Femoral Neck Bone Stress Injuries in Pediatrics and Adolescents: Diagnosis, Etiology, and Treatment

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Abstract:
Femoral neck bone stress injuries (FNBSI) are an uncommon diagnosis of groin or hip pain in the adolescent athlete. The true incidence is currently unknown and needs to be considered in the young athlete with atraumatic hip or groin pain. The current literature is sparse in describing the workup and treatment of FNBSI in the adolescent and pediatric population, and the literature lacks consensus of FNBSI nomenclature and appropriate use of imaging for all ages. This leads to inconsistency in understanding the etiology of the injury, prevalence of injury, workup of risk factors for FNBSI, and communication of diagnosis and management. The purpose of this Current Concept Review is to explore the pathophysiology, risk factors, and clinical presentation for pediatric and adolescent femoral neck bone stress injuries, discuss existing classification of atraumatic FNBSI, review imaging tools available to clinicians caring for young athletes and differing treatment options.

Key Concepts:

- Atraumatic hip or groin pain should be evaluated for a femoral neck bone stress injury.
- FNBSI occur in the young population as early as age 5 and increases in incidence during adolescence.
- Sexual bone dimorphism does not seem to play a role until after the age of 6.
- Female incidence is higher than male and certain sports are at higher risk of BSI as a whole.
- MRI is the gold standard for diagnosing and grading FNBSI.
- Young athletes may be successfully managed with conservative treatment, but surgical fixation should be considered for tension sided injury, compression injury >50%, or for those who fail conservative management.

Introduction

Bone stress injuries (BSI) have been reported as far back as 1905 by Blecher in his reports on the German military[6] and later defined by Blickenstaff and Morris in 1966 who compiled a series of 41 "fatigue" femoral neck fractures in 36 men (average age 22.5 years) during the first 8 weeks of basic military training.[7] "Fatigue" fracture was used to simplify terminology for the reader; the authors make note that this pathology is a process due to repetitive stress on the bone altering the balance between osteoblastic and clastic activity and that no fracture line may in fact be seen.[7] Since that time, modern developments in diagnosis and imaging have allowed for a better understanding of the complexities of bone physiology in the skeletally mature person. Still needed is an understanding of BSI specific to the femoral neck in an immature osseous skeleton or one that has just only recently fused.

Data on the true incidence of bone stress injury in pediatric patients is lacking, and even less literature speaks directly about BSI of the femoral neck. It has been proposed that BSIs in general account for 0.7–21.1% of all sports-related injuries, with tibia, tarsals, and metatarsals being the most common locations reported.[8]

Recent research postulates a nearly fivefold increase in pediatric BSI from 2000–2015 from a rate of 1.37 cases per 100,000 outpatient visits in 2006 to 5.32 per 100,000 visits in 2015.[8–12] Perhaps this is related to advances in and more widespread use of radiology studies like MRI. This timing may also relate to a concurrent shift from recreational and multi-sport participation to a more specialized, private, and profit-driven engagement. Unfortunately, early sports specialization has been linked to higher risk of injury, burnout, as well as other psychological ramifications.[13] Race and socioeconomic disparities also factor into the culture of sports and early sport specialization, as many of these club and private teams are for-profit and costly for families.[13,14] With future studies, ascertaining the intrinsic versus extrinsic factors amongst a pediatric population may better assist in understanding the modifiable risk factors and allow for earlier intervention.

Limited literature was identified specific to femoral neck bone stress injuries in the young athlete. In this review, we summarize nearly 50 pediatric and adolescent publications specific to bone stress injuries but not necessarily specific to the femoral neck or pediatric population. In addition, we reviewed multiple papers describing pediatric growth as well as papers detailing possible intrinsic and extrinsic risk factors in this youth population. Lastly, we looked at imaging modalities and grading scales for FNBSI and did not find a consensus of terminology and best imaging modality.

Etiology: Pediatric Risk Factors

Current literature is sparse in discussing the predisposing risk factors for pediatric and adolescent FNBSI. Further research detailing incidence as well as summarizing a collection of risk factors both intrinsic (age, sex, femoral neck geometry, as well as other anatomical factors) and extrinsic (sport played, training routines, hormonal milieu, nutrition, sleep, and the role of energy sufficiency versus deficiency) may help medical providers prognostically understand what contributes to the development of a FNBSI.

