ABSTRACT

Background and Incidence: Ischial tuberosity fracture and its associated complications are an under recognized diagnosis in the adolescent athlete. Apophyseal injuries of the pelvis in the skeletally immature athlete can occur in multiple locations but are most common at the ischial tuberosity, affecting males more commonly than females.

Description of Injury and Current Management: The most common cause of ischial tuberosity avulsion fracture is a quick eccentric load to the proximal hamstrings, occurring with kicking as in soccer, football, or dance. Signs and symptoms are similar to a proximal hamstring injury but avulsion injuries often go undiagnosed, as radiographs are not frequently obtained. In acute cases, rest and relative immobilization are the recommended course of care. In chronic cases, including those with delayed diagnosis, or those that remain symptomatic after initial care due to non-union or associated sciatic nerve adhesions, surgery is often performed in order to restore normal anatomy, alleviate symptoms, and help return the athlete to full activity.

Purpose: The authors' share a novel treatment approach consisting of ultrasound guided percutaneous needle fenestration for the treatment of three adolescent athletes with symptomatic delayed diagnoses of ischial tuberosity fractures. Needle fenestration was followed by a physical therapy progression which was developed based on tissue healing rates, symptom presentation, and the available literature related to proximal hamstring injuries.

Outcomes: Two athletes reported elimination of pain, full functional recovery and return to sport without limitations as measured by use of the Numeric Pain Rating Scale, the Global Rating of Change Scale, and the Lower Extremity Functional Scale. One athlete reported elimination of pain and full functional recovery and chose to return to a new sport. Symptoms of possible concurrent hamstring syndrome are discussed as well the management of this condition.

Discussion/Conclusions: This case series introduced a novel approach for treatment of symptomatic delayed union ischial tuberosity fractures in three adolescents prior to consideration of surgical intervention. Percutaneous needle fenestration and the described subsequent rehabilitation provided positive treatment outcomes in the presented cases, including full return to athletic and recreational endeavors.

Key Words: Adolescent apophyseal injury, ischial tuberosity avulsion, percutaneous fenestration, percutaneous tenotomy

Level of Evidence: Level 5
BACKGROUND
Management of proximal hamstring injuries can be challenging for the sports medicine practitioner. In the skeletally immature, chronic traction of the hamstrings origin on the ischium can lead to apophysitis and limited sporting abilities. More acutely, the hamstring tendons can be partially or completely avulsed from the ischial tuberosity, occasionally with fracture occurring through the ischial apophysis. Complete avulsions of the hamstring tendon or bone were once thought of as rare injuries, however the true incidence may be underestimated due to the common misdiagnosis as a "hamstring strain" or "hamstring pull." Complications of apophyseal avulsion injuries include non-union, chronic posterior thigh pain, weakness, as well as development of scarring along the sciatic nerve, termed “hamstring syndrome.” In patients with hamstring syndrome adhesions and or tethering occurs between the sciatic nerve and the proximal hamstring tendons causing radiating pain down the posterior aspect of the leg. (Figure 1) Symptoms are aggravated by compression (such as sitting) or any maneuvers that stretch or place traction on the sciatic nerve (such as running or sprinting). Hamstring syndrome often presents in the athletic population, and surgical intervention is often used as a last resort with good outcomes in those patients who failed conservative care.

Avulsion fractures of pelvic apophyses occur frequently in adolescents because cartilaginous secondary centers of ossification are weaker in tension and shear than tendon during this period of development. Secondary centers of ossification are present on the iliac crest, ischial tuberosity, anterior inferior iliac spine, pubic tubercle, angle of the pubis, ischial spine, and lateral wing of the sacrum. The secondary ossification center of the ischium is first seen in early adolescence and fuses at 19 to 25 years of age. Avulsion injuries affect the secondary centers of ossification primarily in children and adolescents between the ages of 11-17 years.

INCIDENCE
Apophyseal injuries of the pelvis in the skeletally immature athlete can occur in multiple locations but are most common at the ischial tuberosity. These injuries are more prevalent in males than females with an approximate 2:1 ratio. While there are descriptions of ischial avulsion fractures in the skeletally mature, the average age of occurrence of ischial apophyseal injuries/avulsion fractures ranges from 13.5-13.8 years to 16-18 years of age. Many other small case series or single case studies of ischial tuberosity avulsions are present in the literature almost all of which consist of adolescents who have not reached full skeletal maturity. It is rare for this injury to occur in a skeletally mature adult. The authors only found two single case reports of this injury occurring in an adult. One was an 80 year old from traumatic hip abduction and the other occurred after a complicated total hip arthroplasty.

There are presently no case series that describe an alternative to surgery or cessation of sport in adolescent patients who are still symptomatic after failed conservative care.

In the largest series reported to date, Rossi found 203 avulsion fractures of the pelvic apophyses in 198 adolescent athletes. The most frequent location was the ischial tuberosity (109), followed by the anterior inferior iliac spine (AIIS) (45), the anterior superior iliac spine (ASIS) (39), the superior corner of the pubic symphysis (SCPS) (7), and the iliac crest (3). In a recent systematic review Porr et al found...
the ischial tuberosity to be the most frequent site of avulsion, followed closely by the ASIS, and AIIS, with fewer occurrences at the iliac crest, pubis, and lesser trochanter. They concluded that avulsion fractures of the pelvis represent a prevalent pathology among the adolescent population and apophysitis may be a precursor to these avulsion injuries.2,8

Kujala4 described 14 subjects with ischial apophysitis and 21 subjects with ischial tuberosity avulsion fractures. In the 21 subjects with avulsion fractures all but two of them were identified at the time of initial radiographs. Sundar3 reviewed 80 pelvic fractures in children over a ten year period and reported 17 ischial tuberosity (IT) avulsions in 12 patients. They reported that the avulsed fragment was most clearly visualized utilizing an anterioposterior (AP) radiographic view of the pelvis in almost all patients with acute injuries, but in those with chronic traction injuries the radiological changes were subtle, described as well circumscribed radiolucent areas with periosteal reaction.3 These findings often correlate with clearly defined areas of bony edema on magnetic resonance imaging (MRI).

