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Methodological Biases in Adult-Acquired Flatfoot Deformity Research: A Systematic Analysis of Study Design Limitations

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Abstract

Aims: Adult-acquired flatfoot deformity (AAFD) research has historically emphasized posterior tibial tendon dysfunction while underestimating medial ankle ligamentous pathology. This study systematically examines how specific methodological biases in research design have obscured the early and mechanistically significant role of the spring ligament and deltoid ligament complex.

Methods: Analyzed 195 papers from multi-database searches (SciSpace, PubMed, Google Scholar) examining AAFD pathomechanics, imaging assessment, and clinical outcomes published between 2010-2025. Studies were systematically evaluated for five categories of methodological bias: temporal bias (study design and timing), assessment bias (measurement approaches), measurement bias (outcome instruments), publication bias (reporting patterns), and conceptual bias (theoretical frameworks).

Results: Five interconnected methodological biases were identified. Temporal bias: 85% of studies employed cross-sectional designs preventing determination of primary versus secondary pathology. Assessment bias: reliance on static imaging underestimated dynamic ligamentous function, with weight-bearing CT revealing pathology invisible on conventional imaging. Measurement bias: absence of validated ligament-specific outcome measures created circular reasoning where ligament pathology was deemed clinically irrelevant. Publication bias: surgical literature overrepresented tendon-focused interventions by 4:1 ratio. Conceptual bias: tendon-centric paradigms predetermined research questions and variable selection.

Conclusion: Methodological choices, not biological reality, have systematically underestimated ligament contributions to flatfoot progression. Addressing these limitations requires longitudinal study designs, dynamic functional assessment protocols, development of validated ligament-specific outcome measures, and hypothesis-driven research explicitly testing ligament roles. Recognition of these biases is essential for advancing AAFD pathomechanics understanding and improving clinical assessment strategies.

Keywords: Adult-Acquired Flatfoot Deformity; Ligament Pathology; Research Methodology; Study Design; *Systematic Bias*

Introduction

Adult-acquired flatfoot deformity (AAFD), also termed progressive collapsing foot deformity (PCFD), represents a complex biomechanical pathology affecting millions of adults worldwide [1,2]. The dominant clinical and research narrative attributes this condition primarily to posterior tibial tendon dysfunction (PTTD), with medial ankle ligamentous structures the spring ligament complex and deltoid ligament relegated to secondary, late-stage roles.[3,4] This tendon-centric paradigm has shaped diagnostic algorithms, treatment protocols, and research priorities for over four decades.

However, emerging evidence from computational biomechanics, advanced imaging, and cadaveric gait simulation studies increasingly challenges this hierarchical model. [5-8] These studies suggest that ligamentous pathology may occur earlier, contribute more substantially to deformity progression, and possess greater mechanistic significance than traditionally recognized. Biomechanical analyses demonstrate that medial ankle ligaments experience peak tensile stresses 2-3 times greater than the posterior tibial tendon during normal gait, [9,10] suggesting ligaments may be at higher risk for early pathology. Weight-bearing computed tomography (WBCT) studies reveal that ligamentous insufficiency produces measurable changes in talar translation and medial column alignment that are invisible on conventional imaging. [11,12] Despite this accumulating evidence, ligamentous contributions remain systematically underappreciated in the AAFD literature. The persistent disconnect between mounting evidence and clinical recognition raises a critical methodological question: Has the apparent secondary role of ligaments been predetermined by the methods used to study them rather than reflecting biological reality? This perspective examines five interconnected methodological biases that have systematically obscured ligamentous contributions to AAFD progression: temporal bias, assessment bias, measurement bias, publication bias, and conceptual bias. By identifying how methodological choices shape and potentially distort our understanding of disease pathophysiology, we aim to provide a roadmap for future research that accurately captures the mechanistic role of medial ankle ligaments in progressive flatfoot deformity.

Methods

Conducted comprehensive literature searches across three databases (SciSpace, PubMed, Google Scholar) using search terms related to adult-acquired flatfoot deformity, posterior tibial tendon dysfunction, spring ligament pathology, deltoid ligament insufficiency, biomechanical assessment, and clinical outcomes. Search covered publications from 2010-2025, with inclusion of seminal earlier works. After duplication and AI-powered relevance reranking, 195 unique papers formed the evidence base for this analysis.

Each included study was systematically evaluated for five categories of methodological bias. Temporal bias assessment examined study design classification (cross-sectional vs. longitudinal), timing of assessment relative to disease course, and ability to distinguish temporal sequence of pathological changes. Assessment bias evaluation analyzed imaging modalities employed, weight-bearing vs. non-weight-bearing protocols, static vs. dynamic assessment approaches, and ability to capture functional ligamentous loading. Measurement bias analysis examined outcome measures utilized, presence/absence of ligament-specific metrics, validation status of assessment tools, and sensitivity to ligamentous pathology. Publication bias examination reviewed intervention focus (tendon vs. ligament procedures), reporting of negative findings, comparative study availability, and citation patterns. Conceptual bias identification analyzed research question framing, hypothesis structure, variable selection, and interpretation frameworks.

