

Subtle Cavus Foot: Diagnosis and Management

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Abstract

The subtle cavovarus foot (SCF) is a mild malalignment caused by either primary hindfoot varus or a plantarflexed first ray, resulting in a typical constellation of symptoms because of altered foot mechanics. Key clinical signs are a peek-a-boo heel and a positive Coleman block test. The cavovarus position places lateral ankle soft-tissue structures, such as the anterior talofibular ligament and the peroneal tendons, on stretch during normal gait. This can lead to common conditions such as lateral ankle instability, peroneal tendon tears, and stress fractures of the lateral metatarsals and cuboid. The gait cycle is altered because a greater proportion of time is spent with the transverse tarsal joints locked due to the overall varus foot position. In contradistinction to physiologic valgus at heel strike, which maintains the transverse tarsal joints unlocked and affords approximately 50% force dissipation, the increased rigidity of the foot causes a maldistribution of forces that leads to accelerated wear of the midfoot joints and increased stresses along the plantar fascia and the Achilles tendon insertion. Successful nonsurgical management requires correction of the biomechanical anomaly; surgical management of a subtle cavovarus foot typically is part of a comprehensive plan for correcting the symptoms and the malalignment.

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Subtle cavus foot (SCF) is traditionally characterized by mild heel varus and a plantarflexed first ray. Although the term cavus is frequently associated with neurologic disorders (eg, hereditary motor and sensory neuropathy, spinal pathology), SCF is considered to be a variant of normal; thus, information has been sparse. Conversely, studies relating foot structure to pathologic conditions have produced a bank of substantial knowledge over the years for conditions such as the planovalgus or "flatfoot." In a 2005 review of SCF by Manoli and Graham,¹ however, three factors were identified that explained why SCF has not received similar emphasis. These factors include training bias, subtle clinical

examination findings, and the absence of a simple clinical or radiographic sign. A growing body of literature, however, is now allowing for an increased awareness of this foot position and its association with foot and ankle disease.

Etiology

First reported by Manoli and colleagues^{1,2} in 1993, SCF is described as an "underpronator." It is presumed to be idiopathic, although Manoli et al² have speculated about the existence of a familial inheritance pattern and poorly delineated genetic determinants. Whereas genetic data, as well as formal incidence and prevalence

data, are not available, it is estimated that 25% of the population has SCF.³ In a preliminary study by a pedorthic practice, consisting of a year-long patient log, it was noted that slightly over half of all patients were fitted with cavus-correcting foot orthoses.⁴ Whereas no classification system exists to date, it is considered to be a mild malalignment along the spectrum of normal.

Other theories may explain this foot position, including aberrant morphology of the calcaneus and/or subtalar joint, plantar flexion of the first ray, and/or an overactive peroneus longus tendon. To better describe these concepts, a brief review of foot mechanics is helpful. With each succession of the gait cycle, the foot first passes through a flexible phase at heel strike and then a more rigid phase at toe-off. The flexible phase is highlighted by relative valgus of the calcaneus, eversion of the subtalar joint, and nonparallelism of the talus and calcaneus on an AP radiograph of the foot. In this position, the hindfoot is flexible and able to absorb the force of the heel strike. Progression to footflat and toe-off results in a shift into relative varus of the calcaneus, inversion of the subtalar joint, and parallelism of the talus and calcaneus on the AP view. In this position, the foot is rigid enough to act as a lever for push-off and forward propulsion.⁵⁻⁷

Hindfoot-driven SCF is described as a malposition deriving from the calcaneus and/or the subtalar joint. Theories regarding this etiology include aberrant bony morphology, such that the calcaneal tuberosity is excessively medial to the long axis of the calcaneal body, as seen on a Harris heel view. Underlying calcaneal varus has been evaluated radiographically. A prospective case-control study was conducted on 11 patients with recurrent ankle instability and 12 control subjects. CT analysis of the calcaneus was conducted; this study revealed a statistically significant increase in the central

calcaneal varus angle, thought to correlate with increasing hindfoot varus.⁸ It may also be caused by a malalignment at the subtalar joint. An abbreviated flexible valgus phase of the gait cycle is often seen in conjunction with limited hindfoot eversion.

Other etiologies of hindfoot-driven SCF include tarsal coalition, malunion of a calcaneal and/or talus fracture, poliomyelitis, or scarring of the deep posterior compartment as a sequela of compartment syndrome, or it is simply idiopathic.^{1,9,10}

Forefoot-driven hindfoot varus refers to a position that a flexible hindfoot assumes when compensating for a plantarflexed first ray.¹¹ The etiology of this anomaly is unknown. The effect is such that the first metatarsal head contacts the ground before the hindfoot reaches full eversion. The first ray then acts as a kickstand and abbreviates the flexible phase of the gait cycle. Cotton's¹² "static triangle of support," comprising the heel, first metatarsal, and fifth metatarsal, is also disrupted (Figure 1). Specifically, the plantarflexed first ray tips the plane so that the heel is in varus. When walking is viewed as a cyclical loading event, these factors may lead to less shock absorption at heel strike, eccentric bony loads, and possible attenuation of the lateral soft-tissue structures.^{12,13}

Peroneal tendon overdrive may also contribute to this malalignment.¹⁴ With normal activity occurring mostly in the stance phase of gait,¹⁵ the insertion of the peroneus longus plantarly at the lateral bases of the first metatarsal and medial cuneiform makes it possible for it to be a deforming force. If hyperactivity of the peroneus longus tendon is present, the first ray may be prematurely plantarflexed at the footflat and/or toe-off phases of gait.¹⁶ This activity would potentially "lock" the midfoot earlier in the gait cycle and simultaneously swing the hindfoot into varus.

