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Sequela of Specialization in Youth Athletes

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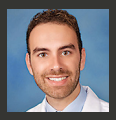

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Clinical Vignette

SS is a 12-year-old female athlete who presented to the PM&R musculoskeletal sports medicine clinic after initial orthopaedic urgent care evaluation for four months of persistent right forefoot pain. She first noticed the pain while working on back handsprings during gymnastics which was attributed to landing awkwardly on her right forefoot. Her pain worsened through summer soccer camp practicing 1.5 hours, three days a week, which improved significantly with eight sessions of physical therapy. About one month prior to her visit with us, she injured her right great toe playing soccer and she could not complete the game. She was treated with activity modification and relative rest for one week before returning to play with self-taping for presumed turf toe. About one week prior to her visit, she ran a 5k with pain during the race that worsened post-race. She only had pain with activities such as walking, soccer, and gymnastics. She did not have pain at rest and denied weakness, numbness, or swelling.

Urgent care diagnosed her with turf toe and recommended conservative management with a controlled ankle movement (CAM) boot. Her mother was not convinced of the turf toe diagnosis given persistent symptoms and recurrent injuries, so she sought a second opinion at our clinic.

Epidemiology of Lower Extremity and Overuse Injuries in Youth Athletes

Recent studies have found that the prevalence of overuse injuries in youth and adolescent athletes was around 50%.[1] Foot and ankle injuries are the most common lower extremity problems.[1] Female athletes have a higher percentage of chronic overuse injuries than acute traumatic injuries, with the opposite pattern seen in male athletes.[2] In addition, female youth athletes have higher rates of lower extremity and spine injuries compared to males, who have higher frequency of upper extremity injuries.[3]

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Drs. Chiang and Rivetti report no relationships with proprietary entities producing health care goods and services.

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Studies have shown that soccer athletes and gymnasts have higher rates of lower extremity injuries, especially in female youth athletes.[4-6] In an epidemiological study by Rössler et al involving soccer players aged 7 to 12 years across two seasons found that over 75% of injuries were in the lower limbs, with joint and ligament injuries having the highest frequency followed by contusions, muscle and tendon injuries, and bone fractures.

Nearly a quarter of all injuries resulted in greater than a 28-day absence from participation in soccer.[7] With respect to injury patterns among gymnasts, a cross-sectional survey found that foot injuries accounted for 21% of all acute injuries and stress fractures primarily involving the spine and foot were found in 16.7% of gymnasts.[8]

Differential Diagnosis

The foot is divided into three sections: forefoot, midfoot, and hindfoot (Figure 1).

The forefoot contains structures distal to the tarsometatarsal joint, also known as the Lisfranc joint. It includes the metatarsal, sesamoid, and phalanges bones.

The midfoot is the section between the Lisfranc joint and the Chopart joint, also known as the transverse tarsal joint and midtarsal joint. It includes the navicular, cuboid, and cuneiform bones.

The hindfoot, which is below the ankle joint and connects to the midfoot by the Chopart joint, contains the talus and calcaneus bone.

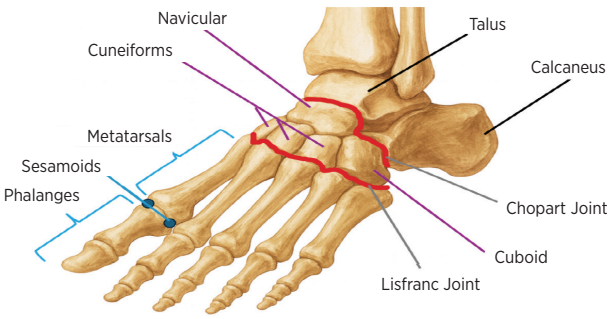


Figure 1: Bones of the foot separated by forefoot (blue), midfoot (purple), and hindfoot (black) labels. The Lisfranc and Chopart joints are delineated in red.

