine navicular height found to maintain significant correlation with the standing navicular height (Correlation coefficient as 0.78, p=0.000 in males and 0.60, p=0.03 for the females) and in parallel, the regression analysis also could show their linear regression equation – For male as **NHSTD = [0.95 x NHSUP – 0.28] ± 0.98** (Table-1, Fig.3)

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

| | Male n =90 | | Female n= 13 | |
|---|---|---|---|---|
| | NHSUP | NHSTD | NHSUP | NHSTD |
| Mean | 4.07 | 3.52 | 3.77 | 3.07 |
| Std. Devn. | 0.65 | 0.79 | 0.46 | 0.34 |
| Correlation coefficient | 0.78 (p= 0.000) | | 0.60 (p= 0.03) | |
| Regression coefficient | 0.95 (p= 0.000) | | 0.44 (p= 0.03) | |
| Regression constant | -0.28 | | 1.43 | |
| Std. Error of Estimate | 0.49 | | 0.28 | |
| Wald statistics (F value) | 136.05 (p=0.000) | | 6.22 (p= 0.016) | |

Independent variable: Supine navicular height (NHSUP)
Dependent variable: Standing navicular height (NHSTD)

The table represents the correlation and regression of NHSUP to NHSTD in both the sexes

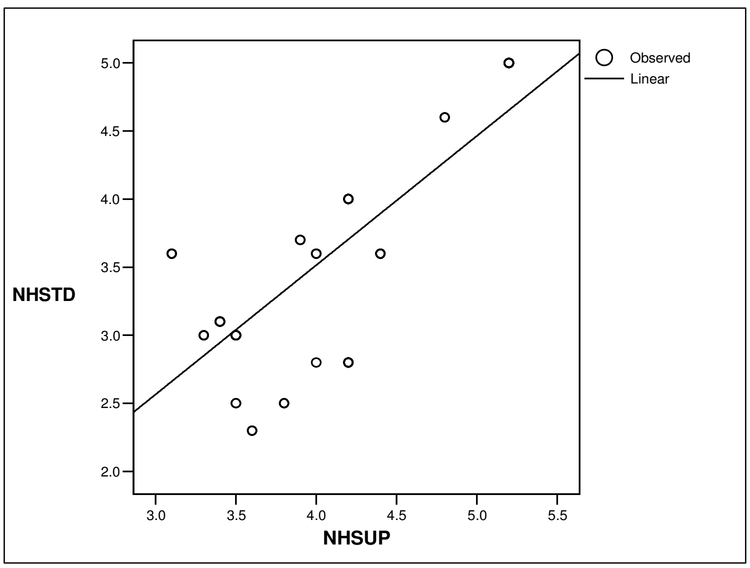
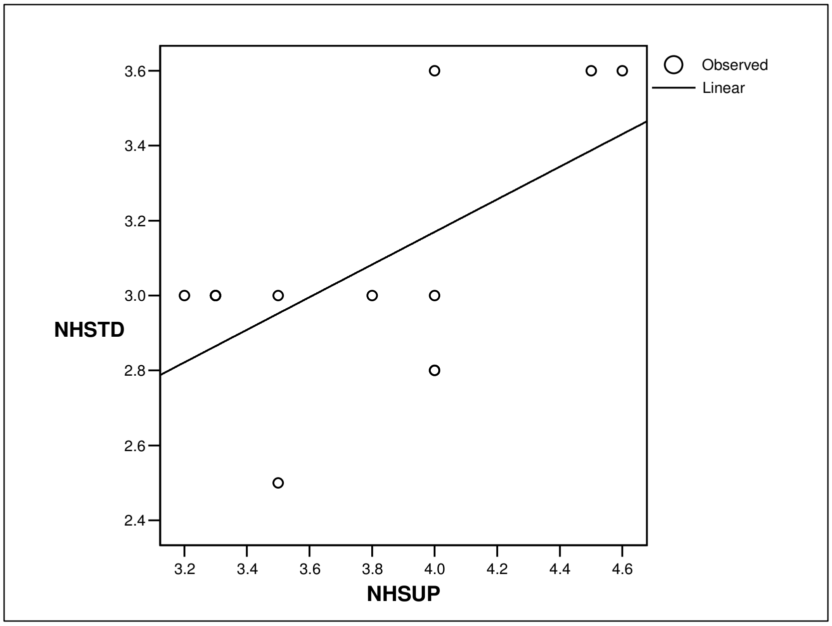



