[Orthopaedic Surgery]

On-Ice Functional Assessment of an Elite Ice Hockey Goaltender After Treatment for Femoroacetabular Impingement

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Background: Femoroacetabular impingement (FAI) is a major cause of performance inhibition in elite-level athletes. The condition is characterized by pain, osseous abnormalities such as an increased alpha angle, and decreased range of motion at the affected hip joint. Arthroscopic surgical decompression is useful in reshaping the joint to alleviate symptoms. Functional kinematic outcomes of sport-specific movements after surgery, however, are presently unknown.

Hypothesis: The ability of an ice hockey goaltender to execute sport-specific movements would improve after arthroscopic surgery.

Study Design: Clinical research.

Level of Evidence: Level 5.

Methods: An ice hockey goaltender was evaluated after arthroscopic correction of FAI on the symptomatic hip. Passive range of motion and radiographic parameters were assessed from a computed tomography–derived 3-dimensional model. An on-ice motion capture system was also used to determine peak femoral shock and concurrent hip joint postures during the butterfly and braking movements.

Results: Maximum alpha angles were 47° in the surgical and 61° in the nonsurgical hip. Internal rotation range of motion was, on average, 23° greater in the surgically corrected hip compared with contralateral. Peak shock was lower in the surgical hip by 1.39 g and 0.86 g during butterfly and braking, respectively. At peak shock, the surgical hip demonstrated increased flexion, adduction, and internal rotation for both tasks (butterfly, 6.1°, 12.3°, and 30.8°; braking, 14.8°, 19.2°, and 41.4°).

Conclusion: On-ice motion capture revealed performance differences between hips after arthroscopic surgery in a hockey goaltender. Range of motion and the patient's subjective assessment of hip function were improved in the surgical hip. While presenting as asymptomatic, it was discovered that the contralateral hip displayed measurements consistent with FAI. Therefore, consideration of preemptive treatment in a presently painless hip may be deemed beneficial for young athletes seeking a long career in sport, and future work is needed to determine the costs and benefits of such an approach.

Clinical Relevance: Surgical treatment of symptomatic FAI can achieve pain relief and improved kinematics of the hip joint with athletic activities. Additional studies are necessary to determine whether improved kinematics enhance the longevity of the native hip and alter the progression of osteoarthritic changes in those with asymptomatic FAI deformity.

Keywords: hip arthroscopy; kinematics; computed tomography; FAI; athlete

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Femoroacetabular impingement (FAI) is a common overuse injury of the hip joint, particularly in elite-level ice hockey players.[2,4,10,27] Cam deformity appears most frequently in active men[18] and has been found with increased prevalence in elite hockey players.[2,27] If left uncorrected, shear forces on the chondral surfaces of the acetabular rim can lead to long-term degenerative joint disease.[6,7] While the etiology of FAI is controversial and not well understood, it has been suggested that hip loading during youth training can predispose athletes to future injury.[28]

Surgical correction of the femoral head-neck junction and/or resection of the acetabular overcoverage, via either the open or arthroscopic technique, may alleviate the symptomatic impingement due to FAI.[13] Because of the less invasive nature of arthroscopy, many athletes elect this type of surgery for a quicker recovery and return to sport.[21] A case study involving 45 professional athletes showed 93% of participants were able to return to high-level competition after arthroscopic surgery for treating FAI.[20] The procedure significantly improves alpha angles and allows return to sport after an average of 9.4 months.[16]

Symptomatic patients typically present with groin pain and restricted range of motion (ROM), primarily in flexion and internal rotation.[5,7,12,14,30] Ice hockey goaltenders who employ the butterfly save technique are hypothesized to frequently use these motions,[14] which have been implicated as a major source of overuse hip injuries.[20,23] However, whereas pain reduction and clinical ROM after arthroscopic surgery have been well documented, there is a lack of data on functional kinematical improvements in sport-specific movements. The following case history compares an asymptomatic and surgically corrected hip in a National Collegiate Athletic Association (NCAA) Division I ice hockey goaltender presenting with unilateral FAI using a computed tomography (CT)–based computer-assisted simulation and a novel on-ice motion capture system.