Bone mass accrual is an integration of factors including but not limited to gender, race, genetics, puberty and a hormonal milieu, nutrition, and physical activity.[15] If bone mineral accrual is highest during adolescence, this implores the question, why do bone stress injuries seem to occur during these formative years? In a study by Patel and colleagues, the number of stress fractures between 2000 and 2015 were shown to rise fivefold, with 14- to 18-year-old patients being the most affected. Even though the average age of all the patients was 14.4 years ($\pm$ 2.8 years), those under 14 and as early as 6 years of age, also showed similar rates of increasing incidence, making up 33.6% of this study population.[14] This data highlights a concern that clearly other factors aside from puberty alone are at play.

Gender, Sport, and BSI

Adolescence is a heightened time to succumb to bone stress injuries. Multiple studies indicate that females appear to be at higher risk than their male counterparts;[16,17] however, sport played and hours of sports involvement per week are likely strong contributing factors as well.[17,18] In 2011, Field and colleagues published data regarding adolescent females and stress fracture incidence based on sport and noted that those who played 8+ hours/week of higher impact sports (basketball, running, cheerleading/gymnastics) were twice as likely as their peers to develop a stress fracture.[18] Girls who had a delay in menarche as well as a family history of low BMD were also at higher risk.

In 2015, Changstrom and colleagues expanded on the known literature and published an epidemiological study on the rates of stress fractures amongst U.S. high school athletes, both males and females across 22 sports, using data from High School RIO™ (Reporting Information Online). The authors found that stress fractures occurred more often in girls' (54%) versus boys' sports (46%). In gender-comparable sports, bone stress injuries in girls (63%) still outweighed those seen in boys (36.7%) with girls having a statistically significant higher injury risk per athletic exposure (AE). Similar to Field et al., Changstrom found that girls' track and field, boys' and girls' cross country, and girls' gymnastics reported the highest rates per 100,000 AE. Across all 22 sports, 'stress factures' were most prevalent in the lower leg (40.3%), followed by the foot (34.9%), and lower back/lumbar spine/pelvis (15.2%). Unfortunately, neither the Fields nor the Changstrom papers delineated specific data as it directly relates to FNBSI.[17,18]

Sexual Dimorphism in the Bones of Preschoolers

Bone sexual dimorphism in the peri- and pubescent population exists, as evidenced by the above studies, but what about in a younger pre-pubertal population? Although these studies are sparse and not specific to the femoral neck, insight may be gleamed from similar literature. It appears that girls and boys up to age 6 years have very comparable bone mineral content (BMC), volumetric bone mineral density (vBMD), and bone structure.[19] The study postulates that the role of early physical fitness, even at a young age, plays a strong and modifiable role in bone architecture and strength even if vBMD is not altered. Physical activity can encompass cardiovascular fitness, strength training, speed, agility, and balance work. These factors in isolation, as well as collectively, make large contributions to bone mineral density and may have significant ramifications for our youth.

By adolescence, bone health is sexually dimorphic and varies amongst athletes versus nonathletes. Upper and lower body strength, measured by a vertical jump and hand grip exercises, have been cited as a possible proxy for bone health. These measurements could one day serve as tools for monitoring 'at-risk' populations; however, more research is needed.[20]

Femoral Neck Geometry

Femoral neck bone stress injuries occur as either compression or tension-sided injuries. Often, severity is determined by the specific side of injury. Compression-sided injuries occur in the infero-medial femoral neck or the concave margin (Figure 1). Tension-sided injuries occur along the supero-lateral aspect, or convex side, of the femoral neck (Figure 2).[21] Tension-sided fractures are less stable and often require surgical fixation due to increased risk for displacement, malunion, or subsequent avascular necrosis and poor outcome.[22] A patient's underlying femoral neck-shaft angle and the loads

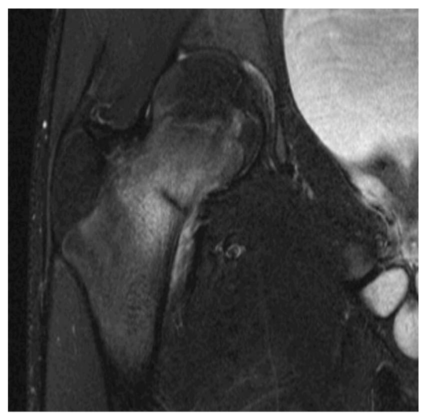

Figure 1. *MRI coronal TIRM of the right hip in a 15-year-old male runner, demonstrating a nearly 50% compression-sided femoral neck bone stress injury.*

