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Hip Injuries in Ice Hockey Goaltenders

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Hip and groin injuries are among the most common locations for sports-related injuries in ice hockey players due to the specialized movements and physical nature of the sport. Goaltenders are at particular risk for hip injuries due to the unique demands of their position, particularly with the widespread use of the "butterfly style" technique, placement of the hip in extremes of motion during play, and the emphasis on repetition of skills. Hip injuries in ice hockey goalies are mainly attributed to overuse, traumatic contact injuries, or a developmental process. These injuries can be acute or chronic and involve the intra-articular joint and/or extra-articular structures including core muscles, adductors, or hip flexors. They can be treated either conservatively or operatively, depending on the player's goals and level of play. A more complicated picture arises when intra- and extra-articular hip pathologies coexist, presenting challenges in diagnosis and treatment. Fundamental understanding of goaltenders' hip kinematics, diagnostic physical exam maneuvers, and operative indications is crucial to accurately diagnosing, treating, and preventing hip-related injuries in goalies.
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Introduction

The goaltender position in ice hockey is a dynamic position that involves unique physical demands compared to positional players. Goaltenders rely on their lower body to protect the bottom part of the goal, placing a large amount of stress on their hip joints. Flexibility and lateral movement, driven from the lower body, are fundamental to remaining in position for shots on goal and reacting to sudden changes of play. Therefore, it is not surprising that goaltenders are particularly predisposed to hip injury. Men's ice hockey has the second-highest rate of hip injuries, and they account for 18.2% of all injuries in National collegiate athletic association level ice hockey goaltenders.[1] Epstein et al showed that goaltenders are at significantly greater risk of intra-articular hip injury than other on-ice players when measured per game played, and that 15% of goalies who played at least 1 game in the National Hockey League (NHL) between 2006 and 2010 suffered an intra-articular hip injury.[2] Extra-articular hip injuries also represent a high proportion of musculoskeletal injury in goalies and are a major cause of game-time loss.[3-5]

Pathomechanics and Risk Factors

While historically goalies used a "stand-up" style of play, improvements in protective equipment and the adaptation of the mask prompted players to develop a new style of play in the late 1960s. In this technique, called the "butterfly" style, the goaltender drops to his knees to cover the lower half of the net, making the leg pads parallel to the ice. Frayne et al showed that in the ready stance, goaltenders' hips are approximately 70° flexed, 10° abducted, and 25°-30° internally rotated.[6] The hip then extends, adducts, and internally rotates, and an axial ground-reaction force of up to 1.45 +/− 0.43 times body weight is applied as the knee contacts the ice.[6,7] Epstein et al estimated that goalies perform this movement upward of 300 times in a practice,[2] and Bell et al reported that NHL goaltenders perform the butterfly an average of 34 +/− 6 times per game.[8] Repetitive end-range hip internal rotation inherent in the butterfly may predispose goalies to overuse injuries, particularly femoroacetabular impingement (FAI), and consequential

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intra-articular pathology. More recently, modifications to the butterfly style such as "profly," "V-H," and "hybrid" have been developed which require additional flexion abduction and external rotation, further predisposing goalies to symptomatic hip and groin pathology.

Goaltenders perform a variety of vertical, lateral, skating, and sprawling movements that require as much or more hip mobility as the butterfly.[8,9] It has been postulated that having the hips in a compromising flexed and internally rotated ready stance can predispose goalies to injury in the performance of common maneuvers, which apply high forces through the hip joint.[6] The hips undergo increased internal rotation as the goaltender prepares to raise the knee off the ice, which often surpasses the amount of internal rotation that occurs at initial ice contact.[6] Deceleration during skating/repositioning was shown to have 54% greater magnitude of hip internal rotation than the butterfly, beyond the end-range of passive motion, and recovery movements have been shown to involve greater flexion-extension and adduction-abduction than the butterfly.[9] The flexibility required of goaltenders and their need to quickly react to the play predisposes them to adductor muscle strains, hip flexor injuries, and core muscle injuries.