Given our nascent understanding of this deformity, it also is possible that

the deformity is multifactorial. In a 2010 study by Maskill et al,¹⁷ 29 feet with subtle cavus deformities and persistent lateral pain after ankle sprain were surgically managed after failing to respond to nonsurgical management. Findings in this group revealed that all patients had primary, hindfoot-driven varus. This is a departure from the findings expressed by Manoli and Graham¹ in 2005. It is important to note, however, that the results of the Coleman block test in the latter study were interpreted as forefoot-driven hindfoot varus when the heel was fully corrected to 5° of valgus, as opposed to neutral. None of the patients fully corrected to this extent; therefore, all required a calcaneal osteotomy. It was also noted that 86% of the patients had a residual forefoot deformity after the lateralizing calcaneal osteotomy, thus requiring first metatarsal osteotomy and/or peroneal tendon transfer. In this series, the patients' clinical scores improved significantly after combined bony and soft-tissue management. This implies that the causes of the SCF position may be multifactorial.

Pathophysiology and Correlation With Foot and Ankle Disorders

It was initially thought that SCF was primarily a forefoot-driven malalignment. As noted previously, in the series reported by Maskill et al,¹⁷ all patients underwent a calcaneal osteotomy, and the majority of patients also underwent other procedures, such as a first metatarsal osteotomy or a peroneus longus to brevis transfer. Regardless of the etiology, salient biomechanical features of SCF include a varus hindfoot posture and increased stiffness. These features potentially alter gait mechanics with walking and running. Over time, aberrant progression through the gait cycle may possibly explain the

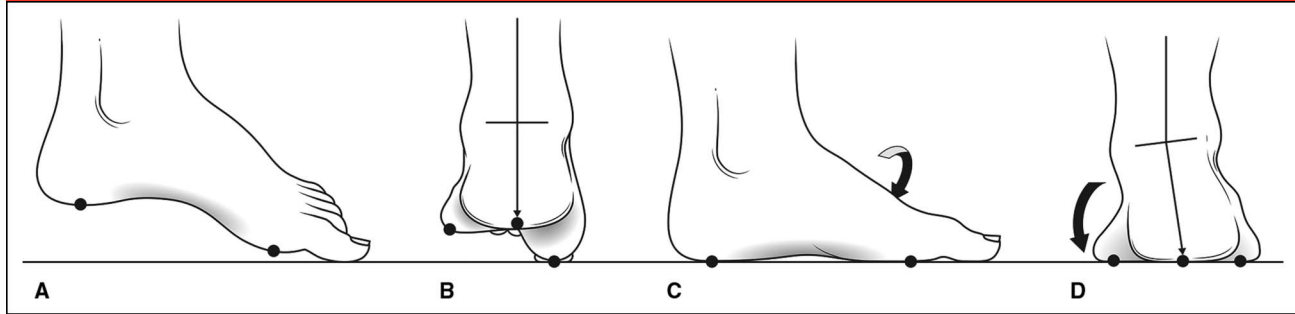
Figure 1

Diagram delineating the mechanics of forefoot-driven hindfoot varus with the effect of weight bearing on a foot with a plantarflexed first ray. A non-weight-bearing left foot is seen from the side (A) and from the back (B), where the first ray is seen closer to the ground or more plantarly positioned than any other plantar structure. C, Weight bearing forces the foot into a plantigrade position. The ground reactive force acts on this plantarflexed first ray, forcibly elevating it to make the plantar surface of the foot level. However, this causes a compensatory varus (D) in the hindfoot. (Reproduced with permission from Paulos L, Coleman SS, Samuelson KM: Pes cavovarus: Review of a surgical approach using selective soft-tissue procedures. *J Bone Joint Surg Am* 1980;62:942-953.)

various pathologies that may be associated with SCF, including lateral column overload, stress fractures, and injury to the peroneal tendons and the lateral ankle ligaments.

Clinical support for such potential associations is inferred primarily from studies examining the relationship of arch height to athletic and overuse injuries.¹⁸⁻²² A 2001 survey of 40 runners by Williams et al¹⁸ consisted of 20 runners with a high arch and 20 runners with a low arch, as determined by arch ratio. Results showed that the high-arched runners reported a higher rate of foot and ankle injuries. Specifically, the high-arched runners had more lateral ankle injuries, whereas the low-arched runners had more knee injuries. The rate of injury in the high-arched group was also higher overall. In a prospective study of 449 Navy SEAL candidates over a 2-year period, candidates with an elevated arch had a higher rate of stress fractures than did normal-arched candidates.²⁰ Cowan et al,²¹ in a study of Army infantry recruits, also reported a significant linear trend for an increased risk of injury with increasing arch height.

