

Can Hip Passive Range of Motion Predict Hip Microinstability?

A Comparative Study

Daniel M. Curtis,* MD, W. Michael Pullen,^{†‡} MD, Justin N. Hopkins,[§] MD, Iain R. Murray,^{||} PhD, Adam Money,[¶] MD, Nicole A. Segovia,[#] MPH, and Marc R. Safran,[#] MD

Investigation performed at Stanford University, Palo Alto, California, USA

Background: Hip microinstability is an increasingly recognized cause of pain and disability in young adults. It is unknown whether differences in passive hip range of motion (ROM) exist between patients with versus without hip microinstability.

Hypothesis: Underlying ligamentous and capsular laxity will result in differences in clinically detectable passive ROM between patients with femoroacetabular impingement (FAI), patients with microinstability, and asymptomatic controls.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A retrospective review of all patients undergoing hip arthroscopy between 2012 and 2018 was conducted. Patients with a diagnosis of isolated microinstability based on intraoperative findings were identified and classified as having isolated FAI, instability, or FAI + instability. Patients without a history of hip injury were included as controls. Range of motion was recorded in the supine position for flexion, internal rotation, and external rotation. Univariate and multivariate analysis was performed on each measurement in isolation as well as combinations of motion to include total rotation arc, flexion + rotation arc, and flexion + 2 × rotation arc. Models were then created and tested to predict instability status.

Results: In total, 263 hips were included: 69 with isolated instability, 50 with FAI, 50 with FAI + instability, and 94 control hips. A higher proportion of patients in the instability and FAI + instability groups were female compared with the FAI and control groups ($P < .001$). On univariate analysis, differences were found in all groups in all planes of motion ($P < .001$). Multivariable analysis demonstrated differences in all groups in flexion and flexion + rotation arc. In symptomatic patients, the best performing predictive model for hip microinstability was flexion + rotation arc $\geq 200^\circ$ (Akaike information criterion, 132.3; $P < .001$) with a sensitivity of 68.9%, specificity of 80.0%, positive predictive value of 89.1%, and negative predictive value of 51.9%.

Conclusion: Patients with hip microinstability had significantly greater ROM than symptomatic and asymptomatic cohorts without hip microinstability. Symptomatic patients with hip flexion + rotation arc $\geq 200^\circ$ were highly likely to have positive intraoperative findings for hip microinstability, whereas instability status was difficult to predict in patients with a flexion + rotation arc of $< 200^\circ$.

Keywords: hip arthroscopy; hip microinstability; hip capsule; hip labrum

Hip microinstability is increasingly recognized as a cause of pain and disability in young adults, although the diagnosis remains controversial.^{2,4,15,19,22,23,25} Defined as extraphysiologic motion resulting in pain with or without hip joint unsteadiness,^{4,27} hip instability is theorized to result from a combination of pathoanatomic factors. These risk factors include lack of adequate bony support (hip dysplasia), weakness of the periarticular hip muscular stabilizers, disruption of the labral suction seal, and ligamentous or capsular laxity/deficiency.⁸ Additionally, although hip microinstability is increasingly described, no gold standard is available for diagnosis.^{15,25} Currently, a combination of

preoperative factors (history of giving way, soft tissue laxity on physical examination) and intraoperative factors (ease of hip distraction, ligamentum teres pathology, and the location of pathologic chondral and labral findings) have been proposed as the leading diagnostic criteria.^{7,20,22,25,29} However, many of these are intraoperative findings, such that surgical intervention is required to confirm the diagnosis. Thus, further identification and validation of preoperative findings would be paramount in both recognizing and appropriately treating this unique cohort.

Multiple biomechanical studies have demonstrated that capsular deficiency or laxity, particularly anterior to the iliofemoral ligament, results in increased hip range of motion (ROM).^{1,8,13} Furthermore, increased hip ROM has been associated with various degrees of hip dysplasia¹⁷ as well as underlying generalized ligamentous laxity.²⁴

The Orthopaedic Journal of Sports Medicine, 11(6), 23259671231169978

DOI: 10.1177/23259671231169978

© The Author(s) 2023

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For article reuse guidelines, please visit SAGE's website at <http://www.sagepub.com/journals-permissions>.