A sprain of the first metatarsophalangeal (MTP) joint, commonly referred to as "turf toe" should be considered in an athlete presenting with forefoot pain, as this involves a hyperextension injury of the first MTP joint with plantar plate sprain or tear. It is often seen in sports that involve significant forefoot loading as well as rapid directional change, such as football, soccer, and dance.[9] The clinical and radiographic findings in the first MTP joint injuries can vary in severity and range from mild sprains to complete ruptures of the plantar plate and sesamoid apparatus.[10]

Injuries involving the tarsometatarsal or Lisfranc joint complex must also be assessed. The Lisfranc ligament complex has three components, including dorsal, interosseous, and plantar ligaments that attach at the lateral aspect of the medial cuneiform to the medial aspect of the proximal second metatarsal.[11] A common mechanism of injury occurs when the foot is in a plantarflexed position with excessive axial force applied to the joint, or if the body is pulled backwards with the forefoot pinned.[12] On exam, tenderness over the tarsometatarsal region on palpation and swelling over the proximal second metatarsal and midfoot region are appreciated. Pain worsens with passive pronation or supination of the forefoot with the heel held stationary.[13]

Tendinitis of the flexor hallucis longus (FHL) and/or flexor digitorum longus (FDL) tendons can be a source of forefoot pain for athletes. FHL tendinitis, occasionally referred to as dancer's tendonitis, is particularly seen in ballet dancers and runners due to repetitive plantarflexion required in the sport. It typically presents with posteromedial ankle pain that may radiate distally along the medial arch and that is exacerbated by weightbearing and activities requiring plantarflexion.[14] FDL tendonitis by comparison is relatively uncommon and can be difficult to differentiate from plantar fasciitis. It is often seen in similar sports, with the mechanism of injury including excessive pronation or toe plantarflexion during propulsion, leading to inflammation of the tendon at the medial plantar aspect of the foot. Pain with resisted toe flexion helps to differentiate FDL tendinitis from plantar fasciitis.[15]

Athletes with pes planus and pes cavus can also present with forefoot pain over time. Patients with pes planus have higher pressure, force, and contact areas across the medial arch, central forefoot, and hallux as well as lower peak pressures at the fourth and fifth MTP joints compared to normal or pes cavus, contributing to forefoot discomfort.[16] Pes planus in

pediatric patients can become painful when the foot is rigid or associated with underlying pathology, such as arthritis or tarsal coalition.[17] In comparison, those with pes cavus have higher pressures at the heel and lateral forefoot, with lower pressure, force, and contact across the midfoot and hallux.[16]

Fractures and growth plate injuries are of consideration in youth and early adolescent athletes. The Salter-Harris classification is often utilized to differentiate types of growth plate fractures involving the physis, metaphysis, and/or epiphysis, which guides prognosis and treatment recommendations. The metaphysis is the part of bone located between the epiphysis, or the ends of the bone near the joint, and the diaphysis, or the shaft of the bone. The physis, also known as the growth plate, is a cartilaginous layer at the ends of long bones responsible for increasing bone length. Among youth soccer players, injuries to the physis account for an important source of injury burden, with one study estimating that these injuries represent approximately 27% of total layoff time.[6,18] See Table 1 and Figure 2 for a description of the Salter-Harris classifications.[19-20]

Sesamoid fractures in young athletes are seen commonly in long-distance runners and athletes participating in sports that necessitate rapid acceleration-deceleration and rotation on the toes, including tennis, racquetball, soccer, football, volleyball, and dance.[21] Athletes typically present with poorly localized pain around the first MTP for several weeks with swelling generally not seen until progression of the injury.[22]

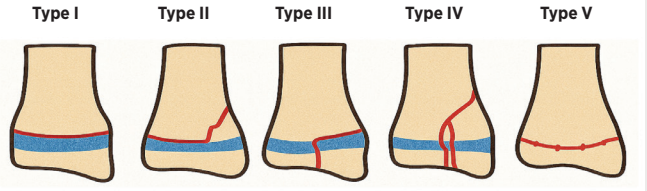
Additional bony pathology to consider in the differential for pediatric and adolescent athletes presenting with forefoot pain includes osteochondritis dissecans (OD) of the first metatarsophalangeal (MTP) joint and fifth metatarsal traction apophysitis. Osteochondritis dissecans of the first MTP joint is a disorder of subchondral bone and overlying articular cartilage due to repetitive microtrauma, vascular insufficiency, or aberrant endochondral ossification.[23] While more commonly seen at the femoral condyles, capitellum, and talar dome, OD can also involve the first MTP joint.[24-25] Fifth metatarsal traction apophysitis (Iselin disease), or inflammation and stress to a growth plate where muscle and tendon attach to bone, involves avulsion of the apophysis at the base of the fifth metatarsal that arises during a period of rapid growth in skeletally immature adolescents.[26]

