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## Abstract

Heel pain is a prevalent issue in young athletes, often arising from overuse and increased sporting demands. While Sever's Disease is the predominant cause, various other entities, including stress-related injuries and pathologies like tumors and bone lesions, contribute to this condition. The complex hind foot anatomy, encompassing ossicles, physis, and soft tissues, may lead to heel pain. This study aims to provide physicians with a clinically oriented narrative review of adolescent heel pain, supported by illustrative cases.

Conclusion: This study aims to offer physicians a comprehensive understanding of the concepts surrounding heel pain in adolescents. By presenting clinically relevant information and illustrated cases, it seeks to enhance medical practitioners' ability to diagnose and manage heel pain effectively in this specific demographic

Key words: heel pain, adolescents, Sever’s disease, athletes, sports injuries, stress-related injuries

## Introduction

The benefits of exercise and sport are vast. For young athletes, sports participation improves physical fitness, enhances self-esteem, improves peer socialization, and improves academic performance but also carries the risk of injury. Musculoskeletal overuse injuries are the most common injuries in the pediatric athletes.[1,2] Heel pain is a common issue among young athletes, often stemming from overuse and heightened sports demands. While Sever's disease is a prevalent cause, several other factors contribute to this condition, including stress-related bone and tendon injuries, as well as pathologies like tumors and bone lesions.[3]

The hind foot's complex anatomy, including ossicles, physis, and soft tissues, may lead to heel pain, with symptoms such as diffuse pain, swelling, and potential bony expansion.[3]

Pathophysiology in Sever ‘s disease is assumed to be repeated traction of the Achilles’ tendon at the secondary ossification center of the calcaneus. Though Ogden[4] suggested that reason is microtraumatically induced calcaneal stress fracture of trabecular bone in refractory cases.

Differential diagnosts can be difficult.  Differential diagnosis involves modern imaging modalities, including magnetic resonance imaging (MRI). MRI can effectively distinguish normal stress-related situations, bony pathologies, and lesions involving the epiphysis.[5]

34 Treatment modalities vary from operative treatments to conservative methods. The choice for
35 appropriate treatment for each individual patient depends on the aetiology, which emphasize
36 the importance of a correct diagnosis.
37
38 This study aims to provide physicians with a clinically oriented narrative review of
39 adolescent heel pain, accompanied by illustrative cases.

## Sever´s Disease

Sever's Disease, also known as calcaneal apophysitis, manifests as a painful overuse injury that induces discomfort in the posterior aspect of the calcaneus. This condition can be attributed to the traction exerted by the Achilles tendon on the unossified apophysis.[6] The apophysis initiates ossification around the age of 7 to 9 years, with complete fusion occurring by the age of 15 to 17.[6] Throughout the growth period until full ossification, the calcaneal apophysis is susceptible to inflammation.

Typically, Sever's Disease is prevalent at the onset of the growth spurt, where the tibia outpaces the development of the gastrocnemius-soleus muscle complex.[7] This asymmetry increases the traction on the Achilles tendon insertion, especially during activities involving running and jumping, such as basketball, soccer, track, cross country, and gymnastics. Additional risk factors include prolonged or year-round activity, ill-fitting or worn footwear, suboptimal training mechanics, and obesity. [6–8]Biomechanical factors like poor ankle dorsiflexion, pes cavus, pes planus, genu varum, and forefoot varus also contribute to the susceptibility.[8]

Clinical examination commonly reveals swelling and tenderness at the Achilles insertion to the calcaneus. Passive dorsiflexion can induce pain, and applying pressure simultaneously on the lateral and medial sides of the calcaneus may exacerbate discomfort, known as the Sever sign.[8] Standing on tiptoes can further aggravate the pain. Radiologic imaging is generally unnecessary for diagnosis, but it may be utilized to rule out alternative conditions. MRI aids in differential diagnosis[5], while fragmentation and sclerosis of the apophysis are not specific findings to Sever's disease.[9]

Calcaneal apophysitis is a self-limiting condition and at skeletal maturity, all complaints get resolved. Management involves modifying and restricting physical activity to alleviate heel irritation. Treatment measures include heel raises and orthoses for those with abnormal foot posture. Modifying footwear to prioritize well-cushioned and supported options helps absorb impact during activity.[7,10] Physical therapy, focusing on eccentric calf strengthening on a flat surface, contributes to recovery.[9,11] While Sever's Disease is self-limiting, adequate conservative treatment enables a return to sports within two months. However, a premature return may hinder the recovery process.[11,12]

## Plantar Fasciitis

The plantar fascia, a fibrous structure, originates from the anteromedial aspect of the plantar aspect of the calcaneus and extends into each of the five proximal phalanges. An anatomical connection exists between the Achilles tendon and the plantar fascia, providing support to the plantar arch and contributing to efficient movement.