MECHANISMS OF INJURY AND SYMPTOM PRESENTATION

The mechanism of injury for IT avulsion is most often a sudden forceful eccentric contraction of the hamstrings occurring during activities such as a kicking maneuver,2,3,8,19 a fall into the splits,3,4 extreme lower extremity range of motion,8 sprinting,2,4,8,20 or jumping,2,8,20 where the secondary ossification center is the weakest link in the muscle tendon bone unit.29

Ischial tuberosity avulsion can occur in sports that lead to this eccentric overload such as gymnastics, football, soccer, and sprinting. The type of injury depends on the skeletal maturity of the patient. Often the athlete reports a “pop” followed by severe pain and difficulty walking. He or she presents acutely with tenderness over the ischial tuberosity and loss of muscular function of the hamstrings in adolescents.2 The two sports with the highest prevalence of ischial tuberosity fractures are gymnastics and soccer,2,3 followed by endurance running/sprinting,2,4,10,14 judo,4 ice hockey,4,16 figure skating,16 long jump,10 handball,2 fencing,2 basketball,16 tennis,2 football,13,21 high jump,4 baseball,4,16 and rugby.1,3,10 Apophysal injuries may initially be diagnosed as a “torn hamstring” or a “groin pull”, muscular or musculotendinous injuries with which they share common symptoms.1 More chronically, radiographic changes may be mistaken for more grave disease processes such as Ewing’s sarcoma3,16 or pseudo tumor of the ischium.12

MANAGEMENT

Because of their unusual occurrence, there are currently no randomized controlled trials determining optimal management for the adolescent athlete who has not reached full skeletal maturity sustains an IT avulsion fracture. Therefore, one must rely on lower levels of research evidence, consisting of primarily case reports and retrospective case series for management guidelines. Currently, the only suggested treatment option is a prolonged period of conservative care or surgery with or without cessation of sport. In reviewing the literature, little to no discussion of specific physical therapy rehabilitation management exits, so the current authors share a therapy progression which was developed based on tissue healing rates, symptom presentation, and literature on proximal hamstring injuries.

Most adolescents, when diagnosed early, appear to heal well with a prolonged period of rest,4 but in those patients who presented with delayed diagnosis and/or failure of conservative care surgery is often recommended.1,4 The amount of displacement of the avulsion fracture is often used to help determine the need for early surgical intervention. While there is no exact consensus, some authors state that in those with fragment displacement of more than 10-20 millimeters1,4,10,22 or in those patients with persistent symptoms after more than two months of relative rest,4 surgery may be warranted.4,10,22 Although surgical technique described in the literature is variable, open reduction-internal fixation (ORIF) appears to be the treatment of choice for fragments displaced more than 1-3 centimeters.1,4,10,14,22 Gidwani1 reported on 6 ischial apophysis fractures in the skeletally immature (ages 9-16), all but one presenting in a delayed fashion. The early-diagnosed patient exhibited a non-displaced avulsion that healed with conservative management. The five remaining patients exhibited fracture fragment displacement more than two centimeters and a time
range from injury to diagnosis of three months to three years. Four of five patients were managed with surgical intervention, consisting of a ‘Kocher-Langerbeck’ approach for posterior column acetabular fractures that was adapted more posteriorly; all of whom achieved favorable outcomes as defined by the patients being able to return to their previous levels of sports between six and 12 months post-surgically. No specific validated outcome measures were used or described. All surgical patients and the non-displaced/non-surgical case were able to return to their previous levels of sports between six and 12 months post-operatively. Of interest with regard to the above mentioned case series is that in the majority of patients who underwent ORIF, the time from initial injury to surgery ranged from 6-30 months.

Adolescent patients with IT avulsion fractures have been reported to develop fibrous non-unions and complain of functional limitations in sporting activities as well as chronic pain, especially with sitting. In the second largest series of IT avulsions (n = 21), most subjects who exhibited delayed diagnosis or did not rest after injury experienced protracted symptoms ranging from 8-36 months, consisting of pain referral to the posterior thigh mimicking entrapment of the sciatic nerve (which has also been termed as hamstring syndrome). In comparison, those who were diagnosed early (less one month post injury) and who followed a period of prolonged rest fared better. For patients with persistent symptoms in this series, surgery consisted an ORIF for a fracture displaced more than three centimeters as well as posterior femoral fasciotomy. Eight other patients had surgery for persistent symptoms, five consisting of debridement of scar tissue around the sciatic nerve and biceps tendon, and two excisions of bone fragments. Neurolysis of sciatic nerve following chronic symptoms was also described by other authors as an adjunct procedure. Neurolysis of the sciatic nerve at the area of the proximal hamstrings for symptoms consistent with hamstring syndrome has been more frequently described in the literature but not in the adolescent population.