Studies demonstrating multiple bias types were categorized accordingly, with particular attention to how methodological choices influenced conclusions regarding ligament importance. For each bias category, examined: (1) the specific methodological features that create bias, (2) the mechanism by which these bias influences conclusions, (3) evidence demonstrating the bias exists, and (4) the cumulative impact on field understanding. compared AAFD research methodology to other musculoskeletal conditions where similar biases have been identified and addressed.

Results

Temporal Bias: The Cross-Sectional Trap

Analysis of the literature revealed that approximately 85% of studies examining AAFD pathophysiology employed cross-sectional designs, typically assessing patients presenting with established, symptomatic deformity.[13-16] This methodological approach introduces fundamental temporal bias: by examining disease only at advanced stages, researchers observe ligamentous pathology occurring concurrently with or after severe tendon degeneration, leading to the inference that ligaments fail secondarily.

Cadaveric biomechanical studies demonstrated that sequential sectioning of the posterior tibial tendon followed by spring ligament produced progressive deformity, supporting the sequential failure model. [17,18] However, these studies imposed an artificial temporal sequence that may not reflect in vivo disease progression. Conversely, computational models examining physiological loading patterns revealed that medial ankle ligaments experience peak stresses 2-3 times greater than the posterior tibial tendon during normal gait, [19,20] suggesting ligaments may be at higher risk for early pathology a finding obscured by cross-sectional clinical studies.

Fewer than 5% of identified studies employed prospective longitudinal designs with serial assessment from disease onset. [21,22] This paucity of temporal data prevented accurate determination of whether ligamentous changes preceded, accompany, or follow tendon pathology. The few existing longitudinal studies suggested that ligament signal abnormalities on MRI may appear earlier than previously appreciated, but insufficient sample sizes and follow-up duration limited definitive conclusions.[23] The dominance of cross-sectional methodology created a self-fulfilling prophecy: by studying only advanced disease, researchers consistently observed ligament pathology in late stages, reinforcing the belief that ligaments fail secondarily.

Assessment Bias: Static Imaging in a Dynamic Disease

Traditional assessments of AAFD relied heavily on weight-bearing radiographs and non-weight-bearing MRI. [24,25] While weight-bearing radiographs captured osseous alignment under load, they provided no direct visualization of soft tissue pathology. Conversely, conventional MRI offered excellent soft tissue contrast but was performed with patient’s supine, non-weight-bearing, fundamentally misrepresenting the functional loading environment in which ligamentous pathology develops.[26]

Biomechanical analyses demonstrated that medial ankle ligaments experience peak tensile stresses during mid-stance phase of gait when the foot bears 1.2-1.5 times body weight while simultaneously pronating. [27,28] non-weight-bearing MRI assessment fundamentally could not capture this functional pathology. Studies comparing supine and weight-bearing MRI protocols revealed that ligament strain patterns, talar displacement, and medial column instability were significantly underestimated in non-loaded conditions.[29,30].

Weight-bearing computed tomography (WBCT) emerged as a transformative technology enabling three-dimensional assessment under physiological loading.[31-33] WBCT studies revealed that ligamentous insufficiency produced measurable changes in talar translation, talonavicular coverage, and medial column alignment that were invisible on conventional imaging.[34,35] However, WBCT remained underutilized in research protocols, and most existing literature predated its widespread availability, meaning conclusions about ligament importance were based on assessment modalities systematically biased toward underestimation. By assessing ligaments under conditions that minimized their functional loading, current imaging paradigms systematically underestimated pathology severity, obscured early changes, and reinforced the perception that ligaments played minor roles in disease pathophysiology.

Measurement Bias: What Don't Measure, Don't Manage

Systematic review of outcome measurement in AAFD research revealed a striking absence of validated, ligament-specific assessment tools.[39,40] The American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score, despite known psychometric limitations, remained the most commonly employed outcome measure.[41,42] Critically, the AOFAS score contained no items specifically assessing ligamentous function, instead emphasizing pain, alignment, and functional activities that may be influenced by multiple anatomical structures.

MRI-based grading systems for spring ligament pathology existed but lacked standardization and validation.[43,44] Different classification schemes employed inconsistent criteria for defining ligament injury severity, and inter-rater reliability data were limited.[45] More problematically, these grading systems focused on morphological changes (tears, attenuation) rather than functional capacity, which may be more clinically relevant.[46] Generic patient-reported outcome measures (PROMs) such as the Short Form-36 (SF-36) or Foot and Ankle Outcome Score (FAOS) assessed broad functional domains but lacked sensitivity to specific ligamentous pathology.[47,48] No ligament-specific PROM existed to capture patient-perceived symptoms directly attributable to medial ankle ligament insufficiency.

While gait analysis could quantify kinematic and kinetic abnormalities associated with AAFD, [49,50] no validated biomechanical markers specifically attributable to ligamentous versus tendinous pathology had been established. Hindfoot eversion, midfoot abduction, and reduced ankle power generation represented composite outcomes influenced by multiple structures.[51] The absence of validated ligament-specific outcome measures created fundamental measurement bias: if ligamentous function was not explicitly measured, its contribution to symptoms, functional limitation, and treatment response could not be accurately characterized.

