Acquired *Pes Planovalgus*: Current Concepts – "From Adult Acquired *Pes Planovalgus* to Progressive Collapsing Foot Deformity"

Pé plano valgo adquirido: Conceitos atuais – "Do pé plano valgo adquirido do adulto à deformidade colapsante progressiva do pé"

Hugo Bertani Dressler[1] Kepler Alencar Mendes de Carvalho[2] Roberto Zambelli[3] Nacime Salomão Barbachan Mansur[4] Cesar de Cesar Netto[2]

[1] Orthopedics and Traumatology Service, Rede Mater Dei de Saúde, Belo Horizonte, MG, Brazil
[2] Duke University, Durham, NC, United States
[3] Subspecialization in Foot and Ankle Surgery, Orthopedics and Traumatology Service, Rede Mater Dei de Saúde, Belo Horizonte, MG, Brazil
[4] MedStar Orthopedic Institute, MedStar Union Memorial Hospital, Baltimore, MD, United States

Address for correspondence Cesar de Cesar Netto, MD, PhD, Duke University, Durham, NC, United States (e-mail: cesar.netto@duke.edu).

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Abstract

The clinical disorder traditionally known as *pes planovalgus due to posterior tibial tendon insufficiency* or *adult-acquired pes planovalgus* has been the subject of several publications over the past two decades. Now, it is understood that the problem does not lie in the posterior tibial tendon per se and may even occur without tendon injury. Studies have brought new concepts and understanding that question the views on this subject, culminating in the replacement of existing classifications with one that is more assertive and discriminative of the potential presentation patterns of the deformity. In addition, a change in the name of the disorder to *progressive collapsing foot deformity* (PCFD) has been proposed.

Regarding surgical treatment, the concept of an *à la carte* approach persists, emphasizing axis realignment through osteotomies, arthrodeses, and soft tissue balancing, which consists of tendon transpositions/repairs and reconstruction of ligament structures, especially the deltoid ligament complex and the spring ligament.

Keywords
- adult
- flatfoot
- foot deformities
- posterior tibial tendon dysfunction

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Resumo

O distúrbio clínico tradicionalmente conhecido como *pé plano valgo por insuficiência do tendão tibial posterior* ou *pé plano valgo adquirido do adulto* tem sido objeto de diversas publicações nas últimas duas décadas, e entende-se agora que o problema não está no tendão tibial posterior em si, pois o distúrbio pode ocorrer até mesmo sem a lesão desse tendão. Estudos trouxeram novos conceitos e entendimentos que questionaram o olhar sobre o tema, o que culminou na substituição das classificações existentes por uma que fosse mais assertiva e discriminativa dos possíveis padrões de apresentação da deformidade. Além disso, também propôs-se a mudança da nomenclatura para "deformidade colapsante progressiva do pé" (DCPP; *progressive collapsing foot deformity*, PCFD, em inglês).

Quanto ao tratamento cirúrgico, ainda persiste o conceito de abordagem *à la carte*, com ênfase no realinhamento dos eixos, o que pode ser obtido por meio de osteotomias, artrodeses e equilíbrio de partes moles, que consiste em transposições/reparos tendinosos e reconstrução de estruturas ligamentares, sobretudo do complexo ligamentar deltoide e do ligamento mola.

Palavras-chave

- adulto
- deformidades do pé
- disfunção do tendão tibial posterior
- pé chato

Introduction

Since the description of the 3 classic stages by Johnson and Strom in 1989,[1] which was modified by Myerson in 1997[2] and, later, by Bluman et al.[3] in 2007, the clinical disorder historically known as *adult acquired pes planovalgus due to insufficiency of the posterior tibial tendon* (PTT) has been the subject of countless publications and questions regarding the role of the PTT in its pathogenesis and the sequence of events that result in the development of this complex, multifactorial, multifocal, and three-dimensional deformity of the foot and ankle.