The windlass mechanism describes the manner by which the plantar fascia supports the foot during weight- bearing activities and provides information regarding the biomechanical stresses placed on the plantar fascia.[13]

Plantar fasciitis is recognized as an overuse injury with a multifactorial etiology; no singular background factor has been identified. Factors such as obesity and biomechanical variants, including pes planus, pes cavus, and a tight Achilles tendon, elevate the risk of developing plantar fasciitis.[14,15]

In the pediatric population, plantar fasciitis can be seen in any age group, particularly in children who participate in sports that involve high levels of running, jumping, and inclines and can be simultaneuously with Sever's disease. [16]

Diagnosis primarily relies on clinical evaluation and patient history. Post-static dyskinesia, characterized by pain with the initial steps after a period of rest, is a typical manifestation. While walking may temporarily alleviate pain, prolonged walking or training can trigger discomfort. Palpation of the anteromedial side of the calcaneus and passive dorsiflexion of digits or the ankle can exacerbate pain.[14,15] Various diagnostic tools, including plain radiographs, MRI, and bone scans, help exclude stress fractures of the calcaneus or metatarsals, potential differential diagnoses. Ultrasonography (US) proves effective in diagnosing fasciitis.[17]

Treatment strategies encompass pain control and targeted exercises. Non-steroidal anti-inflammatory drugs (NSAIDs) are employed for pain relief. The literature describes various types of treatment including rest, heat, ultrasound, electrical stimulation, Diverse orthotic devices, exercise, and surgery.[15,16,18] Notably, corticosteroid injections are discouraged for adolescents due to potential adverse events, such as fat pad atrophy. [19]In our opinion surgical treatment such as medial gastrocnemius recession or plantar fascia release are not part of treatment of pediatric patients.

103 ## Calcaneal stress fracture
104

105 With the escalating levels of physical training, particularly in organized sports, stress fractures
106 have become more prevalent in adolescents. The calcaneus ranks as the second most common
107 site for stress fractures, following the metatarsals.[20]
108

109 Stress fractures arise when a bone is not afforded sufficient time to recover from stress,
110 categorizing into fatigue types (normal bone under unusual stress) and insufficiency types
111 (abnormal bone under normal stress).[20] These fractures often stem from alterations in the
112 mode, intensity, or duration of training, accompanied by factors like transitioning to a more
113 strenuous training surface or notable weight gain. Patient-specific predisposing factors
114 encompass a high longitudinal arch, leg-length discrepancy, limited range of motion (ROM)
115 in foot joints, and excessive forefoot varus.[21–23]
116

117 Clinical signs include a positive squeeze test, and there may be swelling and warmth.
118 Calcaneal pain intensifies gradually during activity, typically locating posterior and inferior to
119 the posterior facet of the subtalar joint.[24] Initial plain radiographs are normal in 90% of cases,
120 but a fracture may become visible within 10 days. More sensitive diagnostic tools, such as
121 MRI and bone scans, are preferred, with MRI being the primary choice for adolescents due to
122 its non-radiating nature.[24,25]
123

124 Calcaneal stress fractures are deemed "low risk," with spontaneous bone healing likely.[26]
125 Nonoperative care involves activity modification, modified rest, and immobilization. Non-
126 weightbearing is recommended for four weeks, followed by partial weightbearing for an
127 additional four weeks, and a return to normal activity around the 12-week mark.[27]
128

## Heel fat pad syndrome

Situated between the calcaneus and the skin, the heel fat pad primarily consists of adipose tissue with an average thickness of 18mm.[28] Serving as a shock absorber, it shields against excessive local stress and diminishes plantar pressures.[25,29] Inflammation of the fat pad commonly underlies symptoms, though pain can also result from heel pad atrophy.[30,31] Chronic heel pain from contusion may occur in runners who use shoes with inadequate cushion.[32]

Patients typically experience deep pain in the middle of the heel, reproducible through palpation. Walking barefoot or on hard surfaces exacerbates the pain, whereas relief is found in the absence of heel pressure.[31] While imaging is not mandatory for diagnosis, it becomes useful when uncertainty arises. Plain radiographs help exclude bony pathologies, while MRI reveals the precise extent of the syndrome.[5] Heel pad syndrome is commonly misdiagnosed as plantar fasciitis. Pain is localized to the heel pad; the plantar fascia is not tender, and pain is not accentuated as the examiner dorsiflexes the toes.