The use of dynamic pedobarography in patients with hereditary

motor and sensory neuropathy before and after surgical management has revealed information about significant alterations in loading and gait patterns, specifically in the heel, the first ray, and the lateral border of the foot.²³ Preoperative findings included prolonged contact times in all three regions. In cadaver studies of induced cavovarus foot, ankle joint contact pressures migrated anteriorly and medially with increasing deformity.²⁴ Pedobarographic studies have also shown that cavus alignment is linked with lateral foot and ankle pathology. In a pressure plate analysis that compared barefoot walking of normal control subjects with patients having chronic ankle instability, the patients with instability had elevated lateral forefoot loading and increased midfoot and lateral pressure during the stance phase.^{25,26}

Whereas there are no such similar data specifically available on SCF, it can be postulated that abnormal joint pressure distribution would also occur, albeit to a lesser extent. Such maldistribution of force over time could explain the higher rates of stress fracture in athletes, as well as peroneal tendon pathology and ankle instability, among other conditions.^{4,19} In

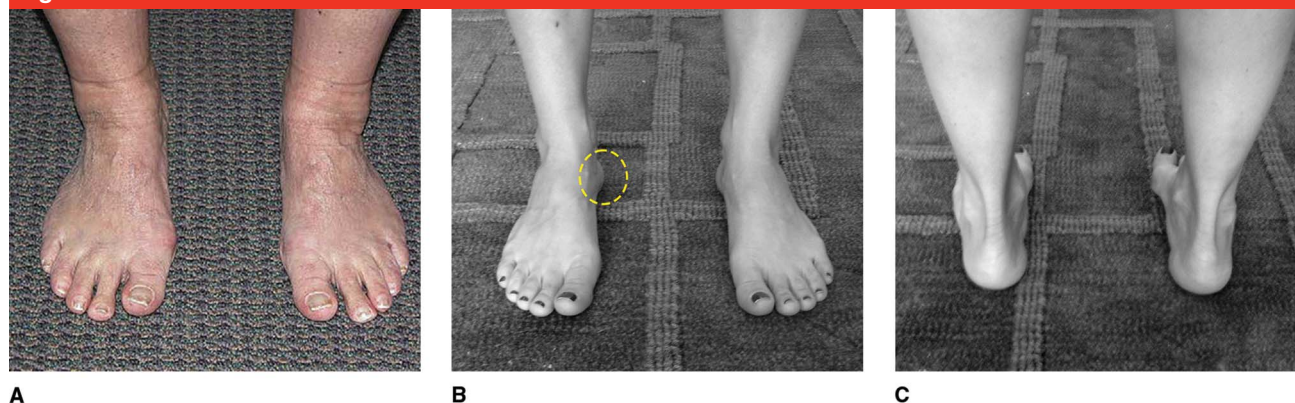
a 2012 review of the surgical management of peroneal tendon disorders, including peroneal tendon tears and instability, it was found that 33% of patients also had underlying hindfoot varus that required surgical correction.²⁷ In a review of patients with persistent pain or recurrent instability after a lateral ligament reconstruction, underlying hindfoot varus occurred in 28% of the patients.²⁸

Clinical Presentation

History

The clinical history is often remarkable for chronic symptoms. Many patients with SCF report long-standing mild symptoms, such as recurrent ankle instability, lateral column pain, or peroneal tendon subluxation, often present since adolescence. A common presentation is an athlete in the third or fourth decade of life with a history of chronic ankle instability or lateral foot pain. Another typical presentation is a chronic fifth metatarsal stress fracture or a recurrent lateral metatarsal fracture.

Patients with SCF may have failed to respond to prior nonsurgical and surgical interventions.²⁹ Examples

Figure 2

A, The patient's left foot is in a neutral standing posture; the medial heel is not visible when viewed from the front. The right foot is subtly cavus, with the medial edge of the heel visible. **B**, The patient has bilateral subtle cavus feet. Evaluation from the front clearly reveals a medial prominence of the heel pads bilaterally (dashed oval). **C**, Evaluation of the patient in panel B from the back. Because this is a subtle deformity, examination from the back reveals an almost normal alignment, highlighting the benefit of examination from the front. (Panel A reproduced with permission from Chilvers M, Manoli A II: The subtle cavus foot and association with ankle instability and lateral foot overload. *Foot Ankle Clin N Am* 2008;13:315-324.)

include a recurrence of lateral ankle instability^{29,30} or peroneal tendon subluxation after repair, as well as nonunion of fifth metatarsal fractures after surgical fixation.

Physical Examination

The key clinical sign of SCF is a “peek-a-boo” heel; this can be seen as a medial prominence of the heel pad on standing alignment evaluation from the front with the feet directed straight ahead. In a normally aligned foot, the heel pad should not be visible. In SCF, the low-grade varus of the heel can be very difficult to identify from a standing evaluation from the back. As such, a standing evaluation from the front should also be used to identify this mild deformity³ (Figure 2). Whereas it is a more common occurrence that the medial longitudinal arch is elevated, it is important to note that the shape of the arch is less important than the position of the heel and that some patients may even have a normal-appearing arch.

Callosities on the plantar aspect of the foot form when there is an excess load being borne on that area.^{31,32}

With SCF, a medial plantar callosity often forms under the first metatarsophalangeal joint^{32,33} (Figure 3). A large proportion of the patients also have a contracture of the gastrocnemius. This should be further evaluated using the Silfverskiöld test. This test assesses the relative passive dorsiflexion of the ankle with two different positions of the knee.