Goaltender equipment may also alter the risk of injury. Pad width does not affect goaltender hip kinematics, but broken-in leg pads have been shown to reduce the amount of internal rotation required to perform the butterfly position compared to newer pads.[7]

Intra-articular Injuries

FAI

FAI is a common overuse injury in elite-level hockey players caused by repetitive abnormal contact between the proximal femur and the acetabulum. Over time, cam lesions on the femoral head-neck and/or pincer lesions on the acetabulum can develop and become symptomatic, causing time away from sport. FAI can lead to chondrolabral injuries and may be a cause of early-onset osteoarthritis. While ice hockey players may be uniquely predisposed to symptomatic FAI,[10-12] goalies are particularly at risk due to the biomechanics of their position and the emphasis on repetition of skills from a young age. Among 180 hips in 130 elite-level hockey players, goaltenders had the greatest prevalence of cam deformities at 93.8%.[13] Age of first exposure may be a risk factor for development of FAI, as hip loading during youth training can predispose athletes to future injury.[10]

The distinctive hip kinematics of goalies can lead to specific injury patterns. Ross et al showed that butterfly goalies with symptomatic FAI had an elevated alpha angle and loss of offset that was larger and more lateral than position players.[14]

A goalie with symptomatic FAI will present with anterior hip/deep groin pain exacerbated by activity, and may complain of loss of motion or flexibility especially when in the butterfly position, skating and squatting. The pain is typically insidious in onset and has slowly progressed until the time of presentation.[15] They may also present with symptoms of mechanical hip pain such as stiffness, locking, clicking, or catching. Physical exam findings will reveal pain with the flexion, adduction, internal rotation (FADIR) test, and strength deficits in abduction and flexion may exist. Furthermore, hip flexion and internal rotation at 90° of flexion may also be restricted or have a hard-end feel.

Radiographs are the first line of imaging in confirming the diagnosis of FAI. Typically, to assess for symmetry, an antero-posterior view of the pelvis is obtained with the legs 15° internally rotated to better visualize the contour of the lateral femoral head-neck junction.[16] Antero-posterior and cross-table lateral views are also routinely obtained, and a Dunn lateral in 45° of flexion can also be obtained to reveal pathomorphologies of the anterior femoral head-neck junction.[16,17] A false-profile view may also be useful in for quantification of acetabular over-coverage.[16]

Parameters such as the femoral head-neck offset and alpha angle can help quantify the cam deformity, corroborated by a pistol-grip deformity on X-ray. Tonnis angle, increased lateral center edge angle (LECA) and presence of "crossover" sign can indicate acetabular overcoverage and presence of a pincer lesion. MRI is the gold standard for identifying injuries of the labrum or articular cartilage that result as a consequence of FAI. Although not routinely performed, computed tomography-based modeling can precisely and reliably characterize the topography of the joint, identifying locations, and severity of cam and pincer deformities.

The first line of treatment for symptomatic FAI is rest, avoiding painful maneuvers, physical therapy, and anti-inflammatory medication. Physical therapy focuses on improving core stabilization and improving hip external rotation and abduction in hip extension and flexion.[3] While conservative approaches do not alter the underlying osseous abnormality, addressing secondary functional neuromuscular issues has been shown to provide pain relief and restore hip function and return to hockey.[18]

If a trial of conservative treatment fails to provide adequate symptomatic relief, FAI and associated chondrolabral pathology can be treated surgically using hip arthroscopy, which is now preferred over open techniques. During surgery, osteochondroplasty of the cam deformity and/or resection of the pincer deformity are performed, along with any repair of the acetabular labrum that is necessary. Although hip arthroscopy for FAI has been shown to have positive outcomes in hockey players,[19] few studies have examined outcomes in goalies specifically. Anecdotally, however, many elite-level goaltenders have returned to a high level of play following arthroscopic correction of FAI, though it does involve a significant amount of playing time lost. NHL goaltenders are more likely to miss consecutive games due to injury than position players,[20] and NHL players who suffer intra-articular hip injuries, of which goaltenders are at a higher risk, lead to an average of 8 man-games missed per injury.[2]

Rehabilitation protocols for goaltenders should be tailored to the unique demands of their position; position-specific protocols have been described in the literature.[21,22] In contrast to position-player protocols, which focus more on hip abduction and pivoting in skating and shooting, goaltender-specific rehabilitation incorporates on-ice functional rehabilitation including edge control, crease work, and slow transition into the

butterfly. They also minimize aggravating other commonly-injured extra-articular hip structures such as the iliopsoas.[22]

Labral Tears

The acetabular labrum is a fibrocartilaginous ring that surrounds the acetabular socket and functions in joint lubrication, maintaining stability, and shock absorption. In goaltenders, labral pathology most commonly arises as a consequence of FAI, but traumatic tears can also occur following contact injury causing subluxation or dislocation of the femoral head. Labral pathology is exceedingly common in professional hockey players and its prevalence is likely underestimated as this injury many not be reported in those who are asymptomatic or in whom it is not functionally limiting.

Goaltenders with labral tears commonly present concurrently with FAI in the manner described above. They may report either a sudden traumatic injury resulting in anterior hip/groin pain, or a more progressive course of symptoms with an insidious onset. These patients may complain of joint stiffness and loss of motion, as well as mechanical symptoms such as locking, painful clicking, snapping, or catching of the hip. On physical exam, the FADIR impingement test will reproduce the patients' symptoms. Isolated labral tears in the absence of FAI usually do not present with a hard-end of passive range of motion.

Hip radiographs including AP, cross-table lateral, Dunn lateral, and false profile should be obtained to evaluate for FAI or other bony abnormality such as joint degeneration or hip dysplasia. MRI arthrogram is the study of choice to detect labral tears, which appear as discontinuities around the femoral head. This may also be combined with intra-articular injections of lidocaine or steroid to provide therapeutic relief.

Nonoperative therapy for labral tears involves the same principles as FAI: avoiding aggravating movements and physical therapy that focuses on core muscles, flexibility, and hip stability. Should this fail to resolve the patient's symptoms, arthroscopic surgery has been shown to have positive long-term outcomes. Recent studies have shown that labral repair is more beneficial than debridement, as the former preserves the native anatomy and poses a lower long-term risk of osteoarthritis. The role of labral reconstruction is less clear, and is generally indicated in large tears or those that are not amenable to repair. Use of allograft or autograft may restore the native suction seal of the joint, which can increase postoperative stability; however, labral repair is the preferred treatment.

Dysplasia

Hip dysplasia is a malformation of the hip joint that is characterized by undercoverage of the femoral head by the acetabulum. Most commonly caused by a retroverted acetabulum, this alteration in hip biomechanics can predispose patients to labral pathology or premature joint degeneration. Ross et al found that among those with symptomatic FAI, acetabular dysplasia (29%) was more common in butterfly-style goalies than in positional athletes (15%).[14] Of the goaltenders with dysplastic hips, 16.2% of them demonstrated borderline abnormality. They noted that these rates are significantly higher than the prevalence of acetabular dysplasia reported in population-based investigations of hip joint malformations (3.9% of 3620 hips).[14,23] This may be a protective adaptation against the larger cam deformities found in goalies,[14] or it may be due to selection bias as those with acetabular dysplasia possess the extreme motion necessary to become an elite goaltender.

Patients with acetabular dysplasia may present with an identical history and physical examination as other intra-articular hip conditions, since the deformity is inherently asymptomatic. Radiographs are diagnostic, demonstrating undercoverage of the femoral head quantified by decreased lateral center edge angle, increased Tonnis angle, and decreased femoral head-neck offset ratio.

The treatment of dysplasia depends on the severity of the malformation. Given the high prevalence of dysplasia and its concomitance with symptomatic FAI, it may represent somewhat of an incidental finding in those who were functioning at a high level. These patients may need correction of their symptomatic joint disease and readjustment of their biomechanics to preserve their ability to play at their desired level. In those with more severe dysplasia, peri-acetabular osteotomy can be considered, though the longer recovery and altered anatomy can lead to significant time away from sport and lower functional baseline.

Extra-articular Injuries

Adductor Muscle Strains

The hip adductor muscles are a group of 6 muscles—the adductor longus, magnus, and brevis and the gracilis, obturator externus, and pectineus—that originate on the pubis and attach on the medial side of the femur. This muscle group functions to adduct the thigh in open chain motions, and to stabilize the lower extremity and pelvis in closed chain motion. Adductor strains most commonly occur during eccentric contraction, when the muscle contracts while being lengthened, or during passive stretch. The adductor longus is most commonly injured during sporting activity.[24]

Adductor muscle strains are exceedingly common in hockey players as they are maximally activated in the "push-off" phase of the abduction-adduction sequence of skating. The adductors are also crucial in the lateral movement push-offs of goaltenders and are passively stressed during sprawling saves in which the hips are externally rotated on a maximally adducted leg. Emery et al found that adductor injuries increased across 6 seasons of NHL play,[25] and groin strains have been reported to account for up to 10% of all injuries in professional hockey and for over 40% of all muscle strains.[26,27]

Mismatch in the abductor and adductor muscle group strength has been identified as a risk factor in adductor strains in hockey players.[28] Tyler et al found that adduction strength was found to be just 78% of abduction strength in those players who sustained an adductor injury, and that a player was 17 times more likely to sustain an adductor muscle strain if their adductor strength was less than 80% of their abductor strength.[28] Furthermore, they found that preseason hip

adduction strength was 18% lower in players who went on to sustain an adductor muscle strain compared to uninjured players.[28]

Some players who sustain adductor muscle injuries are able to recall the mechanism and onset of injury, while others experience a more chronic and gradual course of pain. Goaltenders will complain of groin pain that is functionally limiting and interferes with their ability to move laterally across the goal or make athletic, reactionary saves using their lower body. Skating is often impaired as well. On physical exam, patients will have tenderness to palpation along the abductor longus insertion on pubic ramus, as well as pain and/or decreased strength with resisted leg adduction compared to the contralateral side. MRI and ultrasound are the imaging studies of choice to identify the location and severity adductor strains. MRI findings include avulsion of the adductor muscle from the pubic ramus, edema, or hemorrhage.