Treatment primarily involves reducing pressure on the fat pad through rest. Common strategies for pain relief include ice, rest, and non-steroidal anti-inflammatory drugs (NSAIDs). Heel cups, appropriate footwear, and taping may also prove effective in alleviating symptoms.[32,33]

## Insertional Achilles tendinopathy with posterosuperior bony prominence

The insertion of the Achilles tendon is found at the posterior calcaneus. Excessive traction at the insertion over time can cause bony hypertrophy or even an exostosis known as a Haglund deformity. Prolonged mechanical stress may precipitate the onset of inflammation in the superficial bursa, Achilles tendinopathy, and retrocalcaneal bursitis.[34] Inflammatory processes and swelling within the tissues situated between the calcaneus and the Achilles tendon contribute to the development of retrocalcaneal bursitis[35], a condition notably associated with the risk factor of wearing rigid shoes, particularly prominent in sports such as skating.[36] Biomechanically, rearfoot equinus, compensated rearfoot varus, compensated forefoot valgus, plantarflexed first ray, and pes cavus are intricately linked to this complex heel pain syndrome.[37,38]

Clinical examination reveals pain upon direct palpation of the dorsal and lateral aspects of the calcaneus. On examination, the presence of a Haglund deformity suggests relatively high stress at the Achilles insertion. Symptoms may present bilaterally and are exacerbated by inadequate footwear.[37,39] Radiographic assessment, specifically standing plain radiographs, illustrates a bony prominence on the superior posterior aspect of the calcaneal tuberosity in lateral views. MRI imaging further delineates a bony prominence on the superior posterior corner of the calcaneal tuberosity, with T2-weighted images highlighting excessive fluid in the retrocalcaneal bursa and retro-Achilles bursa, along with bone marrow edema in the calcaneal tuberosity.[24,40]

A conservative therapeutic approach encompasses the use of NSAIDs, and execise. Alterations in footwear and heel elevation are considered as optional interventions, all aimed at mitigating pressure and alleviating stress on the symptomatic area. The treatment with the highest level of evidence is exercise rehabilitation.[31,39,41,42] In cases resistant to conservative measures and marked by prolonged disability warrant consideration for potential surgical intervention. [43]

## Os trigonum syndrome

The talus bone exhibits two prominent posterior tubercles, serving as attachment sites for the deltoid ligament medially and the posterior talo-fibulare ligament laterally. These tubercles create a groove for the flexor hallucis longus tendon. Originating from secondary ossification centers during adolescence, typically between the ages of 7 to 13, the tubercles fuse with the talus within a year of their appearance. However, on occasion, these ossification centers may not fuse as expected, leading to the formation of a synchondrosis known as an additional ossicle, or os trigonum, with the talus.[44]
Os trigonum syndrome is diagnosed when a patient with an os trigonum experiences symptoms. Trauma or overuse of the ankle, especially in sports involving significant plantarflexion, such as football, ballet, downhill running, or kicking, can trigger the syndrome.[45]
Diagnosis relies on clinical history and plain radiographs. Typical symptoms include ankle stiffness in plantar flexion, chronic pain, and ankle swelling. Rest often alleviates symptoms, and posterolateral tenderness on palpation may be present. Passive plantar flexion can trigger pain.[45] Lateral radiographs, obtained in a fully plantarflexed standing position, help evaluate talotibial impingement, a characteristic feature of os trigonum syndrome. MRI provides additional information on bone marrow edema and scarring of nearby soft tissues, aiding in presurgical planning by visualizing fibrous, fibrocartilaginous, or cartilaginous synchondrosis.[46] Ultrasound can assess flexor hallucis longus tenosynovitis as a potential differential diagnosis.[45,46]

Nonoperative treatment is the initial preference, involving rest, ice packs, NSAIDs, and avoidance of aggravating ankle movements.[45] Physical therapy focuses on strengthening and stretching lower leg muscles, excluding the gastrocnemius to reduce the traction force causing posterior impingement on the calcaneus. [45]Corticosteroid injections may confirm the diagnosis and provide lasting relief in trauma-induced os trigonum syndrome. In cases developed through chronic stress with repetitive full plantarflexion, corticosteroid injections offer temporary relief, but symptoms may return upon resuming previous activities, such as ballet.[47] Surgery becomes a consideration after failed conservative treatment, employing techniques such as posterior endoscopy or open procedures to remove the nonfused fragment. [45]Patients undergoing operative intervention generally exhibit a good prognosis, often returning to sports within three months post-surgery.[48–50]

