Bilateral Functional Performance in Recreationally Active Females Three Months After Hip Preservation Arthroscopy: A Case Series

Lynette Carlson, DHS, ATC[1]
Timothy Hanke, PT, PhD[2]
Janey Prodoehl, PT, PhD[2]
Kathy Hall, PT, EdD[2]
Benjamin Domb, MD[3]

[1]University of Tennessee, Chattanooga, TN
[2]Midwestern University, Downers Grove, IL
[3]American Hip Institute, Des Plaines, IL

ABSTRACT

Background: Postsurgical timeframe is used to inform return to sport decision-making for patients after hip surgery. Understanding individual differences in lower extremity functional performance and patient-reported outcomes at 3 months postsurgery may provide guidance for return to sport decisions. **Methods:** A prospective case series describing lower extremity functional performance (four hop test battery of single hop for distance, 6-meter timed hop, triple hop for distance, and crossover hop for distance, and the Star Excursion Balance Test and Vail Hip Sport Test), hip abductor strength, and patient-reported outcomes in 3 recreationally active women at 3 months following hip preservation arthroscopic surgery. **Findings:** At 3 months postsurgery, there was considerable variability and deficits in lower extremity functional performance and strength across participants as well as variability in patient-reported outcomes. **Clinical Relevance:** Assuming that a 3-month postsurgical time point for return to sporting activities is appropriate for recreationally active individuals post hip arthroscopy may not be a valid assumption. **Conclusion:** Based on the patient-reported outcomes and lower extremity functional performance of 3 recreational athletes, the authors suggest that patients following arthroscopic hip surgery may require more than 3 months to return to sporting activity.

Key Words: hip preservation, femoroacetabular impingement, return to sport, physical therapy

BACKGROUND AND PURPOSE

Over the past decade, the number of hip preservation arthroscopic procedures performed has increased from 3.6 per 100,000 in 2005 to 16.7 per 100,000 in 2013.[1] Rehabilitation typically follows hip arthroscopic surgery although there is considerable variability in recommended postoperative physical therapy protocols.[2] Thus, it is not surprising that a systematic review of physical impairments and activity limitations in individuals presenting with femoral acetabular impingement concluded that rehabilitation protocols targeted at restoring postoperative functional impairments need to be re-evaluated, especially with respect to developing evidence-based rehabilitation programs and return to sporting activities.[3]

In contrast with criterion-based rehabilitation protocols,[4] return to sport decision-making may rely instead on postsurgical time, commonly between 12 and 20 weeks after surgery.[5] However, significant individual variation complicates return to sport activity decisions based on the extent of injury, surgery performed, and the rehabilitation process. Understanding individual patient differences may provide guidance for return to sport decision-making as well as provide guidance for rehabilitation protocol development. Variability in performance following hip arthroscopy was the topic of a recent clinical commentary that outlined an impairment-based rehabilitation protocol for use postsurgery that is currently under testing in a multicenter, international randomized controlled trial.[6] This protocol is designed to target known postsurgical deficits and provides clinicians with a systematic approach to treatment progression through return to sport.

Recreationally active women are a population at risk for future osteoarthritis if not appropriately managed.[7] Identifying functional deficits in this population at 3 months may be useful in elucidating outcome variability among individuals to help physical therapists modify such impairment-based programming as it becomes validated for individuals facing return to sport decisions. The purpose of this case series was to describe lower extremity functional performance, hip strength, and patient-reported outcomes in 3 recreationally active women 3 months following hip preservation arthroscopy and to identify variability in outcomes across individuals. Findings from this study will help health care professionals such as physical therapists, athletic trainers, and orthopedic surgeons to inform coaches and individuals regarding appropriate time points for allowing return to sporting activities.

METHODS

Patient Description

Three female recreationally active participants, 3 months (±2 weeks) following primary, unilateral hip preservation arthroscopy volunteered to participate in this study. Table 1 details their demographic information, diagnosis, and surgical procedures. The Institutional Review Board at Midwestern University, Downers Grove, IL, approved this study, and participants provided written consent to participate. Recreationally active was defined as engaged in mild, moderate, or high-intensity physical activity for at least 2.5 but not more than 10 hours per week (prior to injury).[8] Participants were patients of an orthopedic surgeon specializing in hip preservation surgery. Inclusion and exclusion criteria are listed in Table 2. The first 3 patients to meet criteria via the surgeon's chart review were asked to participate. Participants underwent a standard rehabilitation protocol with their respective physical therapists prior to enrollment into the current study.