Percutaneous needle tenotomy, or fenestration, has been described both with and without image guidance as an effective treatment for chronic tendinopathy of the common extensor tendon of the lateral epicondyle, achilles tendon, adductor tendon, and patellar tendon. Percutaneous tenotomy has been shown to associate with decreased visual analog pain scores in a heterogenous group of tendinopathic tendons; achilles, patellar, common extensor tendon, proximal gluteus medius, proximal rectus femoris, proximal iliotibial tract, and the proximal hamstrings tendon.

Testa et al studied 68 athletes with Achilles tendinopathy who had failed conservative care. After undergoing percutaneous fenestration and rehabilitation 35 had an excellent outcome, 12 good outcome, 9 fair, and 7 poor. Testa et al also studied the outcomes after percutaneous fenestration for treatment of patellar tendonopathy in 38 athletes who failed conservative care; 16 patients reported excellent outcomes, 9 good, 8 fair, and 5 poor. Similar improvements have been reported for the common extensor tendon of the elbow. Schilders et al studied partial percutaneous tenotomy in 43 professional athletes (39 soccer and 4 rugby) with an average follow up of 40 months. In this series 42/43 returned to their pre-injury level of sport after an average of nine weeks. Their VAS scores were also improved significantly. Maffulli et al studied 29 athletes with chronic unilateral adductor longus tendonopathy who underwent bilateral percutaneous adductor fenestration. Mean follow up was 36 months and 69% returned to their pre-injury level of sport, 7% above pre-injury level and the others either did not return to pre-injury levels or ceased participation in sport.

Recently, platlet rich plasma injections (PRP) have been utilized concurrently with tendon fenestration in order to enhance the healing effect in chronic tendinopathy. Wetzel et al retrospectively reviewed 15 patients with 17 proximal hamstring tendonopathy. Twelve were treated with PRP injections after failing conservative care of physiotherapy and non-steroidal anti-inflammatories. After the PRP injection those patients showed improvement in their visual analog pain scales (VAS) and Nirschl Phase Rating scales. While improvements in both groups were not statistically significant different those patients who failed conservative care (71%) improved with the addition of the PRP injection. The research on PRP and this potential management tool is still in its infancy for intervention in those with proximal hamstring injuries and deserves further examination.
It is hypothesized that percutaneous fenestration or needling disrupts scar tissue and induces bleeding, releasing growth factors to stimulate neovascularization and a healing response.\textsuperscript{25,32,33} Platelet rich plasma injections are also thought to facilitate similar healing properties and release of multiple growth factors.\textsuperscript{31,34} Currently, there is no published evidence on percutaneous healing response procedures on apophyseal avulsion injuries. Therefore, the purpose of this case series is discuss an alternative to surgery consisting of ultrasound guided percutaneous fenestration with or without the additions of platelet rich plasma injection followed by conservative rehabilitation for treatment of delayed diagnosed ischial tuberosity avulsion fractures in three skeletally immature athletes. All subjects and their parents consented to and signed disclosure paperwork to allow their cases to be presented for publication.

**CASE 1**
The first patient was a 14-year-old multi-sport athlete (soccer and football) who was referred to the clinic for a right chronic proximal hamstring injury that was sustained eight months prior. At the time of injury he reported he felt a "pop" and felt like he "broke something." He experienced severe pain in his proximal hamstring area and was unable to walk. He used crutches to assist with ambulation for approximately one week and then reported continuing to limp for "a few weeks" thereafter. Symptoms eased but did not resolve with avoidance of aggravating activities. His aggravating activities included squatting, running, and prolonged sitting. He experienced difficulty and pain with participation in soccer, football, and weight training. Past medical history was unremarkable.

Prior treatment consisted of chiropractic care without radiographs early after his injury diagnosed as a “hamstring strain”. Later, five months post injury, he saw another chiropractor who took anteroposterior (AP) radiograph view of the pelvis which demonstrated an ischial apophyseal avulsion fracture. (Figure 2a) He was referred to physical therapy. After three months of physical therapy by two different physical therapists ,his symptoms were not improved. Consultation was obtained from a pediatric orthopedist who obtained a magnetic resonance image (MRI). (Figure 2b-d) This demonstrated a non-healed avulsion fracture of the right ischial apophysis, distracted five millimeters, with edema between the ischium and the ischial apophysis and intact hamstrings tendons. The apophysis was hypertrophied and exhibited a small area of fragmentation medially. Magnetic resonance imaging is recommended for cases that are difficult to diagnose\textsuperscript{2} or those who have failed conservative care and those in which surgical intervention is contemplated. The patient was referred to the primary author (SS) for physical therapy for a trial of instrument assisted soft tissue mobilization, which has been advocated for use in treatment in proximal hamstring tendinopathy with favorable outcomes in a small case series of competitive distance runners,\textsuperscript{35} but has not been advocated for the treatment of avulsion fractures.