The literature has dedicated efforts to understanding the disorder better and classifying it in a more reproducible manner to guide treatment and improve its outcomes. The nomenclature used for pes planovalgus deformities, including rupture, dysfunction, or insufficiency of the PTT and acquired pes planovalgus in adults, does not reflect its pathogenesis. It has been recognized that pes planovalgus is not necessarily associated with PTT disruption, it may begin in childhood, and arch flattening is only one aspect of this multiplanar deformity.[4]

Understanding the Deformity

Although PTT dysfunction is widely accepted as a significant contributor to pes planovalgus, there are several other structures involved besides the tendon,[5] which may represent only the tip of the iceberg when considering the degree of medial and plantar soft tissue injury and strain.

Progressive collapsing foot deformity (PCFD) is complex and consists of several components with varying degrees of severity: midfoot abduction deformity, primarily due to lateral deviation at the talonavicular joint; peritalar subluxation, resulting in foot and hindfoot deviation in all three major planes and progressing to subtalar joint eversion; plantar flexion of the talus and forefoot abduction; varus forefoot with the first ray elevated above the fifth metatarsal; and hindfoot valgus.[6]

The stages arbitrarily defined as consecutive in the classic classifications can actually occur in a disorganized fashion, without following a spectrum of progression that is necessarily consecutive. Therefore, even if the PTT remains present and has no rupture or insufficiency, deformities can occur, including in the tarsometatarsal joints and the naviculocuneiform joints, potentially with a rupture or attenuation of the plantar fascia, the spring ligament, and the deltoid ligament in any combination.[5,7] Researchers have neglected the significant participation of the spring ligament and its sling effect for decades, and they did not even consider it for classification purposes.[8] It is known that this suspensory effect of the spring ligament evolves with failure, contributing to a collapse worsening.

In summary, the deformities result from an imbalance of bone, muscle, and ligament components acting together.

In the propedeutic evaluation, the following conventional weight-bearing radiographs are required to evaluate patients with PCFD: anteroposterior of the foot and ankle with weightbearing, mortise, and lateral of the ankle and foot with weightbearing.[9]

If available, a hindfoot alignment view is strongly recommended, as is weight-bearing computed tomography (WCT). A WBCT scan from patients with the deformity reveals important findings, such as sinus tarsi impingement, subfibular impingement, increased valgus tilt of the posterior facet of the subtalar joint, and subluxation of the subtalar joint at the posterior and middle facets or both[10,11] (►**Fig. 1**).

Although WBCT in Brazil remains available for research purposes alone, not for routine clinical use, it is critical to consider its relevant application to understand deformities. This tool enables the assessment of the relationship between

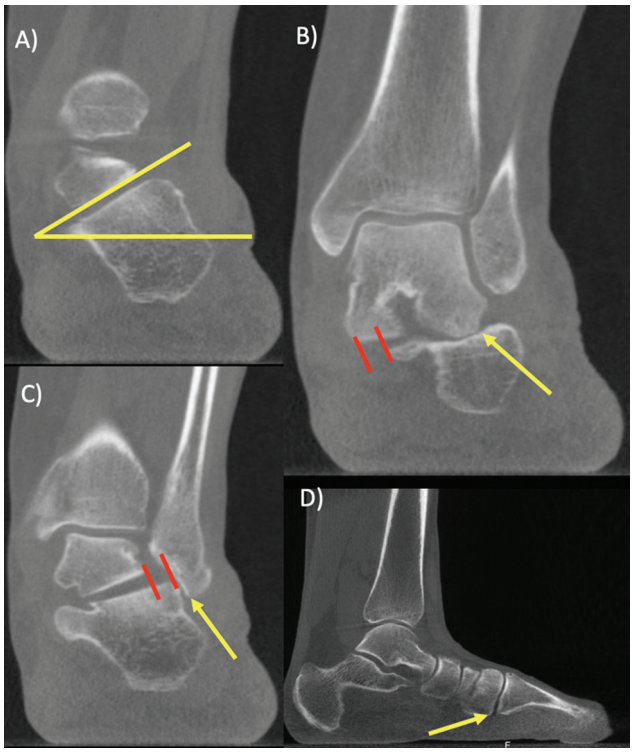

Fig. 1 Coronal weight-bearing computed tomography scan demonstrating: (**A**) the misalignment of the subtalar joint; (**B**) sinus tarsi impingement and medial facet subluxation; and (**C**) subfibular impingement and posterior facet subluxation. (**D**) Sagittal scan demonstrating instability with the plantar opening of the tarsometatarsal joint.