Specifically, elite ballet dancers have been shown to demonstrate excessive ROM, resulting in asymptomatic femoral head translation and/or subluxation, as well as labral and chondral compression.^{3,9,18} Although excessive ROM has been associated with hip microinstability, to our knowledge, no investigation has focused on using this physical examination finding to aid in diagnosis of hip microinstability. This finding may allow for better preoperative discernment between patients with and without instability, especially in the setting of concomitant femoroacetabular impingement (FAI).

In this study, we aimed to determine whether hip ROM would differ among 4 groups: an asymptomatic cohort, patients with FAI, patients with FAI plus intraoperative findings consistent with instability, and patients with isolated hip microinstability. A secondary goal of the current study was to create a simple clinical tool to help surgeons predict a patient's risk of intraoperatively diagnosed hip instability. Our hypothesis was that hip ROM would be significantly greater in patients with intraoperatively diagnosed hip instability relative to FAI patients and an asymptomatic control group and that hip ROM may be able to assist in the preoperative diagnosis of hip instability.

METHODS

Study Groups

This study was reviewed and approved by the institutional review board at our university. A retrospective review of patients who underwent hip arthroscopy with the senior surgeon (M.R.S.) between 2012 and 2018 was conducted to identify pre- and postoperative diagnoses. We identified 69 patients with isolated hip microinstability (without bony FAI morphology) based on previously published intraoperative criteria (ease of hip distraction, residual hip subluxation after release of traction, straight anterior or lateral chondral and labral pathology).^{4,6,7,14,15,22,26}

The force required for hip distraction was measured based on a consistent and standardized method, recorded as the number of turns of traction (1 turn = 4 mm of axial traction) to obtain 10 mm of hip distraction, as has been previously reported.⁶ The initial state was obtained by placing the patient firmly against a perineal post with body weight traction applied by the senior surgeon as previously

described.^{5,6} A diagnosis of hip microinstability was made based on ≤ 11 turns (≤ 44 mm of traction).²⁵ We also identified a consecutive series of 50 patients with isolated FAI (no intraoperative findings of hip microinstability) and FAI with a concomitant diagnosis of instability. Study inclusion criteria were patients aged 17 to 50 years undergoing primary hip arthroscopy with documented physical examination and imaging findings. The diagnosis of cam-type FAI was based on an alpha angle $>55^\circ$. The diagnosis of pincer-type FAI was defined by a radiographic crossover sign and/or a lateral center-edge angle (LCEA) $>35^\circ$. Mixed-type FAI was defined by meeting definitions of both cam-type and pincer-type FAI. Exclusion criteria were revision cases, hip dysplasia (LCEA $<18^\circ$), or patients treated with hip arthroscopy for an alternative diagnosis (synovial chondromatosis, pigmented villonodular synovitis, etc).

Patient charts were reviewed, and hip ROM (flexion, internal rotation, and external rotation measured in the supine position) was recorded by visual estimation by the senior author (M.R.S.). ROM was recorded in the supine position with maximum hip flexion being recorded with the knee flexed. Internal and external rotation were recorded in the supine position with the hip and knee flexed to 90° . Prior research has shown good agreement between visual estimation and goniometry for hip ROM.^{10,11}

Control Group

Separately, based on an a priori power analysis, 47 individuals with 94 asymptomatic hips were recruited as a control group. This sample size would provide $\geq 80\%$ power to detect a medium effect size (Cohen $d = 0.5$) difference in ROM measures. This number adjusts for pairwise comparisons among all diagnosis groups. These patients were recruited through sports preparticipation physical examinations or among patients seen at our clinic with upper extremity complaints. Patients were included if their age was 17 to 50 years and they had no history of hip pain or prior lower extremity fracture, major injury, or surgery. Because these data were collected prospectively and by >1 individual, hip ROM, including flexion and internal and external rotation, was recorded using a digital goniometer to ensure accuracy and consistency. Assessment of flexion was performed in the supine position and rotation was measured in the prone position with the hip in neutral

[†]Address correspondence to W. Michael Pullen, MD, Medical University of South Carolina, 96 Jonathan Lucas Street Suite 708, MSC 622, Charleston, SC 29425, USA (email: pullenwi@muscc.edu).