METHODS

Patient

Prior to data collection, our institutional review board approved this study, and the athlete provided informed written consent. A 22-year-old male NCAA Division I ice hockey goaltender presented with refractory left groin pain resulting in inability to compete. Physical examination revealed restricted hip flexion and internal rotation in 90° of flexion and concordant pain with the flexion, adduction, and internal rotation (FADIR) maneuver. CT imaging of the left hip revealed an alpha angle of 81° at the 1:00 position (anterior-superior) and acetabular version of –4°, –6°, and 14° at 1:00, 2:00, and 3:00, respectively. These findings were consistent with mixed cam and pincer–type impingement. The patient elected to undergo an arthroscopic cam and rim osteoplasty and labral refixation to alleviate symptoms and correct the bony pathomorphology. After successful surgery, the patient underwent a rehabilitation program consisting of gentle and progressive range of motion, periarticular muscular strengthening, and controlled return to athletic activities at 4 months postoperatively. At the time of follow-up, hip bony morphology, passive ROM, and on-ice kinematics during goaltender-specific drills were assessed after return to play to evaluate surgical outcomes. It must be noted that the nonsurgical hip was not used as a normal reference, rather as a hip presenting without symptoms of FAI for comparison with a surgically corrected hip.

Computed Tomography–Based Analysis

A 3-dimensional (3D) reconstruction of each hip joint was created from bilateral hip and pelvis CT sequences[15] and uploaded into a dynamic software program (DYONICS PLAN; Smith & Nephew). Several morphological measures were determined for both hips following the methods described by Milone et al.[15] Simulated hip ROM was performed for several movements typically employed to examine hip impingement[8]: straight flexion (FLEX), abduction (ABD), internal rotation at 90° of hip flexion (IRF), and internal rotation at 90° of hip flexion and 15° of hip adduction (FADIR). To analyze goaltender-specific internal rotation ROM, a typical butterfly save posture (BUTTERFLY, 70° of flexion and 10° of abduction) was evaluated. Terminal ROM was determined as the first instance of bony contact between the acetabular rim and the femoral head-neck junction.

On-Ice Kinematics

The kinematical assessment occurred 7 weeks prior to the CT examination at the patient's team practice facility. The patient wore a Lycra bodysuit containing 17 miniature inertial measurement units adhered to particular body segments, which measured hip and femur kinematical data at 120 Hz (XSens MVN BIOMECH; Xsens Technologies). The athlete wore his standard game-day equipment and apparel, including skates and pads, over the suit.

After a self-selected warm-up and stretching, the testing protocol involved 3 standard goaltender tasks: (1) butterfly save with recovery to standing, (2) butterfly save transitioning into a sliding save, and (3) long rebound sequence (butterfly save at the top of the crease, transitioning into a pivoting recovery, and skating to the opposite post) (Figure 1). Cumulatively, 18 butterfly saves (Figure 2A) and 12 stopping movements (Figure 2B) were collected from the 3 tasks. The athlete was instructed to simulate each task as he would perform during a game, including using his stick throughout.

During the butterfly save and stopping motion, peak axial shock of the femur (defined as peak acceleration along the long axis of the bone in the direction of the hip joint) was quantified using the inertial measurement units attached to the upper leg. At the instant of peak femoral shock, the 3D hip angles were also measured in each task. Peak axial shock magnitudes and hip angles at peak axial shock were averaged across trials to determine the mean peak axial shock and hip angles for each leg and movement.