To administer the Silfverskiöld test, the examiner begins by fully extending the knee. With the subtalar joint in neutral, an upward force is symmetrically placed across the forefoot. The examiner notes the angle of dorsiflexion at the ankle, normally about 10°. In this same position, the patient is then instructed to flex the knee, which relaxes the gastrocnemius muscle. The angle of dorsiflexion at the ankle is then reassessed, typically now 20° above neutral.

The utility in this test is that it can identify the anatomic level of contracture. If the angle of ankle dorsiflexion does not change with flexion of the knee, the equinus is derived from the Achilles tendon proper or a lesion in the ankle, such as an anterior spur or arthrofibrosis of the ankle. However, if the patient has a loss of

normal dorsiflexion that corrects with flexion of the knee, then the gastrocnemius is identified as the source.^{34,35}

Passive subtalar range of motion may reveal limited eversion. Motor and sensory examination should be normal and symmetric, as should the vascular examination. Ankle stability should be assessed with the anterior drawer test and the talar tilt test. The peroneal tendons should be assessed for strength, tenderness, and instability.

A valuable examination tool is dynamic hindfoot evaluation from behind during active heel rise. With the examiner positioned behind the standing patient, the hindfoot can be examined during double-limb heel rise. In a neutrally aligned foot, the hindfoot will visibly swing from 5° of physiologic valgus into varus as the hindfoot is raised. This does not occur in a patient with SCF. Instead, the heel will simply elevate but not invert through an arc of motion (Figure 4).

Performing the Coleman block test, described in 1977 to determine the flexibility of a cavovarus foot of neurologic origin, is critical when evaluating a patient with SCF.^{17,36} It is used to assess for forefoot-driven hindfoot varus. If there is a flexible subtalar

Figure 3

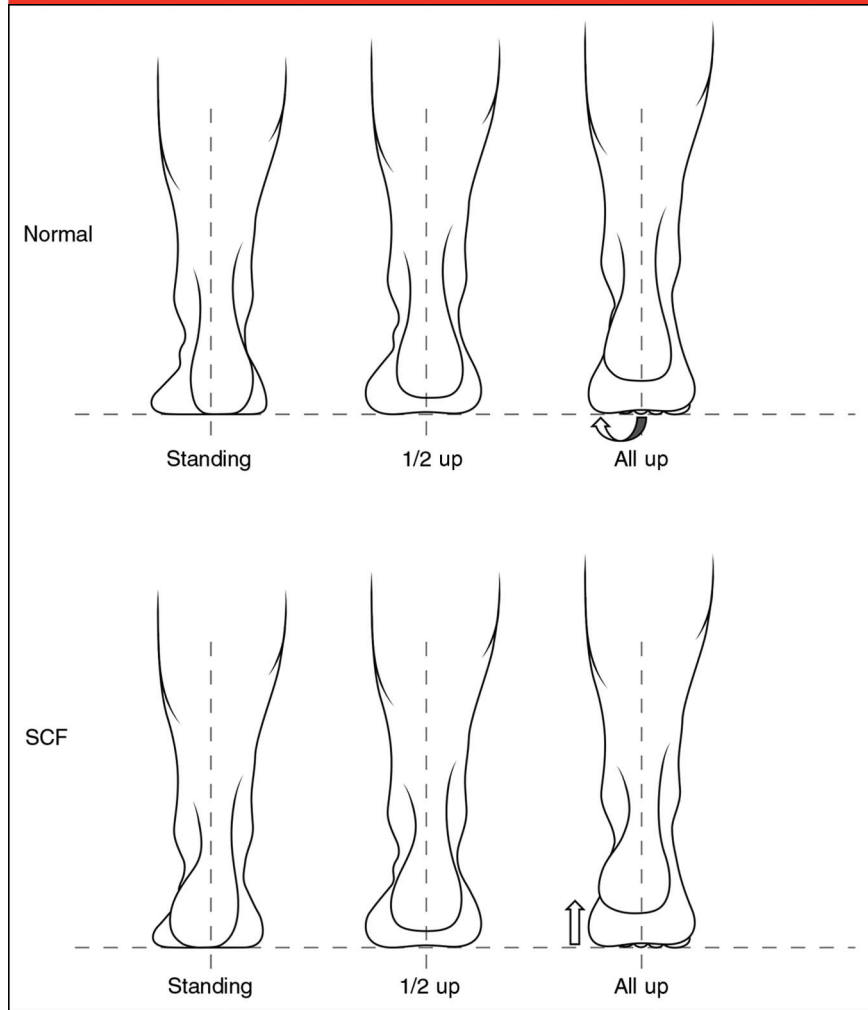
Plantar medial callosity (dashed circle) and prominent medial heel pads in a patient with subtle cavus foot. (Reproduced with permission from Chilvers M, Manoli A II: The subtle cavus foot and association with ankle instability and lateral foot overload. *Foot Ankle Clin N Am* 2008;13:315-324.)

joint, the Coleman block test effectively eliminates the contribution of the first ray to hindfoot alignment. Specifically, by having the patient stand supported by a 1-inch block under the heel and lateral border of the foot, the first ray is unloaded and its contribution to the alignment of the foot is eliminated. If hindfoot varus corrects to 5° of valgus with unloading of the first ray, it is then considered to be forefoot driven (Figure 5).