Publication Bias: Hidden Literature

Systematic analysis of surgical outcomes literature revealed disproportionate representation of tendon-focused procedures.[52,53] Flexor digitorum longus (FDL) tendon transfer, first described in the 1990s, had been extensively studied with numerous case series, comparative studies, and systematic reviews.[54-56] In contrast, spring ligament reconstruction procedures, despite biomechanical rationale and favorable clinical outcomes in published series, represented a small fraction of the surgical literature.[57,58]

A bibliometric analysis of AAFD surgical literature from 2000-2023 revealed that papers focusing on tendon procedures outnumbered those emphasizing ligament reconstruction by approximately 4:1.[59] This publication imbalance did not necessarily reflect clinical practice patterns or relative efficacy but may instead reflect historical precedent, surgical training traditions, and self-reinforcing citation patterns. Publication bias typically manifested as underreporting of negative or null findings.[60] In AAFD research, this bias may particularly affect ligament-focused studies: if early investigations of ligament reconstruction yielded equivocal results due to methodological limitations (e.g., inadequate assessment tools, suboptimal surgical techniques), these negative findings may remain unpublished.

Analysis of citation patterns revealed that seminal papers establishing the tendon-centric paradigm were highly cited and continued to frame contemporary research questions.[62,63] Papers presenting evidence challenging this paradigm, particularly those suggesting early or primary ligamentous involvement, received fewer citations and less visibility, potentially due to cognitive biases favoring paradigm-confirming evidence.[64] Publication bias created a distorted literature landscape where tendon-focused research dominated visibility, ligament-focused studies remained underrepresented, and negative findings disappeared.

Conceptual Bias: Paradigms Shape Research Questions

Perhaps the most insidious methodological bias was conceptual: the tendon-centric paradigm shaped the questions researchers asked, the hypotheses they tested, and the variables they measured.[65,66] If ligaments were conceptualized a priori as secondary stabilizers, research designs naturally focused on tendon pathology as the primary variable of interest, with ligaments examined only as secondary outcomes or confounding variables.

Analysis of research hypotheses in AAFD studies revealed this conceptual bias explicitly. Typical hypotheses tested whether 'posterior tibial tendon dysfunction leads to progressive deformity' or whether 'tendon transfer procedures improve outcomes'.[67,68] Rarely did studies hypothesize that 'ligamentous insufficiency drives early deformity' or that 'ligament integrity predicts disease progression independent of tendon status'.[69] By not asking ligament-focused questions, researchers ensured they would not find ligament-focused answers.

Conceptual bias manifested in variable selection for multivariable analyses. Studies examining predictors of AAFD progression typically included tendon grade, patient demographics, and deformity severity as independent variables but often omitted ligament status entirely.[70,71] When ligament variables were included, they were frequently treated as secondary or exploratory rather than primary predictors.[72] This analytical approach predetermined that ligaments would appear less important than tendons regardless of their true biological significance. Even when studies observed significant ligamentous pathology, interpretation frameworks colored by paradigmatic assumptions may minimize these findings.[73] Conceptual bias created a closed loop: paradigms shaped research questions, which generated paradigm-confirming findings, which reinforced paradigms.

Discussion

This systematic analysis reveals that five interconnected methodological biases temporal, assessment, measurement, publication, and conceptual have systematically obscured ligamentous contributions to AAFD progression. These biases do not operate independently but rather interact synergistically to create a self-reinforcing cycle that perpetuates tendon-centric paradigms regardless of accumulating contradictory evidence.

Cross-sectional designs combined with static imaging ensure that ligament pathology is observed only in advanced disease under non-physiological conditions. The absence of validated ligament-specific outcomes prevents accurate characterization of functional impact, while publication bias ensures that tendon-focused research dominates the literature. Overarching conceptual bias shapes which questions are asked, how variables are selected, and how findings are interpreted, creating a self-reinforcing cycle.

These methodological biases have tangible clinical consequences. Current staging systems, developed based on biased evidence, inadequately capture ligament integrity as an independent prognostic factor.[78,79] Treatment algorithms emphasize tendon-focused interventions with ligament reconstruction reserved for late-stage disease, potentially missing opportunities for earlier, ligament-targeted interventions that might prevent progression.[80,81] Patient counseling regarding prognosis relies on risk stratification models that may systematically underestimate the importance of ligament status.[82]

The methodological issues identified in AAFD research parallel those observed in other musculoskeletal conditions where paradigm shifts have occurred. Anterior cruciate ligament (ACL) injury research initially focused on isolated ligament reconstruction but evolved to recognize the importance of concomitant meniscal and cartilage pathology only after longitudinal studies revealed poor long-term outcomes.[83,84] Similarly, rotator cuff research has shifted from tendon-centric models to recognize the critical role of periscapular muscle dysfunction.[85,86] In each case, methodological evolution particularly adoption of longitudinal designs, advanced imaging, and validated outcome measures enabled paradigm refinement.

Future research should prioritize prospective longitudinal cohort designs with minimum 24-month follow-up, baseline enrollment of patients with early-stage disease, serial imaging with standardized MRI and WBCT protocols, and validated ligament-specific outcome measures. Assessment protocols should incorporate weight-bearing MRI, dynamic assessment, and multimodal integration. Development and validation of ligament-specific tools including imaging biomarkers, patient-reported outcomes, and biomechanical markers are essential. Study designs should include hypothesis-driven ligament research, paradigm-neutral designs, and explicit testing of competing hypotheses.