Figure 2. *AP hip radiograph of a 17-year-old female athlete, demonstrating a tension-sided stress fracture of the femoral neck (red arrow).*

experienced by the hip may play a role in how forces are transmitted across the bone. An average femoral neck shaft angle measurement in the adult is typically between 125 to 131 degrees. Coxa vara, defined as a femoral neck shaft angle of less than 120 degrees,[23] decreases the efficiency of gluteus medius, gluteus minimus, and tensor fasciae latae, and theoretically may increase tension-sided forces.[24,25] Coxa valga is defined as an angle of greater than 140 degrees resulting in a joint load that is more vertical,[23] whereas coxa vara joints see more horizontally driven forces.[26,27]

Pubertal Changes and the Pubertal Window

During the peripubertal years, 30% of lifetime BMD will be accrued; by 19–20 years of age, 95% of one's lifetime bone health is established.[28] The imbalance in bone resorption over deposition and expansive linear growth in height may create transient decreases in bone tensile strength.[22,29] Faulkner and colleagues showed that there is a period of relative bone weakness resulting from a dissociation of bone accrual and bone expansion around the time of peak height velocity (PHV) compared with peak bone mineral content velocity (PBMCV) in both boys (mean age of PHV13.6 years, but PBMCV 14.1 years) and girls (mean age of PHV 11.9 years, but PBMCV 12.5 years). This study confirmed that increases in linear height preceded an increase in bone mass and peak velocity of bone mineral content lagged about 6 months behind PHV.[29] This lag was theorized to contribute to potential fracture risk around the time of pubertal growth spurts. Total body PBMCV was also broken down further to examine if sex played a role in accrual values. After controlling for height, weight, and other sex differences, striking distinctions were seen—total body PBMCV was 15% higher in males than females and at the femoral neck, and PBMCV was also significantly higher for males over females. There were no sex differences noted at the lumbar spine.[28]

Adolescence is a critical time for bone mass accrual—perhaps even a "window of opportunity" that could mitigate future fracture risk.[30,31] Once pubertal development ensues, growth factors like growth hormone (GH), insulin-like growth factor-1 (IGF-1), and sex hormones play an important and dynamic role in bone formation and eventually maturation. Peaks in height attainment relate to pubertal onset for girls between the ages of 10–12 years and 12–14 years in boys, although more studies are needed in boys to confirm this. When pubertal maturity is reached, the hormonal cascade may reduce the sensitivity of bones to mechanical stress.[30]

Physical Activity and BSI: The Mechanostat Theory

Loading and impact exercises result in an increase in bone mineral gains, especially at the lumbar spine and femoral neck. Bone accrual in the early years may set the foundation for fracture risk in later years.[30] Determining the factors that lead to bone mass accrual versus those that detract from it may be worthwhile from a health and prevention strategy. BMD increases through osteogenesis when strength is above a certain intensity.[32,33] The human body, when in a state of homeostasis, responds to mechanical forces, muscular forces, and loads upon the tissues by undergoing remodeling in accordance with Wolff's Law,[21] which Harold Frost first defined as the Mechanostat Theory.[31,34] This theory describes the stimulation by mechanical, local, and elastic deformation of bone-on-bone growth and bone loss.[35]

Increases in osteogenesis and bone density accrual likely result from both muscle tensile contractions acting on bone as well as from weight-bearing forces. A study by Cassell and colleagues compared young female gymnasts and swimmers, ages 7–9, and assessed their growth parameters and body mass indices to see how these related to overall BMD. The gymnast population had a lower body weight and lower body fat compared to the swimmers and the control population. The authors found that after adjusting for differences in body weight, prepubertal female gymnasts had much higher BMD compared to age matched swimmers. In fact, swimmers were much closer in BMD to that of the control group. The authors concluded that weight-bearing is crucial to bone mineral accrual, even in the young, pre-pubescent population. Muscular contraction forces in isolation may not be enough to produce substantial changes in bone mass accrual.[36]

Multiple studies also demonstrate that playing ball sports as a child and early adolescent may be protective and reduce the risk of developing a BSI.[37–39] Fredericson et al. looked at 156 female and 118 male elite runners aged 18–44 years and found that those who played ball sports during childhood had an almost 50% reduction in BSI when controlling for other confounders.[39] Fehling et al. looked at actual BMD via DXA in multiple sites including at the femoral neck in college-age female athletes. The authors compared impact loading sports (volleyball and gymnastics) versus active loading sports (swimming) versus a control group and found that the impact loading group had significantly higher BMD at multiple sites, including the femoral neck, compared with the active loading and control groups, even after controlling for height and weight.[37]