The mechanism of injury results from repetitive traction forces by the peroneus brevis tendon on the apophysis, often seen with activities that incorporate inversion and stressors on the ankle during running, jumping, and cutting. The exam is notable for pain at the base of the fifth metatarsal.[27] Radiographs are useful for diagnostic purposes and differentiating Iselin disease from acute fractures or os vesalianum pedis, which is a variant sesamoid next to the peroneus brevis tendon insertion.[28]

Table 1. Description of the Salter-Harris fracture types with the associated typical management.[19-20]

Salter-Harris Type	Description	Management
I	Separation of the physis from the metaphysis	Nonoperative
II	Fracture through the physis and the metaphysis with sparing of the epiphysis	Nonoperative for nondisplaced; Surgery for displaced (closed reduction)
III	Through the physis with extension into the epiphysis; damage to the articular cartilage may occur	Open Reduction Internal Fixation (ORIF) for displaced fractures
IV	Fracture passes through the epiphysis, physis, and metaphysis; can lead to joint incongruity and growth disturbances	ORIF
V	Crush or compression injury to the physis	Operative intervention often required

Figure 2: Salter-Harris fracture types with the physis depicted in blue with fracture pattern outlined in red.



Relative Energy Deficiency in Sport (RED-S) and endocrine disorders must be considered in this patient population. RED-S is a state of low energy availability where energy intake is insufficient to support energy expenditure for normal physiological function under higher level exercise demands. This can lead to endocrine dysfunction, impaired bone health, menstrual irregularities, and psychological distress.[29-31] Another condition, avascular necrosis of the metatarsal heads or Freiberg disease, is an ischemic injury to the epiphysis. More frequently seen in active adolescent female athletes with gradual onset of dull achy plantar forefoot pain, Freiberg's most commonly affects the second metatarsal, followed by the third metatarsal, and the fourth metatarsal.[26,32-34] Osteomyelitis, while more commonly seen in the long bones of pediatric patients, can include bones of the foot and should be considered in patients with localized pain, fever, and systemic symptoms.[35] Benign bone tumors, such as simple (unicameral) bone cysts, osteochondromas, and fibrous dysplasia, as well as benign soft tissue tumors including vascular malformations (e.g., hemangiomas), plantar fibromatosis, and schwannomas can be more broadly included on the differential as well.[36-37]

Evaluation and Workup

When evaluating a youth or adolescent athlete presenting with forefoot pain, there are several important components to the initial assessment. Points of emphasis should include the mechanism of injury, chronicity, pain characteristics, aggravating and alleviating factors, associated symptoms, previous injury history, training and activity history, growth and development, psychosocial factors, and impact on functional status.[38] The physical exam should incorporate inspection for swelling, ecchymosis, and joint alignment, palpation of bony landmarks for localized tenderness, passive and active range of motion, strength assessment, special musculoskeletal tests, neurovascular examination of distal pulses and capillary refill, and a biomechanical gait assessment.[38-39] If infection or rheumatologic etiologies are suspected, laboratory workup with complete blood count, inflammatory markers, and blood cultures could be warranted. Initial radiographs should be obtained to assess bone pathologies with consideration of ultrasound or MRI imaging for further evaluation of soft tissue, ligaments, tendons, and joint spaces.

Salter-Harris Management

The decision for operative versus nonoperative management for Salter-Harris injuries is dictated both by the type of injury as well as radiographic characteristics. For Salter-Harris types I and II fractures, nonoperative management is recommended unless there is neurovascular compromise or unacceptable alignment that cannot be corrected with closed reduction.[40] While rare, surgery might be necessary in cases of persistent deformity or failed reduction.[40-42] For Salter-Harris types III fractures, conservative management can be considered for stable nondisplaced fractures with close follow up to monitor for premature growth plate closure. Surgery is strongly considered for any misalignment to prevent growth arrest.[42] For Salter-Harris type IV and V fractures, surgical intervention is standard of care to restore joint alignment and prevent complications, such as growth arrest and post-traumatic arthritis.[42-43] In summary, ORIF is often required to achieve anatomic reduction, maintain joint congruency, and prevent growth arrest in Salter-Harris IV to V fractures.[41-44]