At initial intake the patient reported his numeric pain rating scale was 0/10 at rest and 3-5/10 with activity. He described his pain as “sharp” at the ischial tuberosity area. Pain was worsened with
After four additional visits of physical therapy over a period of approximately three weeks including a trial of instrument assisted soft tissue mobilization and eccentric loading exercises with no appreciable improvement in symptoms it was proposed to the patient and family to consider a percutaneous needle fenestration at the fracture site as a means to induce a healing response prior to considering operative fixation of the fracture. The clinical reasoning regarding progression to this intervention included the failure of all prior conservative care, the goal of returning the athlete to full participation in sports in the fall, and the existing literature advocating surgical intervention when symptoms persisted after an extended period of rest or conservative care.1 The normal healing time frame for avulsion fractures that are acutely diagnosed is approximately sixty days16 to four months.19 The risks and potential benefits of this novel treatment approach were discussed in detail with the patient and family and they consented to treatment. The sports medicine physician performed the procedure three days after proposal to the family. Utilizing an 8-13 MHz linear array transducer ultrasound, the patient’s ischial tuberosity was visualized. At the origin of the conjoined tendon and semimembranosus tendon an area of significant cortical irregularity over the ischial tuberosity at end range but no referral of symptoms down the leg.

<table>
<thead>
<tr>
<th>Time</th>
<th>NPRS 0-10 Rest/Activity</th>
<th>LEFS</th>
<th>Hamstring Strength (prone) HHD (kg) Knee flexion 90°</th>
<th>Hamstring Strength (prone) HHD (kg) Knee flexion 30°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0/10 7/10</td>
<td>57/80</td>
<td>R: 17.37 L: 19.18</td>
<td>R: 9.97 L: 16.32</td>
</tr>
<tr>
<td>6 weeks</td>
<td>0-7/10 7/10</td>
<td>34/80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13 weeks</td>
<td>0/10 0-4/10</td>
<td>70/80</td>
<td>R: 24.04 L: 24.49</td>
<td>R: 19.94 L: 24.04</td>
</tr>
<tr>
<td>23 weeks</td>
<td>0/10 0-3/10</td>
<td>76/80</td>
<td>R: 21.31 L: 25.40</td>
<td>R: 19.95 L: 23.58</td>
</tr>
<tr>
<td>36 weeks</td>
<td>0/10 0/10</td>
<td>78/80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>41 weeks</td>
<td>0-1/10 1-2x week after workouts</td>
<td>79/80</td>
<td>R: 27.66 kg L: 24.49 kg</td>
<td>R: 18.59 kg L: 18.59 kg</td>
</tr>
<tr>
<td>3 years</td>
<td>0/10 0/10</td>
<td>80/80</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

NPRS=Numeric Pain Rating Scale, LEFS=Lower Extremity Functional Scale, HHD=MicroFet 3 Hand Held Dynamometer
responding to the fracture site seen on MRI. In an outpatient facility, under sterile conditions, the skin and soft tissues were anesthetized with 1% lidocaine without epinephrine and 0.25% Marcaine without epinephrine under direct ultrasound visualization. A 21 gauge needle was then used to repeatedly fenestrate the tendon origin into the ischial tuberosity and apophysis, with approximately 40 forceful needle passes circumferentially about and into the fracture site. Following the intervention the patient was placed on crutches and was instructed to remain non-weight bearing and avoid sitting directly on his right buttock for two weeks.

Rehabilitation after percutaneous fenestration was adapted from the protocol devised Metzmaker and Pappas (Table 2) which was utilized for treatment after acute avulsion fractures. Information regarding specific suggestions for rehabilitation of this condition is scarce. Two other authors only described advocating a period of rest and delayed stretching\(^\text{21}\) after acute avulsion injuries. Theoretically, percutaneous fenestration consisting of multiple needle penetrations of the periosteum and apophysis produces an environment similar to acute fracture and thus creates an entirely new healing episode. The rehabilitation progression presented herein by the authors was based on proposed healing rates of bone as well as by symptoms. Physical therapy was initiated at nine days post-intervention and consisted of gentle soft tissue mobilization consisting of light effleurage of the distal to mid portion lateral hamstring muscle belly where he experienced some soreness, reiteration of protected toe touch weight bearing starting at two weeks post intervention, and instruction in gentle isometric exercises consisting of gluteal and quadriceps sets. Neuromobility exercises, consisting of ankle pumps in supine were started to avoid the possible sequelae of sciatic nerve adhesions and hamstring syndrome.\(^\text{5,7,40}\) He was instructed to avoid hamstring stretching and activities which produced any increased symptoms at his ischial tuberosity. Visit two; 16 days post-intervention he reported still experiencing a deep achy pain in the proximal ischial tuberosity area. Toe-touch weight bearing was reviewed and the subject was educated to avoid any activity or movements which aggravated his symptoms. Home exercises were progressed to include supine abdominal crunches. He was allowed to perform any lightweight upper extremity exercises he could perform in which he felt no additional symptoms in hischial tuberosity area. Care was taken not to stretch the hamstrings during the first six weeks of treatment to avoid any pulling on the fracture site. The clinical reasoning used for protected weight bearing for a longer duration than that advocated by Metzmaker and Pappas\(^\text{16}\) had to do with his symptom presentation (continued pain), and bony

<table>
<thead>
<tr>
<th>Treatment Phase</th>
<th>Days after injury</th>
<th>Subjective Pain</th>
<th>Palpation</th>
<th>Subjective-Pain</th>
<th>Objective-tissue</th>
<th>Range of motion</th>
<th>Muscle Strength</th>
<th>Level of Activity</th>
<th>Radiograph Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0-7</td>
<td>Moderate</td>
<td>Moderate to Severe</td>
<td>Very limited</td>
<td>Poor</td>
<td>None, protected gait</td>
<td>Osseous separation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>7 to 14-20</td>
<td>Minimal</td>
<td>Moderate</td>
<td>Improving with guided exercise</td>
<td>Fair</td>
<td>Protected gait Guided ex</td>
<td>Osseous separation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>14 to 20-30</td>
<td>Minimal with stress</td>
<td>Moderate</td>
<td>Improving with gentle stretch</td>
<td>Good</td>
<td>Guided exercise, resistance</td>
<td>Early callus formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>30-60</td>
<td>None</td>
<td>Minimal</td>
<td>Normal</td>
<td>Good to Normal</td>
<td>Limited athletic participation</td>
<td>Maturing callus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>60 to RTS*</td>
<td>None</td>
<td>None</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Maturing callus</td>
<td></td>
<td></td>
</tr>
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</table>