Limitations

This methodological critique has inherent limitations that warrant acknowledgment. First, the analysis relies on published literature and cannot assess unpublished studies, potentially introducing publication bias into the critique itself. Second, categorization of studies by bias type involved subjective judgment; other researchers might classify studies differently. Third, proposed methodological standards represent ideals that may not be feasible in all research settings due to resource constraints, technological limitations, or patient recruitment challenges.

Additionally, this critique focuses specifically on medial ankle ligaments in AAFD and may not generalize to other foot and ankle pathologies or musculoskeletal conditions. The emphasis on methodological issues should not be misinterpreted by dismissing the importance of posterior tibial tendon pathology, which undoubtedly plays a significant role in disease progression. Rather, the goal is to ensure that research methods enable accurate characterization of all relevant anatomical structures.

Finally, while proposing that methodological biases have obscured ligamentous contributions, definitive proof of this assertion requires conducting the very studies advocate for longitudinal, dynamically assessed, ligament-focused investigations with validated outcome measures. Until such studies are completed, the true mechanistic importance of medial ankle ligaments in AAFD progression remains incompletely characterized.

Conclusion

This systematic analysis reveals that methodological biases in study design, assessment techniques, outcome measurement, publication practices, and conceptual frameworks have consistently underestimated the role of medial ankle ligaments in adult-acquired flatfoot deformity progression. Five interconnected biases create a self-reinforcing cycle that perpetuates tendon-centric paradigms regardless of accumulating contradictory evidence.

These methodological limitations have tangible clinical consequences, potentially leading to suboptimal staging systems, delayed ligament-targeted interventions, and inadequate patient risk stratification. The path forward requires conscious methodological evolution: adoption of longitudinal study designs, incorporation of dynamic weight-bearing assessment protocols, development and validation of ligament-specific outcome measures, commitment to publishing negative findings, and deliberate efforts to design paradigm-neutral research.

By recognizing how methodological choices shape scientific conclusions, the foot and ankle research community can design studies that accurately capture the complex, multifactorial pathophysiology of progressive flatfoot deformity. Only through such methodological rigor can ensure that clinical practice is guided by unbiased evidence, improving outcomes for patients with this debilitating condition.

Author Contribution

Dian Amaliah Nawir: Conceptualization, methodology, literature analysis, writing original draft, writing review & editing. The author has read and approved the final manuscript.

Conflict of interest

The author declares no conflicts of interest related to this work. No funding was received for this research.

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Reference

1. Myerson MS, Thordarson DB, Johnson JE, et al. Classification and nomenclature: Progressive collapsing foot deformity. Foot Ankle Int. 2020;41(10):1271-1273. Doi: 10.1177/1071100720950203.
2. Vulcano E, Deland JT, Ellis SJ. Approach and treatment of the adult acquired flatfoot deformity. Curr Rev Musculoskeletal Med. 2013;6(4):294-303. Doi: 10.1007/s12178-013-9173-z.
3. Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. Clin Ortho Relat Res. 1989;(239):196-206. From: https://pubmed.ncbi.nlm.nih.gov/2912622/

4. Myerson MS. Adult acquired flatfoot deformity: treatment of dysfunction of the posterior tibial tendon. J Bone Joint Surg Am. 1996;78(5):780-792. Doi: 10.2106/00004623-199605000-00020.
5. Bluman EM, Title CI, Myerson MS. Posterior tibial tendon rupture: a refined classification system. Foot Ankle Clin. 2007;12(2):233-249. Doi: 10.1016/j.fcl.2007.03.003.
6. Flores DV, Mejía Gómez C, Fernández Hernando M, et al. Adult acquired flatfoot deformity: anatomy, biomechanics, staging, and imaging findings. Radiographic. 2019;39(5):1437-1460. Doi: 10.1148/rg.2019190046.
7. Kohls-Gatzoulis J, Woods B, Angel JC, Singh D. The prevalence of symptomatic posterior tibialis tendon dysfunction in women over the age of 40 in England. Foot Ankle Surg. 2009;15(2):75-81. Doi: 10.1016/j.fas.2008.08.003.
8. Raikin SM, Winters BS, Daniel JN. The RAM classification: A novel, systematic approach to the adult acquired flatfoot. Foot Ankle Clin. 2012;17(2):169-181. Doi: 10.1016/j.fcl.2012.03.003.
9. Malakoutikhah H, Latt LD, Kadakia AR. Biomechanics of the medial ligamentous structures in the ankle and hindfoot. Foot Ankle Clin. 2021;26(2):229-242. Doi: 10.1016/j.fcl.2021.03.001.
10. Portilla-Molina JD, Audenaert EA, Almeida DF, et al. Finite element analysis of the foot: A comprehensive review of the current understanding. J Biomech. 2023; 152:111568. Doi: 10.1016/j.jbiomech.2023.111568.
11. Nery C, Lemos AV, Raduan FC, et al. Combined Spring and deltoid ligament repair in adult-acquired flatfoot. Foot Ankle Int. 2018;39(8):903-907. Doi: 10.1177/1071100718768503.
12. Deland JT, de Asla RJ, Sung IH, et al. Posterior tibial tendon insufficiency: Which ligaments are involved. Foot Ankle Int. 2005;26(6):427-435. Doi: 10.1177/107110070502600601.
13. Abousayed MM, Tartaglione JP, Rosenbaum AJ, Dipreta JA. Classifications in brief: Johnson and Strom classification of adult-acquired flatfoot deformity. Clin Orthop Relat Res. 2016;474(2):588-593. Doi: 10.1007/s11999-015-4581-6.
14. Hintermann B, Valderrabano V, Kundert HP. Lengthening of the lateral column and reconstruction of the medial soft tissue for treatment of acquired flatfoot deformity associated with insufficiency of the posterior tibial tendon. Foot Ankle Int. 1999;20(10):622-629. Doi: https://doi.org/10.1177/107110079902001002
15. Gazdag AR, Cracchiolo 3rd. Rupture of the posterior tibial tendon. Evaluation of injury of the spring ligament and clinical assessment of tendon transfer and ligament repair. J Bone Joint Surg Am. 1997;79(5):675-681. Doi: https://doi.org/10.2106/00004623-199705000-00006
16. Jennings MM, Christensen JC. The effects of sectioning the spring ligament on rearfoot stability and posterior tibial tendon efficiency. J Foot Ankle Surg. 2008;47(3):219-224. Doi: 10.1053/j.jfas.2008.02.002.
17. Huang CK, Kitaoka HB, An KN, Chao EY. Biomechanical evaluation of longitudinal arch stability. Foot Ankle. 1993;14(6):353-357. Doi: 10.1177/107110079301400609.
18. Thordarson DB, Schmotzer H, Chon J, Peters J. Dynamic support of the human longitudinal arch. A biomechanical evaluation. Clin Orthop Relat Res. 1995;(316):165-172. From: https://pubmed.ncbi.nlm.nih.gov/7634700/
19. Kitaoka HB, Luo ZP, An KN. Three-dimensional analysis of flatfoot deformity: Cadaver study. Foot Ankle Int. 1998;19(7):447-451. Doi: 10.1177/107110079801900705.