Rehabilitation Plan

Salter-Harris type III injuries if non-displaced can be managed nonoperatively with an initial period of non-weightbearing and immobilization. During the first phase of treatment, patients are immobilized and on strict non-weight-bearing protocol for at least three to four weeks with casting, followed by a boot for three to four weeks until interval imaging confirms absence of joint incongruity or physeal bar formation.[43] There have also been case reports demonstrating healing of Salter-Harris III injuries while wearing a rocker sole shoe modification and activity limitation.[45] Weekly follow up appointments are recommended for the first two to three weeks to monitor fracture stability as it heals.[43]

After weight-bearing restriction is cleared, athletes can start physical therapy to restore range of motion, strength, and function once fracture stability and signs of healing are confirmed by imaging. Serial radiographs are recommended for monitoring complications, including malunion or growth arrest.[46-47] A recent retrospective cohort review by Yamamura et al found that all clinically significant growth plate disturbances after physeal fracture occurred within two years of injury, suggesting serial monitoring with

radiographs is recommended for this duration.[48] While the timeline of progression towards physical therapy is not well defined in the literature, it is often initiated once pain-free ambulation is achieved and the patient has progressed from a cast to a boot.[43,46]

In the early stages of physical therapy when pain is a limiting factor for dynamic mobility or joint movement is restricted, isometric exercises at low to moderate intensity are recommended.[49] This can be followed by progressive eccentric protocols, which are commonly implemented in lower extremity physical therapy post-fracture to reduce joint shear stress.[50] Progressive closed-chain eccentric exercises also have a biomechanical advantage in lower extremity rehabilitation, decreasing joint load and energy requirements.[51] Given the limited literature surrounding specific rehabilitation protocols for first MTP stress fracture injuries, applying principles from first MTP joint sprains can be beneficial. After improvement in pain and swelling, as well as confirmation of fracture healing on radiographs, strengthening exercises to restore toe flexion and extension can be implemented, including toe crunches, short foot exercises, and aquatic exercises.[9] This is followed by a gradual increase in weight-bearing tolerance, advancing strength and range of motion, and progressing gait mechanics without exacerbating pain.[9]

Early Sports Specialization: Definition, Etiology, and Epidemiology

The principle of Early Sports Specialization (ESS) has generated increasing attention in sports medicine as a significant risk factor for injuries in youth or adolescent athletes.[52] ESS reflects a pattern of activity of young athletes devoting intense focus to a single sport, often to the exclusion of other sports or free play.[53] ESS typically involves prepubescent children under 12 years of age (grade 7) who are participating in organized sports for greater than eight months out of the year.[54] Injury patterns among highly specialized youth athletes have been linked to a higher proportion of overuse injuries when compared to low or moderately specialized athletes.[55]

There are several factors that contribute to athletes engaging in ESS. One influence is the belief of parents and coaches that specializing in a single sport can provide a competitive edge for scholarships.[56] In addition, there is a perception that ESS is required to achieve elite status in sports, particularly those in which peak performance is reached before physical maturation, such as figure skating, diving, and gymnastics.[52,57] The American Orthopaedic Society for Sports Medicine (AOSSM) consensus statement surrounding ESS notes that there is no evidence to support that young athletes will benefit from ESS in the majority of sports, and that concentrated activity can lead to overuse injury and burnout.[58] This AOSSM statement also adds that long term athletic success will not be negatively impacted by multisport participation.[58]

Prevention and Risk Reduction for Early Sports Specialization

In a 2016 consensus statement from the AOSSM, several recommendations were put forth in preventing burnout and injury related to ESS in youth athletes. These included avoiding overscheduling and excessive time commitments, emphasizing lifelong physical activity skills, and the consideration of valid and reliable tools to monitor burnout.[58] More specifically, the statement recommended sports training to be less than 16 hours per week with the total hours training per week to be less than the athlete's age.[58] In addition, several case studies have emphasized the importance of assessing balance between intensive sports participation and other formative commitments for youth athletes, such as friendships, school, and extracurricular activities for overall wellness.[59]