An assessment of the relative contribution of the peroneus longus to first metatarsal plantar flexion should also be completed.³⁷ With the patient seated, the knee is extended and the ankle is actively dorsiflexed. The examiner places a thumb underneath the first metatarsal head and the other thumb underneath the lesser metatarsal heads. The patient is then instructed to maximally plantarflex the foot against resistance. Excessive plantar flexion of the first ray with this maneuver may be indicative of peroneus longus hyperactivity^{1,17} (Figure 6).

Diagnostic Imaging

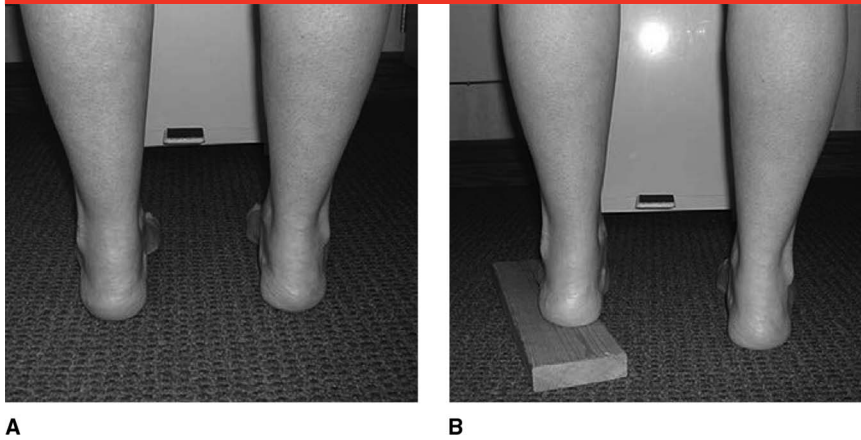
Because SCF is a mild deformity, standing radiographs may not show

Figure 4

Dynamic examination from the back as a patient rises on the toes from a footflat position. In the normal patient, there is a dynamic arc from a slightly everted heel while standing to an inverted heel at maximal plantar flexion (ie, all up). In the patient with subtle cavus foot (SCF), the dynamic inward swing of the heel is lost on heel rise. The slightly inverted heel while standing simply rises higher on plantar flexion (ie, all up). In this instance, the examiner does not appreciate an inward sweep to the heel on maximal heel rise.

any obvious abnormalities. To date, no high-level evidence correlates radiographic criteria with clinical findings; however, certain radiographic parameters should be considered. On standing lateral views of the foot and ankle, the arch height, the shape of the midfoot joints, the Meary angle (ie, talonavicular–first metatarsal angle), and the position of the fibula should be noted³⁸ (Figure 7). Measured as the distance from

the base of the medial cuneiform to the base of the fifth metatarsal on a lateral view of the foot, an arch height value of >14 mm is indicative of a plantarflexed first ray; a normal arch height value measures approximately 10 mm.¹³ A vertically oriented midfoot with a “stacked” conformation of the talonavicular joint and coracoclavicular joint may also be noted.¹ The Meary angle should be zero ± 4°. In SCF, the

Figure 5

The Coleman block test. **A**, Examination from the back reveals bilateral hindfeet are in varus. **B**, The patient stands with a book or block under the lateral side of the forefoot, midfoot, and hindfoot. Examination of the hindfoot reveals that the heel varus corrects to valgus, indicating that the deformity is flexible and that the varus position is secondary to the plantarflexed first ray.

Figure 6

Plantar flexion of the first metatarsal relative to metatarsals 2, 3, 4, and 5, revealing peroneus longus overdrive. (Reproduced with permission from Klammer G, Benninger E, Espinosa N: The varus ankle and instability. *Foot Ankle Clin N Am* 2012;17:57-82.)

Meary angle may be negative, depicting a plantarflexed first ray in relation to the hindfoot.^{34,35} On a true lateral view, the ankle is considered to be in a “posterior” position when the fibula is overlying the posterior one third of the tibial shadow. This is another typical finding in a varus ankle.^{1,22} Other incidental findings that may be noted include a previous fracture of the fifth metatarsal and avulsion

osteophytes in the lateral gutter of the ankle joint.

Nonsurgical Management

It is crucial to correct the biomechanical anomaly present in SCF for nonsurgical management to succeed. In addition to other treatments prescribed, such as stretching for plantar fasciitis or proprioceptive reeducation for functional ankle instability, orthotic management of SCF may offer further benefit. LoPiccolo et al³⁹ recently reviewed 93 patients who presented with ankle instability and pain with associated SCF. They were given a custom, full-length orthosis made of ethyl vinyl acetate with a recess under the first metatarsal head, a ramp at the lateral forefoot, a lowered arch, and a heel cushion. A follow-up questionnaire conducted at 1 and 2 years after initiating orthotic management revealed a significant improvement in pain and instability events. Twenty-three of the 25 patients (92%) who had reported instability noted an improvement in their stability, with decreased epi-

sodes of “rolling the ankle” with use of the custom orthotic.³⁹

The principles of orthotic prescription are important because they are a deviation from the accommodative device typically offered to patients with a high arch. A shoe or orthotic with an elevated arch functions only to tip the foot into further varus. Aside from custom orthoses with a recessed first ray, a lateral wedge, and a lowered medial longitudinal arch, an over-the-counter orthosis is available, as well.⁴⁰ This orthosis is a less expensive device that meets these same criteria; it is available by shoe size and offers an adequate amount of correction for patients with mild or true SCF. Patients whose varus hindfoot is more severe would most likely benefit from custom orthoses. The benefit of a custom orthosis over a prefabricated orthosis is that the recess underlying the first metatarsal head can be made deeper and the lateral heel wedge can be of greater magnitude (Figure 8).