212 ## Subtalar arthritis
213
214 The subtalar joint, although commonly described as a singular joint, encompasses the articular
215 connections between the talus, calcaneus, and navicular bones. Its primary function facilitates
216 the pronation and supination movements of the ankle. Anatomically, it is further divided into
217 the anterior subtalar joint (ASTJ) and the posterior subtalar joint (PSTJ). The ASTJ comprises
218 the talonavicular and talocalcaneal parts, with the talocalcaneal half featuring anterior and
219 middle facets. In contrast, the PSTJ is formed by a single posterior facet between the calcaneus
220 and talus.
221 Subtalar arthritis can stem from various etiologies, with juvenile idiopathic arthritis (JIA) being
222 a common cause in adolescents. [51]
223 Patients with subtalar arthritis may exhibit systemic features, a family history of rheumatic
224 diseases, ankle edema, warmth on joint palpation, and decreased range of motion. Joint
225 stiffness may occur, alleviating throughout the day and with activity. Diagnostic evaluation
226 includes laboratory tests such as white blood cell count, platelet count, erythrocyte
227 sedimentation rate, C-reactive protein, albumin, and hemoglobin, with some indicating chronic
228 inflammation.[51]
229 Treatment involves nonsteroidal anti-inflammatory drugs (NSAIDs) and disease-modifying
230 antirheumatic drugs (DMARDs). The prognosis for subtalar arthritis varies, with notable
231 improvements in recent years. In rare cases, when the disease progresses to end-stage arthritis,
232 subtalar arthrodesis may be considered as a potential intervention.[51,52]
233

234

## 235 Benign bone lesions

236

237 A diverse array of benign bony lesions can impact the pediatric population, although
238 occurrences affecting the calcaneus are infrequent, representing as low as 3% of all pediatric
239 bone tumors.[53] Benign calcaneal lesions may manifest with symptoms such as pain, mass,
240 and/or swelling, or they can be asymptomatic and incidentally discovered through imaging.
241 Predominantly, the pediatric calcaneus is affected by three primary benign lesions: osteoid
242 osteoma, simple bone cysts, and aneurysmal bone cysts.[53,54]
243 Osteoid osteoma (OO) stands out as the most prevalent benign tumor in the foot and ankle,
244 constituting 35% of all tumors in this region.[53] This tumor classically presents with nocturnal
245 pain alleviated by NSAIDs.[55] Radiographically, OO is characterized by lucency surrounded by
246 sclerosis, occasionally leading to misdiagnosis as a simple bone cyst. CT demonstrates a nidus,
247 which is a round or oval smoothly marginated lytic lesion with central mineralization.[53,55]
248 Surgical excision or radiofrequency ablation constitutes the primary treatment modalities, both
249 demonstrating high success rates.[55]
250 Simple bone cysts are believed to arise from venous blockage, resulting in cancellous bone
251 resorption and the formation of a cyst.[56] These cysts are often incidental findings in
252 radiographs, but calcaneal cysts can induce symptoms due to the weightbearing nature of the
253 bone.[56] Plain radiograph shows a round well delineated lucent lesion. MRI T1-weighted image
254 shows a hypointense lesion, and T2-weighted images show a hyperintense lesion in the bone.[57]
255 Surgical intervention is not recommended for patients with small, asymptomatic cysts.
256 Operative care involves cyst removal and filling with osteostimulative materials such as
257 autograft bone tissue, calcium phosphate, or calcium sulfate products. Approximately 80% of
258 patients treated with bone grafting experience complete resolution.[57,58]
259 Aneurysmal bone cysts (ABCs) are benign, blood-filled, cystic lesions typically found in the
260 metaphyseal regions of bones. Comprising roughly 1% of all bone tumors, only around 1.5%
261 of ABCs occur in the calcaneus.[59] Calcaneal ABCs are generally symptomatic, presenting with
262 pain during weight-bearing and noticeable swelling. [59,60]Physical examination may reveal
263 tenderness, palpable mass, and swelling. The primary treatment for ABC involves curettage
264 and bone grafting, with a high risk of recurrence prompting the use of adjuvants such as high-
265 speed burring, argon beam, phenol, and cryotherapy.[60,61] While the risk of malignant

266 transformation is low, it is typically associated with a history of irradiation. Overall prognosis
267 is favorable with appropriate surgical intervention.[61]
268

269 ## Calcaneal physeal fracture

270 The calcaneus is the first bone of the foot to ossify, while the primary ossification center
271 develops already in utero. Subsequently, a secondary ossification center emerges between the
272 ages of 7 to 9, achieving fusion by the ages of 15 to 17.[6] During its immature phase, the
273 calcaneus is enveloped in cartilage tissue which makes is prone to injuries. The peak age is
274 between 8 and 12 years, and the most prevalent trauma mechanisms are falls from height.