Testing Protocol

Each participant attended one 90-minute testing session in an outpatient physical therapy clinic. Lower extremity functional performance was assessed using four hop tests (single hop for distance, 6-meter timed hop, triple hop for distance, and crossover hop for distance),[9] the Star Excursion Balance Test (SEBT), and the Vail Hip Sport Test (VHST). In addition, hip abductor strength was measured as well as 3 patient-reported outcome scores. Testing order was consistent across all 3 subjects to maintain testing consistency given the small sample

Table 1. Demographic Data of the Three Recreationally Active Female Participants

Variable	Participant 1	Participant 2	Participant 3
Age (years)	25	33	40
Body Mass Index (BMI)	21.5	22	26.5
Weeks Postoperative	13	11.5	14
Preoperative Diagnosis	Labral tear Hip flexor tendinitis Internal snapping hip Pincer lesion Cam lesion Instability	Labral tear Hip flexor tendinitis Pincer lesion Cam lesion Instability	Labral tear Loose body Pincer lesion Cam lesion Instability
Postoperative Diagnosis	Labral tear Iliopsoas bursitis Hip flexor tendinitis Pincer lesion Cam lesion Instability	Labral tear Iliopsoas bursitis Hip flexor tendinitis Pincer lesion Cam lesion Instability	Labral tear Loose body Ligamentum teres tear Iliopsoas bursitis synovitis Pincer lesion Cam lesion Instability
Surgical Procedure	Labral debridement Acetabuloplasty Iliopsoas bursectomy and fractional lengthening Femoroplasty Capsular plication	Labral repair Acetabuloplasty Iliopsoas bursectomy and fractional lengthening Femoroplasty Capsular plication	Removal of loose body Labral repair Ligamentum teres reconstruction Acetabuloplasty Iliopsoas bursectomy Synovial biopsy Femoroplasty Capsular plication
Prior Level of Activity	3-5 hours/week running, hiking, snowboarding	2.5 hours/week flag football, recreational softball	10 hours/week walking, swimming, biking

size. Patient-reported outcomes were the Hip Outcome Score – Sports Subscale (HOS-SSS), Nonarthritic Hip Score (NHS), and the International Hip Outcome Tool (iHOT-12). Collectively, results from the functional performance tests, strength test, and patient-reported outcomes were compared bilaterally for each participant and across participants.

1. Hop tests. Four hop tests (single hop for distance, 6-meter timed hop, triple hop for distance, and crossover hop for distance) were measured using standardized testing methods.[10] Although there have been no published reports on hop testing following hip arthroscopy, the 4 hop tests used in this study have been shown to be reliable in patients after anterior cruciate ligament reconstruction surgery and are typically used together.[11] Participants performed all hop tests bilaterally, beginning with the nonsurgical limb. Two trials for each limb were measured with rest allowed as needed. Means and standard deviations were calculated from the two trials. The participants were free to swing their arms to aid in completing the jump and for balance. During the single hop for distance, triple hop for distance, and crossover hop for distance tests participants were required to maintain balance on the test limb until prompted to relax. Failure to maintain balance resulted in an invalid trial. A toe-to-toe measure was used for all tests requiring measurements of the total distance hopped. Means were calculated for two trials. Limb symmetry index (LSI) was then calculated for each test mean and expressed as a percentage (surgical limb/nonsurgical limb x 100).[10] An LSI score of at least 90% was considered as passing.[12]
2. Star Excursion Balance Test (SEBT) was measured bilaterally using established methods.[13] Participants performed 4 practice trials to stabilize

Table 2. Inclusion and Exclusion Criteria

Inclusion	Exclusion
Primary unilateral hip arthroscopy	Prior knee or ankle surgeries
Unilateral hip pathology	Evidence of arthritis Tönnis grade 2 or greater based on pre-operative radiograph by the orthopedic surgeon
Self-reported recreationally active	Gluteus medius tear based on pre-operative MR arthrogram by the orthopedic surgeon
20-40 years old	Labral reconstruction surgery
Body mass index 18.5-29.9	Microfracture hip procedure
Cleared by physician for jumping and pivoting activities	Current hip incidence related to workers' compensation injury case
	Vestibular or balance disorders
	Current concussion or mild traumatic brain injury

excursion distances.[14] To decrease fatigue, one reach distance was measured in 4 directions (anterior, posteromedial, posterolateral, and medial) on the fifth trial. Reach distance measurements were normalized by limb length and expressed as a percentage score (excursion distance/limb length x 100).[15] A composite score was calculated (mean of the normalized reach distances in the anterior, posterolateral, and posteromedial directions). A passing score of at least 94% for each reach direction or the composite score was considered as passing.[16]