Interventions in BMD may be feasible, even at a pre-pubertal age. Morris and colleagues studied a cohort of 71 premenarchal girls, aged 9–10, who participated in a 10-month high-impact strength building program. They found that bone accrual is modifiable, and increases are possible even at a prepubertal age. In fact, the high-impact strength building group increased their BMD in multiple locations, including at the femoral neck, over their age-matched controls. In the femoral neck specifically, there was a notable increase in bone area, possibly having long term implications for future fracture risk.[40] Mosti et al. was also able to implement positive changes after 12 weeks of strength training in a group of women (22 ± 2 years). In the training group, P1NP values (procollagen type 1 N-terminal propeptide, used as a marker for cell turnover) increased by 26% over controls; BMD also increased by 2.2% in the lumbar spine and 1% at the hip.[41]

Endurance and Running Athletes

As reported previously, the optimal benchmark period for bone accrual likely occurs during peri-pubescence into pubescence (Tanner stages 2–4), when peak levels of GH, IGF-1, estrogen, and testosterone are present.[30] Women in an hypoestrogenic state may experience accelerated bone loss.[42] Studies in women aged 13–35 years and collegiate athletes have determined that BMI (<18.5 kg/m^2) and oligomenorrhea/amenorrhea are highly predictive of risk for low BMD (Z-score < -1.0) in females.[43,44] Amenorrhoeic runners are likely to experience increased bone resorption as well as reduced bone turnover due to hormonal deficiencies.[42] Periods of accumulated energy deficits can suppress circulating levels of IGF-1, a stimulant of type I collagen expression and a major constituent of bone. This could alter the ability of bone to handle tensile stress and mechanical load.[42]

While the female athlete appears to be more at risk than the male athlete, far fewer studies have been performed in male athletes to decipher specific risk factors in this population. In 2017, Barrack et al. looked at 69 male adolescent athletes aged 13–19 years. Of these athletes, 51 were endurance runners and 18 were nonrunners. The runners exhibited lower body weight, lower BMI, lower BMI z-scores and lower percent expected weight compared to nonrunners. The runners were noted to have a four-fold higher risk for low BMD compared to non-runners and only had prior histories of stress fractures one-sixth of the time.[45]

Essential History and Physical Examination

Clinicians should include femoral neck BSI within the differential diagnosis for those who present with anterior hip, groin, or thigh pain.[9,46] A thorough history and physical exam needs to be performed when presenting symptoms are suggestive of BSI. Questions that should be asked during the HPI and review of systems are similar for all bone stress injuries, including recent weight changes in the last 3 months, menarche and menstrual cycle history (if applicable), current medications including vitamins and supplements, history of prior fractures and bone stress injuries (including location and treatment), history of DXA with results, and any family history of bone disorders including low BMD or early osteoporosis.

When evaluating an athlete, it is also recommended to obtain an athletic history to review their training regimen, sports played, specialization, as well as extra-curricular workouts, weekly running mileage (if applicable), sleep history, involvement with weight training, recent mood changes, and assessing for time off from sports during the week and the year. Other important questions to ask are if there are any recent dietary changes, food restrictions, calcium, vitamin D and iron intake.

Sleep and BSI

Regular sleep deprivation has been linked to impacts on reaction time, strength, and speed thus placing a child and adolescent at risk for injury that could have otherwise been prevented. The American Academy of Pediatrics recommends that children aged 6–12 years get 9 to 12 hours of sleep per 24 hours, while adolescents need 8 to 10 hours.[47] Spiegel et al. found that regular sleep deprivation resulted in increased cortisol concentration, lower glucose tolerance as well as other changes to the sympathetic and hypothalamic-pituitary axis.[48] Elevated cortisol has been shown in mice models to result in decreased BMD as well as bone formation rate, which may have significant impact on athletes, especially pubescent athletes if they are also succumbing to chronic sleep deprivation.[49] As mentioned previously, P1NP is the preferred marker for bone formation. Swanson and colleagues showed an ability to negatively impact the P1NP values in men (i.e., reduce bone turnover) by impeding circadian rhythms and restricting sleep over an interval of 3 weeks.[50] The authors theorize that in a younger population, these down regulations in one undergoing peak bone attainment may significantly impair bone consolidation.[50] Casazza et al. looked at children aged 4–12 years and also found direct correlations between longer sleep durations and greater bone mineral content.[51] Thus, during a period of rapid linear growth along with robust hormonal changes, bone turnover and remodeling are clearly altered in the setting of chronic sleep deprivation.

