The Role of the Transverse Arch in Progressive Collapsing Foot Deformity

Eli Schmidt[1], Ki Chun Kim[2], KEPLER CARVALHO, Kevin Dibbern[3], Christopher Cychosz[1], Nacime Salomao Barbachan Mansur[4], Samuel Braza, Matthieu LALEVEE[5], Cesar De Cesar Netto[6]
[1]University of Iowa, [2]Seoul Medical Center, [3]Department of Orthopedics and Rehabilitation, [4]Escola Paulista De Medicina - UNIFESP, [5]University Hospital of Rouen, [6]University of Iowa - Department of Orthopaedics An

INTRODUCTION:

A recent study published in Nature (Venkadesan et al.) demonstrated that mechanical coupling of the transverse arch (TA) with the medial longitudinal arch (MLA) significantly increased the intrinsic stiffness of the midfoot. Since the proximal base of each metatarsal forms the arch and the distal head lies flat on the ground, it is possible to use the intrinsic rotation or torsion of the 4th metatarsal to indirectly assess TA curvature. Using this method, the TA was not present in quadrupedal monkeys nor ancient hominins suggesting TA development as the potential evolutionary advancement that provided the foot stiffness required for human bipedalism.

Progressive collapsing foot deformity (PCFD) is a complex deformity which ultimately results in the loss of stiffness and collapse of the MLA. The newfound understanding of the TA's impact on the MLA and intrinsic stiffness may play a key role in the pathogenesis of this deformity.

The objectives of this study were 1) assess and compare the TA curvature in PCFD and controls 2) replicate the indirect measure of TA curvature performed by Venkadesan et al. in PCFD and controls to assess if PCFD can be partially explained by differences in metatarsal bone torsion 3) evaluate where collapse occurs along the TA in PCFD patients and 4) evaluate the relationship of TA collapse with the accepted measures of PCFD.

METHODS:

A retrospective review was conducted for 32 PCFD and 32 controls. Measurements were performed using weight-bearing CT (WBCT). A novel measurement, the transverse arch plantar (TAP) angle, was developed to directly measure the TA in both PCFD (Figure 1a) and controls (Figure 1b). TA curvature was indirectly assessed using the equation for normalized curvature described by Venkadesan et al. (Figure 6) utilizing width, length (Figure 3a), 3rd metatarsal thickness (Figure 3b), and 4th metatarsal torsion (Figure 4a-b).

To assess the location of TA collapse, a line was drawn connecting the most inferior aspect of the medial cuneiform and the 5th metatarsal. The distance between that line and the 2nd metatarsal was measured and repeated for the 3rd and 4th metatarsal (Figure 8).

Finally, uni-and multivariate analyses were performed to analyze the relationship between the TAP angle, Foot and Ankle Offset (FAO), peritalar subluxation, and measurements associated with each PCFD class including: hindfoot moment arm (class A), talonavicular coverage angle (class B), Meary angle (class C), medial facet uncoverage angle (class D), and talar tilt (class E).

Normality of different variables were assessed using the Shapiro-Wilk test. Two groups were compared using t-test for normal, and Mann-Whitney for non-normal variables.

RESULTS:

Measurements of the TAP angle were found to be significantly higher in the PCFD group than the control group with a mean angle of 115.24° (SD 10.68) and 100.76° (SD 7.92) respectively ($p<0.001$) (Figure 2).

No significant difference was found in the calculated TA curvature between PCFD and controls with mean values of 17.84 (SD 4.41) and 18.18 (SD 3.68) respectively ($p=0.741$) (Figure 5).

A shorter distance between the 2nd metatarsal and medial cuneiform was found in PCFD compared to controls with a mean distance of 10.88mm (SD 1.79) and 11.92mm (SD 1.48) ($p=0.014$) (Figure 7a). All other distances measured showed no significant differences (Figure 7b-d).

The univariate analysis performed showed a moderate positive correlation between the TAP angle and the FAO ($\rho=0.58$;$r2=0.34$;$p<0.001$).

The multivariate analyses showed, among the different PCFD class measurements and the TAP angle, that Meary's angle was the only predictive factor of higher TA collapse ($\beta=0.55$,$p<0.001$).

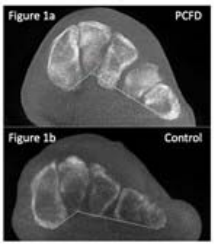
DISCUSSION AND CONCLUSION:

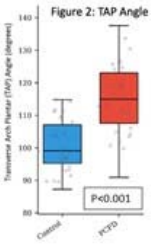
Our novel direct measurement demonstrated a collapse of the TA in PCFD. However, the indirect measure, as described by Venkadesan et al., did not show a difference. Since this calculation relied on 4th metatarsal torsion, this result suggests that insufficient or excess bone torsion is not a factor in PCFD.

Collapse of the TA, when present, is most substantial between the medial cuneiform and 2nd metatarsal.

Considering the implication of the TA among the different PCFD classes, it does not appear to play a significant role in the overall PCFD deformity as defined by our included measurements (Classes A-E). TA collapse was mainly influenced by

Meary's angle (Class C), which most directly assesses the MLA. This further supports the idea behind TA and MLA coupling suggesting that when the TA is collapsed, the foot does not possess the required stiffness to maintain the MLA.





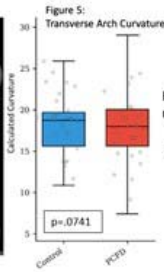


Figure 6: Equation for normalized curvature ($\hat{c}$)

$$\hat{c} = \frac{\theta_{MT4}}{(\frac{w}{L})(\frac{t}{L})}$$