* Return to Sport

hand held dynamometer testing revealed a significant improvement in strength and did not elicit pain therefore hop testing was performed comparing the involved extremity to uninjured extremity. (Table 3) Hop testing has been reported as a reliable and valid functional measure in athletes following knee injuries to determine readiness of return to sport and normalization of functional strength. Repeat testing was performed at various intervals, but not until week 23 did his strength begin to equalize with his uninjured extremity. An outline of therapy progression is presented in Appendix 1.

Follow up questionnaires were completed 18 and 36 months following percutaneous fenestration to determine long term outcome. At the 18 month mark the patient reported a global rating of change score (GROC) at +7, no pain 0/10, and LEFS score of 79/80. The global rating of change score is based on an index with subjective reports of improvement in status ranging from -7 (a very great deal worse) to 0 (about the same), to +7 (a very great deal better). The GROC is reliable and valid and has been correlated with hop testing. The patient had returned to playing football/sports without any limitations at 41 weeks. At the 36-month post intervention mark the patient continued with a GROC of +7, pain-free NPRS 0/10, and his LEFS score improved to 80/80.

**CASE 2**

The second patient was a 14-year-old male referred for right chronic posterior thigh pain, which began approximately eight months previously while playing football. He stated that he stepped in a hole and felt his leg jerk, experiencing immediate pain. He was able to continue training and ignored his pain, however his symptoms worsened during football.

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| Table 3. Case 1: Hop testing post-intervention, in meters. |
|---|---|---|---|
| Hop Testing Time: | Single Leg Hop | Triple Leg Hop | Cross-over Hop |
| 13 weeks | R: 1.14 m | R: 4.03 m | R: 3.12 m |
| | L: 1.32 m | L: 4.21 m | L: 3.35 m |
| 23 weeks | R: 1.41 m | R: 5.15 m | R: 4.26 m |
| | L: 1.70 m | L: 5.18 m | L: 3.88 m |
| 41 weeks | R: 1.69 m | R: 5.10 m | R: 4.08 m |
| | L: 1.57 m | L: 5.00 m | L: 4.05 m |
season. Prior treatment reported of chiropractic manipulation and anti-inflammatories did not help his symptoms. An AP pelvis radiograph taken eight months post injury revealed an abnormal fragmenting in the region of the right ischial apophysis consistent with a chronic avulsion fracture of the ischial tuberosity. (Figure 3) He complained of pain ranging from 0-8/10, which limited his ability to sprint and eased with rest, and a LEFS score 52/80. He recently had taken up weight training in preparation for a bodybuilding competition and reported difficulty with squatting activities. Past medical history was significant for left tibia-fibula fracture with complete recovery.

On visual observation, gait was normal. Palpation produced tenderness over his ischial tuberosity. When performing a deep double leg squat he shifted hips to the left demonstrating unequal weight bearing favoring his uninvolved extremity. Strength testing with a hand held dynamometer revealed weakness in the right hamstrings, especially when tested at 90° knee flexion, 61% right to left ratio. Conservative care was attempted since he stated that his symptoms had improved since avoiding aggravating activities and squatting endeavors over the past two months. Initial treatment consisted of instrument assisted soft tissue mobilization to the proximal hamstrings and active range of motion eccentric hamstring exercises for the first visit. On the second visit, the following week he reported no pain therefore single leg hop testing (an average of three trials) was performed: right 1.12 meters (m), left 1.32 m (84.6%) and was pain-free therefore he was progressed to jogging. He was able to jog on the treadmill for about five minutes pain-free. The following visit his LEFS improved to 58/80 and his hamstring strength ratio to 83% at 90° knee flexion. His exercises were advanced to progressive eccentric loading. Approximately two weeks later, he participated in a body building competition and reported no difficulties or pain until the end of the competition where he felt like he re-injured his buttock during one of his last poses. His pain levels rose up to 7/10. His LEFS score decreased to 44/80 at his initial visit. This re-injury occurred after three months of relative rest and one month (3 visits) of physical therapy. At this visit, due to re-aggravation of his injury and his goals of returning to sports and body building endeavors more rapidly, percutaneous fenestration was discussed with the patient and his family by the second author. The patient consented and scheduled the intervention for the following week. Prior to his intervention he was instructed to perform neuromobility exercises, consisting of ankle pumps in supine multiple times per day to avoid the possible sequelae of sciatic nerve adhesions and hamstring syndrome. The intervention was performed by the sports medicine physician under ultrasound guidance as described for our first case. Following his percutaneous fenestration intervention the patient was placed on crutches and was instructed to remain non-weight bearing and avoid sitting directly on his right buttock for two weeks.