*Reno Orthopedic Center, Reno, Nevada, USA.

†Medical University of South Carolina, Charleston, South Carolina, USA.

§Kaiser Permanente, Roseville, California, USA.

||University of Edinburgh, Edinburgh, UK.

*Rothman Institute, Orlando, Florida, USA.

#Stanford University, Palo Alto, California, USA.

Final revision submitted January 25, 2023; accepted February 6, 2023.

One or more of the authors has declared the following potential conflict of interest or source of funding: D.M.C. has received education payments from Arthrex and Smith & Nephew. A.M. has received education payments from Arthrex, Fones Marketing Management, and Smith & Nephew. M.R.S. has received consulting fees from Anika Therapeutics, Linvatec, Medacta, and Smith & Nephew; royalties and nonconsulting fees from Smith & Nephew; and honoraria from Medacta. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Stanford University (reference No. 48466).

TABLE 1
Characteristics of the Study Population Overall and by Group^a

	Overall (N = 263)	FAI (n = 50)	Instability (n = 69)	FAI + Instability (n = 50)	Control (n = 94)	P
Side affected						.381
Left	114 (43)	18 (36)	29 (42)	20 (40)	47 (50)	
Right	149 (54)	32 (64)	40 (58)	30 (60)	47 (50)	
Sex						<.001
Female	173 (66)	16 (32)	65 (94)	42 (84)	50 (53)	
Male	90 (34)	34 (68)	4 (6)	8 (16)	44 (47)	
Age, y	27.8 [20.5-35.9]	26.6 [21-36.3]	29.4 [20.5-38.8]	22.7 [17.8-32.8]	29.4 [21.1-34]	.103

^aData are presented as n (%) or median [interquartile range]. Bolded P value indicates statistically significant difference between the instability and FAI + instability groups compared with the FAI and control groups (P < .05). FAI, femoroacetabular impingement.

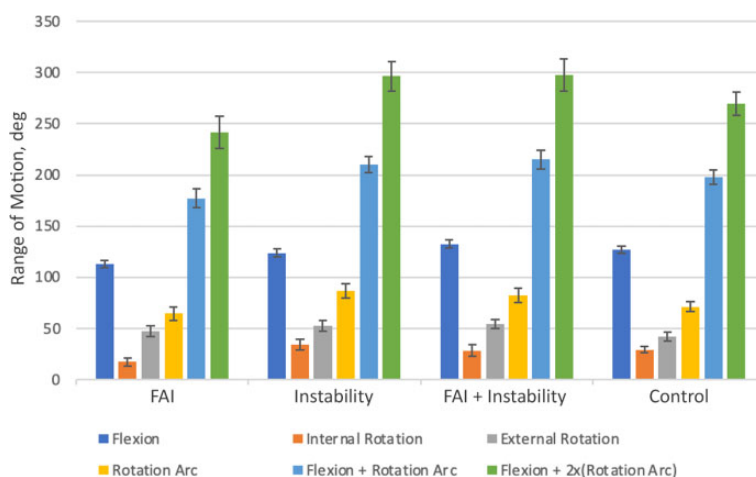


Figure 1. Individual planes of motion and combinations of motion (eg, flexion + rotation arc) by diagnosis with significant differences between all planes of motion on univariate analysis. FAI, femoroacetabular impingement.

flexion-extension. Radiographs were not obtained within the control group.