the position of the foot's tripod (weight-bearing points of the first and fifth metatarsal heads and the calcaneal tuberosity) and the center of the ankle joint (the most proximal and central point of the talar dome) and the representation of different components of the three-dimensional deformity in a single measurement, a parameter known as the foot and ankle offset[12] (FAO) (►**Fig. 2A–E**).[13]

Updated Nomenclature

Recently, a consensus of experts[14] proposed a new nomenclature and a new classification system, both based on the flexibility, type, and location of the deformities. This group[14] recommended changing the condition's name to PCDF, considering it is a complex and variable three-dimensional deformity. The words *progressive* and *collapsing* convey a better idea of the increasing and evolving nature of the complexity of this multiplanar deformity. These considerations may improve understanding and avoid an underestimation of the disorder, as occurred with the previous terminology.

Since the PTT per se is not the main problem, the new nomenclature does not include it. Furthermore, avoiding the use of *acquired pes planovalgus* as a terminology has been suggested, since many people are born with flatfoot and are never symptomatic; in addition, arch flattening is only one component of a complex, three-dimensional deformity.[7,8] In general, a flatfoot can be a normal finding; however, the factor requiring consideration is a progressive worsening of this deformity or, more precisely, a progressive collapse.

Updated Classification

The evolution in the understanding of pes planovalgus in adults and the continuous improvement in three-dimensional imaging resulted in the perception of more limitations in the previous classification systems. An ideal classification for any condition should be concise, easy to use, and reproducible, and it should enable universal use and incorporate different deformities, to promote report standardization and guide treatment to achieve optimal outcomes.

The alphanumeric classification system for PCDF consists of 2 sequential stages of flexibility/rigidity of the deformities (stage 1: flexible deformity; and stage 2: rigid deformity) and 5 different deformity classes (A: hindfoot valgus; B: midfoot/forefoot abduction; C: forefoot varus deformity/medial column instability; D: peritalar subluxation/dislocation; and E: ankle valgus deformity), which can occur alone or in any combination. Thus, each deformity class can be flexible or rigid (►**Table 1**). This new classification system has been validated with satisfactory intra- and interexaminer reliability.[7,15–17]

Therefore, the PCDF classification relies on flexible (stage I) or rigid (stage II) deformities and is further described by the addition of one or more deformities (isolated or combined – classes A to E). A case of rigid hindfoot valgus (2A), flexible and unstable medial column (1C), and forefoot abduction that cannot undergo reduction (2B), for instance, should be reported as A2B2C1, because the examiner will first determine the location of the deformities, and then, whether they are rigid or flexible.

Treatment

A non-surgical approach should be considered in initial cases and in those with some clinical impediment to the surgery. This treatment modality cannot correct any existing deformity; however, it may improve symptoms and the quality of life of patients. It is possible to use anti-inflammatory medications, insoles, ankle stabilizing orthoses, and rigid shoes with a rocker-bottom or blotting-paper pattern.[18]

Considering the deformity spectrum in PCDF, the surgical strategy should be individually evaluated to define the required procedures. Therefore, it is critical to determine the specific existing abnormalities and deformities. This highlights the importance of the new classification, since it considers the type and location (classes) and the flexibility/rigidity of the deformities (stages), reinforcing the *à la carte* nature of the management of this disease.