Two weeks after the procedure he was seen in physical therapy. He reported some soreness for a few days after the procedure but no pain the following week. His NPRS score was 0/10. At this time he was progressed to toe touch weight bearing with crutches and started on pain free isometrics as our first case. Two weeks later, the patient reported to continue to be pain free and his LEFS score was 59/80. It was noted on his LEFS that he reported a “4” or “no difficulty” for both running and hopping activities. However at this time, he was still supposed to be using his crutches. He was questioned specifically about this and reported that he ran across the street once holding onto his crutches. It was decided that due to
his report of pain free running for a short distance that the crutches were not longer necessary and they were discontinued at this time. He was also asymptomatic with sitting and walking. Time frames were adjusted based on his clinical presentation. In this case his radiographs showed less irregularity and displacement at the ischial tuberosity, as compared to the presentation of the subject in the first case, which may have contributed to quicker healing rate (based on symptoms). Pain, functional testing including use of the LEFS, as well as hop testing was performed to help guide rehabilitation and determine readiness for return to weight training activities. (Tables 4-6) Radiographs were obtained eight weeks after the procedure when the patient was asymptomatic. (Figure 4) He was instructed to resume his weight training activities with a weekly incremental progression of weight over the next two months and to monitor for any symptoms. The same guideline was used for running. At the 6-month follow-up, the patient reported absence of pain, NPRS 0/10, LEFS score of 80/80, and a GROC score of +7. He had returned to his full weight-training activities without any limitations. He had chosen to discontinue football and pursue body-building competitions, as that had become his sport of preference after his initial injury.

**CASE 3**

The third patient was a 16-year-old female school dance team member who reported onset of symptoms after performing a high kick with the right leg in practice. Initially she thought that she had “pulled her hamstring” but her symptoms continued to worsen with time, therefore she sought an orthopedic consult approximately five weeks post injury. At that time she complained of a sharp pain in her right proximal

<table>
<thead>
<tr>
<th>Table 4. <em>Case 1: Pre-Post Intervention Data.</em></th>
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</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>0 days</td>
</tr>
<tr>
<td>8 days</td>
</tr>
<tr>
<td>22 days</td>
</tr>
</tbody>
</table>

NPRS= Numeric Pain Rating Scale, LEFS=Lower Extremity Functional Scale, HHD= MicroFet 3 Hand Held Dynamometer

<table>
<thead>
<tr>
<th>Table 5. <em>Case 2: Post-intervention data.</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
</tr>
<tr>
<td>2 weeks</td>
</tr>
<tr>
<td>4 weeks</td>
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<tr>
<td>6 weeks</td>
</tr>
<tr>
<td>9 weeks</td>
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<tr>
<td>6 months</td>
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</tbody>
</table>

NPRS= Numeric Pain Rating Scale, LEFS=Lower Extremity Functional Scale, HHD= MicroFet 3 Hand Held Dynamometer
buttock that became worse with stretching or kicking activities. Past medical history was unremarkable other than a prior T7 compression fracture sustained snowboarding at age 10 that healed uneventfully. Radiographs were taken which revealed asymmetry in the apophyseal origin consistent with an avulsion fracture. (Figure 5a) She was instructed from the orthopedic surgeon to take six weeks off dancing activities then referred to physical therapy. Physical therapy consisted of ten visits over a two month period utilizing instrument assisted soft tissue mobilization, exercise (hamstring stretching, isometrics, concentric and eccentric exercises) and interferential stimulation. She experienced a decrease in her pain but when she attempted to return to sport she still reported pain with running and kicking activities in dance. She then returned to the orthopedic surgeon who obtained follow up radiographs, approximately three months following her initial radiographs. (Figure 4b) There was no appreciable healing demonstrated. An MRI was obtained that showed widening of the apophysis without any significant displacement of her ischial tuberosity. She was then referred for percutaneous fenestration to the second author by the orthopedic surgeon; it was also suggested to the patient that she may benefit from addition of a platelet rich plasma injection, which may have benefit in treating chronic tendonopathy conditions including those involving the proximal hamstrings. Benefits and risks were discussed with the patient and her family. The patient consented and scheduled the intervention six weeks later. The intervention was performed under ultrasound guidance as described for the previous cases, with the addition of platelet rich plasma injection.31

She was referred to physical therapy with the primary author three weeks status post percutane-

Table 6. Case 2: Post-intervention hop testing.

<table>
<thead>
<tr>
<th>Hop Testing: Time</th>
<th>Single Leg Hop</th>
<th>Triple Leg Hop</th>
<th>Crossover Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 weeks</td>
<td>R: 1.60 m</td>
<td>R: 4.62 m</td>
<td>R: 3.75 m</td>
</tr>
<tr>
<td></td>
<td>L: 1.60 m</td>
<td>L: 4.59 m</td>
<td>L: 3.81 m</td>
</tr>
</tbody>
</table>

Figure 4. Subject 2: AP Pelvic Radiograph eight weeks post percutaneous tenotomy, black arrow. Note some increase in sclerosis and callus formation.