3. The Vail Hip Sport Test (VHST) is a safe method to observe muscular strength, endurance, and the ability to produce and absorb multi-planar forces without kinetic collapse.[4] Each portion of the test battery is designed to stress the hip joint and identify functional deficits. The VHST consists of 4 dynamic functional activities using the resistance of a Sportcord®. Participants performed tests bilaterally using methods previously reported[4] and earned points for the successful completion of 4 functional tasks over time. Although the reliability of this test battery using the above scoring system has not been reported, an earlier study suggested that a VHST score of 17/20 or better during the final phase of rehabilitation following hip arthroscopy was necessary for athletes to return to unrestricted practice to train and prepare for competition.[17] Therefore, a passing score was set at 17/20.
4. Isometric hip abduction strength was measured using a hand-held dynamometer (Power Track II™ Commander; JTech Medical, Midvale, UT) using established methods.[18] The mean of 3 trials was calculated and a LSI of strength was determined. A passing strength LSI score of 90% was set.[4]
5. Patient-reported Outcome scores were the Hip Outcome Score – Sports Subscale (HOS-SSS), Nonarthritic Hip Score (NHS), and International Hip Outcome Tool (iHOT-12). The maximum score for all patient-reported outcomes scores was 100. The HOS has strong content and construct validity,[19] reliability, and responsiveness[20] in younger active patients with nonarthritic intra-articular hip pain.[21] The NHS is used to assess younger active patients with nonarthritic hip pain and has content and construct validity and reliability.[22] The iHOT-12 measures health-related quality of life in young, active patients with hip disorders and is reliable, shows face, content, and construct validity, and is responsive to clinical change.[23]

FINDINGS

Each of the participants varied in their functional and patient-reported abilities. Participant 2 was unable to complete any of the hop tests on the surgical limb at 3 months postsurgery while the other two participants achieved passing LSI scores on some but not all hop tests (Table 3). All 3 participants were able to perform the SEBT but passed fewer portions of the SEBT on the surgically operated limb (Table 4). No participant achieved a passing SEBT composite score. Considering the nonsurgical limb, participants 1 and 2 were able to attain a passing score on one component of the SEBT (Table 4). No participant achieved a passing score on the VHST (Table 5). Hip abductor muscle strength also varied among participants (Table 6) with participant 1 the only participant to show a passing LSI. Participants 2 and 3 demonstrated LSI hip abductor muscle weakness. Patient-reported outcomes also demonstrated large variability among participants, with 3-month postsurgical scores ranging from 14 to 89 (Table 7). When compared with presurgical scores, the majority (7/9 scores) of outcome scores had improved 3 months postoperatively for the 3 participants. Only the HOS-SSS score for participants 2 and 3 was worse at 3 months compared to the presurgery scores. A score of 100 on any of the patient-reported outcomes indicates no self-reported limitation. There is limited evidence to aid interpretation of any score less than 100 on these self-reported measures. However, a self-reported normal score on the HOS-SSS in a small group of individuals status post hip arthroscopy has been shown to be 94/100 (range 78-100).[19] The highest score achieved on the HOS-SSS at 3 months in the current study was 63/100 (Participant 1).

DISCUSSION

The purpose of this case series was to describe the functional performance of 3 recreationally active women 3 months after hip preservation arthroscopic surgery and to identify variability in outcomes across individuals. There were two main findings. First, variability across participants was a common finding in all domains of assessment with the least variability between participants' ability to pass the VHST (none passed) and the most variability in their ability to complete hop testing. Second, residual deficits in functional performance and patient-reported outcomes were still present at 3 months postsurgery. However, hip abductor strength asymmetry was present in 2 of the 3 participants at 3 months follow-up. These findings highlight the need for a thorough assessment of lower extremity function using tests and measures that represent multiple domains of function to assist in decision-making regarding return to sporting activity even in recreationally active women and to inform the need for additional rehabilitation visits to achieve that goal.