The general objective of the correction is the realignment of the tripod with the ankle, promoting the correction of the FAO determined by WBCT.[19] Achieving this objective reduces

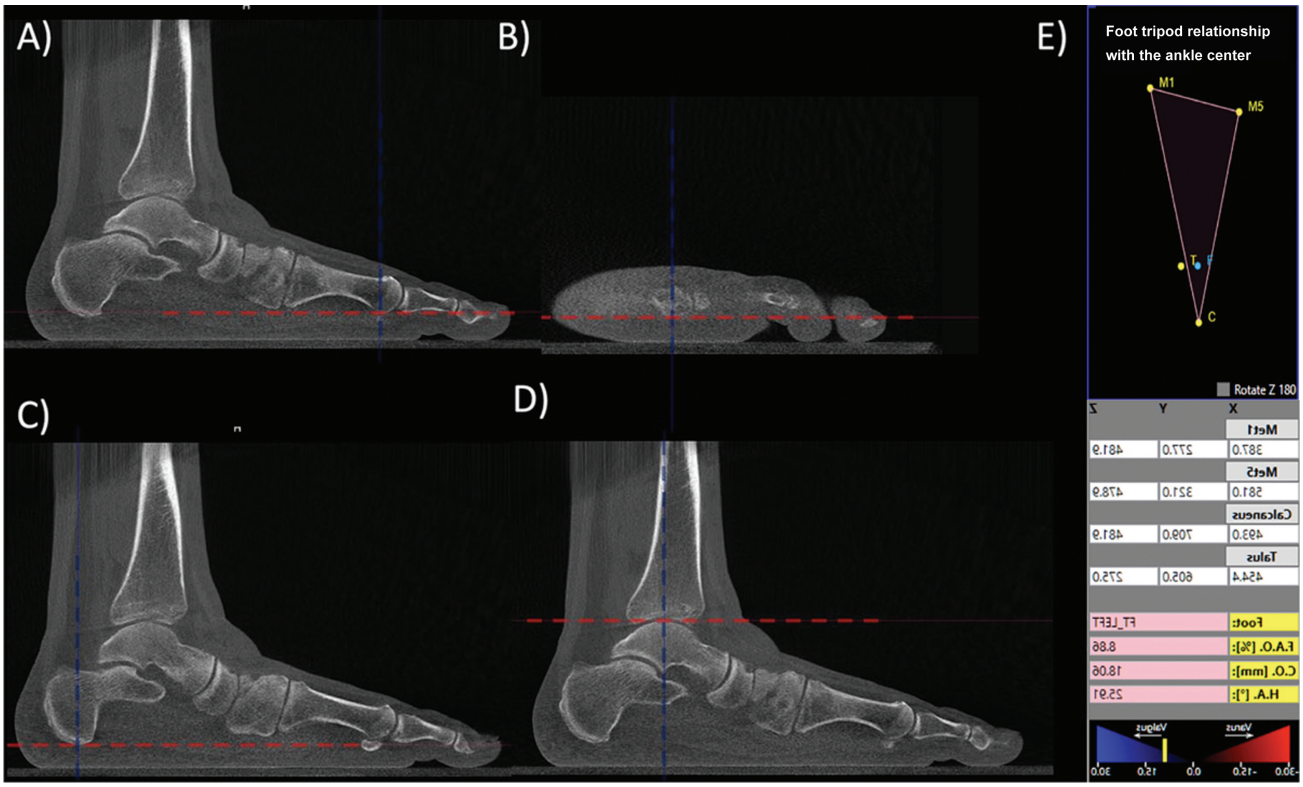

Fig. 2 Three-dimensional coordinates to calculate the foot and ankle offset (FAO) weight-bearing computed tomography. (**A**) Sagittal section with marking at the lowest point of the head of the first metatarsal; (**B**) sagittal section with marking at the lowest point of the head of the fifth metatarsal; (**C**) axial section with marking at the lowest point of the calcaneal tuberosity; (**D**) sagittal section with marking at the highest point of the talar dome; and (**E**) example of a screen display of the software (CubeVue with the TALAS tool, CurveBeam AI, Hatfield, PA, United States) for semiautomatic calculation of the FAO displacement. We evaluated three-dimensional coordinates (x, y, z planes) of weight-bearing computed tomography images for the first (Met1, M1) and fifth (Met5, M5) metatarsals, the calcaneus (C), and the talus (T). These coordinates generated semiautomatic calculations of the foot tripod (triangle) and the ideal (F) and current actual (T) positions of the ankle joint center. In this example, the ankle joint center (T) is medial to the ideal ankle joint center (F), representing a valgus alignment of the hindfoot and an unbalanced tripod.