Statistical Analysis

Baseline demographic characteristics were collected and analyzed for each group. Univariate and multivariable analyses were performed to evaluate for differences between the 4 groups. Models were then created using a variety of isolated measurements and combinations of measurements (flexion, total rotation arc, flexion + rotation arc, flexion + 2x rotation arc). This analysis was performed excluding the asymptomatic control group because the laxity status of these patients was unknown. Each model was assessed using area under the curve, the Youden index, and the Akaike information criterion (AIC). The AIC was used to estimate model prediction error, with lower values indicating more optimal model performance. The optimal model was then identified, and the sensitivity, specificity, and negative and positive predictive values (NPV and PPV, respectively) were calculated. Additionally, models were created for specific demographic characteristics (males aged ≤30 years, males aged >30 years, females aged ≤30 years, females aged >30 years) to be used as clinical

prediction tools. All analyses were completed in RStudio Version 1.1.456 using a level of significance of .05.

RESULTS

In total, 263 hips were included in the initial analysis, with the majority being female (n = 173; 66%). The median age was 27.8 years (interquartile range, 20.5-35.9 years). No significant differences were found between the groups in age (P = .103). However, both instability groups had a higher proportion of female patients than the FAI and asymptomatic control group (P < .001) (Table 1).

In univariate analysis, significant differences were seen between all groups for flexion, internal rotation, external rotation, total rotation arc, flexion + rotation arc, and flexion + 2x rotation arc (P < .001 for all) (Figure 1).

The results of the multivariable analysis after controlling for age and sex are shown in Table 2. With the FAI group serving as the baseline, significant differences were found between all groups in flexion and flexion + rotation arc (P < .05). In the flexion + 2x rotation arc measurement, no statistically significant difference was seen between the FAI group and the control group. In internal rotation, there

TABLE 2
Multivariable Analysis of Each Range of Motion Plane With FAI Group Used as Reference^a

Variable	Estimate	P	Variable	Estimate	P
Flexion			Rotation arc		
Intercept	117.5	<.001	Intercept	85.6	<.001
FAI vs			FAI vs		
Instability	8.6	.003	Instability	13.4	.005
FAI + instability	17.7	<.001	FAI + instability	9.5	.053
Control	11.1	<.001	Control	2.5	.542
Male sex	-3.1	.153	Male sex	-13.1	<.001
Age	-0.1	.373	Age	-0.4	.006
Internal rotation			Flexion + rotation arc		
Intercept	30.5	<.001	Intercept	203.1	<.001
FAI vs			FAI vs		
Instability	11.6	<.001	Instability	22.1	<.001
FAI + instability	5.7	.112	FAI + instability	27.2	<.001
Control	9.2	.003	Control	13.6	.009
Male sex	-8.1	.002	Male sex	-16.2	<.001
Age	-0.3	.017	Age	-0.5	.010
External rotation			Flexion + 2× rotation arc		
Intercept	55.1	<.001	Intercept	288.7	<.001
FAI vs			FAI vs		
Instability	1.8	.626	Instability	35.5	<.001
FAI + instability	3.7	.327	FAI + instability	36.7	<.001
Control	-6.7	.037	Control	16.1	.075
Male sex	-5.0	.072	Male sex	-29.3	<.001
Age	-0.1	.214	Age	-0.9	.007

^aBolded P values indicate statistically significant values (P < .05). FAI, femoroacetabular impingement.

TABLE 3
Evaluation of Each Microinstability
Clinical Prediction Model Performance^a

Model	AIC (Performance)	P
Patient characteristics only	147.7	.016
Flexion	134.3	<.001
Rotation arc	142.8	.009
Flexion + rotation arc	132.3	<.001
Flexion + (2× rotation arc)	137.4	<.001

^aLower Akaike information criterion (AIC) values represent better model performance. Bolded P values indicate statistically significant values (P < .05). Flexion + rotation arc was found to be the optimal model tested.

was no significant difference between the FAI and FAI + instability groups, whereas total rotation arc showed significant differences only between the FAI and isolated instability groups. In external rotation, significant differences were found only between the FAI group and the asymptomatic control group.