Surgical Management

Surgical management of SCF is usually performed in the setting of procedures undertaken for other pathologies. The most common procedures include lateral ligament reconstruction, as well as peroneal tendon repair and stabilization. Thus, surgically managing a subtle cavovarus foot is typically part of a larger plan to correct the inciting symptom and the malalignment. Surgery may also be performed for isolated lateral foot pain, without concomitant pathology.¹⁷ Nevertheless, it should be noted that a need remains for high-level evidence supporting the correction of SCF in conjunction with other reconstructive procedures (eg, comparison of the results of lateral ligament repair with and without SCF correction).

Figure 7



Lateral radiograph showing three highlighted features of subtle cavus foot. **A (blue)**, The Meary angle is positive at 10° , whereas normal is $0^\circ \pm 4^\circ$. **B (yellow)**, The arch height, represented as the vertical distance between the base of the first metatarsal and the base of the fifth metatarsal, is 15 mm, whereas normal is approximately 10 mm. **C (red)**, The fibula is overlying the posterior one third of the tibia on the lateral projection. (Reproduced with permission from Chilvers M, Manoli A II: The subtle cavus foot and association with ankle instability and lateral foot overload. *Foot Ankle Clin N Am* 2008;13:315-324.)

Figure 8



A subtle cavus foot orthosis with a recessed first metatarsal head, low medial arch, and lateral hindfoot wedge. (Reproduced with permission from Chilvers M, Manoli A II: The subtle cavus foot and association with ankle instability and lateral foot overload. *Foot Ankle Clin N Am* 2008;13:315-324.)

2010. The two calcaneal osteotomies that are most commonly used to correct a varus hindfoot are a laterally based closing wedge and a lateral calcaneal slide.⁴⁰⁻⁴² A 2005 review by Younger and Hansen³⁵ details these procedures in depth.

The natural response of the forefoot after a valgus-producing calcaneal osteotomy is to gently pronate, necessitating reexamination of the forefoot intraoperatively. This pronation essentially plantarflexes the first ray and may necessitate further surgical intervention.^{2,12} The examination is similar to that performed for peroneal overdrive, as described previously. The forefoot is loaded underneath the lesser metatarsal heads, and the ankle is dorsiflexed to neutral. With his or her free hand, the surgeon examines the level of the first metatarsal head. If it is at or above the level of the second metatarsal head, nothing further needs to be done. However, if the first metatarsal head is plantar to the second metatarsal head or if the examiner notes a need to “push up” on it to bring it up to the level of the second metatarsal head, a tight or overactive peroneus longus is likely present. In this setting, the surgeon should consider performing a peroneus longus to brevis transfer via a lateral

Planned incisions must allow for adequate skin bridges and for all necessary procedures to be safely and properly performed. For example, in a patient who has ankle instability and requires a lateral ligament reconstruction as well as first metatarsal and calcaneal osteotomies, three incisions may be used (Figure 9). The first incision is centered over the distal fibula, taking care to protect the superficial peroneal nerve. The second incision overlies the lateral wall of the calcaneal tuberosity, and the third incision is centered over the first metatarsal base. Alternatively, an extensile curvilinear lateral incision may be used, although this requires that larger flaps be raised.

Thereafter, surgical planning is a stepwise approach based primarily on the results of the Coleman block test. If the patient's hindfoot fully corrects to physiologic valgus on the Coleman block, then the surgeon should begin with a peroneus longus to brevis transfer, with a possible first metatarsal dorsiflexion osteotomy based on intraoperative correction. If the hindfoot does not fully correct to physiologic valgus on the Coleman block, the surgeon should then begin with a lateralizing calcaneal osteotomy with a possible subsequent peroneal tendon transfer and/or a first metatarsal dorsiflexion osteotomy to correct residual first ray plantar flexion. This algorithm was proposed by Maskill et al¹⁷ in

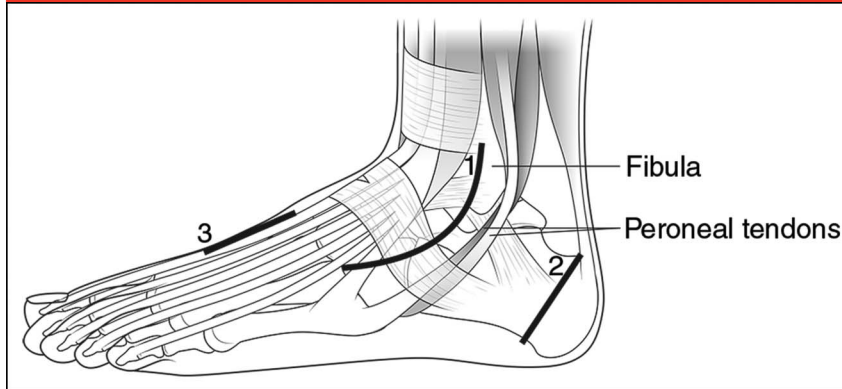
Figure 9

Illustration demonstrating approaches for lateral ligament reconstruction and subtle cavus foot correction. Incision one is used to achieve reconstruction of the lateral ligament. Incision one (1) also affords access to the peroneal tendons should a peroneal tendon transfer be required. Incision two (2) is used to achieve a lateralizing calcaneal osteotomy. Incision three (3) affords access to the base of the first metatarsal should a dorsiflexion osteotomy be required. (Copyright the American Academy of Orthopaedic Surgeons, Rosemont, IL.)

approach to the foot at the level of the cuboid.⁴³ The preoperative examination of the peroneus longus for dynamic overdrive is a strong indicator that this procedure will be needed, but no formal scientific correlations have been made to date. A plantar fascia release is not typically included in the SCF reconstruction because it usually is not pathologic in this mild form of varus.