It is vital to recognize ESS and have strategies to minimize early specialization and promote sports diversification.[24,52] For athletes in competitive sports with demanding training schedules, we suggest tracking activity patterns. Tools such as the acute-to-chronic workload ratio (ACWR) are helpful for monitoring training load and recovery to balance stress and minimize the risk of injuries.[60] Additionally, enhancing education for coaches, parents, and athletes on topics of ESS in injury prevention, sport readiness, and the value of unstructured play is critical.[61]

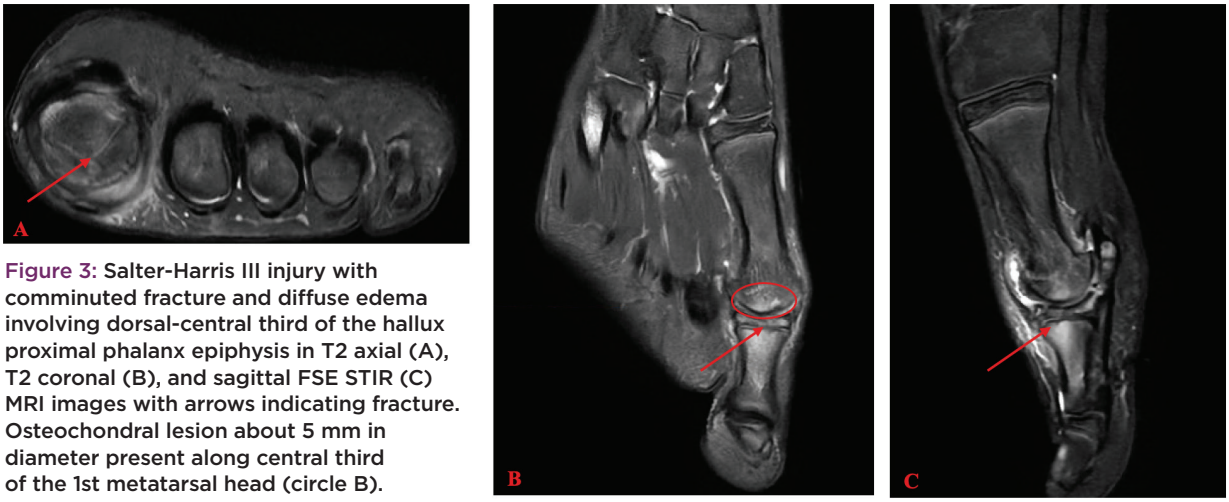


Figure 3: Salter-Harris III injury with comminuted fracture and diffuse edema involving dorsal-central third of the hallux proximal phalanx epiphysis in T2 axial (A), T2 coronal (B), and sagittal FSE STIR (C) MRI images with arrows indicating fracture. Osteochondral lesion about 5 mm in diameter present along central third of the 1st metatarsal head (circle B).

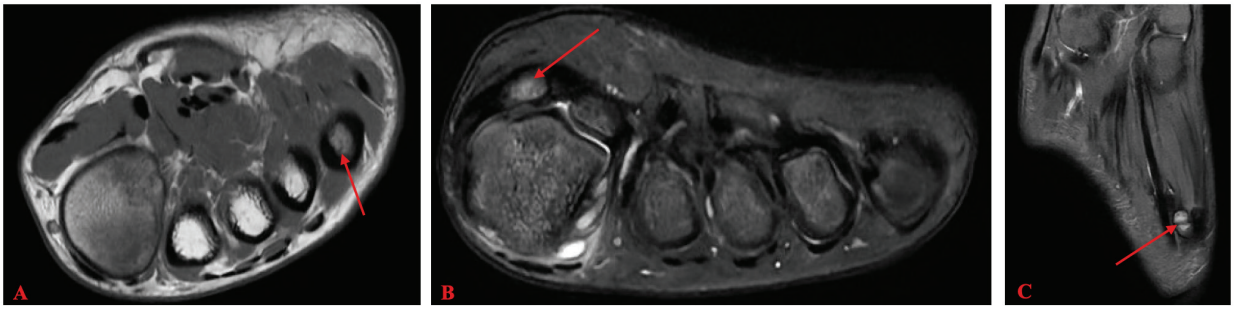


Figure 4: T1 axial MRI showing nondisplaced 5th metatarsal stress fracture (A). Bipartite medial hallux sesamoid with edema of the proximal greater than distal pole raising consideration for sesamoiditis/stress response in T2 axial (B) and T2 coronal (C) MRI images.