Fig.-3: Scatter plot showing regression amongst NHSUP and NHSTD in male subjects. [n=90]

The graph represents the prediction of NHSTD from NHSUP in male subjects.

For female as **NHSTD = [1.43 + 0.44 x NHSUP] ± 0.55** (Table no. 1, Fig. 4)

Fig.-4: Scatter plot of correlation of NHSUP and NHSTD in female. [n=13]




The above graph represents the prediction of NHSTD from NHSUP in female subjects.

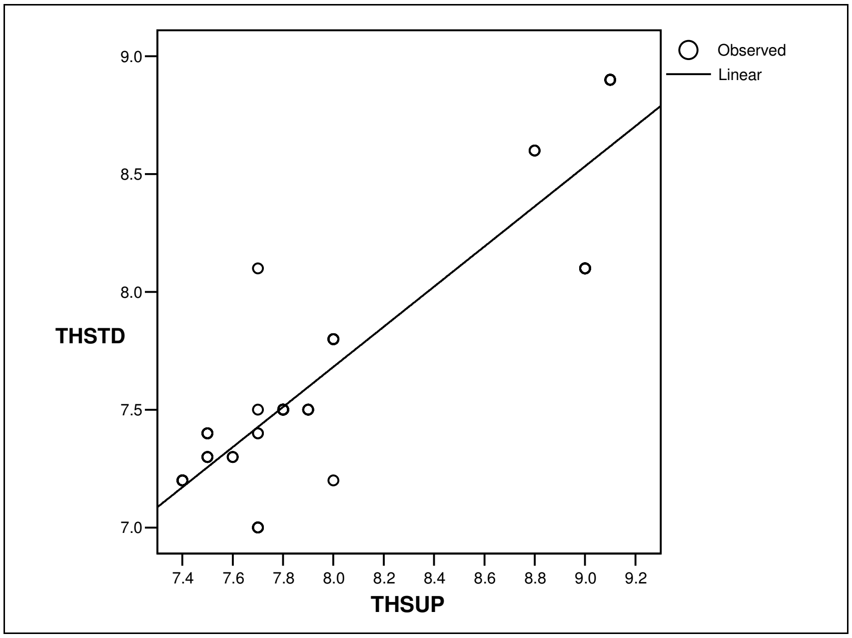
Similar trend also noted for the talar height in both the groups (Correlation coefficient as 0.92,p=0.000 in males and 0.68,p=0.04 for the females). Here also regression equations could be derived-
For males as **THSTD= [0.87 + 0.85 x THSUP] ± 0.47** (Table no. 2, Fig.5)

Table-2: Estimation of standing talar height (THSTD) from supine talar height (THSUP) in both sexes

| | Male n =90 | | Female n= 13 | |
|---|---|---|---|---|
| | THSUP | THSTD | THSUP | THSTD |
| Mean | 8.07 | 7.74 | 7.71 | 7.31 |
| Std. Devn. | 0.64 | 0.59 | 0.28 | 0.27 |
| Correlation coefficient | 0.91 (p= 0.000) | | 0.69 (p= 0.01) | |
| Regression coefficient | 0.85 (p= 0.000) | | 0.64 (p= 0.01) | |
| Regression constant | 0.87 | | 2.41 | |
| Std. Error of Estimate | 0.24 | | 0.20 | |
| Wald statistics ( F value) | 461.86 (p=0.000) | | 9.80 (p= 0.01) | |
| Independent variable: Supine talar height (THSUP)<br>Dependent variable: Standing talar height (THSTD) | | | | |