Variability in Performance

Variability in lower extremity functional performance and patient-reported outcomes was present among the participants, suggesting that a 3-month postsurgical time point cannot be expected to lead to stable performance outcomes in all patients. Specific to hop testing, participant 2, who was tested earliest in her recovery (1½ to 2½ weeks earlier than the other participants) and had the lowest presurgery activity level, was unable to perform any hop tests. In comparison, participant 3 with the highest presurgery activity level achieved a passing score on 3 of 4 hop tests. Variability in performance and outcomes among participants is consistent with a previous study that showed bilateral impairments in individuals who performed single hop testing 12 to 24 months following hip arthroscopy.[24] Even in the nonsurgical limb, participants in the current study showed hop distances lower than those seen in healthy women of similar age to participants in this study.[25] Kollock et al[25] assessed young, healthy recreationally active women whose hop distances were 15% to 70% greater than the averages recorded for our participants' nonsurgical limbs. These differences may be a result of subjectively reported pain in the surgical hip during the nonsurgical hop tests in our participants, possibly due to the non-stance leg helping to propel the body forward when hopping. Differences could also be a result of contralateral weakening of the nonsurgical limb due to inactivity during the months prior to or following surgery. The results of the current study also support that a battery of hop tests may be necessary to show

Table 3. Results for the Hop Tests (passing scores in bold type)

Test Categories/Specific Tests	Participant	Surgical limb	Nonsurgical limb	Limb Symmetry Index
Hop Tests (passing score is ≥ 90% LSI)				
Single hop for distance (cm)	1	90.3	101.3	89.1
	2	Unable to complete	85.3	0.0
	3	85.0	89.8	**94.7**
6 meter timed hop (sec)	1	2.8	2.6	**92.9**
	2	Unable to complete	3.1	0.0
	3	3.7	3.1	83.8
Triple hop for distance (cm)	1	267.3	286.5	**93.3**
	2	Unable to complete	96.5	0.0
	3	260.8	264.0	**98.8**
Cross-over hop for distance (cm)	1	Unable to complete	253.5	0.0
	2	Unable to complete	244.0	0.0
	3	252.0	221.8	**113.6**
Abbreviation: LSI, Limb Symmetry Index				

Table 4. Results for the Star Excursion Balance Test (passing scores in bold type)

Test Categories/Specific Tests	Participant	Surgical limb	Nonsurgical limb
Star Excursion Balance Test (passing score is ≥ 94% of limb length)			
Anterior (% limb length)	1	92.3	**99.0**
	2	85.6	88.6
	3	86.0	85.5
Medial (% limb length)	1	83.5	87.0
	2	**95.8**	92.8
	3	93.6	90.3
Posteromedial (% limb length)	1	78.0	89.0
	2	**99.4**	**100.6**
	3	90.3	88.2
Posterolateral (% limb length)	1	76.9	78.0
	2	83.8	86.2
	3	80.7	81.7
Composite (% limb length)	1	82.4	88.7
	2	89.6	91.8
	3	85.7	85.1

deficits at 3 months. Participant 1 was unable to complete the crossover hop for distance test but was able to pass two of the other 3 hop tests and came close to passing the third. It is not clear whether the crossover hop for distance test is testing a different aspect of functional performance than the other hop tests or is simply more challenging. This should be explored in future studies.

Variability in performance was also present in the SEBT. The youngest participant, participant 1, demonstrated the lowest SEBT scores over most of the reach directions. On the other hand, participant 2, who was unable to perform any of the hop tests, scored highest in the medial and posteromedial SEBT reaches. Regardless, all participants in the current study would be classified as having a higher risk of injury based on their SEBT scores.[13] The participants also had less than a 94% composite reach for their nonsurgical limbs, identifying a bilateral factor to their functional performance deficits. Variability among participants was also seen in the VHST scores. None of the participants in the current study was able to reach the established passing score suggesting that the participants were not yet ready to begin dynamic multi-planar activities, a finding consistent with the hop and SEBT measurements. Interestingly, the hop test scores and the VHST scores mapped well together with participant 2 scoring lowest and participant 3 scoring highest on both tests. The VHST may therefore capture similar functional constructs as the hop tests and this should be

Table 5. Results for the Vail Hip Sport Tests

Test Categories/Specific Tests	Participant	Surgical limb
Vail Hip Sport Tests (passing scores is ≥ 17 points)		
Single Knee Bends (6 max points)	1	6
	2	2
	3	2
Lateral Agility (5 max points)	1	2
	2	1
	3	5
Diagonal Agility (5 max points)	1	0
	2	1
	3	5
Forward Lunge on Box (4 max points)	1	4
	2	2
	3	4
Total Score	1	12
	2	6
	3	16

explored since hop testing can be quite arduous for patients to complete postsurgically.