Models were then created using the instability, instability + FAI, and FAI groups (Table 3). After assessment of each model, flexion + rotation arc with a cutoff of 200° was found to have the best performance (AIC, 132.3) with the odds of instability being 7 times higher for patients above this cutoff compared with patients below (P < .001) (Figure 2). The sensitivity of this model was 68.9% and specificity was 80.0%, with PPV of 89.1% and NPV of 51.9%.

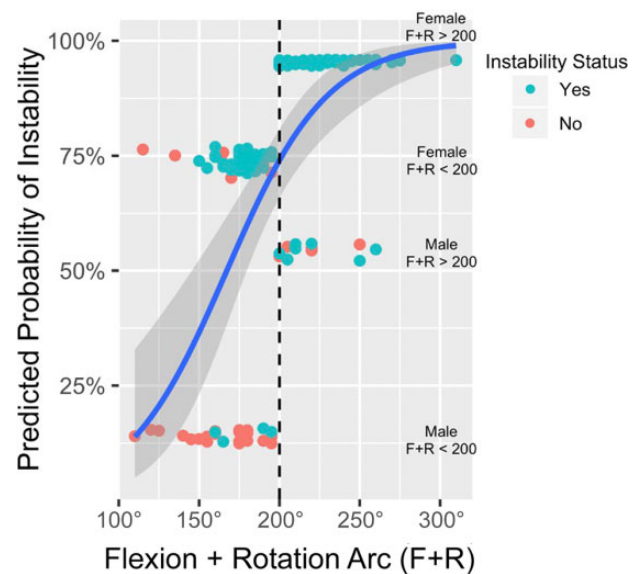


Figure 2. Graphic representation of the optimal clinical prediction model for instability: flexion + rotation arc of $\geq 200^\circ$. On the vertical axis, patients are stratified based on age and sex, with the likelihood of instability demonstrated. Female patients above the 200° threshold (dashed line) are represented by the top group, followed by female patients below the threshold, male patients above the threshold, and male patients below the threshold.

Regarding specific demographic scenarios, the optimal cutoff for female patients ≤ 30 years old ($n = 86$) was a flexion angle of 112.5° (PPV = 93.0%; NPV = 36.4%); for female patients >30 years old ($n = 76$), it was a flexion + rotation arc of 202.5° (PPV = 100%; NPV = 23.3%). For male patients ≤ 30 years old ($n = 55$), the optimal prediction tool was a flexion + rotation arc of 185° (PPV = 46.7%; NPV = 93.8%), whereas in male patients >30 years old ($n = 30$), the cutoff was 200° (PPV = 100%; NPV = 90.9%), 16 of the patients were missing ages so they were not categorized into one of the four age/sex groups.

DISCUSSION

The results of this study demonstrate that there are differences in clinically detectable ranges of motion between patients with instability, patients with FAI, and an asymptomatic control group. In most planes (flexion, internal rotation, total rotation arc, flexion + rotation arc, and flexion + $2 \times$ rotation arc), patients with instability had greater ROM than patients with FAI or asymptomatic controls. This was true in univariate and multivariable analyses, controlling for age and male versus female sex.

Few studies have assessed ROM in relation to the intraoperative diagnosis in hip arthroscopy patients. Philippon et al²¹ reported the clinical presentation of patients with FAI, demonstrating a mean hip flexion angle of 111° , internal rotation of 31° , and external rotation of 38° —all reduced relative to the contralateral hip. Mean hip flexion was consistent with our results in FAI patients, whereas we found slight differences in rotation with less internal and more external rotation in our study. Our study used an asymptomatic control group for comparison rather than the contralateral hip given the high prevalence of similar anatomy in patients as well as the relative frequency of bilateral symptoms in patients with FAI.¹⁶ In patients with generalized ligamentous laxity, Saadat et al²⁴ found increased flexion, internal rotation, and external rotation values as Beighton score increased. Similarly, Matsuda et al¹⁷ demonstrated an association between the presence and severity of dysplasia, as well as the presence of a cam lesion, with hip internal and external rotation. Although generalized ligamentous laxity and borderline hip dysplasia are not synonymous with a diagnosis of microinstability, they are proposed risk factors and significant overlap likely exists.