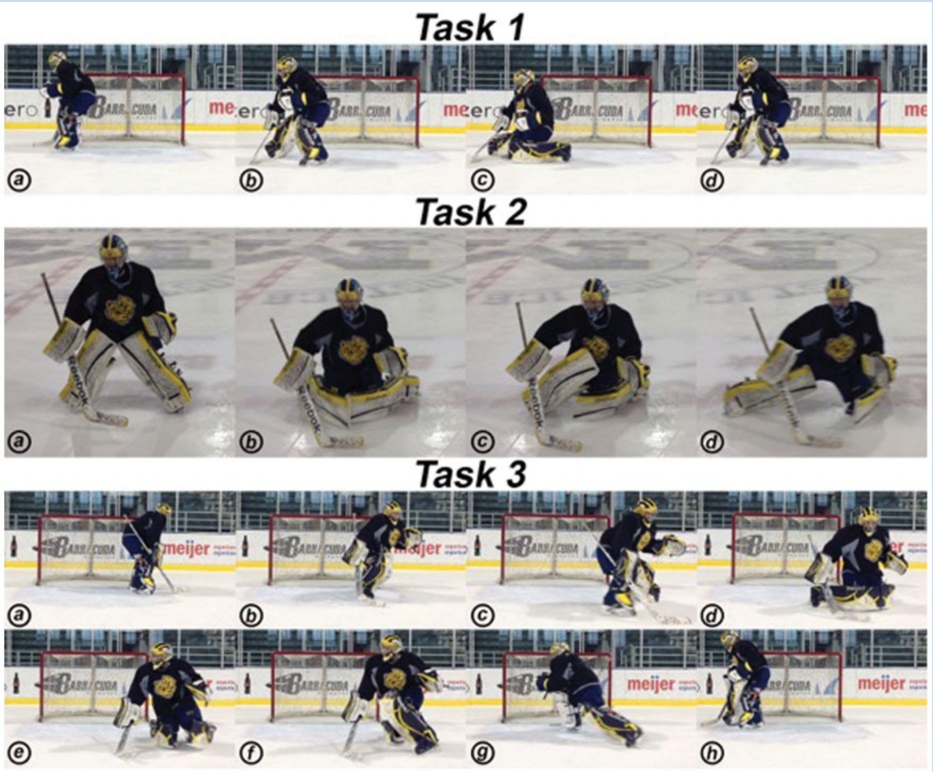

Figure 1. Movement sequences for the 3 on-ice tasks: (1) butterfly save with recovery to standing, (2) butterfly save transition into a sliding save, and (3) long rebound sequence.

RESULTS

Computed Tomography Measurements

The maximum alpha angle for the surgically treated hip was 47° and was located at 12:45. The maximum alpha angle in the contralateral, native hip was 61° and was located at 2:00 (Figure 3, Table 1). The femoral neck version was 10° greater in the surgical hip. While the surgically treated hip had borderline acetabular dysplasia with a lateral center-edge angle (LCEA) of 23°, the nonsurgical hip had a more dysplastic acetabulum (LCEA, 20°).

Simulation Outcomes

When comparing the simulated range of motion between the hips, FLEX was only 5° greater in the surgical hip, and no difference in ABD was measured between hips (Table 2). However, the surgically corrected hip demonstrated increased internal rotation in the IRF, FADIR, and BUTTERFLY positions when compared with the contralateral hip by 24°, 23°, and 23°, respectively.

On-Ice Motion Capture Outcomes

Peak shock was 10.01 g and 11.40 g during the butterfly and 8.05 g and 8.91 g during braking in the surgical and nonsurgical hips, respectively. At the instant of peak shock during the butterfly save, the surgical hip was in 6.1° more flexion, 12.3° more adduction, and 30.8° more internal rotation, relative to the contralateral hip. Flexion was 14.8° greater and adduction 19.2° higher when braking with the surgical limb.

Figure 2. Goaltender executing (A) butterfly save and (B) stopping movements.

DISCUSSION

As expected,[5,7,12,14,17,19,30] the alpha angle of the left hip improved from 81° to 47° after surgery, and acetabular anteversion improved from –4° to 3°. Furthermore, the 24°

Figure 3. Preoperative (left) and postoperative (right) radiographic images of the surgical hip. (A) Anteroposterior view and (B) lateral view.

Table 1. Computed tomography–based hip morphological measurements

	Surgical Hip	Nonsurgical Hip
Maximum alpha angle, deg	47	61
Femoral neck anteversion, deg	29	19
Femoral neck-shaft angle, deg	140	142
LCEA, deg	23	20
Acetabular anteversion, deg, 1:00	3	–2
Acetabular anteversion, deg, 2:00	7	7
Acetabular anteversion, deg, 3:00	17	15
Acetabular anteversion, deg, 4:00	19	16

LCEA, lateral center edge angle.

Table 2. Simulated hip ranges of motion (in degrees)

Range of Motion	Surgical Hip	Nonsurgical Hip
FLEX	126	121
ABD	81	81
IRF	68	44
FADIR	56	33
BUTTERFLY	74	51

ABD, pure abduction; BUTTERFLY, 70° of flexion and 10° of abduction; FLEX, pure flexion; FADIR, internal rotation at 90° of hip flexion and 15° of hip adduction; IRF, internal rotation at 90° of hip flexion.

difference in IRF between the surgically corrected and asymptomatic hips suggests a positive surgical outcome.[12,25] The left surgical hip showed superiority in internal rotation capability for the simulated butterfly save, a key movement for successful goaltending,[3] reflecting the potential benefits of surgery for game-specific activities.