Variability among participants was also present for hip abductor strength. Two out of 3 participants demonstrated isometric hip abduction weakness. A recent study by Cobb et al[26] of 108 healthy men and women using the same strength testing method used in the current study found a mean of 0.82 ± 0.20 Nm/kg hip abduction strength. All participants in the current study demonstrated much lower bilateral strength means (see Table 6). Therefore, caution should be taken when comparing isometric hip abduction strength bilaterally. A therapist using limb symmetry index in the presence of bilateral hip strength weakness might underestimate strength deficits. Thus, use of normative values rather than a limb symmetry index for interpreting strength deficits may be more valid for clinical decision-making.

The variability in performance among participants may partly be explained by demographic variability of the participants themselves. However, while it is tempting to attribute variance in performance to a single factor such as age or surgical repair, it is likely that a complex interaction among factors influenced postsurgical performance. This complex interaction may impact healing rate and the need for additional rehabilitation before recommending return to sport activity. Careful consideration of such factors and their potential influence should be a focus in future studies with a larger cohort of subjects but should be considered when making discharge decisions for individual patients.

Return to sporting activity decision-making

Although protocols have been described to guide postoperative rehabilitation following hip arthroscopy,[4,17,27-33] understanding the appropriate time at which to allow any athlete to return to higher level sporting activities continues to be challenging. Readiness for return to sport specific activities is further complicated by the lack of evidence regarding functional performance in patients following hip arthroscopy. Differences between the operated and nonoperated limb were found across participants in the current study and were highlighted by non-passing scores on the majority of hop tests and the SEBT. Asymmetry is thought to be a driving factor for poor functional performance in athletes following surgery[34,35] and may be an important factor to evaluate before returning to sport. For example, components of the SEBT have been shown to be valid predictors of lower extremity injury[16] and to be influenced by variations in hip joint kinematics and muscle function.[36] Female high school basketball players with decreased normalized composite reach distances of less than 94% have been shown to be 6.5 times more likely to have a lower extremity injury.[16] However, an acceptable threshold of asymmetry across multiple domains of functional performance before allowing an athlete to return to sport activity remains unknown. While future studies may offer insight into return to sport as a function of the specific sport itself, the small sample and diversity of recreational sport activity engaged in by these participants (eg, swimming, running, softball, snowboarding) precludes any recommendation at this time.

Using pre- and postoperative comparisons of both patient-reported outcomes and sports-specific activity may provide valuable information in comprehensively assessing successful return to sport activity.[37] Overall, participants in the current study reported varying scores on each outcome tool. In addition, when compared with preoperative scores, the majority of patient-reported outcome scores had improved at 3 months. The two scores that decreased were from the HOS-SSS for participants 2 and 3. The

Table 6. Results for Hip Abduction Isometric Strength (passing scores in bold type)

Test Categories/Specific Tests	Participant	Surgical limb	Nonsurgical limb	LSI
Hip Abduction Isometric Strength (passing score is ≥ 90% LSI)				
Normalized hip abduction strength (Nm/kg)	1	0.52	0.45	**115.6**
	2	0.41	0.55	74.5
	3	0.37	0.49	75.5
Abbreviation: LSI, Limb Symmetry Index				

Table 7. Patient-reported Outcomes Pre- and Postsurgery

Test Categories/Specific Tests	Participant	Presurgical Scores	3-month Scores
Patient Reported Outcomes			
Non-Arthritic Hip Score	1	51	89
	2	58	68
	3	25	54
Hip Outcome Score – Sports Subscale	1	19	63
	2	42	36
	3	17	14
International Hip Outcome Tool	1	12	87
	2	37	38
	3	1	29

HOS-SSS represents a patient's self-reported ability to perform sports movements such as cutting and lateral movements. These scores highlight the participants' perception that they were unable or unprepared to perform these sports-related movements 3 months postoperatively, which was consistent with hop and SEBT test results. However, the 3 participants had completed their structured rehabilitation protocols. Further elucidation of the instructions and activities that should fill the gap between the end of structured physical therapy and return to sport activities is needed to help guide return to sport decisions.