Physical examination tests have been previously described for hip microinstability, including the abduction–hyperextension–external rotation (AB-HEER) test, the prone external rotation instability test, and the hyperextension–external rotation test.¹⁴ Hoppe et al¹² demonstrated that the AB-HEER test was most accurate, with a sensitivity of 80.6% and specificity of 89.4%. The combination of positive examination findings on all 3 tests demonstrated a high PPV of 95.0%. Similar to our results, all tests had high PPV with moderate NPV. O'Neill et al²⁰ reported the axial distraction test as a physical examination maneuver in their series of iatrogenic instability cases, finding that 77% of patients had either pain, toggling, or apprehension. No studies have investigated the combination of these

examination maneuvers and ROM in predicting the intraoperative diagnosis of hip microinstability.

This study is unique in that we used groups of patients with isolated instability, instability with FAI, and isolated FAI morphology to assess for differences in ROM in patients with symptomatic hips. We also used an asymptomatic control group to potentially identify normative values allowing for the variability of asymptomatic laxity in the native population. Through this analysis, we attempted to provide a simple, prospective clinical tool for predicting a patient's risk of hip instability: hip flexion + rotation arc of $\geq 200^\circ$. Based on our results, patients with a hip flexion + rotation arc of $\geq 200^\circ$ are highly likely to have a positive intraoperative diagnosis of instability (PPV, 89.1%). In patients with a hip flexion + rotation arc of $<200^\circ$, an intraoperative instability diagnosis is much less predictable and other factors should be used for diagnosis. In younger female patients, an alternative metric may be more optimal, with a clinical predictor of flexion angle $>112.5^\circ$ demonstrating high PPV in our analysis. However, this should be applied in the appropriate context and in conjunction with the balance of the physical examination and intraoperative findings. To that end, we found that our control cohort as a whole had a slightly higher mean flexion than our instability cohort as a whole. We cannot specifically account for these findings, and the reasons are likely multifactorial. This finding does, however, require appropriate and thoughtful consideration for its application as a screening tool. We used our FAI cohort as our comparator for generating our model. This was chosen because we were unable to fully identify any underlying pathology in the asymptomatic controls. However, because we were able to find significant differences in ROM between our FAI cohort and those patients with instability, we believe that these criteria can be used to assist surgeons in identifying patients at risk for instability. Furthermore, this information could aid surgeons in preoperative counseling with their patients about the potential cause of their hip pain and likely intraoperative findings and procedures. This tool should be used as an adjunct to intraoperative findings—namely, ease of distraction, residual subluxation, and location of pathologic findings, in order to assess and determine a patient's instability status. Heightened awareness of potential instability may help inform intraoperative capsular management decisions—specifically, capsular plication.^{13,14}

Limitations

This study is not without limitations. ROM measurements were retrospectively collected from patient charts through the assessment of a single, nonblinded surgeon for a portion of the study. These ROM measurements were obtained in the clinical setting and were based on visual measurements. This does call into question the reliability of the measurements; however, as mentioned previously, prior studies have validated the accuracy of visual ROM measurements about the hip.¹¹ Intrarater reliability was not calculated, and interrater reliability could not be assessed. However, this study was intended as a pilot study to

identify potential models and threshold values for future prospective data collection and analysis. Moreover, prior studies have demonstrated the reliability of hip joint ROM, especially with experienced hip surgeons.¹⁰ Therefore, consistent measurements from a single surgeon were deemed sufficient for analysis in this case. Another limitation to this pilot study is that additional variables also contribute to variability in ROM—namely, femoral version and spinopelvic kinematics. In a similar manner, we did not correlate the ROM findings with other physical examination findings associated with hip microinstability. These issues should be considered in future investigations. Further, the surgeon was not blinded to physical examination results at the time of surgery. This leaves open the possibility of confirmation bias for the diagnosis of instability. That stated, the diagnosis of instability or FAI was made based on strict intraoperative criteria and was not influenced by preoperative examination findings.