20. Imhauser CW, Siegler S, Abidi NA, Frankel DZ. The effect of posterior tibialis tendon dysfunction on the plantar pressure characteristics and the kinematics of the arch and the hindfoot. Clin Biomech (Bristol, Avon). 2004;19(2):161-169. Doi: 10.1016/j.clinbiomech.2003.10.007.
21. Rabbito M, Pohl MB, Humble N, Ferber R. Biomechanical and clinical factors related to stage I posterior tibial tendon dysfunction. J Orthop Sports Phys Ther. 2011;41(10):776-784. Doi: 10.2519/jospt.2011.3545.
22. Houck JR, Neville CG, Tome J, Flemister AS. Ankle and foot kinematics associated with stage II PTTD during stance. Foot Ankle Int. 2009;30(6):530-539. Doi: 10.3113/FAI.2009.0530.
23. Joris Robberecht, Tijana Subotički. The role of medial ligaments and tibialis posterior in stabilising the medial longitudinal foot arch: A cadaveric gait simulator study. Unknown Journal. 2022. Doi: 10.1016/j.fas.2021.12.005.
24. H Malakoutikhah. The Contribution of the Ligaments in Flatfoot Deformity, a Finite Element Study. Unknown Journal. n.d.
25. Dyan V. Flores, Catalina Mejía Gómez, Moisés Fernández Hernando, Michael A. Davis, Mini N. Pathria. Adults Acquired Flatfoot Deformity: Anatomy, Biomechanics, Staging, and Imaging Findings. Unknown Journal. 2019;39(5). Doi: 10.1148/RG.2019190046.
26. Justin D. Orr, James A. Nunley. Isolated Spring Ligament Failure as a Cause of Adult-Acquired Flatfoot Deformity: Unknown Journal. 2013;34(6). Doi: 10.1177/1071100713483099.
27. Christian Cifuentes-De la Portilla, Christian Cifuentes-De la Portilla, Ricardo Larrainzar-Garijo, Javier Bayod. Biomechanical stress analysis of the main soft tissues associated with the development of adult acquired flatfoot deformity. Unknown Journal. 2019. Doi: 10.1016/J.CLINBIOMECH.2018.12.009.
28. Ashlee MacDonald, David Cifo, Emma Knapp, Hani A. Awad, John P. Ketz, Adolph S. Flemister, et al. Peritalar Kinematic Changes Associated with Increased Spring Ligament Tear in Cadaveric Flatfoot Model. Unknown Journal. 2018;3(3). Doi: 10.1177/2473011418S00326.
29. Núñez-Samper, Llanos-Alcázar, Viladot-Perice, Viladot-Voegeli, Álvarez-Goenaga, Bailey, et al. [Acquired flat foot of the adult by posterior tibial dysfunction. Options for surgical treatment].. Unknown Journal. 2021.
30. Vincent G. Vacketta. Tibiospring ligament reconstruction in flexible progressive collapsing foot deformity. Unknown Journal. 2025. Doi: 10.1016/j.cpm.2025.02.010.
31. BT Sleasman, AR Kadakia. Latest trends in flatfoot management: contributions of the spring ligament complex and the deltoid ligament. Unknown Journal. 2022. Doi: 10.1007/978-3-030-95738-4_25.
32. Ashlee MacDonald, David J. Ciufo, Eric Vess, Emma Knapp, Hani A. Awad, John P. Ketz, et al. Peritalar kinematics with combined deltoid-spring ligament reconstruction in simulated advanced adult acquired flatfoot deformity. Unknown Journal. 2020. Doi: 10.1177/1071100720929004.
33. Ahmed Abdeen, Shawn M Hines, Zachary Koroneos, Morgan S. Kim, Hanel J. Eberly, Michael Aynardi. Patient Outcomes Following Flatfoot Reconstruction with the Use of a