Limitations

A limitation of this study lies in the nature of a case series and that participants were female. However, participation of females in sports continues to increase.[38] To improve generalizability, further research should consider a more diverse sample that would include patients from more than one surgical practice. A second limitation is that participants in this study completed all functional performance and strength tests in the same testing order. This was chosen to maintain consistency across subjects in the case series. However, it is possible that consistently performing the hop test first may have negatively impacted performance on the other tests.

CLINICAL RELEVANCE

The current study identified varying bilateral functional abilities in 3 recreationally active women 3 months after hip preservation arthroscopy, suggesting that a strict 3-month timeframe may not be appropriate to inform return to sport decisions for patients. To potentially decrease the likelihood of reinjury, physical therapists, athletic trainers, and orthopedic surgeons should recognize that strict adherence to a 3-month postsurgical timeframe for allowing return to sporting activities may not be appropriate for all individuals. Further studies are recommended to examine an appropriate time period needed for rehabilitation for patients after hip preservation arthroscopic surgery.

CONCLUSION

This study suggests that lower extremity functional performance deficits and patient-reported outcomes are quite variable 3 months post hip arthroscopy in recreationally active females. Further studies are warranted to explore this in larger samples, across sports, gender, and age groups.

REFERENCES

1. Maradit Kremers H, Schilz SR, Van Houten HK, et al. Trends in utilization and outcomes of hip arthroscopy in the United States between 2005 and 2013. *J Arthroplasty*. 2017;32(3):750-755.
2. Cvetanovich GL, Lizzio V, Meta F, et al. Variability and comprehensiveness of North American online available physical therapy protocols following hip arthroscopy for femoroacetabular impingement and labral repair. *Arthroscopy.* 2017;33(11):1998-2005.
3. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS. Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. *Br J Sports Med.* 2015;49(4):230-242.
4. Wahoff M, Dischiavi S, Hodge J, Pharez JD. Rehabilitation after labral repair and femoroacetabular decompression: criteria-based progression through the return to sport phase. *Int J Sports Phys Ther*. 2014;9(6):813-826.
5. Kraeutler MJ, Anderson J, Chahla J, et al. Return to running after arthroscopic hip surgery: literature review and proposal of a physical therapy protocol. *J Hip Preserv Surg*. 2017;4(2):121-130.
6. Heerey J, Risberg MA, Magnus J, et al. Impairment-based rehabilitation following hip arthroscopy: postoperative protocol for the HIP ARThroscopy International Randomized Controlled Trial. *J Orthop Sports Phys. Ther*. 2018;48(4):336-342.
7. Ellis HB, Briggs KK, Philippon MJ. Innovation in hip arthroscopy: is hip arthritis preventable in the athlete? *Br J Sports Med*. 2011;45(4):253-258.
8. Montgomery MM, Shultz SJ. Isometric knee-extension and knee-flexion torque production during early follicular and postovulatory phases in recreationally active women. *J Athl Train.* 2010;45(6):586-593.
9. Narducci E, Waltz A, Gorski K, Leppla L, Donaldson M. The clinical utility of functional performance tests within one-year post-ACL reconstruction: a systematic review. *Int J Sports Phys Ther.* 2011;6(4):333-342.
10. Logerstedt D, Grindem H, Lynch A, et al. Single-legged hop tests as predictors of self-reported knee function after anterior cruciate ligament reconstruction: the Delaware-Oslo ACL cohort study. *Am J Sports Med*. 2012;40(10):2348-2356.
11. Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther.* 2007;87(3):337-349.
12. Munro AG, Herrington LC. Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res*. 2011;25(5):1470-1477.
13. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012;47(3):339-357.
14. Munro AG, Herrington LC. Between-session reliability of the star