275 Typical manifestations include local tenderness, with more severe cases featuring swelling and
276 an impaired ability to walk.[62] Traditional plain radiographs may lack sensitivity in detecting
277 fractures due to the substantial cartilage component. Complementary imaging modalities such
278 as CT or MRI prove valuable in accurately delineating fracture lines.[5,63]

279 Calcaneal fractures typically exhibit an extra-articular nature and demonstrate favorable
280 healing outcomes without enduring complications. Conservative management involves
281 immobilization, especially for undisplaced or minimally displaced fractures, extending up to 5
282 to 6 weeks. Operative intervention becomes necessary in instances of severe displacement or
283 joint depression.[62]

284 Occasionally, acute fracture of the apophysis is described and should be treated with
285 suture.[64] This is different from Sever's disease, which is secondary to an inflammatory or
286 overload process

287 ## Discussion
288

289 Heel pain in adolescents poses both diagnostic and therapeutic challenges, particularly among
290 athletes, where it can significantly impact sporting activities. However, this issue is not
291 exclusive to athletes and is prevalent among non-athletes as well. This study presents
292 differential diagnoses for diffuse heel pain, emphasizing the importance of physicians being
293 well-versed in a broad spectrum of conditions that may lead to substantial disabilities. While
294 prevention is crucial, a prompt diagnosis, complemented by modern imaging methods like
295 MRI, becomes essential when symptoms prompt a visit to the outpatient clinic.
296

297 The heel area is more susceptible to disorders during the rapid growth phase in adolescents
298 compared to adults. Stress-related factors predominantly underlie heel pain, with initial pain
299 arising post-activity.[9,11] Over time, prolonged overuse escalates the pain, progressing to a
300 point where it occurs even at rest. [9] Certain causes exhibit specific pain regions without
301 apparent swelling, allowing for clinical diagnosis. Many of these pathologies lack a history of
302 acute trauma, and heel pain is often a protracted condition necessitating complementary
303 imaging studies such as MRI for accurate diagnosis.[5] MRI, with its high tissue contrast
304 resolution, is a non-radiating choice adept at accurately depicting chronic and acute
305 pathologies. It proves valuable in monitoring rehabilitation post-treatment and differentiating
306 soft tissue from bone-related conditions.[5,65] While plain radiography offers a fast and cost-
307 effective option for revealing gross bony pathologies and obtaining weight-bearing images,
308 MRI excels in identifying the root cause of heel pain.[65]
309 Heel pain typically responds well to proper therapy and activity modification. Nonoperative
310 modalities involve physical therapy to modify stress loading and strengthen muscles,
311 especially through gastrocnemius-soleus complex stretching. NSAID drugs and R.I.C.E
312 (Rest, Ice, Compression, Elevation) help reduce inflammation and alleviate prolonged pain. It
313 is crucial for physicians to recognize that overuse injuries should respond to activity
314 modification, and patient recovery requires careful monitoring. Although nonoperative means
315 are the primary approach, surgery may be necessary in specific pathologies.[66]
316

317 In conclusion, a thorough history and clinical examination, complemented by appropriate
318 imaging, play a pivotal role in differential diagnosis. While Sever's disease is a prevalent
319 cause of heel pain in adolescents, this study emphasizes the need to consider a range of other
320 potential etiologies.

Key Points:

1. **Diverse Etiologies:** Heel pain in young athletes can result from various causes, with Sever's Disease being the most common. Stress-related injuries, tumors, and bone lesions also contribute to this condition.
2. **Hind Foot Anatomy:** The hind foot's structure, comprising ossicles, physis, and soft tissues, plays a significant role in heel pain. Disruptions in this anatomy can manifest as symptoms like diffuse pain, swelling, and possible bony expansion.
3. **Diagnostic Approaches:** Differential diagnosis involves modern imaging modalities, including magnetic resonance imaging (MRI). MRI can effectively distinguish normal stress-related situations, bony pathologies, and lesions involving the epiphysis.
4. **Treatment Modalities:** Treatment options range from operative interventions to conservative methods. The choice of treatment depends on the underlying etiology, underscoring the importance of an accurate diagnosis. Physically active adolescents may experience heel pain from various causes, impacting their gait and causing prolonged discomfort.

338

339

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