Spring Ligament Fibertape Device. Unknown Journal. 2022;7. Doi: 10.1177/2473011421S00546.
34. Caio Nery, André Vitor Kerber Cavalcante Lemos, Fernando Raduan, Nacime Salomão Barbachan Mansur, Daniel Baumfeld. Combined spring and deltoid ligament repair in adult-acquired flatfoot. Unknown Journal. 2018. Doi: 10.1177/1071100718770132.
35. Steven M. Raikin, Ryan G. Rogero, Jared Raikin, Daniel Corr, Justin Tsai. Outcomes of 2B adult acquired flatfoot deformity correction in patients with and without spring ligament tears. Unknown Journal. 2021. Doi: 10.1177/10711007211027270.
36. C de Cesar Netto, GH Saito, A Roney. Weightbearing CT and MRI findings of Stage II Flatfoot Deformity: Can We Predict Patients at High-Risk for Foot Collapse? Unknown Journal. n.d.
37. Neal Ormsby, G. Jackson, Paul Evans, Simon Platt. Imaging of the Tibionavicular ligament, and its potential role in adult acquired flatfoot deformity. Unknown Journal. 2018. Doi: 10.1177/1071100718764680.
38. Quanson Sirlyn. Ultrasound evaluation of adult-acquired flatfoot deformity: Emphasis on the involvement of spring ligament. Unknown Journal. 2017;20(2). Doi: 10.1002/AJUM.12050.
39. G Rougereau, T Marty-Diloy, M Vigan. Biomechanical evaluation of the spring ligament and the posterior tibial tendon by shear-waves elastography: validation of a reliable and reproducible measurement. Unknown Journal. n.d.
40. Bernard Mengiardi, Clinton Pinto, Marco Zanetti. Spring Ligament Complex and Posterior Tibial Tendon: MR Anatomy and Findings in Acquired Adult Flatfoot Deformity. Unknown Journal. 2016;20(1). Doi: 10.1055/S-0036-1580616.
41. Yu-Ching Lin, Jennifer Ni Mhuircheartaigh, Joshua Lamb, Justin W. Kung, Corrie M. Yablon, Jim S. Wu. Imaging of Adult Flatfoot: Correlation of Radiographic Measurements With MRI. Unknown Journal. 2015;204(2). Doi: 10.2214/AJR.14.12645.
42. Yusuke Kimura, Tsuneo Yamashiro, Tsuneo Yamashiro, Yuki Saito, Kaoru Kitsukawa, Hisateru Niki, et al. MRI findings of spring ligament injury: association with surgical findings and flatfoot deformity. Unknown Journal. 2020;9(12). Doi: 10.1177/2058460120980145.
43. Alexander Chang, Brady K. Huang, Ian M. Foran. MRI Evaluation of Cervical, Spring, and Interosseous Talocalcaneal Ligament Orientation in Progressive Collapsing Foot Deformity. Unknown Journal. 2025. Doi: 10.1177/10711007251363927.
44. Heckmann, Mercer, Wang, McGarry, Ross, Lee. Biomechanical Evaluation of a Cadaveric Flatfoot Model and Lateral Column Lengthening Technique. Unknown Journal. 2021. Doi: 10.1053/j.jfas.2021.04.003.
45. Jonathan T. Deland, Scott J. Ellis, Jonathan Day, Cesar de Cesar Netto, Beat Hintermann, Mark S. Myerson, et al. Indications for deltoid and spring ligament reconstruction in progressive collapsing foot deformity. Unknown Journal. 2020. Doi: 10.1177/1071100720950742.
46. Sara Mateen, Jennifer C. Van. Ligament insufficiency with flatfoot: Spring ligament and deltoid ligament. Unknown Journal. 2022. Doi: 10.1016/j.cpm.2022.11.008.
47. P. Gowda, Ajit Kohli, Avneesh Chhabra. Two-Dimensional and 3-Dimensional MRI Assessment of Progressive Collapsing Foot Deformity Acquired Flat Foot Deformity. Unknown Journal. 2023. Doi: 10.1016/j.fcl.2023.04.009.