At this point, the first ray in relation to the other metatarsals should be examined again. Any persistent plantar flexion of the first metatarsal after peroneal transfer is addressed via a dorsiflexion osteotomy of the first metatarsal. In the patient whose hindfoot fully corrected with a Coleman block test and who had a forefoot-driven hindfoot varus, the surgeon should still reassess the first ray after transferring the peroneus longus tendon in order to evaluate for a persistently plantarflexed first ray. If this situation is present, as previously noted, a dorsiflexion osteotomy is in order.

Once the SCF has been corrected and the osteotomies stabilized, adjunct procedures are performed.

These may include fixation of a fifth metatarsal fracture, lateral ligament reconstruction, and peroneal repair and/or stabilization. We recommend performing these procedures after osteotomy stabilization because manipulation of the osteotomy segments can be vigorous and potentially disrupt a ligament or tendon repair. However, if an Achilles or gastrocnemius contracture is detected, it should be released at the beginning of the procedure. This allows the surgeon to more accurately assess the hindfoot varus deformity.

Postoperatively, the ankle is typically immobilized in a non-weight-bearing cast for 6 weeks. Thereafter, progressive weight bearing and mobilization are initiated, with formal physical therapy if necessary.

Summary

SCF is frequently recognized as an important component of several common disease processes of the foot and ankle, including lateral ankle instability, fifth metatarsal fracture, peroneal tendon disease, and several

others. It is part of an underlying biomechanical anomaly that, with treatment, can improve the success of surgical and nonsurgical interventions. Properly diagnosing and treating SCF may improve the overall results when treating these conditions.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 15, 19, 25, and 33 are level II studies. References 8, 18, and 20-22 are level III studies. References 2-4, 9, 12, 13, 17, 23, 24, 26, 27, 29-31, and 38-42 are level IV studies. References 1, 5-7, 10, 11, 14, 16, 28, 32, 34-37, and 43 are level V expert opinion.

References printed in **bold type** are those published within the past 5 years.

1. Manoli A II, Graham B: The subtle cavus foot, "the underpronator". *Foot Ankle Int* 2005;26(3):256-263.
2. Manoli A II, Smith DG, Hansen ST Jr: Scarred muscle excision for the treatment of established ischemic contracture of the lower extremity. *Clin Orthop Relat Res* 1993;292:309-314.
3. Chilvers M, Manoli A II: The subtle cavus foot and association with ankle instability and lateral foot overload. *Foot Ankle Clin* 2008;13(2):315-324, vii.
4. Manoli A II, Graham B: Foot Morphology in a Pedorthic Practice. Presented at *The Annual Meeting of the Michigan Orthopaedic Society*, Mackinac Island, MI, June 19, 2004.
5. Sammarco VJ: The talonavicular and calcaneocuboid joints: Anatomy, biomechanics, and clinical management of the transverse tarsal joint. *Foot Ankle Clin* 2004;9(1):127-145.
6. Manter J: Movements of the subtalar and transverse tarsal joints. *Anat Rec* 1941;80: 397-410.
7. Elftman H: The transverse tarsal joint and its control. *Clin Orthop* 1960;16(16): 41-46.
8. Van Bergeyk AB, Younger A, Carson B: CT analysis of hindfoot alignment in chronic lateral ankle instability. *Foot Ankle Int* 2002;23(1):37-42.
9. Beals T, Bohay D, Lee C, Manoli A II: Tarsal coalitions presenting with cavovarus