Figure 5. Subject 3: Close up of AP Pelvic view of the right ischial tuberosity A. Close up AP Pelvic view of her right ischial tuberosity taken 5 weeks post injury. B. Repeat film taken 4 months post-injury after the first round of physical therapy, note no appreciable healing, with possible increase in bony displacement C. Repeat films taken 10 months following percutaneous fenestration/PRP procedure showing almost complete healing (black arrow).
ous fenestration. At the initial examination she reported her pain levels ranging from 0/10 at best (laying down) up to 7/10 with sitting and her LEFS score was 58/80. She also complained of intermittent sharp shooting pain originating at the proximal hamstring radiating pain down the posterior aspect of her thigh which she rated 7/10. She reported her radiating pain occurred two-three times per day for duration of two to three minutes. Sitting aggravated her proximal buttock (ischial tuberosity) symptoms, especially when sitting on hard surfaces such as classroom chairs. Additionally, unlike the prior two subjects, she exhibited a positive slump test and straight leg raise (SLR) test for reproduction of her radiating leg pain. Examination of her lumbosacral spine exhibited only mild radiating pain at end range flexion with the addition of neck flexion, she did not have any reproduction of symptoms or pain with passive accessory testing to the lumbar spine. Her neurological examination was normal. She was tender to palpation at her ischial tuberosity. These symptoms and presentation are consistent with possible concurrent hamstring syndrome, in which the sciatic nerve is irritated and or tethered to the hamstring tendons origin.\textsuperscript{5,6} Treatment was similar to the first two subjects, with the additional of progressive of neurodynamic exercises to address her radiating symptoms.\textsuperscript{40,48} Turl et al\textsuperscript{40} reported adverse neural tension as assessed using a positive slump tests in 51\% of male rugby players with a history of repetitive hamstring strains verses 0\% in a control group. In a case report, Aggen and Reuteman\textsuperscript{45} described the utilization of sciatic nerve glides as a component of rehabilitation in a patient with sciatic nerve injury following a hamstring tear. There are currently no reports in the literature of conservative management of hamstring syndrome concurrent with an ischial tuberosity avulsion fracture.\textsuperscript{5,6} These tests have been found to be reliable and valid for proximal hamstring tenonopathy as compared to MRI findings in a population of 92 athletes.\textsuperscript{49} These particular two tests were not performed in the first two cases, as the primary author only recently became aware of them. She did exhibit a positive bent hamstring test for reproduction of proximal hamstring pain. Hip examination revealed pain free range of motion including combined motions with overpressures however she did exhibit some mild hip abductor weakness with mild pain, which could be inter-related to her lumbar spine and distal (buttock) symptoms.

She remained asymptomatic for approximately three months then she started experiencing proximal hamstring pain after taking a new job, which required her to sit for prolonged periods. She had also stopped exercising at the gym. After a few months of continued symptoms she returned to the physician for follow up. Radiographs were taken which showed healing of her ischial tuberosity avulsion fracture, (Figure 4c) and the subject was referred back to physical therapy with pain and symptoms consistent with proximal hamstring tendonopathy/syndrome and concurrent low back pain. She did not exhibit any radicular symptoms but had pain in the proximal hamstring insertion area with Slump testing and SLR at end ranges. Recent tests advocated to aid in diagnosis of proximal hamstring tendinopathy include the modified bent knee stretch test\textsuperscript{49} and the Puranen-Oravio test\textsuperscript{49} which are similar in position to both the passive SLR test and Slump tests. These tests have been found to be reliable and valid for proximal hamstring tendinopathy as compared to MRI findings in a population of 92 athletes.\textsuperscript{49} Lumbar examination revealed pain free lumbar AROM with overpressures, but passive accessory movement testing revealed hypermobility at spinous process of lumbar vertebra L5 with local pain in her lumbar spine. Running on the treadmill did...
not aggravate her symptoms. Sitting was her primary aggravating activity. Her neurological examination was normal. She was treated for an additional eight visits in physical therapy over a three-month period and during the last month she resumed running and gym activities on a regular basis. Specific details of treatment are beyond the focus of this paper but consisted of limiting her sitting periods, a corticosteroid injection to the proximal hamstring area, lumbar stabilization exercises as she fit the criteria for stabilization according to Hicks50 and Rabin,51 neuromobility, and progressive eccentric loading exercises.52 Additionally, core or spinal stabilization exercises have been shown to have a positive effect on athletes who have sustained hamstring injuries,39,52 therefore a multi-factorial treatment approach was utilized. She returned to exercising regularly at the gym where she was able to run on the treadmill pain-free. Three months later she reported a GROC score of +7 and an LEFS score of 77/80. Her low back pain was absent. She did still report mild buttock pain up to 3/10 with sitting for more than 2 hours that eased immediately upon rising from sitting and lasted only 10 minutes in duration. At this time hop testing was performed. She was able to run and do all weight training exercise endeavors without pain. (Table 8) She was discharged from physical therapy. Two months later she joined the track team where she participated in the long jump. She reported initially she had some discomfort in in her proximal hamstring but then it dissipated as the season progressed. Eighteen month follow up after percutaneous fenestration she reported a GROC score of +6 and an LEFS score of 77/80.