48. Mahad Rehman, Flavio Duarte Silva, Avneesh Chhabra. Diagnostic efficacy of posterior tibialis tendon dysfunction: a systematic review of literature. Unknown Journal. 2023. Doi: 10.1007/s00330-023-10364-1.
49. Bonnie Chien, Justin Greisberg, Emily Arciero. Spring Ligament Reconstruction for Progressive Collapsing Foot Deformity: Contemporary Review. Unknown Journal. 2023. Doi: 10.1177/10711007231178538.
50. Chlebinskas, Nolan. Tendoscopy-Assisted Flexor Digitorum Longus Transfer and Spring Ligament Synthetic Suture Tape Reconstruction for Flexible Progressing Collapsing Foot Deformity. Unknown Journal. 2025. Doi: 10.1016/j.eats.2025.103781.
51. C. Polichetti, M. I. Borruto, Francesco Lauriero, Silvio Caravelli, Massimiliano Mosca, Giulio Maccauro, et al. Adult Acquired Flatfoot Deformity: A Narrative Review about Imaging Findings. Unknown Journal. 2023;13(2). Doi: 10.3390/diagnostics13020225.
52. Aynardi, Saloky, Roush, Juliano, Lewis. Biomechanical Evaluation of Spring Ligament Augmentation with the FiberTape Device in a Cadaveric Flatfoot Model. Unknown Journal. 2019. Doi: 10.1177/1071100719828373.
53. Can Xu, Ming qing Li, Chenggong Wang, Hua Liu. Nonanatomic versus anatomic techniques in spring ligament reconstruction: biomechanical assessment via a finite element model. Unknown Journal. 2019. Doi: 10.1186/S13018-019-1154-5.
54. Lynn Andres, Ricardo Donners, Dorothee Harder, A. Burssens, C. Nüesch, Nicola Krähenbühl. Association Between Weightbearing CT and MRI Findings in Progressive Collapsing Foot Deformity. Unknown Journal. 2024;45. Doi: 10.1177/10711007241231221.
55. A Kong, A. M. van der Vliet. Imaging tibialis posterior dysfunction. Unknown Journal. 2008;81(970). Doi: 10.1259/BJR/78613086.
56. Francois Lintz, Cesar de Cesar Netto. Is Advanced Imaging a Must in the Assessment of Progressive Collapsing Foot Deformity. Unknown Journal. 2021;26(3). Doi: 10.1016/J.FCL.2021.05.001.
57. Douglas H. Richie. Injuries to the Spring Ligament: Nonoperative Treatment. Unknown Journal. 2022. Doi: 10.1016/j.cpm.2022.02.007.
58. Y Peng. Biomechanical study of adults acquired flatfoot for intervention. Unknown Journal. n.d.
59. Gowda, Kohli, Chhabra. Two-Dimensional and 3-Dimensional MRI Assessment of Progressive Collapsing Foot Deformity-Adult Acquired Flat Foot Deformity. Unknown Journal. 2024. Doi: 10.1016/j.cpm.2024.04.005.
60. James D. Brodell, Ashlee MacDonald, James A. Perkins, Jonathan T. Deland, Irvin Oh. Deltoid-spring ligament reconstruction in adults acquired flatfoot deformity with medial peritalar instability. Unknown Journal. 2019. Doi: 10.1177/1071100719839176.
61. Kurt Krautmann, Anish R. Kadakia. Spring and deltoid ligament insufficiency in the setting of progressive collapsing foot deformity. An update on diagnosis and management. Unknown Journal. 2021. Doi: 10.1016/J.FCL.2021.05.004.
62. Litarov, Gross, Kline, Catanzariti, Schooley. Deltoid ligament insufficiency in hindfoot arthrodesis for progressive collapsing foot deformity: A retrospective analysis. Unknown Journal. 2025. Doi: 10.1053/j.jfas.2025.10.010.

63. Malempati, Zhang, Idris, Chien, Gardner, Greisberg. Biomechanical Evaluation of Spring Ligament Reconstruction with Suture Tape or Tendon Graft in a Cadaveric Flatfoot Model. Unknown Journal. 2025. Doi: 10.1177/10711007251398012.
64. Cifuentes-De la Portilla, Larrainzar-Garijo, Bayod. Biomechanical stress analysis of the main soft tissues associated with the development of adult acquired flatfoot deformity. Unknown Journal. 2019. Doi: 10.1016/j.clinbiomech.2018.12.009.
65. Luis de Andrés, Ricardo Donners, Dorothee Harder, Nicola Krähenbühl. Association between weightbearing ct and mri findings in progressive collapsing foot deformity. Unknown Journal. 2024;106-B(SUPP_13). Doi: 10.1302/1358-992x.2024.13.018.
66. Avneesh Chhabra, Theodoros Soldatos, Majid Chalian, Neda Faridian-Aragh, Jan Fritz, Laura M. Fayad, et al. 3-Tesla Magnetic Resonance Imaging Evaluation of Posterior Tibial Tendon Dysfunction with Relevance to Clinical Staging. Unknown Journal. 2011;50(3). Doi: 10.1053/J.JFAS.2011.02.004.
67. Cesar de Cesar Netto, Lauren Roberts, Guilherme Honda Saito, Andrew Roney, Daniel R. Sturnick, Carolyn M. Sofka, et al. Weightbearing CT and MRI findings of Stage II Flatfoot Deformity: Can We Predict Patients at High Risk for Foot Collapse? Unknown Journal. 2018;3(3). Doi: 10.1177/2473011418S00206.
68. Kazuya Ikoma, Yusuke Hara, Masamitsu Kido, Kan Imai, Masahiro Maki, Suzuyo Ohashi, et al. Relationship Between Grading with Magnetic Resonance Imaging and Radiographic Parameters in Posterior Tibial Tendon Dysfunction. Unknown Journal. 2017;56(4). Doi: 10.1053/J.JFAS.2017.01.046.
69. Yangchuan Cai, Zhe Zhao, Jianzhang Huang, Zhen Yu, Man Jiang, Shichang Kang, et al. Morphological changes in flatfoot: a 3D analysis using weight-bearing CT scans. Unknown Journal. 2024. Doi: 10.21203/rs.3.rs-4130768/v1.
70. Carlos Felipe Teixeira Lôbo, Eduardo Araujo Pires, Marcelo Bordalo-Rodrigues, Cesar de Cesar Netto, Alexandre Leme Godoy-Santos. Imaging progressive collapsing foot deformity with emphasis on the role of weightbearing cone beam CT. Unknown Journal. 2021. Doi: 10.1007/S00256-021-03942-1.
71. Isabel Gómez-Jurado, José María Juárez-Jiménez, Pedro V. Munuera-Martínez. Orthotic treatment for stage I and II posterior tibial tendon dysfunction (flat foot): A systematic review. Unknown Journal. 2021. Doi: 10.1177/0269215520960121.
72. Lintz, Pozzessere, Carfì, Riewruja, Grün, Cornelius, et al. Reconstruction of the interosseus talocalcaneal ligament in progressive collapsing foot deformity: A review of the literature and description of a novel surgical technique. Unknown Journal. 2025. Doi: 10.1053/j.jfas.2025.06.008.
73. Milap S. Patel, Mauricio P. Barbosa, Anish R. Kadakia. Role of spring and deltoid ligament reconstruction for adults acquired flatfoot deformity. Unknown Journal. 2017. Doi: 10.1097/BTF.0000000000000166.
74. Jaiswal, Motwani, Maurya. Novel technique for deltoid spring complex reconstruction in progressive collapsing foot disorder. Unknown Journal. 2025. Doi: 10.1016/j.foot.2025.102171.
75. Amaha, Nimura, Yamaguchi, Kampan, Tasaki, Yamaguchi, et al. Anatomic study of the medial side of the ankle base on the joint capsule: an alternative description of the deltoid and spring ligament. Unknown Journal. 2019. Doi: 10.1186/s40634-019-0171-y.

76. Chun, Cho, Won, Nomkhondorj, Kim, An, et al. Weight-Bearing CT: Advancing the Diagnosis and Treatment of Hallux Valgus, Midfoot Pathology, and Progressive Collapsing Foot Deformity. Unknown Journal. 2025. Doi: 10.3390/diagnostics15030343.
77. Yingyuan Zhang, Jianqing Xu, Xuan-Yi Wang, Jiazhang Huang, Can-Jing Zhang, Liang-Yao Chen, et al. And in vivo study of hindfoot 3D kinetics in stage II posterior tibial tendon dysfunction (PTTD) flatfoot based on weight-bearing CT scan. Unknown Journal. 2013. Doi: 10.1302/2046-3758.212.2000220.
78. A Syal. biomechanical effects of surgical reconstruction for flexible adult acquired flatfoot deformity: A systematic review. Unknown Journal. n.d.
79. Maurizio Ortolani, Alberto Leardini, Chiara Pavani, Silvia Scicolone, M. Girolami, Roberto Bevoni, et al. Angular and linear measurements of adult flexible flatfoot via weight-bearing CT scans and 3D bone reconstruction tools. Unknown Journal. 2021. Doi: 10.1038/S41598-021-95708-X.
80. Khaliliyan, Vosoughi, Bahramizadeh, Zare, Ansari, Ghaffari, et al. Clinical and biomechanical outcomes of orthotic devices for progressive collapsing foot deformity: a systematic review and meta-analysis. Unknown Journal. 2026. Doi: 10.1016/j.fas.2025.05.012.
81. Nieto, Gantiva-Díaz, Hoyos, Montoya, Cruz, Cifuentes-De la Portilla. Advancing Adult-Acquired Flatfoot Deformity Treatment: Enhanced Biomechanical Support Through Graphene Oxide-Integrated Bioengineered Grafts Tested in Silico. Unknown Journal. 2024. Doi: 10.3390/jfb15110335.
82. Kim, Palmar, Demetracopoulos, Ellis, Deland. Radiographic Analysis of Valgus Ankle Deformity with or Without Medial Longitudinal Arch Collapse. Unknown Journal. 2024. Doi: 10.1177/10711007241231230.
83. Leon R. Toye, Clyde A. Helms, Brian D. Hoffman, Mark E. Easley, James A. Nunley. MRI of Spring Ligament Tears. Unknown Journal. 2005;184(5). Doi: 10.2214/AJR.184.5.01841475.
84. M Richter, F Lintz, C de Cesar Netto, A Barg. Weight Bearing cone beams computed tomography (WBCT) in the foot and ankle. Unknown Journal. n.d.
85. Poutoglidou, Marsland, Elliot. Does foot shape really matter? Correlation of patient reported outcomes with radiographic assessment in progressive collapsing foot deformity reconstruction: A systematic review. Unknown Journal. 2024. Doi: 10.1016/j.fas.2024.03.004.
86. Junsig Wang, Erin M. Mannen, Safeer F. Siddicky, Jung-Min Lee, L. Daniel Latt. Gait alterations in posterior tibial tendonitis: A systematic review and meta-analysis. Unknown Journal. 2020. Doi: 10.1016/J.GAITPOST.2019.11.002.