Diet, Calcium, and Vitamin D

When getting a BSI health history, asking questions regarding any recent dietary changes, overt or inadvertent food restrictions, as well as calcium and vitamin D intake is imperative. Calcium absorption in the small intestine is stimulated when vitamin D is also active, thus the concert of activity is essential to bone metabolism. In a cross-sectional survey study by Lovell et al., 18 female gymnasts aged 10–17 years had their vitamin D levels and dietary calcium intake assessed. Most of the gymnasts had subpar dietary calcium intake and vitamin D was also below recommended levels.[52] Green et al. looked at the nutritional intake of elite Division 1 gymnasts and found gymnasts had suboptimal intake of calcium, vitamin D, potassium, iron, and vitamin K.[53] Understanding the proper vitamin D range is important for assessing these athletes. Backx et al. collected blood samples on 128 highly trained athletes (18-32 years) and scaled their 25(OH)D concentration as deficient (<50 nmol/l), insufficient (50-75 nmol/l), or sufficient (>75 nmol/l). Interventions were then implemented and the resultant changes to levels were calculated over a 12-month time frame. Greater than 70% of this population was insufficient or deficient at baseline testing. Supplementation at 2200 IU/day resulted in sufficient levels in 80% of athletes within 12 months.[54] Greene and Naughton looked at a peripubertal female identical twin population and measured tibial bone parameters through peripheral quantitative computed tomography (pQCT). They found that the calcium supplementation group had positive gains in bone metrics, namely trabecular density, trabecular area, and strength.[55] More studies specific to the femoral neck need to be done, but these studies bring important translational intervention protocols to the FNBSI.

Physical Examination

There are no validated special tests specific to FNBSI; however, composite findings may aid in diagnosis. Age, weight, and BMI should be documented and graphed on a CDC growth chart for accurate percentile measurements. The exam should consist of active and passive hip range of motion (ROM) and manual muscle testing. ROM is typically affected with FNBSI, particularly at

Table 1. Differential Diagnosis of Femoral Neck Bone Stress Injury

Hip muscle strain	Infection (osteomyelitis, myositis)	Osteitis pubis
Iliopsoas tendonitis	Femoral head avascular necrosis	Hip fracture
Transient synovitis	Sacroiliitis	Groin strain
Osteoid osteoma	Sacroiliac dysfunction	Pelvis fracture
Legg-Calvé-Perthes disease	Piriformis syndrome	Malignancy (i.e., osteosarcoma)
Slipped capital femoral epiphysis	Snapping hip syndrome	

end ranges and internal rotation.[56–59] Clinicians should complete a standing, seated, and dynamic musculoskeletal exam. Start the exam by assessing for an antalgic gait, ability to complete a double- and single-leg hop test and performing a double- and single-leg squat. Next, assess hip range of motion, hypermobility, and examine for muscular tightness. Lastly, palpate for tender landmarks and perform special hip tests to evaluate for other hip pathology.

If there is a high-risk profile, a timely work up and referral to subspecialty care is warranted. A team approach with subspecialists and allied professionals, including, but not limited to, sports medicine physicians, orthopaedic surgeons, bone health specialists, endocrinologists, and nutritionists play a key role in the diagnosis, treatment, and management of these patients.

Imaging Modalities for BSI

Diagnostic evaluation has varied in published studies and no clear consensus currently exists specific to FNBSI. The American College of Radiology Appropriateness Criteria supports that x-ray is the initial step in any patient with pain or alteration in range of motion and/or gait.[4] Typically, anteroposterior (AP) and lateral images of the hips and pelvis are first obtained.[22] Although initial x-rays may not show a definitive BSI, plain films are paramount for assessing all osseous structures, especially in those with open physes.[12,60,61] If pain has been ongoing for a few weeks, radiographs may show evidence of subacute healing in the form of periosteal or endosteal bone formation, sclerosis, or fracture line.[62] A negative x-ray should not preclude further work up, particularly when accompanied by a positive clinical finding or strong clinical suspicion.[12,61,63]