Table 1 Progressive collapsing foot deformity classification[7]

Stage 1 (flexible)		Stage 2 (rigid)
Deformity types (classes - isolated or combined)		
	Deformity type/location	**Clinical and radiographic findings**
Class A	Hindfoot valgus	Hindfoot valgus/increased hindfoot alignment angle and foot and ankle offset
Class B	Midfoot/forefoot abduction	Decreased talar coverage/presence of sinus tarsi impingement
Class C	Forefoot varus/medial column instability	Increased talus–first metatarsal angle/medial plantar tarsometatarsal or naviculocuneiform gap/forefoot varus
Class D	Peritalar subluxation or dislocation	Significant subtalar subluxation/sinus tarsi impingement and subfibular impingement
Class E	Ankle valgus instability	Valgus talar tilt

reconstruction failures through calcaneal medialization/lowering osteotomies[6,20] and simple or combined arthrodeses of the hindfoot associated or not with the soft-tissue approach. One must always consider the contracture in the posterior leg muscles, specifically the soleus and gastrocnemius muscles, as a deforming force in hindfoot eversion. This may require lengthening of the gastrocnemius or even of the entire calcaneal tendon and medialization osteotomy of the calcaneus, repositioning it as an inverter.[6]

Tendon transfers, such as tenodesis of the peroneus brevis on the peroneus longus, help to reduce the everting moment of the foot and act on the flexion of the first ray by enhancing

the action of the peroneus longus. In addition, the approach to the medial structures plays a significant role in tendon retensioning and reconstruction of the deltoid ligament and spring ligament through direct repair and/or reconstruction associated with stabilization tapes.[8,21–24]

One must also consider methods for column realignment, such as lowering and stabilizing the medial column (Cotton, LapiCotton, or both)[25,26] or lateral column alignment (Evans).[23]

Final Considerations

Progressive collapsing deformity of the foot is complex, and it is essential to understand that pes planovalgus is not necessarily a problem requiring intervention but warranting attention and treatment. As the condition progresses and worsens, cases that were initially flexible often become rigid and evolve with clinical and functional worsening.

There is no ideal and clear treatment algorithm to address PCDF deformities, and treatment must be individualized.

In general, surgical intervention for PCDF improves functional performance, but more studies are needed to demonstrate the reliability and durability of these corrections.[27]

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Conflict of Interests
The authors have no conflict of interests to declare.