- foot deformities. Presented at the Annual Meeting, American Orthopaedic Foot and Ankle Society, Fajardo, Puerto Rico, 1999. Level IV.
10. Solis G, Hennessy M, Saxby TS: Pes cavus: A review. *Foot Ankle Surg* 2000;6(3):145-153.
 11. Apostle KL, Sangeorzan BJ: Anatomy of the varus foot and ankle. *Foot Ankle Clin* 2012;17(1):1-11.
 12. Cotton FJ: Foot statistics and surgery. *New Eng Surg Soc* 1936;218(8):353-362.
 13. Ledoux WR, Shofer JB, Ahroni JH, Smith DG, Sangeorzan BJ, Boyko EJ: Biomechanical differences among pes cavus, neutrally aligned, and pes planus feet in subjects with diabetes. *Foot Ankle Int* 2003;24(11):845-850.
 14. Morton D: *The Human Foot: Its Evolution, Physiology and Functional Disorders*. Morningside Heights, NY, Columbia University Press, 1935.
 15. Louwerens JW, van Linge B, de Klerk LW, Mulder PG, Snijders CJ: Peroneus longus and tibialis anterior muscle activity in the stance phase. A quantified electromyographic study of 10 controls and 25 patients with chronic ankle instability. *Acta Orthop Scand* 1995;66(6):517-523.
 16. Mosca VS: The cavus foot. *J Pediatr Orthop* 2001;21(4):423-424.
 17. Maskill MP, Maskill JD, Pomeroy GC: Surgical management and treatment algorithm for the subtle cavovarus foot. *Foot Ankle Int* 2010;31(12):1057-1063.
 18. Williams DS III, McClay IS, Hamill J: Arch structure and injury patterns in runners. *Clin Biomech (Bristol, Avon)* 2001;16(4):341-347.
 19. Larsen E, Angermann P: Association of ankle instability and foot deformity. *Acta Orthop Scand* 1990;61(2):136-139.
 20. Kaufman KR, Brodine SK, Shaffer RA, Johnson CW, Cullison TR: The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 1999;27(5):585-593.
 21. Cowan DN, Jones BH, Robinson JR: Foot morphologic characteristics and risk of exercise-related injury. *Arch Fam Med* 1993;2(7):773-777.
 22. Berkowitz MJ, Kim DH: Fibular position in relation to lateral ankle instability. *Foot Ankle Int* 2004;25(5):318-321.
 23. Metaxiotis D, Accles W, Pappas A, Doederlein L: Dynamic pedobarography (DPB) in operative management of cavovarus foot deformity. *Foot Ankle Int* 2000;21(11):935-947.
 24. Krause F, Windolf M, Schwieger K, Weber M: Ankle joint pressure in pes cavovarus. *J Bone Joint Surg Br* 2007;89(12):1660-1665.
 25. Nyska M, Shabat S, Simkin A, Neeb M, Matan Y, Mann G: Dynamic force distribution during level walking under the feet of patients with chronic ankle instability. *Br J Sports Med* 2003;37(6):495-497.
 26. Becker HP, Rosenbaum D, Claes L, Gerngross H: [Dynamic pedography for assessing functional ankle joint instability]. *Unfallchirurg* 1997;100(2):133-139.
 27. Grasset W, Mercier N, Chaussard C, Carpentier E, Aldridge S, Saragaglia D: The surgical treatment of peroneal tendinopathy (excluding subluxations): A series of 17 patients. *J Foot Ankle Surg* 2012;51(1):13-19.
 28. Strauss JE, Forsberg JA, Lippert FG III: Chronic lateral ankle instability and associated conditions: A rationale for treatment. *Foot Ankle Int* 2007;28(10):1041-1044.
 29. Kuhn MA, Lippert FG: Revision lateral ankle reconstruction. *Foot Ankle Int* 2006;27(2):77-81.
 30. Vienne P, Schöniger R, Helmy N, Espinosa N: Hindfoot instability in cavovarus deformity: Static and dynamic balancing. *Foot Ankle Int* 2007;28(1):96-102.
 31. Carlson RE, Fleming LL, Hutton WC: The biomechanical relationship between the tendoachilles, plantar fascia and metatarsophalangeal joint dorsiflexion angle. *Foot Ankle Int* 2000;21(1):18-25.
 32. Coughlin MJ, Mann RA: Keratotic Disorders of the Plantar Skin, in Coughlin MJ, Mann RA, Saltzman CL, eds: *Surgery of the Foot and Ankle*, ed 8. Philadelphia, PA, Mosby, 2007, pp 465-490. Level IV.
 33. Burns J, Crosbie J, Hunt A, Ouvrier R: The effect of pes cavus on foot pain and plantar pressure. *Clin Biomech (Bristol, Avon)* 2005;20(9):877-882.
 34. Silfverskiöld N: Reduction of the uncrossed two-joints muscles of the leg to one-joint muscles in spastic conditions. *Acta Chir Scand* 1924;56:315-328.
 35. Younger AS, Hansen ST Jr: Adult cavovarus foot. *J Am Acad Orthop Surg* 2005;13(5):302-315.
 36. Coleman SS, Chesnut WJ: A simple test for hindfoot flexibility in the cavovarus foot. *Clin Orthop Relat Res* 1977;123:60-62.
 37. Klammer G, Benninger E, Espinosa N: The varus ankle and instability. *Foot Ankle Clin* 2012;17(1):57-82.
 38. Steel MW III, Johnson KA, DeWitz MA, Ilstrup DM: Radiographic measurements of the normal adult foot. *Foot Ankle* 1980;1(3):151-158.
 39. LoPiccolo M, Chilvers M, Graham B, Manoli A II: Effectiveness of the cavus foot orthosis. *J Surg Orthop Adv* 2010;19(3):166-169.
 40. Shapiro K: Treatment of Cavus Foot Deformity with the DonJoy Arch Rival. *Ezine Articles* 2009;Oct. Level V.
 41. Sammarco GJ, Taylor R: Combined calcaneal and metatarsal osteotomies for the treatment of cavus foot. *Foot Ankle Clin* 2001;6(3):533-543, vii.
 42. Dwyer F: Osteotomy of the calcaneum for pes cavus. *J Bone Joint Surg Am* 1959;41(1):80-86.
 43. Bentzon P: Pes cavus and the m. peroneus longus. Proceedings of the Northern Orthopedic Association, XIV, Älvaviken, Sweden, 1932. Level V.