Bone scintigraphy (BS) was considered the gold standard for diagnosing FNBSI prior to the widespread use of MRI.[12,64] BS demonstrates increased cell turnover, leading to false positives in children due to other differential diagnoses of hip pain (Table 1).[65] BS may still be useful for diagnosing FNBSI if MRI is contraindicated. BS does carry a significant radiation load which should be strongly considered in the decision-making in pediatrics. In comparative studies, MRI results were as sensitive and much more specific than bone scan in determining the cause of hip pain. Radionuclide bone scan had an accuracy of 68% for femoral neck stress fractures with 32% false-positive results; MRI was 100% accurate.[58]

With improved technological advances, MRI is the new gold standard due to increased sensitivity and specificity for diagnosing FNBSI without the use of ionizing radiation.[64,66,67] MRI has also been helpful in grading the severity of some BSIs through a standardized classification system. Grading of the tibia has been validated by Fredericson, Arendt and Nattiv.[3,61,68] Validation and acceptance for a standardized classification scale for FNBSI is underway, but more studies are needed. Of added necessity is a scale that includes skeletally immature patients to see if standardized algorithms need to be altered to account for patients with open physes.

Table 2. Comparison of FNBSI Classification Systems			
Devas (1965, 1975)[69,71]	Blickenstaff & Morris (1966)[7]	Fullerton & Snowdy (1988)[56]	Provencher (2004)[70]
Compression	Type I: Endosteal and periosteal callus without fracture line	Compression	Generally nonsurgical unless > approximately 50%
Transverse or distracted	Type II: Fractures without displacement	Tension	Generally surgical, individually based decision
	Type III: Displaced	Displaced	Surgical emergency for reduction and fixation
Atypical tensile			Nonsurgical

Grading of Injury Severity

Grading of FNBSI was first applied in 1965 by Devas, who classified injury by compression and transverse fracture of the neck.[69] The earliest detection was noted utilizing x-ray as a "minute, almost microscopic crack in the superior surface of the neck." Devas refined the classification 10 years later by noting the difference between those that "are distracted or being pulled open, and those that are compressed."[69] The classification was refined in 1966 by Blickenstaff and Morris who noted three types of fractures.[7] Type I exhibited a callus without a fracture line, type II exhibited a fracture line without displacement, and type III the fracture was completed and displaced. Fullerton combined these systems and graded by tension versus compression injury; type I injuries were in the early stages and exhibited a normal x-ray but positive bone scan on the tension side.[56] Type II injuries exhibited endosteal or periosteal callus on tension side or a tension-sided fracture line without loss of the medial cortex. Type III injures exhibited complete displacement.[56] Provencher in 2004 proposed a modified classification to include atypical FNBSI and noted MRI to be the superior study to define and classify femoral neck fractures (Table 2).[70] These three grading scales were developed prior to the routine use of MRI but their reference to site of injury continues to be utilized with FNBSI.

Rohena-Quinquilla et al. in 2018 proposed the use of a "low-grade/high-grade," four-stage MRI classification, based on a retrospective review of 127 soldiers with a compression-sided FNBSI (mean age at diagnosis 23 years, range 18-37). Twenty-three percent of the cases were bilateral (29/127), and females had a 2.5 times higher incidence. The authors helped determine return to duty parameters based upon the MRI classification scale at diagnosis. Rohena-Quinquilla noted that MRI findings of endosteal edema without a macroscopic fracture were low-grade FNBSI (grades 1 and 2), but high-grade FNBSI were noted to have macroscopic fractures (grades 3 and 4). Grade 1 FNBSI took significantly less time to recover than grades 2–4.[72]

Use of MRI may provide more specific information on the subtleties of the injury, but more studies are clearly needed. Taking physeal age into account as well as surveying the surrounding bone and soft tissues may prove pertinent to the treatment plan.

Alternative Imaging

Other imaging, such as computed tomography (CT), is helpful for examining high-attenuation tissue like bone, but its role in diagnosing bone stress injuries is limited. CT has a reported sensitivity ranging from 83–96% at the proximal femur,[73] though it cannot demonstrate bone turnover or periosteal/bone marrow edema patterns compared to MRI or BS.[74] There are limited comparative studies of the three imaging modalities in patients with suspected femoral neck bone stress injury and even fewer in pediatric patients. CT scans are fast, widely available, and less expensive than MRI. CT can be used when MRI imaging is contraindicated (e.g., pacemaker, hardware) or to distinguish between an osteoid osteoma and bone stress injury.[63,75] CT may play an adjunctive role by producing thin-section, multiplanar-reconstructed images in order to provide high resolution and detailed depiction of cortical bone when other imaging modalities are equivocal.[76,77] CT also carries a significant radiation load for the pediatric patient and consequently should be used judiciously.