excursion balance test. *Phys Ther Sport.* 2010;11(4):128-132.
15. Gribble PA, Hertel J. Considerations for normalizing measures of the Star Excursion Balance Test. *Meas Phys Educ Exerc Sci*. 2009;7(2):89-100.
16. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther.* 2006;36(12):911-919.
17. Wahoff M, Ryan M. Rehabilitation after hip femoroacetabular impingement arthroscopy. *Clin Sports Med*. 2011;30(2):463-482.
18. Bazett-Jones DM, Cobb SC, Joshi MN, Cashin SE, Earl JE. Normalizing hip muscle strength: establishing body-size-independent measurements. *Arch Phys Med Rehabil*. 2011;92(1):76-82.
19. Martin RL, Philippon MJ. Evidence of validity for the hip outcome score in hip arthroscopy. *Arthroscopy*. 2007;23(8):822-826.
20. Martin RL, Philippon MJ. Evidence of reliability and responsiveness for the hip outcome score. *Arthroscopy*. 2008;24(6):676-682.
21. Kivlan B, Martin R. Outcome instruments for the hip: a guide to implementation. *Ortho Phys Ther Practice*. 2013;25(3):162-169.
22. Christensen CP, Althausen PL, Mittleman MA, Lee JA, McCarthy JC. The nonarthritic hip score: reliable and validated. *Clin Orthop Relat Res*. 2003(406):75-83.
23. Mohtadi NG, Griffin DR, Pedersen ME, et al. The Development and validation of a self-administered quality-of-life outcome measure for young, active patients with symptomatic hip disease: the International Hip Outcome Tool (iHOT-33). *Arthroscopy*. 2012;28(5):595-605; quiz 606-510.e591.
24. Kemp JL, Risberg MA, Schache AG, Makdissi M, Pritchard MG, Crossley KM. Patients with chondrolabral pathology have bilateral functional impairments 12 to 24 months after unilateral hip arthroscopy: a cross-sectional study. *J Orthop Sports Phys Ther*. 2016;46(11):947-956.
25. Kollock R, Van Lunen BL, Ringleb SI, Oñate JA. Measures of functional performance and their association with hip and thigh strength. *J Athletic Training*. 2015;50(1):14-22.
26. Cobb SC, Bazett-Jones DM, Joshi MN, Earl-Boehm JE, James CR. The relationship among foot posture, core and lower extremity muscle function, and postural stability. *J Athl Train*. 2014;49(2):173-180.
27. Enseki KR, Kohlrieser D. Rehabilitation following hip arthroscopy: an evolving process. *Int J Sports Phys Ther*. 2014;9(6):765-773.
28. Voight ML, Robinson K, Gill L, Griffin K. Postoperative rehabilitation guidelines for hip arthroscopy in an active population. *Sports Health*. 2010;2(3):222-230.
29. Domb BG, Sgroi TA, VanDevender JC. Physical therapy protocol after hip arthroscopy: clinical guidelines supported by 2-year outcomes. *Sports Health*. 2016;8(4):347-354.
30. Malloy P, Malloy M, Draovitch P. Guidelines and pitfalls for the rehabilitation following hip arthroscopy. *Curr Rev Musculoskelet Med*. 2013;6(3):235-241.
31. Spencer-Gardner L, Eischen JJ, Levy BA, Sierra RJ, Engasser WM, Krych AJ. A comprehensive five-phase rehabilitation programme after hip arthroscopy for femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(4):848-859.
32. Stalzer S, Wahoff M, Scanlan M. Rehabilitation following hip arthroscopy. *Clin Sports Med*. 2006;25(2):337-357, x.
33. Kuhns BD, Weber AE, Batko B, Nho SJ, Stegemann C. A four-phase physical therapy regimen for returning athletes to sport following hip arthroscopy for femoroacetabular impingement with routine capsular closure. *Int J Sports Phys Ther.* 2017;12(4):683-696.
34. Ithurburn MP, Paterno MV, Ford KR, Hewett TE, Schmitt LC. Young athletes with quadriceps femoris strength asymmetry at return to sport after anterior cruciate ligament reconstruction demonstrate asymmetric single-leg drop-landing mechanics. *Am J Sports Med*. 2015;43(11):2727-2737.
35. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med*. 1991;19(5):513-518.
36. Robinson R, Gribble P. Kinematic predictors of performance on the Star Excursion Balance Test. *J Sport Rehabil*. 2008;17(4):347-357.
37. Domb BG, Dunne KF, Martin TJ, et al. Patient reported outcomes for patients who returned to sport compared with those who did not after hip arthroscopy: minimum 2-year follow-up. *J Hip Preservation Surg*. 2016;3(2):124-131.
38. National Collegiate Athletic Association. Number of NCAA college athletes climbs again. 2018; http://www.ncaa.org/about/resources/media-center/news/number-ncaa-college-athletes-climbs-again. Accessed February 28, 2019.