The above table represents the correlation and regression of THSUP to THSTD in both the sexes

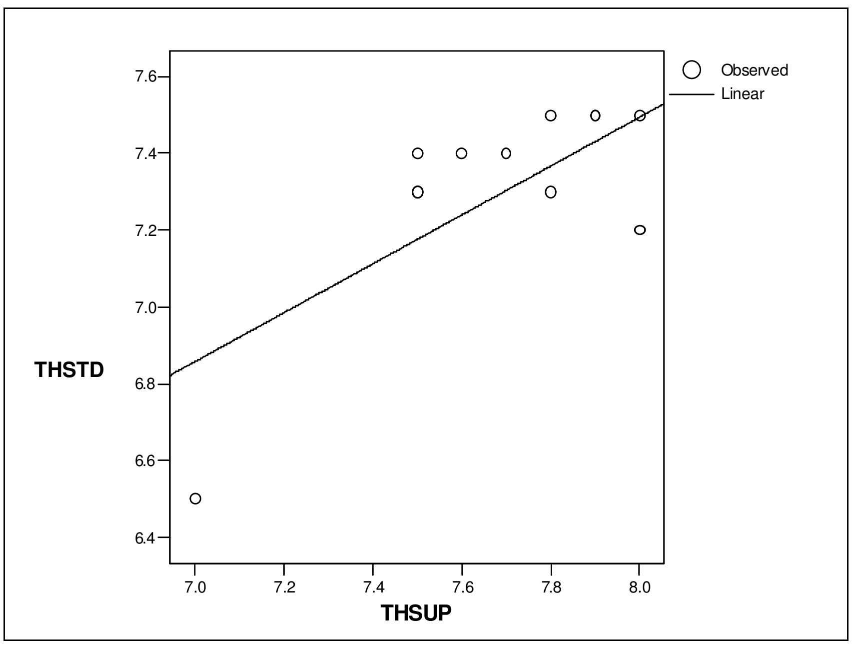
Fig.-5: Scatter plot of correlation of THSUP and THSTD in male. [n=90]




The above graph represents the prediction of THSTD from THSUP in male subjects.

For females as **THSTD= [2.41 + 0.64 x THSUP] ± 0.04.** (Table no. 2, Fig.6)

Fig.-6: Scatter plot of correlation of THSUP and THSTD in female. [n=13]




The above graph represents the prediction of THSTD from THSUP in female subjects.

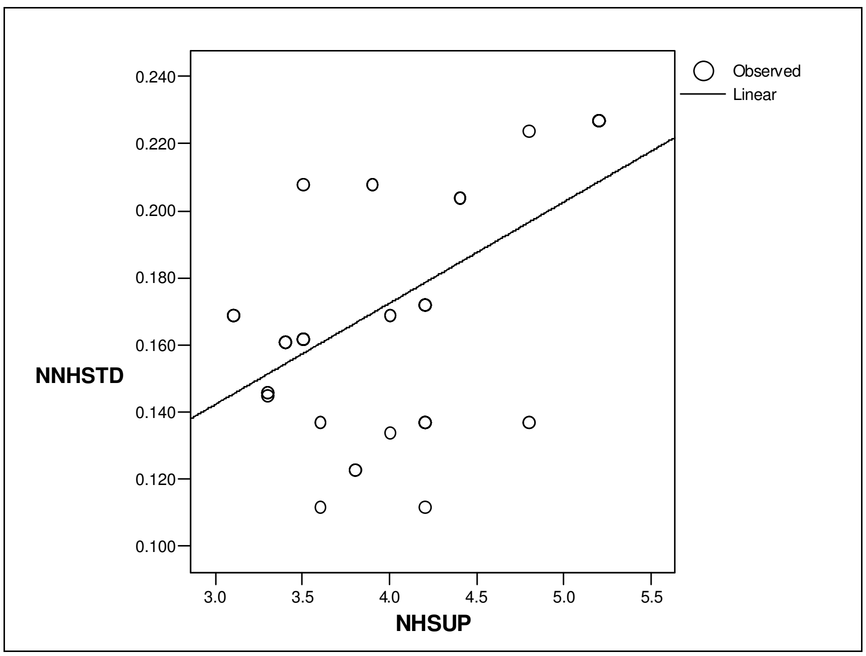
'Standing normalised navicular height (NNHSTD)' was also correlated in a similar manner with the absolute value of supine navicular (NHSUP) and talar heights (THSUP) sequentially. Once again statistically significant relation could be deduced for the NHSUP to NNHSTD in both the groups with correlation coefficient 0.61, p=0.000 and regression coefficient 0.03, p=0.000 for males; and that of 0.62, p=0.001 and 0.04, p=0.003 for females respectively with resultant linear regression equations as-

