*Short Report*

AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY

Foot & Ankle International®
2022, Vol. 43(5) 706–709

DOI: 10.1177/10711007211068473
journals.sagepub.com/home/fai

# Association of Normal vs Abnormal Meary Angle With Hindfoot Malalignment and First Metatarsal Rotation: A Short Report

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## Abstract

**Background:** Recent work has reported a significant association between first metatarsal (M1) rotation and hindfoot alignment, with the finding of a moderate association between the calcaneal moment arm (CMA) and 2 M1 pronation angular measures: Saltzman ($r = 0.641$, $P < .01$) and Kim ($r = 0.615$, $P < .01$). The aim of the current post hoc investigation was to determine if this association is related with Meary angle.

**Methods:** We reanalyzed previously published data set separating patients into 2 groups: (1) those with normal Meary angle (n = 128) and (2) those with abnormal Meary angle (n = 147). Hindfoot alignment and M1 rotation were measured on weightbearing computed tomography. Statistical analyses were performed to evaluate for association between these variables among the groups.

**Results:** The correlation between CMA and M1 rotation of the entire cohort was $r = 0.577$ (Saltzman ankle) and $r = 0.540$ (Kim angle). For the subset with a normal Meary angle, this association was negligible (Saltzman and Kim angles, $r = 0.194$ and 0.240, respectively). Conversely, for the abnormal Meary angle subset, the association was substantial (Saltzman and Kim angles, $r = 0.733$ and 0.675, respectively).

**Conclusion:** Patients presenting with an abnormal Meary angle and hindfoot deformity have a high likelihood of manifesting a proportionate degree of M1 rotation.

**Level of Evidence:** Level III, Retrospective Cohort Study.

**Keywords:** hallux valgus, axial rotation, metatarsal pronation, hindfoot alignment, Meary angle

## Background

A recently published article titled "Association Between Hindfoot Alignment and First Metatarsal Rotation" by Bakshi et al[2] identified a significant association between hindfoot alignment as measured by the calcaneal moment arm (CMA) method[1] and first metatarsal (M1) rotation as measured by the Saltzman[7] and Kim angles.[5] This study reported that valgus hindfoot angulation was correlated to a decreased Meary angle and M1 pronation (M1 plantar surface faces toward the second metatarsal). Conversely, the opposite correlation was found in hindfoot varus, with an increased Meary angle and M1 supination (M1 plantar surface faces away from the second metatarsal). Additionally, Bakshi et al found that as the magnitude of these 3 parameters increased or decreased, the others also proportionately increased or decreased in magnitude, respectively. On further review of some of the cases included in the Bakshi et al[2] article, we recognized the potential lack of M1 rotation in those patients with a normal Meary angle. The aim of this study was to further investigate the possible association between Meary angle, M1 rotation, and hindfoot alignment.

## Methods

After our institution's internal review board granted a compliance approval, the authors collected electronic health records from patients who underwent a weightbearing computed tomography (WBCT) between June 2015 and December 2018 as described by Bakshi et al.[2] We used the same cohort as Bakshi et al with the addition of the 79 feet

**Table 1.** Correlation of First Metatarsal Axial Rotation and Hindfoot Alignment Among Cohorts.

| | Entire Cohort (N = 275) | | Normal Meary Cohort (n = 128) | | Abnormal Meary Cohort (n = 147) | |
|---|---|---|---|---|---|---|
| | Saltzman Angle | Kim Angle | Saltzman Angle | Kim Angle | Saltzman Angle | Kim Angle |
| Correlation coefficient[a] | .577 | .540 | .194 | .240 | .733 | .675 |
| Interpretation | Moderate | Moderate | Negligeable | Negligeable | High | Moderate |
| *P* value[a,b] | <.001 | <.001 | .028 | .006 | <.001 | <.001 |

[a]Coefficients and *P* values were generated with a Spearman rho correlation coefficient test.
[b]All *P* values were considered significant at the < .05 level.

that were omitted with "normal" hindfoot alignment, totaling to 275 feet of 262 included patients.

Hindfoot alignment measurement with the CMA method[1] and M1 rotation measurement with the Saltzman[7] and Kim[5] methods were all performed using weightbearing computed tomographic scans. The lateral weightbearing plain radiography selected for in this study was used to measure the Meary angle.[3,4] The same methodology and observers used by Bakshi et al[2] were implemented in this investigation. Once all measurements were performed, subgroups were created according to the definition of the normal range for the Meary angle previously reported by Gould et al[3] and Kaz et al[4] and others (see Supplementary Table). The most commonly reported range for a normal Meary angle in asymptomatic feet is 176 to 184 degrees, with 180 degrees indicating a parallel lateral talo–first metatarsal axis. Meary angle values greater than this range are associated with an apex dorsal pes cavus, where values less than 176 degrees indicate an apex plantar pes planus deformity. Therefore, 2 groups were created from this range: (1) normal Meary angle (≤184 and ≥176 degrees) and (2) abnormal Meary angle (<176 or >184 degrees). The software and statistical analyses described in Bakshi et al were applied to this investigation in addition to an unpaired *t* test and Mann-Whitney *U* test for hindfoot alignment intergroup comparison. The level of significance for all tests was set at $P \leq .05$.