Musculoskeletal ultrasound (MSK US) may soon become an adjunct imaging technique. It offers immediate point of care results without radiation and at a lower cost than MRI and does not typically require sedation. Ultrasound of bone is challenging because bone is not well visualized due to the acoustic shadow it creates, but more recent literature notes one may appreciate secondary findings, such as changes to the periosteum, subperiosteal hemorrhage or hematoma, soft tissue swelling, hyperemia, cortical interruption or widening of a physis.[78,79] Limitations of MSK US include limited assessment of deep structures or areas below and within the bone, (i.e., marrow edema) and variability in user skill in obtaining images. MSK US, when used in conjunction with other studies, may also present added prognostic value, but further studies are still needed, especially in the pediatric population. Steele and colleagues studied the risk of progression of femoral neck BSI that went on to require surgery. Patients with an average age of 22.6 years (range, 17.2 to 40.1 years) were screened to see if a concomitant hip effusion was present or not. Of those with an effusion, 85% of their stress fractures went on to require surgery, an eight-fold increase in the relative risk. Thus, the authors concluded that having this additional data may impact treatment management.[5]

Summary

There remains much to be learned about the nuanced nature of femoral neck bone stress injury in the youth and adolescent population. Intrinsic and extrinsic risk factors will vary patient to patient and have been shown to play critical contributing roles in FNBSI. Early sport specialization, sport choice, and hours per week spent in training have been shown to have a long-standing impact on injury rates. The pubertal window and changes to the hormonal milieu at the time of peak height velocity also have large implications on bone development. Primary and secondary amenorrhea as well as signs of hypothalamic hypogonadism should be taken seriously in all athletes, as these diagnoses suggest signs of relative energy deficiency in sport or other endocrine disorders and could lead to a compromise in bone health. Lastly, nutrition, supplements, sleep, strength training, and prior sports exposure have all recently been implicated in the profile of BSI. Continued research into these areas will help providers streamline interventions and recommend preventative recommendations.

Patients presenting with anterior hip, thigh, or groin pain must be assessed carefully and thoughtfully. FNBSI should be considered in the differential diagnosis and radiographs completed. If x-rays are negative but there continues to be strong clinical suspicion, moving forward with advanced imaging such as MRI would be a prudent next step.

The overwhelming majority of FNBSI, when diagnosed timely, are compression type injuries, affecting the inferomedial femoral neck. One should be concerned for bilateral hip pathology and ensure that the clinical exam pays heed to the contralateral side. If the diagnosed fracture is a lower risk, compression sided, and less than 50% of the femoral neck width, then conservative management is likely indicated. A period of protected weight-bearing with crutches and activity modification should be implemented until symptoms abate and sclerosis and early periosteal changes can be seen on follow-up imaging. A careful history and risk (intrinsic and extrinsic) stratification should ensue so that steps can be taken to ameliorate risk factors wherever possible. Once the initial protected weight-bearing period is completed and the physical exam and radiographic studies show improvement, a referral to physical therapy for strengthening, mobility, and return to sports progression should be considered.

Overall, there is a lot known about BSI in the pediatric population, but future work specific to the femoral neck is needed. This includes studies confirming which populations are at risk, and once identified, implementing prevention strategies. Studies are needed to validate proper diagnosis, work up and treatment, including specific MRI grading scales for the skeletally immature and mature populations. Once scales are validated, the injury severity can be studied with relationship to length of treatment in order to standardize treatment and eventual return to activity/sport. Keeping kids healthy and active is a pillar of sports medicine and striving to achieve these goals is paramount to the field.

Additional Links

- The AMSSM National Fellow Online Lecture Series: High-Grade Stress Fractures: https://www.youtube.com/watch?v=F3IemapSJzk

- Hip Case 3, Femoral Neck Stress Fracture. Produced by American Academy of Pediatrics, in Sports Medicine in the Pediatric Office, by Dr. Jordan Metzl. (Elk Grove Village, IL: American Academy of Pediatrics, 2008), pa NA, 2 mins: https://video.alexander-street.com/watch/hip-case-3-femoral-neck-stress-fracture

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