For males **NNHSTD= [0.05 + 0.03 x NHSUP] ± 0.05** (Table no. 3, Fig. 7)

| Table- 3: Estimation of standing normalised navicular height (NNHSTD) from supine navicular height (NHSUP) in both sexes | | | | |
|---|---|---|---|---|
| | Male n =90 | | Female n= 13 | |
| | NHSUP | NNHSTD | NHSUP | NNHSTD |
| Mean | 4.07 | 0.17 | 3.77 | 0.16 |
| Std. Devn. | 0.65 | 0.03 | 0.46 | 0.02 |
| Correlation coefficient | 0.61 (p= 0.000) | | 0.62 (p= 0.001) | |
| Regression coefficient | 0.03 (p= 0.000) | | 0.04 (p= 0.003) | |
| Regression constant | 0.05 | | 0.03 | |
| Std. Error of Estimate | 0.03 | | 0.02 | |
| Wald statistics ( F value) | 48.52 (p=0.000) | | 14.94 (p= 0.003) | |
| Independent variable: Supine navicular height (NHSUP)<br>Dependent variable: Standing normalised navicular height (NNHSTD) | | | | |

The above table represents the correlation and regression of NHSUP to NNHSTD in both the sexes

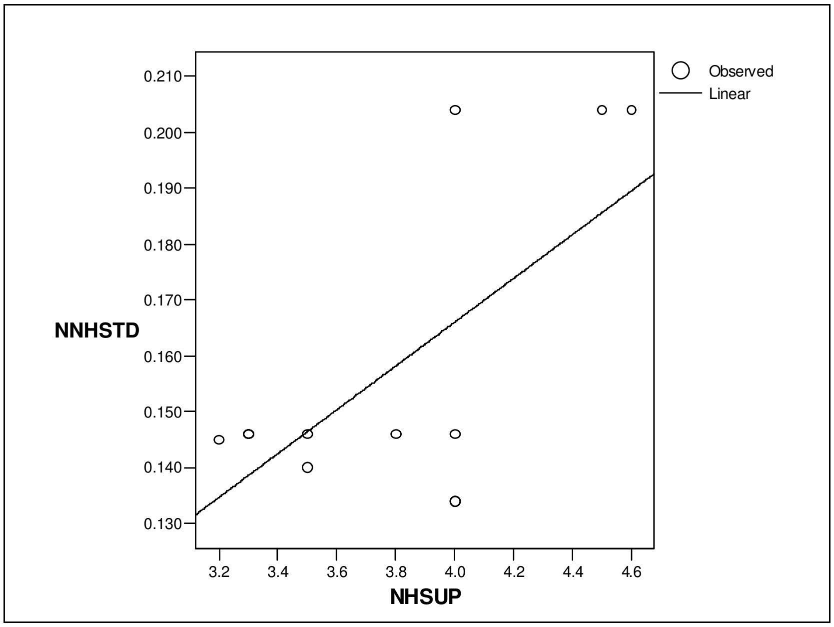
Fig.-7: Scatter plot of regression amongst NHSUP and NNHSTD in male. [n=90]




The above graph represents the prediction of NNHSTD from NHSUP in male subjects.