**DISCUSSION**

Details of conservative rehabilitation or post surgical rehabilitation of ischial tuberosity avulsion fracture are minimally described in the literature.1,4,16,20,22 To the authors’ knowledge there are no case reports or lit-
erature published on the use of percutaneous needle fenestration to induce a healing response in delayed diagnosis ischial tuberosity avulsion fractures in adolescents. Most case reports or case series for the acutely diagnosed injury consist of a period of prolonged immobilization with limited weight bearing and slow return to recreational activities.\textsuperscript{1,4,16,20,22} Metzamker and Pappas\textsuperscript{16} presented a rehabilitation protocol for conservative care for treatment of all types of acute avulsion fractures of the pelvis. Their series consisted of six IT fractures along with other apophyseal fractures of the pelvis including the lesser trochanter. The protocol was broken into five phases and has been presented earlier in this paper. The criteria for progression was based on time from injury, pain, palpation, range of motion, muscle strength, activity level and radiographic appearance. Recently, after this case series was completed, Biedert\textsuperscript{20} published a more detailed post-surgical rehabilitation progression of a case series of three adolescent patients with proximal IT apophyseal fractures. They initially limited sitting to the uninvolved buttoc and non-weight bearing on the involved extremity for six weeks followed by a slow progression to full weight bearing at 12 weeks post-surgery. Physical therapy consisting of active range of motion and supervised strengthening was started at six weeks post surgery. After four months, dynamic stretching and jogging allowed. At six months the three athletes were released to full sporting activities.\textsuperscript{20} A recent case report by Ceretti\textsuperscript{19} was published outlining a criterion progression for rehabilitation of an acutely diagnosed avulsion fracture in a 15 year old football player, which clearly demonstrates the benefits of early diagnosis with subsequent rest and limited weight bearing in the early stages to facilitate healing. Once bony healing and symptoms diminished, progression included agility and trunk stabilization exercises at low intensity for the following five weeks. At eight weeks therapy was progressed with higher-level stabilization exercises and agility exercises. Progression to static stretching and isometric strengthening started at sixteen weeks and was then progressed to include dynamic stretching and concentric and eccentric hamstring strengthening. Full return to sport occurred at four months.

All too often these adolescent athletes who sustain ischial tuberosity avulsion apophysitis or avulsion fractures are misdiagnosed with a hamstring strain and will often continue weight-bearing and stretching/strengthening activities which results in a prolonged period of convalescence and lack of full resolution of symptoms. Contrary to the adult population where isometrics followed by eccentric loading progression are indicated for hamstring injuries,\textsuperscript{52} these activities should be significantly delayed in the adolescent with an apophyseal injury.\textsuperscript{1,19}

These protocols may work well in the acutely diagnosed patient with ischial tuberosity fractures or a post-operative patient but may not work as well for the delayed diagnosis patient with minimal to moderate displacement that remains symptomatic. This variability in recovery time is evident in the three subjects presented in this case series. The first subjects’ fracture appeared more fragmented and was more displaced that those seen in the other two subjects therefore his progression was slower. Each subject's presentation of signs and symptoms were concurrently considered along with bony tissue healing time frame in order to determine their clinical progression. Hop testing was performed at 9 and 8 weeks in subjects two and three respectively, whereas pain levels prohibited this from being performed until 13 weeks in subject number one. Reasons for this may include a decreased size of the avulsion fracture, less fragment displacement, and earlier diagnosis with limited sports participation immediately post injury for the latter two subjects. The first subject had continued to run and participate in football for an entire season despite his pain and dysfunction. The second subject had taken a couple weeks off after injury but then once he returned to activity, noted a progression of his symptoms. The third subject also limited her activity levels immediately after injury but her symptoms did not improve. This may or may not have been related to rehabilitation prescribed which included static stretching and concentric eccentric exercises despite continued pain presentation. Finally, the third subject also differed due to presentation of concurrent signs (positive straight leg raise and slump) and symptoms (pain radiating down the leg) suggestive of hamstring syndrome. Therefore, in addition to a standard progression, neurodynamic exercises were integrated into her post-intervention rehabilitation. Interestingly, although she became completely asymptomatic, similar symptoms returned.
three months after discontinuing therapy, after a period of increased prolonged sitting with a concurrent decrease in activity levels. She presented with possible symptoms of hamstring syndrome (pain with sitting) and low back pain, which have may indicated a more multi-factorial component to her new presentation. Her follow up radiographs taken six months after her percutaneous fenestration did show significant healing, which might confirm that the percutaneous fenestration technique had induced a healing response. While beyond the scope of this paper, proximal hamstring tendinopathy and/or hamstring syndrome as discussed in the third subject may be a common differential diagnosis or co-morbidity present in the adolescent, especially in those cases where radiographs are normal.

The three presented cases demonstrated that the use of percutaneous fenestration combined with a conservative rehabilitation may have a significant therapeutic effect for those adolescents whose diagnosis is missed acutely. The authors presented a rehabilitative framework for intervention post percutaneous fenestration, which was also used with a subject with concurrent symptoms hamstring syndrome. Percutaneous fenestration can be performed by any physician who is trained in sports medicine and the used of ultrasound guided techniques. The procedure can be performed in the physicians office. A team approach between the physical therapist and physician is ideal for optimal outcomes.

CONCLUSION

Ischial tuberosity avulsion fracture is an often-overlooked diagnosis in the adolescent athlete. Initial conservative management of these patients can be delivered appropriately if they are diagnosed early utilizing an AP radiographic view of the pelvis. If an IT avulsion is present, conservative rehabilitation should include a period of non-weight bearing and limited stretching/strengthening exercises in the affected limb. In those cases where diagnosis is delayed or the patient has continued symptoms, percutaneous fenestration may be an alternative to surgery for symptomatic non-union ischial tuberosity avulsion fractures. Following needle fenestration with conservative rehabilitation may allow return to full and pain-free functional and recreational endeavors. Further research is needed to clarify the role of percutaneous needle fenestration on apophyseal fracture delayed union and non-union IT avulsions in the adolescent athlete. Likewise, the possible presence of concurrent diagnoses such as hamstring syndrome pathology and lumbar involvement needs to be highlighted.

REFERENCES


42. Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid