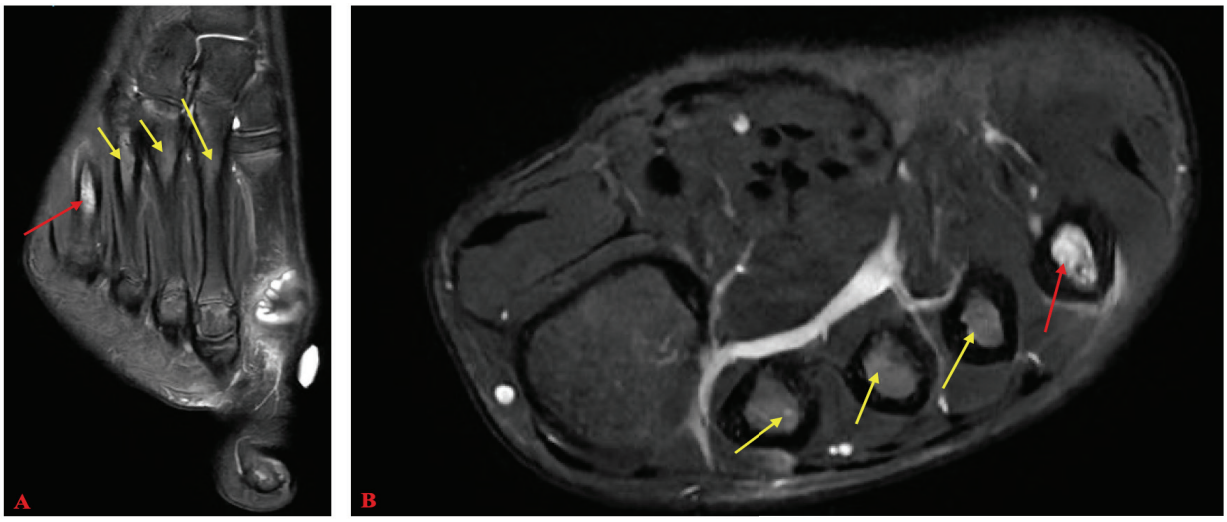


Figure 5: T2 axial (A) and T2 cororal (B) MRI images revealing edema related to 5th metatarsal stress fracture (red arrows) as well as mild edema along the lateral aspects of the 2nd and 3rd metatarsal bases and 4th metatarsal metadiaphysis that may represent areas of stress response (yellow arrows).

Clinical Vignette Outcome

SS's exam was significant for pain with weightbearing affecting her gait. There was a mild effusion and tenderness at the right great toe's MTP joint. She was instructed to weight-bear as tolerated in the CAM boot, limit walking to 2,000 steps, and avoid impact activities such as running or jumping. An MRI of the right foot was ordered given concern for bone stress or growth plate injury to help guide management. The MRI showed a Salter-Harris III injury with comminuted appearance and diffuse edema involving the dorsal central third of the hallux proximal phalanx epiphysis and diffuse edema of the adjacent metaphysis (Figure 3). There was an osteochondral lesion about 5 mm in diameter also present along the central third of the first metatarsal head with mild depression of the subchondral bone plate, surrounding subchondral edema, and suspected overlying deep chondrosis. Additional stress injuries to the right foot are also shown in Figures 4 and 5. The growth plate injury was a result of ESS where SS was playing soccer and gymnastics year-round without a break. SS and her parents were counseled on the injury risks of ESS and the importance of participating in no more than eight months of the same sport.

At her six week follow up appointment, an x-ray of the right foot showed healing of the fracture with stable alignment. The patient was advanced to weight-bearing as tolerated in a boot. At subsequent nine week follow up, she weaned from the boot and began physical therapy with a gradual return to soccer protocol. She successfully returned to full participation in soccer four months from the time of initial presentation to our PM&R Sports Medicine Clinic.

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