Adductor strains are most often managed nonoperatively with rest, protected weight bearing, and initiation of a strengthening and rehabilitation program. While most protocols begin with passive modalities such as stretching and massage, literature has shown that focus on active strengthening consisting of progressive resistive abduction/adduction, core strengthening, balance training, and sports-specific movements was more effective in treating chronic groin strains.[29] A multimodal approach combining active bilateral strengthening with supplemental passive massage and stretching is likely the best approach to treating both acute and chronic adductor strains.

Given their findings that ipsilateral muscle imbalance and asymmetric bilateral adductor strength predisposed hockey players to adductor strains, Tyler et al developed a preseason exercise program to prevent such injuries in this population. Investigating 58 NHL players, they identified 33 who were "at risk" (defined as having ipsilateral abduction strength <80% of adduction strength), and enrolled them in a 6-week preseason strengthening program. They found that adductor strains per 1000 player-game exposures decreased 4.5 times in the 2 subsequent seasons.[30] As these injuries are especially debilitating in goaltenders due to the unique demands of the position, properly treating adductor strains when they arise and recognizing adductor weakness early be both therapeutic and preventative.

Should conservative treatment fail, surgical treatment for adductor strains is a viable option particularly in the chronic setting. Common techniques include adductor tendon debridement and repair, although the literature has not shown surgical repair to yield better outcomes than conservative treatment.

Hip Flexor Muscle Injury/Iliopsoas Tendinitis

Hip flexor injuries, particularly iliopsoas tendinitis, are a common cause of groin playing in the ice hockey player. The iliopsoas tendon, which is a conjoint tendon of the iliacus muscles and the psoas major, is implicated in lumbar and pelvis control as well as hip flexion. This makes goaltenders at particular risk for these injuries due to their heavy reliance on these muscle groups to make saves and maneuver around the crease. Whereas in position players these injuries occur from high-velocity skating, hip flexor injuries in goaltenders more commonly occur from the one-knee down position and from repetitive supraphysiologic movements and ranges of motion.

Goaltenders with iliopsoas tendonitis will complain of groin pain with hip flexion, and may also notice an internal snapping sensation—the movement of the iliopsoas tendon over the iliopectineal eminience. On clinical examination, goaltenders will have pain or tenderness just distal to the inguinal ligament, and have a positive Thomas test (difficulty with passive hip extension and resisted hip flexion). The snapping sensation can be reproduced by dragging the iliospoas tendon across the anterior pelvic brim by circumduction or flexion and extension of the hip. The diagnosis is largely clinical, with MRI and ultrasound having a limited role in locating the source of pain.

Conservative measures are the first line of treatment for iliopsoas tendonitis—NSAIDs, rest and massage yields symptomatic relief the majority of the time. Effective rehabilitation programs will focus on core musculature and hip flexor strengthening with gradual progression according to clinical milestones. Should these measures fail to provide symptomatic relief, ultrasound guided corticosteroid injection can be considered. Arthroscopic tendon lengthening or release is considered a last line treatment for iliopsoas tendonitis, though it has been shown to have success in athletes.[31,32]

Core Muscle Injury/Sports Hernia/Athletic Pubalgia

While adductor strains and hip flexor injuries constitute a major portion of groin pain in hockey players, many athletes experience pain in the lower abdominal musculature and inguinal region. This entity, originally known as "sportsman's hernia" or athletic pubalgia, has many names including Gilmore's groin, hockey groin syndrome and osteitis pubis though recently the preferred term is "core muscle injury" (CMI) as it is believed to be more anatomically descriptive.[33] CMI involves an injury to the abdominal wall at the fascial attachments of the rectus and adductors onto the pubic symphysis. Others have described it as an actual tear in the thin transversalis fascia that forms part of the posterior inguinal wall, which may lead to an incipient posteriorly-protruding hernia.[34] CMI is thought to occur from abdominal hyperextension and thigh abduction[33]—motions which are implicated in abrupt changes of direction to make saves and in passing/clearing the puck. CMI may be a result of acute trauma or repetitive microtrauma from overuse.

