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Could Failure of the Spring Ligament Complex Be the Driving Force behind the Development of the Adult Flatfoot Deformity?

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A R T I C L E I N F O

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A B S T R A C T

We conducted an investigation into the relative associations of magnetic resonance imaging (MRI)–defined pathologic features of the spring ligament and/or tibialis posterior tendon with radiographic evidence of a planovalgus foot position. A total of 161 patient images (MRI and plain radiographs) obtained from the foot and ankle clinic (2008 to 2011) were retrospectively reviewed. All 161 patients (64 male and 97 female; mean age 45.9 years, range 18 to 86) were included in the analysis. Lateral weightbearing radiographs were analyzed for the talo–first metatarsal angle $\geq 5°$, calcaneal pitch $\leq 20°$, and talocalcaneal angle $\geq 45°$. A positive finding for ≥ 1 measurements identified a radiographic planovalgus position of the foot. The radiographic deformity was analyzed against the MRI evidence of either spring ligament or tibialis posterior tendon pathologic features for significance ($p < .05$). Evidence of a spring ligament abnormality was strongly associated with a planovalgus foot position, reaching high levels of statistical significance in all 3 categories of radiographic deformity (odds ratio 9.2, $p < .0001$). Abnormalities of the tibialis posterior tendon failed to demonstrate significance, unless grade I changes were excluded, and grade II and III appearances were analyzed in isolation (odds ratio 2.9, $p = .04$). Although absolute causal relationships were not tested, this investigation has clearly demonstrated that MRI-defined abnormalities of the spring ligament complex are possibly of at least equal importance to tibialis posterior dysfunction for the presence of a moderate to severe radiographic planovalgus foot position.

Initially known as posterior tibial tendon dysfunction, adult-acquired flatfoot deformity (AAFD) was first described in relation to tendon failure (1–3). However, failure of the ligaments that support the arch will occur concurrently, often resulting in progressive deformity of the foot (4–6). Clinically significant deformity will demonstrate an association with dysfunction of various medial structures, including the tibialis posterior (TP), spring, superficial deltoid, plantar metatarsal, and naviculocuneiform ligaments (4).

Biomechanical studies have established that a functioning TP tendon cannot correct a planovalgus foot deformity and that surgical harvest of the tendon for transfer does not result in the deformity (7,8). Ligamentous support could be of greater importance, because severe deformity cannot occur without significant attenuation of some or all of the long and short plantar ligaments, plantar fascia, and/or the spring ligament complex (9,10). Case series have demonstrated that injury to the spring ligament complex in isolation can result in symptomatic AAFD without associated TP dysfunction (11,12). However, treatment of advanced symptomatic flexible deformity with tendon transfers and hindfoot realignment has seemed to correct the problem for most patients, even when the injury to the spring ligament is ignored (3,5).

Because our current understanding of the pathologic process is incomplete, our intent was to demonstrate the relationships between magnetic resonance imaging (MRI)–diagnosed pathologic features of the spring ligament complex and TP tendon and radiographic evidence of a planovalgus foot in an attempt to define the relative associations of each.

Patients and Methods

The hospital records identified 305 musculoskeletal MRI scans performed on adult patients (aged $\geq$ 18 years) who had attended specialist foot and ankle clinics at our institution from 2008 to 2011 (3-year period). The scans and images of patients without plain radiographs on file or a history of surgery or deep infection were excluded, leaving 161 images for the final analysis.

The patient demographics were typical for a foot and ankle clinic population, with a mean patient age of 45.9 (range 18 to 86) years; 64 patients were male and 97 were female. The measurements taken to illustrate arch collapse and hindfoot valgus on the

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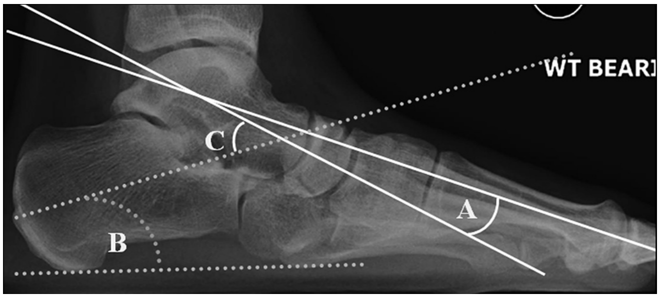

Fig. 1. Weightbearing lateral radiograph of the foot demonstrating (*A*) talo–first metatarsal angle, (*B*) calcaneal pitch, and (*C*) talocalcaneal angle.

lateral weightbearing radiographs were Meary's talo–first metatarsal angle ≥ 5°, calcaneal pitch ≤ 20°, and talocalcaneal angle ≥ 45° (13,14) (Fig. 1). All radiographic measurements were made using Cerner ProVision Web, version 7.1.1-1 (Cerner, Kansas City, MO), radiographic viewing software by 1 of the senior authors (G.W.), who was unaware of the clinical information, diagnosis, or subsequent MRI findings.

All MRI was performed with a 1 .5-T unit with a 17-cm transmit–receive extremity coil or with single or dual-surface coils (7.6 cm) placed on either side of the hindfoot. Spin-echo T_1-weighted and proton dense fat suppressed weighted images were acquired with a 3-mm section thickness. Standardized musculoskeletal protocol MRI sequences were used to produce images in the coronal, axial, and sagittal planes. All images were assessed by a consultant radiologist with > 10 years of musculoskeletal experience and an orthopedic specialist registrar for an abnormality to the spring ligament complex (medioplantar or superior medial components) and TP tendon.

MRI evidence of spring ligament abnormalities was defined as MRI features considered diagnostic for surgically proven tears, including full thickness gaps, high or heterogeneous signal on proton-dense, fat-saturated images other than at the calcaneal origin, thickening proximally > 5 mm and/or thinning distally < 2 mm in respect to the superior medial portion (14–16). Abnormalities of the medioplantar portion of ligament were defined as a high intrasubstance signal other than at the calcaneal origin, obvious loss of a normal striation pattern, and/or widening of the ligament > 7 mm (14,17,18). Tibialis posterior tendinopathy was graded according to the Conti classification as type 1, partial tears, fusiform enlargement with degeneration and/or longitudinal splits; type 2, stretching and elongation; or type 3, complete discontinuity (19).

The Statistical Package for Social Sciences for Windows, version 17.0 (SPSS, Chicago, IL), was used to perform chi-square and Fisher's exact tests and odds ratios to display the relationship between the pathologic findings in respect to the spring ligament or TP tendon and their association with radiographic evidence of deformity (values with $p \leq .05$ were assumed significant). The pre-analysis power calculation assuming MRI abnormalities of the spring or TP tendon would be twice as prevalent in the radiographic flatfeet versus control groups gave an estimated study power of $\beta > 0.8$ ($\alpha = 0.05$), with the additional assumption that comparative group sizes (flatfoot versus normal) could be unequal but would include a minimum of 42 patients.

	Meary's angle ≥ 5 deg		Normal X-ray
TP grade II/III abnormal	9		7
TP normal (patient number)	45		100
Odds ratio	**2.86***	**95% CI (0.90 – 9.19)**	
Chi-square	**p = 0.04***		
Fishers exact	**p = 0.05***		

	Calcaneal pitch ≤ 20 deg		Normal X-ray
TP grade II/III abnormal	6		10
TP normal	59		86
Odds ratio	**0.88**	**95% CI (0.27 – 2.80)**	
Chi-square	**p = 0.81**		
Fishers exact	**p = 1**		

	Talo-calaneal ≥ 45 deg		Normal X-ray
TP grade II/III abnormal	10		6
TP normal	53		92
Odds ratio	**2.89**	**95% CI (0.90 – 9.56)**	
Chi-square	**p = 0.04***		
Fishers exact	**p = 0.06**		

Fig. 3. Contingency table analysis of radiographic planovalgus foot deformity versus magnetic resonance imaging evidence of tibialis posterior (TP) pathologic features, grades II and III (numbers of patients). CI, confidence interval; Talo-cal, talocalcaneal.

Results

Figs. 2 to 4 show the contingency table results for the relative associations of tendon and spring ligament pathologic features with radiographic evidence of a planovalgus foot position. Of 161 scans, 44 demonstrated evidence of spring ligament pathologic features (27%). All 44 revealed pathologic findings in respect to the superior medial portion of the ligament, with proximal thickening > 5 mm and/or

	Meary's angle ≥ 5 deg		Normal X-ray
Spring ligament abnormal	29		12
Spring ligament normal	25		95
Odds ratio	**9.18***	**95% CI (3.84 – 22.34)**	
Chi-square	**p <0.0001***		
Fishers exact	**p <0.0001***		

	Calcaneal pitch ≤ 20 deg		Normal X-ray
Spring ligament abnormal	24		17
Spring ligament normal	41		79
Odds ratio	**2.72***	**95% CI (1.24 – 6.01)**	
Chi-square	**p = 0.006***		
Fishers exact	**p = 0.009***		

	Talo-cal angle ≥ 45 deg		Normal X-ray
Spring ligament abnormal	22		19
Spring ligament normal	41		79
Odds ratio	**2.23***	**95% CI (1.01 – 4.89)**	
Chi-square	**p = 0.03***		
Fishers exact	**p = 0.04***		

Fig. 2. Contingency table analysis of radiographic planovalgus foot deformity versus magnetic resonance imaging evidence of spring ligament pathology (numbers of patients). CI, confidence interval; Talo-cal, talocalcaneal.

	Meary's angle ≥ 5 deg		Normal X-ray
TP abnormal	15		18
TP normal	38		89
Odds ratio	**1.95**	**95% CI (0.83 – 4.53)**	
Chi-square	**p = 0.09**		
Fishers exact	**p = 0.1**		

	Calcaneal pitch ≤ 20 deg		Normal X-ray
TP abnormal	14		19
TP normal	51		77
Odds ratio	**1.11**	**95% CI (0.48 – 2.58)**	
Chi-square	**p = 0.79**		
Fishers exact	**p = 0.84**		

	Talo-calcaneal ≥ 45 deg		Normal X-ray
TP abnormal	16		17
TP normal	47		81
Odds ratio	**1.62**	**95% CI (0.70 – 3.76)**	
Chi-square	**p = 0.22**		
Fishers exact	**p = 0.24**		

Fig. 4. Contingency table analysis of radiographic planovalgus foot deformity versus magnetic resonance imaging evidence of tibialis posterior (TP) pathologic features, grades I, II, and III (numbers of patients). CI, confidence interval; Talo-cal, talocalcaneal.