This study was also limited in that there is no true gold standard for diagnosis of instability intraoperatively. To that end, the prevalence of hip microinstability in our patient population is higher than previously reported in the literature. Potential causes of this finding include heightened awareness of the diagnosis, overdiagnosis within our cohort, or underdiagnosis within the literature. In this study, we used a consistent set of diagnostic criteria that have been used in prior investigations.^{12,14,22,26,28} That stated, this method is not without its challenges, as it is based on a “zero traction” state based on body weight traction, which has the potential for variability. This begets another limitation, the fact that our patients were those who were indicated for surgery, potentially leading to selection bias. A further limitation was the baseline differences in demographic characteristics between groups, with a higher proportion of female patients represented in the instability cohorts. Because ligamentous laxity and microinstability are seen more frequently in female patients, these variables were difficult to control in the patient selection phase. Therefore, we sought to control for these variables in our statistical analysis by performing multivariable regression and attempting to create models specific to certain demographic characteristics.

CONCLUSION

This pilot study demonstrated that clinically detectable hip ROM differed between patients with FAI, patients with instability, and an asymptomatic control group. In patients who undergo hip arthroscopy, a ROM threshold of hip flexion + rotation arc $\geq 200^\circ$ may help to identify patients with hip microinstability.

REFERENCES

- Abrams GD, Hart MA, Takami K, et al. Biomechanical evaluation of capsulotomy, capsulectomy, and capsular repair on hip rotation. *Arthroscopy*. 2015;31(8):1511-1517.
- Bolia I, Chahla J, Locks R, Briggs K, Philippon MJ. Microinstability of the hip: a previously unrecognized pathology. *Muscles Ligaments Tendons J*. 2016;6(3):354-360.
- Charbonnier C, Kolo FC, Duthon VB, et al. Assessment of congruence and impingement of the hip joint in professional ballet dancers: a motion capture study. *Am J Sports Med*. 2011;39(3):557-566.
- Curtis DM, Murray IR, Money AJ, Pullen WM, Safran MR. Hip microinstability: understanding a newly defined hip pathology in young athletes. *Arthroscopy*. 2022;38(2):211-213.
- Curtis DM, Pullen WM, Murray IR, Money A, Safran M. The diagnosis of hip microinstability is correlated with ease of intraoperative hip distraction. *Knee Surg Sports Traumatol Arthrosc*. 2023;31(3):33-39.
- Curtis DM, Pullen WM, Murray IR, et al. Female gender, decreased lateral center edge angle and a positive hyperextension-external rotation test are associated with ease of hip distractibility at time of hip arthroscopy. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(6):2188-2194.
- Economopoulos KJ, Kweon CY, Gee AO, et al. The pull test: a dynamic test to confirm hip microinstability. *Arthrosc Sports Med Rehabil*. 2019;1(1):e67-e74.
- Han S, Alexander JW, Thomas VS, et al. Does capsular laxity lead to microinstability of the native hip? *Am J Sports Med*. 2018;46(6):1315-1323.
- Harris JD, Gerrie BJ, Lintner DM, Varner KE, McCulloch PC. Microinstability of the hip and the splits radiograph. *Orthopedics*. 2016;39(1):e169-e175.
- Harris JD, Mather RC, Nho SJ, et al. Reliability of hip range of motion measurement among experienced arthroscopic hip preservation surgeons. *J Hip Preserv Surg*. 2020;7(1):77-84.