CMI is common in hockey players—Emery et al showed abdominal strains consisted of 23.2% of all groin injuries over 2 years in the NHL.[25] There is a clinical and pathomechanical association between CMI and FAI,[35,36] which as discussed above is particularly present in goaltenders.

Goaltenders with CMI can typically recall the onset of the injury, and often complain of proximal adductor pain and

pain in the inguinal canal near the insertion of the rectus abdominis muscle on the pubis[33,37] that worsens with activity and resolves with rest. Athletes may also experience pain with coughing or radiation of pain into the groin and testicular regions, indicating entrapment of surrounding nerves.[33] Symptoms are usually unilateral, but bilateral symptoms can develop in up to 43% of athletes.[37] On physical examination, patients may have tenderness to palpation of the pubic tubercle and pubic symphysis. The abdominal obliques and conjoined tendon/rectus abdominis should also be palpated to help differentiate CMI from other etiologies of lower abdominal pain. Resisted hip adduction and palpation of the inferolateral edge of the distal rectus abdominis with resisted sit-up may recreate the patient's symptoms.[37] It is also imperative to examine the ipsilateral hip joint to assess for FAI given the high prevalence of concomitant pathology.

Radiographs, including AP pelvis and lateral views of the femur, may show osteitis pubis, apophyseal injuries, stress fractures, degenerative hip disease, and underlying FAI or dysplasia. Non-contrast MRI is sensitive and specific for both rectus abdominis and adductor aponeurosis pathology.[38] It can characterize osteitis pubis due to CMI, show tearing or detachment of other structures from the pubic bone, and can also show concomitant intra-articular hip pathology. Fluoroscopic-guided diagnostic anesthetic injections into the pubic symphysis or surrounding musculature may also prove useful in determining primary pain generators.[33]

The first-line treatment for CMI is therapy focusing on core stabilization, postural retraining and restabilizing the hip and pelvis muscle relationship. Aggressive stretching and flexibility exercises may exacerbate underlying hip pathology/FAI. Gradual return to sport can be attempted after a period of rest. However, there is limited data analyzing the effectiveness of nonsurgical treatment for CMI.

Should the athlete fail to benefit from conservative treatment, surgery can be considered. A broad range of techniques has been described, including open, laparoscopic, use of mesh, and excision/ablation of various nerves. Surgical treatment has been shown to be successful in treating CMI. In a case series of 22 NHL players who underwent external oblique aponeurosis repair and excision/ablation of surrounding neurovascular bundles, Irshad et al showed that 86% players were able to continue playing in the NHL.[39] In another series of NHL players, Jakoi et al found that all players returned to performance levels comparable to presurgical play, though older players may experience more variable outcomes.[40]

Mixed presentation

Groin and hip pain is a common complaint in hockey goalies, and so it is important to differentiate between etiologies and recognize when multiple pathologies present together. Understanding the complete picture of the athlete's presentation can help a clinician treat the athlete appropriately to minimize time away from hockey and recognize risk factors for future injury. In many cases, multiple extra-articular pathologies can be present or underlying intra-articular pathology can be obscured. In some cases, diagnostic anesthetic injections can be a useful tool in eliciting or eliminating sources of pain.

For example, it is important to recognize acetabular dysplasia in players who undergo surgical treatment for FAI to avoid errant rim resection and the secondary risk of iatrogenic structural instability.[14]

Furthermore, Hammoud et al found a high incidence of CMI symptoms in professional athletes with FAI of the hip. Whereas no athlete returned to their previous level of competition after isolated CMI surgery, 39% had resolution of their CMI symptoms with FAI surgery alone. All patients with surgery to correct both CMI and FAI returned to professional competition.[41] This study illustrates the importance of routinely assessing for a complete range of hip and groin pathology during the initial assessment. Especially in professional athletes who get injured mid-season, it is crucial to exercise caution and patience in the diagnostic process to avoid missing an underlying or concomitant pathology amid the pressure to get the athlete back to sport.

Conclusion

Hockey goaltenders are at particular risk for hip and groin injuries due to the unique biomechanical demands of their position. Injury prevention strategies, such as limiting the number of times a young goaltender uses the butterfly position in practice, have been proposed to mitigate and prevent these injuries.[42] Both intra- and extra-articular injuries can be treated conservatively or surgically, though athlete level and timing of injury must be considered. It is crucial for the clinician to have a fundamental understanding of possible symptom etiologies, physical exam maneuvers, and treatment plans in order to recognize and treat both the obvious symptoms and any underlying pathology.

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