The on-ice motion capture further supports these findings and provides a more realistic analysis of the butterfly and braking movements, greatly enhancing our assessment of treatment.[26] The goaltender appears to have increased ROM in the surgical hip, particularly during internal rotation, based on the larger angles used in the surgical hip during peak shock. The patient also reported feeling that he had far better ROM in his left hip, and even noted that he desired surgery on his asymptomatic right hip to improve motion. Comparison between the literature values and the on-ice kinematics indicates a substantially larger difference in ROM between hips in our patient—nearly double that of previously mentioned studies, hinting toward a degree of impingement in the contralateral joint.

Morphological and kinematical abnormalities such as increased alpha angle, retroversion, and reduced femoral neck anteversion were determined for the nonsurgical hip, suggesting it may be at risk for injury. Furthermore, the on-ice kinematic assessment revealed a greater degree of peak shock sustained at the femur of the nonsurgical hip during both the butterfly save and braking. As acceleration and force are directly proportional via object mass, peak shock reported herein can be thought of as an estimate of the relative force applied by the femoral head as it is rotated into the acetabulum during movement. The peak accelerations reported for this patient exceed those for running,[29] suggesting that greater forces at the hip joint are sustained during typical movements in hockey. A study examining peak axial accelerations in patients with and without knee pain found that subjects presenting with pain sustained greater axial accelerations in the tibia and femur compared with subjects without pain.[24] With increased force in the right hip compared with the left during butterfly and braking, one could speculate that the higher accelerations at the nonsurgical hip could be a contributor to future joint pain. Taken together, these radiographic and kinematical findings suggest that the contralateral hip, albeit currently asymptomatic, may be at risk for long-term joint damage.

The contralateral hip presented without pain but displayed a high alpha angle and reduced internal rotation ROM consistent with FAI.[9] This finding agrees with a study of 113 patients with symptomatic cam deformity in 1 hip; bilateral deformity existed in 88 (77.8%) of these individuals, although only 23 (26.1%) presented with bilateral pain.[1] While treatment for FAI is traditionally rendered only once symptoms present, young male patients with higher alpha angles experience a significantly greater risk for eventually requiring bilateral corrective surgery.[11] Hence, osseous deformity of the hip may initiate early cartilage degeneration prior to the onset of pain. While corrective surgery may be unable to fully prevent future articular cartilage deterioration due to our patient's borderline dysplastic LCEA, previous studies have proposed surgical intervention as a successful method for decelerating the processes of degeneration.[12] Degree of chondral damage and time to return to play have been shown to increase in elite ice hockey athletes who prolonged treatment.[22] With this in mind, attention may be warranted for both hips of a patient presenting with unilateral symptomatic FAI.

This study is limited by the small sample size and lack of presurgical kinematic and ROM assessments. Consequently, it cannot be determined conclusively whether the movement differences present between the surgical and contralateral hips represent surgical effects or the presurgical state of the hip. The greater femoral anteversion in the surgical hip or postoperative physical therapy may have resulted in some increased internal rotation capability. A placebo effect from having the procedure cannot be ruled out either. However, based on the patient's subjective assessment of increased hip ROM and function after surgery, the results suggest surgically induced improvements. It should be noted that the CT-simulated passive ROM does not account for restrictions due to the soft tissue structures surrounding the hip joint; therefore, it may overestimate passive ROM. Future work will seek to expand these analyses to presurgical, on-ice kinematical assessments with additional athletes to gain insight into the effect of surgery on competitive play. We acknowledge that our hypothesis, that preemptive corrective surgery to prevent hip damage and pain due to underlying FAI, is speculative, and future studies must be conducted to determine which groups of athletes could potentially benefit from preemptive surgery.

CONCLUSION

The novel on-ice kinematical analysis permitted unique insight into the effects of arthroscopic hip surgery on sport-specific movements. While static radiographic measures suggested that the surgical hip was improved, the on-ice movement profile provided a more complete picture of its excellent recovery and also highlighted areas of concern for the nonsurgical hip. Arthroscopic surgery demonstrated success in restoring performance capability to an elite hockey goaltender. It is important to consider the prospect of future problems in a presently nonpainful hip and determine whether preemptive treatment in younger patients, especially those pursing a professional career in sport, may be favorable in the long term.

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