## Results

The mean age of the cohort was 53.2 ± 18.0 (range: 15-86) years, the group was 40% female, 48% left feet, and possessed a mean body mass index of 29.8 ± 5.6 (range: 16.6-47.5). The mean time between weightbearing computed tomography and weightbearing plain radiography acquisition dates was 14.7 ± 18.4 days. The Meary angle groups did not significantly differ demographically other than that the abnormal Meary angle group was older by a mean of 2.4 years ($P = .037$). The correlation between CMA and M1 rotation of the entire cohort was moderate for both the Saltzman ($r = 0.577$) and Kim angles ($r = 0.540$; Table 1; $P < .001$). However, in the normal Meary angle group, this relationship was no longer evident, and the correlation between the CMA and both the Saltzman ($r = 0.194$) and Kim ($r = 0.240$) angles were found to be negligible ($P = .028$ and .006, respectively). The opposite occurred in the abnormal Meary group (Figure 1). Relative to the entire cohort, the correlation coefficient between CMA and both M1 rotation measures significantly increased. The correlation found with the Saltzman angle was graded as high ($r = 0.733$), whereas the correlation found with the Kim angle was moderate ($r = 0.675$) (Table 1, Figure 2; $P < .001$).

## Discussion and Conclusion

In this study, we found that the correlation between hindfoot alignment and M1 axial rotation found by Bakshi et al[2] was much stronger for those patients with abnormal Meary angles than those with normal alignment. Although our findings suggest that Meary angle affects the relationship between CMA and M1 rotation, the cause is unclear. The dichotomy we have found may be best explained in the normal Meary

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**Figure 1.** Weightbearing computed tomography (WBCT) acquisitions of patient A (62-year-old male) showing considerable valgus hindfoot alignment (A1 and A2), a normal Meary angle (A3; weightbearing plain radiography), and a first metatarsal head that is largely parallel to the ground (A4). The WBCT acquisitions of patient B (74-year-old male) also show considerable valgus hindfoot alignment (B1 and B2). However, the lateral scan conversely demonstrates a pes planus deformity represented by an abnormal Meary angle (<176 degrees, B3; weightbearing plain radiography) and subsequent pronation of the first metatarsal head (B4). Correlation analyses suggest a linkage in hindfoot and forefoot position in patient B but not in patient A.

angle group due to calcaneal malalignment occurring primarily at the level of the subtalar joint rather than more distally, which would affect coupling between the talus and the first metatarsal as measured by the Meary angle. Hindfoot malalignment, in association with an abnormal Meary angle, will force compensatory changes through the Chopart and cuneonavicular joints and their primary ligaments (eg, plantar calcaneonavicular, plantar calcaneocuboid, etc) potentially resulting in further M1 rotational changes.[6] Clinicians who recognize abnormalities in Meary angle in patients with calcaneal malalignment should consider if the first metatarsal is also rotated when treating these patients.

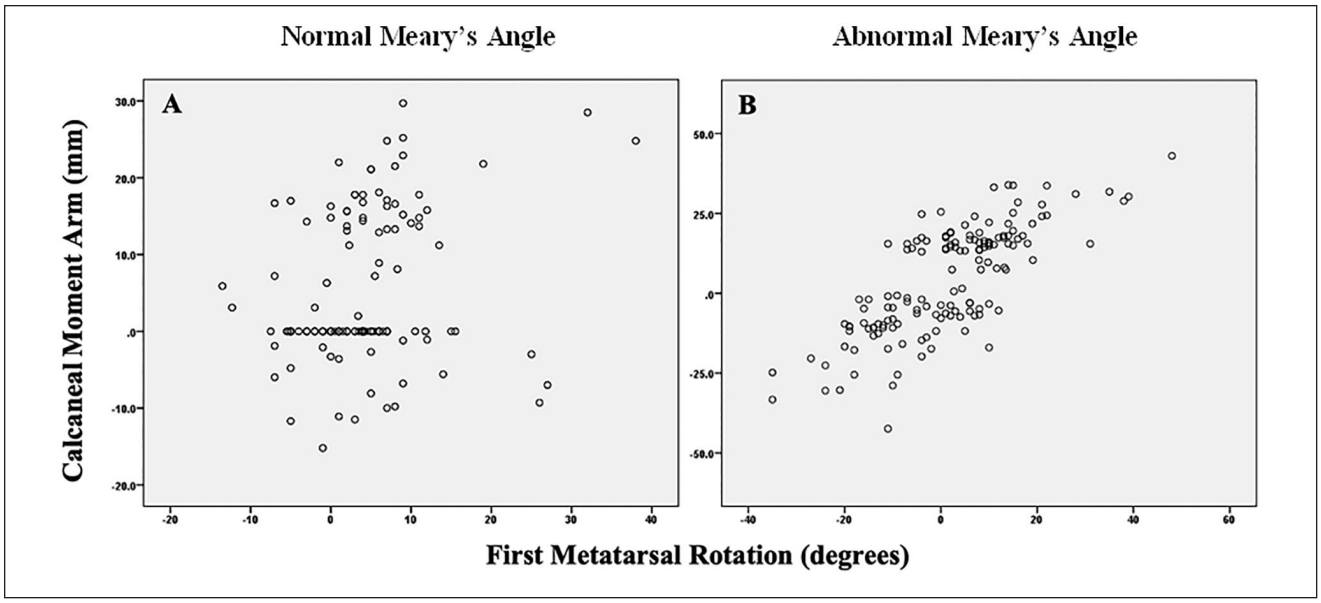


**Figure 2.** Scatter plots illustrating the correlation between the calcaneal moment arm and first metatarsal axial rotation as measured by the Saltzman angle. Plot A illustrates a negligeable correlation between these 2 parameters in the normal Meary angle group ($r = 0.194$, $P = .028$). Plot B illustrates a high correlation between these 2 parameters in the abnormal Meary angle group ($r = 0.733$, $P < .001$).

## Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Charles L. Saltzman, MD, reports being the Editor-In-Chief of *Foot & Ankle International*. ICMJE forms for all authors are available online.

## Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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## Supplemental Material

Supplementary material is available online with this article.

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