For females as **NNHSTD= [0.03 + 0.04 x NHSUP] ± 0.04.** (Table no. 3, Fig. 8)

Fig.-8: Scatter plot of regression amongst NHSUP and NNHSTD in female. [n=13]



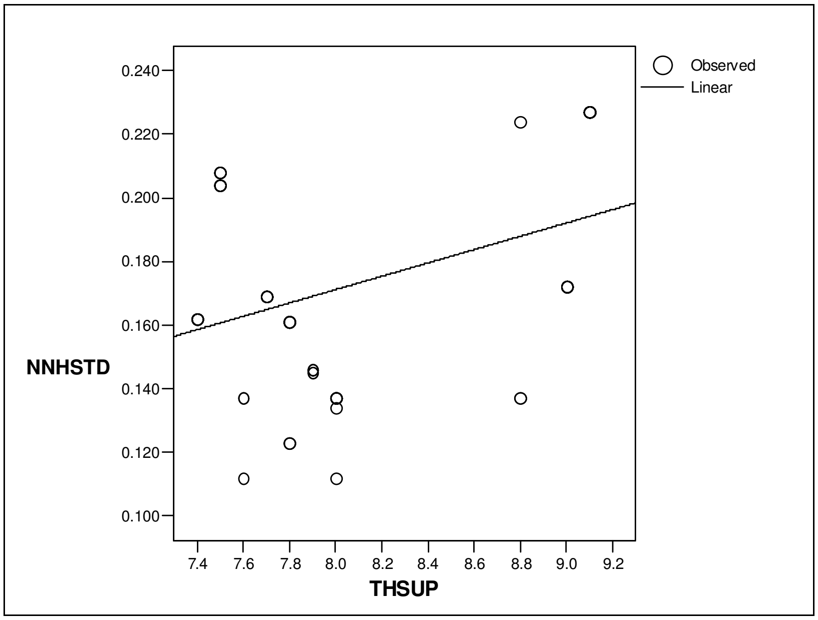

The above graph represents the prediction of NNHSTD from NHSUP in female subjects.

The supine talar height (THSUP) also could be significantly correlated with the NNHSTD with group-wise correlation and regression coefficients are 0.42/p=0.000, 0.021/p=0.000 in males and -0.81/p=0.000, -0.11/p=0.001 in females, resulting linear equation as-

For males **NNHSTD= [0.01+ 0.02 x THSUP] ± 0.06** (Table no. 4, Fig. 9)

| Table-4: Estimation of standing normalised navicular height (NNHSTD) from supine talar height (THSUP) in both sexes | | | | |
|---|---|---|---|---|
| | Male n =90 | | Female n= 13 | |
| | THSUP | NNHSTD | THSUP | NNHSTD |
| Mean | 8.07 | 0.17 | 7.71 | 0.16 |
| Std. Devn. | 0.64 | 0.03 | 0.29 | 0.03 |
| Correlation coefficient | 0.42 (p= 0.000) | | -0.81 (p= 0.000) | |
| Regression coefficient | 0.02 (p= 0.000) | | -0.11 (p= 0.001) | |
| Regression constant | 0.01 | | 0.98 | |
| Std. Error of Estimate | 0.03 | | 0.02 | |
| Wald statistics ( F value) | 18.48 (p=0.000) | | 20.63 (p= 0.001) | |
| Independent variable: Supine Talar height (THSUP)<br>Dependent variable: Standing normalised navicular height (NNHSTD) | | | | |