- Holm I, Bolstad B, Lutken T, et al. Reliability of goniometric measurements and visual estimates of hip ROM in patients with osteoarthritis. *Physiother Res Int*. 2000;5(4):241-248.
- Hoppe DJ, Truntzer JN, Shapiro LM, Abrams GD, Safran MR. Diagnostic accuracy of 3 physical examination tests in the assessment of hip microinstability. *Orthop J Sports Med*. 2017;5(11):2325967117740121.
- Jimenez AE, Owens JS, Shapira J, et al. Hip capsular management in patients with femoroacetabular impingement or microinstability: a systematic review of biomechanical studies. *Arthroscopy*. 2021;37(8):2642-2654.
- Kalisvaart MM, Safran MR. Hip instability treated with arthroscopic capsular plication. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(1):24-30.
- Kalisvaart MM, Safran MR. Microinstability of the hip—it does exist: etiology, diagnosis and treatment. *J Hip Preserv Surg*. 2015;2(2):123-135.
- Larson CM, Safran MR, Brcka DA, et al. Predictors of clinically suspected intraarticular hip symptoms and prevalence of hip pathomorphologies presenting to sports medicine and hip preservation orthopaedic surgeons. *Arthroscopy*. 2018;34(3):825-831.
- Matsuda DK, Wolff AB, Nho SJ, et al. Hip dysplasia: prevalence, associated findings, and procedures from large multicenter arthroscopy study group. *Arthroscopy*. 2018;34(2):444-453.
- Mitchell RJ, Gerrie BJ, McCulloch PC, et al. Radiographic evidence of hip microinstability in elite ballet. *Arthroscopy*. 2016;32(6):1038-1044. e1031.
- Neppe JJ, Ambastha C, Abu-Amer W, Clohisy JC. Mid-term outcomes of combined hip arthroscopy and limited open capsular plication in the non-dysplastic hip. *Iowa Orthop J*. 2021;41(1):133-139.
- O'Neill DC, Mortensen AJ, Cannamela PC, Aoki SK. Clinical and radiographic presentation of capsular iatrogenic hip instability after previous hip arthroscopy. *Am J Sports Med*. 2020;48(12):2927-2932.
- Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(8):1041-1047.
- Pullen WM, Curtis DM, Safran MR. Central femoral head chondromalacia is associated with a diagnosis of hip instability. *Arthrosc Sports Med Rehabil*. 2022;4(2):e453-e457.

23. Rosinsky PJ, Mayo BC, Kyin C, et al. The femoral head “divot” sign: a useful arthroscopic sign of hip microinstability. *Orthop J Sports Med.* 2020;8(5):2325967120917919.
24. Saadat AA, Lall AC, Battaglia MR, et al. Prevalence of generalized ligamentous laxity in patients undergoing hip arthroscopy: a prospective study of patients’ clinical presentation, physical examination, intraoperative findings, and surgical procedures. *Am J Sports Med.* 2019;47(4):885-893.
25. Safran MR. Microinstability of the hip—gaining acceptance. *J Am Acad Orthop Surg.* 2019;27(1):12-22.
26. Shibata KR, Matsuda S, Safran MR. Is there a distinct pattern to the acetabular labrum and articular cartilage damage in the non-dysplastic hip with instability? *Knee Surg Sports Traumatol Arthrosc.* 2017;25(1):84-93.
27. Shu B, Safran MR. Hip instability: anatomic and clinical considerations of traumatic and atraumatic instability. *Clin Sports Med.* 2011; 30(2):349-367.
28. Truntzer JN, Hoppe DJ, Shapiro LM, Safran MR. Can the FEAR index be used to predict microinstability in patients undergoing hip arthroscopic surgery? *Am J Sports Med.* 2019;47(13): 3158-3165.
29. Woodward RM, Vesey RM, Bacon CJ, et al. Microinstability of the hip: a systematic review of the imaging findings. *Skeletal Radiol.* 2020; 49(12):1903-1919.