References

1 Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. Clin Orthop Relat Res 1989;(239):196–206
2 Myerson MS. Adult acquired flatfoot deformity: treatment of dysfunction of the posterior tibial tendon. Instr Course Lect 1997;46:393–405
3 Bluman EM, Title CI, Myerson MS. Posterior tibial tendon rupture: a refined classification system. Foot Ankle Clin 2007;12(02): 233–249, v
4 Li S, Zhu M, Gu W, et al. Diagnostic Accuracy of the Progressive Collapsing Foot Deformity (PCFD) Classification. Foot Ankle Int 2022;43(06):800–809
5 Deland JT, de Asla RJ, Sung IH, Ernberg LA, Potter HG. Posterior tibial tendon insufficiency: which ligaments are involved? Foot Ankle Int 2005;26(06):427–435
6 Schlickewei C, Barg A. Calcaneal Osteotomies in the Treatment of Progressive Collapsing Foot Deformity. What are the Restrictions for the Holy Grail? Foot Ankle Clin 2021;26(03):473–505
7 Myerson MS, Thordarson DB, Johnson JE, et al. Classification and Nomenclature: Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1271–1276
8 Brodell JD Jr, MacDonald A, Perkins JA, Deland JT, Oh I. Deltoid-Spring Ligament Reconstruction in Adult Acquired Flatfoot Deformity With Medial Peritalar Instability. Foot Ankle Int 2019;40(07):753–761
9 Barg A, Amendola RL, Henninger HB, Kapron AL, Saltzman CL, Anderson AE. Influence of Ankle Position and Radiographic Projection Angle on Measurement of Supramalleolar Alignment on the Anteroposterior and Hindfoot Alignment Views. Foot Ankle Int 2015;36(11):1352–1361
10 de Cesar Netto C, Myerson MS, Day J, et al. Consensus for the Use of Weightbearing CT in the Assessment of Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1277–1282
11 de Cesar Netto C, Silva T, Li S, et al. Assessment of Posterior and Middle Facet Subluxation of the Subtalar Joint in Progressive Flatfoot Deformity. Foot Ankle Int 2020;41(10):1190–1197
12 Lintz F, Welck M, Bernasconi A, et al. 3D Biometrics for Hindfoot Alignment Using Weightbearing CT. Foot Ankle Int 2017;38(06): 684–689
13 de Cesar Netto C, Bang K, Mansur NS, et al. Multiplanar Semiautomatic Assessment of Foot and Ankle Offset in Adult Acquired Flatfoot Deformity. Foot Ankle Int 2020;41(07):839–848
14 de Cesar Netto C, Deland JT, Ellis SJ. Guest Editorial: Expert Consensus on Adult-Acquired Flatfoot Deformity. Foot Ankle Int 2020;41(10):1269–1271
15 Griner PF, Mayewski RJ, Mushlin AI, Greenland P. Selection and interpretation of diagnostic tests and procedures. Principles and applications. Ann Intern Med 1981;94(4 Pt 2):557–592
16 Bossuyt PM, Reitsma JB, Bruns DE, et al; Standards for Reporting of Diagnostic Accuracy. Toward complete and accurate reporting of studies of diagnostic accuracy. The STARD initiative. Am J Clin Pathol 2003;119(01):18–22
17 Lee HY, Barbachan Mansur NS, Lalevée M, et al; Progressive Collapsing Foot Deformity Consensus Group. Intra- and Interobserver Reliability of the New Classification System of Progressive Collapsing Foot Deformity. Foot Ankle Int 2022;43(04):582–589
18 Herchenröder M, Wilfling D, Steinhäuser J. Evidence for foot orthoses for adults with flatfoot: a systematic review. J Foot Ankle Res 2021;14(01):57
19 Lintz F, de Cesar Netto C. Is Advanced Imaging a Must in the Assessment of Progressive Collapsing Foot Deformity? Foot Ankle Clin 2021;26(03):427–442
20 C Schon L,de Cesar Netto C, Day J, et al. Consensus for the Indication of a Medializing Displacement Calcaneal Osteotomy in the Treatment of Progressive Collapsing Foot Deformity. Foot Ankle Int 2020;41(10):1282–1285
21 Chien BY, Greisberg JK, Arciero E. Spring Ligament Reconstruction for Progressive Collapsing Foot Deformity: Contemporary Review. Foot Ankle Int 2023;44(08):796–809
22 Krautmann K, Kadakia AR. Spring and Deltoid Ligament Insufficiency in the Setting of Progressive Collapsing Foot Deformity. An Update on Diagnosis and Management. Foot Ankle Clin 2021;26 (03):577–590
23 Obey MR, Johnson JE, Backus JD. Managing Complications of Foot and Ankle Surgery: Reconstruction of the Progressive Collapsing Foot Deformity. Foot Ankle Clin 2022;27(02):303–325
24 Nery C, Lemos AVKC, Raduan F, Mansur NSB, Baumfeld D. Combined Spring and Deltoid Ligament Repair in Adult-Acquired Flatfoot. Foot Ankle Int 2018;39(08):903–907

25 De Cesar Netto C, Ahrenholz S, Iehl C, et al. Lapicotton technique in the treatment of progressive collapsing foot deformity. J Foot Ankle 2020;14(03):301–308
26 Gross CE, Jackson JB 3rd. The Importance of the Medial Column in Progressive Collapsing Foot Deformity: Osteotomies and Stabilization. Foot Ankle Clin 2021;26(03):507–521
27 Estes W, Syal A, Latt LD. Biomechanical Effects of Surgical Reconstruction for Flexible Progressive Collapsing Foot Deformity: A Systematic Review. [published online ahead of print, 2022 Dec 13] Foot Ankle Spec 2022;•••:19386400221139335