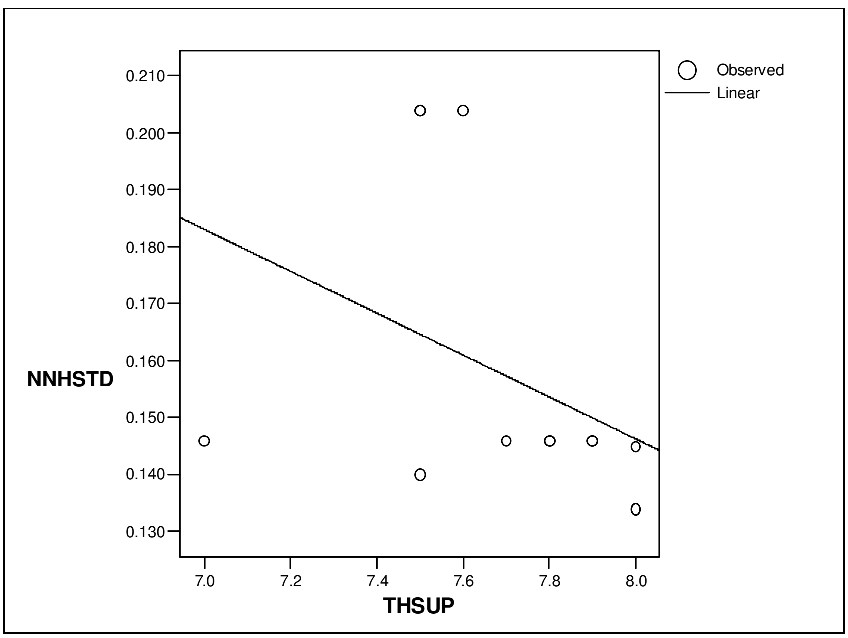
Fig.-9: Scatter plot of regression amongst THSUP and NNHSTD in male. [n=90]




The above graph represents the prediction of NNHSTD from THSUP in male subjects.

For females as **NNHSTD= [0.98 - 0.11 x THSUP] ± 0.03.** (Table no. 4, Fig. 10)

Fig.-10: Scatter plot of regression amongst THSUP and NNHSTD in female. [n= 13]




The above graph represents the prediction of NNHSTD from THSUP in female subjects.

## Discussion

Essence of this study was to reveal the easiest way to derive the standing arch-height measurements from the supine arch-height values, so that it becomes feasible for a clinician to get the idea of actual standing arch-height of an individual indirectly from the method what he usually adopts in OPD, which has 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.

Values of the navicular height, talar heights in both the postures (supine and standing) along with the 'drops' (navicular drop or talar drop) revealed in earlier studies go quiet in parallel with our findings. [2- 4, 7-13], with which the present study additionally could show more magnitude of navicular and talar drops in females than males, highlighting the more pliable nature of the spring ligament. The mean truncated foot lengths in both the sex-groups, as discussed here; also corroborate earlier studies [4], but change of foot length along with the posture, as documented in this study, merely noted earlier in literature still searched for. More dynamicity of foot-lengths in change of posture in females as usual correspond the more elasticity of the plantar ligaments. The estimated 'standing normalised navicular height' in male subjects though tallied with previous literature [3, 14], but unfortunately data for females have scarcity as searched for. So our study humbly put the idea on foot-lengths and their change in posture in adult females. Lastly, studies available till date are mainly focused on establishing the correlation of 'standing *normalised* navicular height' to the 'standing absolute navicular height' carried in western countries, but such an endeavour of regression analysis to implicate in the field of regular medical practice was not found as searched for. This study successfully could show that among the parameters defining arch-height like standing talar height, standing navicular height, standing normalised navicular height, as described earlier [15, 8, 3-4]; which ever be chosen can be derived easily by the simple equations from supine arch-height values applicable for both the sexes by separate equations.

## Conclusion

This study keeps an impression for the indirect assessment of standing arch-height values including the 'standing normalised navicular height' for male and female subjects separately; from the supine arch-height values, by simple linear equation, almost never described before. As standing x-ray of foot is usually avoided in busy OPD, so we opt for the supine arch height estimation as in practice; but it is incomplete till the obtained value is converted to respective standing arch-height, which demands strong recommendation country-wide.

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