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**Avaliação no ambiente clínico e suas
implicações para reabilitação de
pacientes com Impacto
Femoroacetabular**

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Avaliação no ambiente clínico e suas implicações para reabilitação de pacientes com Impacto Femoroacetabular

Tese submetida ao Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Federal de Ciências da Saúde de Porto Alegre como requisito para a obtenção do grau de Doutor.

Orientador: Prof. Dr. Bruno Manfredini Baroni

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Avaliação no ambiente clínico e suas implicações para reabilitação de pacientes com Impacto Femoroacetabular

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Dedicatória

Ao meu amor, Marco Aurélio Vaz, que sempre esteve ao meu lado, me incentivando a sonhar e enfatizando o meu lado mais brilhante.

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Epígrafe

Há vitórias que exaltam, outras que corrompem; derrotas que matam, outras que despertam.

Antoine de Saint-Exupéry

RESUMO

A presente tese é composta de 3 estudos. **Artigo 1:** O primeiro estudo teve como objetivo comparar a amplitude de movimento (ADM) do quadril e a força muscular entre pacientes com síndrome do impacto femoroacetabular (IFA) e sujeitos assintomáticos. Vinte pacientes com síndrome do IFA e vinte sujeitos assintomáticos passaram por avaliações, em ambiente clínico, de ADM do quadril e força muscular por meio da goniometria e da dinamometria manual, respectivamente. A ADM foi significativamente menor nos pacientes com síndrome do IFA para flexão passiva, rotação interna ativa, rotação externa ativa e passiva. Os pacientes com síndrome do IFA também apresentaram déficit de força de extensores, adutores e flexores do quadril em comparação com os assintomáticos. **Artigo 2:** O segundo estudo teve como objetivo comparar a ADM do quadril e a força muscular em pacientes com diferentes versões femorais (VF) e verificar se as medidas de ADM são capazes de prever a VF. Trinta e um adultos jovens com dor no quadril foram submetidos a radiografias biplanares para quantificar a VF, além de avaliações da ADM do quadril e força muscular em ambiente clínico. Entre os 62 quadris avaliados, 18 apresentavam VF normal, 19 eram antevertidos e 25 retrovertidos. Os quadris antevertidos apresentaram maior amplitude de rotação interna, enquanto quadris retrovertidos apresentaram maior amplitude de rotação externa. Os três grupos apresentaram um índice de rotação do quadril (calculado pela diferença entre a rotação externa e a rotação interna) diferente, sendo este um preditor forte e independente da VF. Os pacientes com quadris antevertidos foram mais fracos em comparação aos pacientes com quadris retrovertidos para a rotação externa à 30°, abdução e adução. **Artigo 3:** O terceiro estudo teve como objetivo avaliar a capacidade prognóstica de características basais em pacientes com síndrome do IFA e determinar seu impacto para o desfecho de saúde destes pacientes. Cento e quarenta e cinco pacientes com síndrome do IFA, avaliados em ambiente clínico entre 2013 e 2019, foram reavaliados entre 1 e 8 anos após por meio do instrumento de avaliação do quadril iHOT-33. Quinze variáveis foram investigadas quanto à sua capacidade prognóstica. O ponto de corte do estado satisfatório aceitável para o paciente (PASS) do iHOT-33 foi estabelecido em 67 pontos, enquanto o escore delta do iHOT-33 foi definido como score final menos o escore inicial. Nas reavaliações se observou que 81 pacientes (56%) atingiram o PASS. Apenas o escore iHOT-33 inicial foi um preditor do PASS ≥ 67 . O escore iHOT-33 inicial, a VF normal e o índice de massa corporal foram capazes de prever o escore delta do iHOT-33. **Conclusões:** A ADM do quadril e a força muscular se mostraram diferentes em pacientes com síndrome do IFA e sujeitos assintomáticos, assim como em pacientes com diferentes VFs. O índice de rotação do quadril se mostrou um forte preditor da VF dos pacientes. Apenas o iHOT-33 provou ser um fator prognóstico aceitável para pacientes com síndrome do IFA atingirem o PASS. Por outro lado, o iHOT-33 inicial, a VF normal e o índice de massa corporal foram capazes de prever o escore delta do iHOT-33.

Palavras-chave: Quadril; amplitude de movimento; força muscular; Impacto femoroacetabular; prognóstico; resultados reportados pelo paciente

ABSTRACT

This thesis is composed of three studies. **Manuscript 1.** The first study aimed to compare hip range of motion (ROM) and muscle strength between FAI syndrome patients and healthy controls. **Methods:** Twenty FAI syndrome patients and 20 controls participated in the study. Hip ROM was assessed using goniometry and hip maximal isometric strength was assessed using manual dynamometry. **Results:** Hip ROM was significantly lower in FAI syndrome patients compared to controls for passive flexion, active internal rotation, active and passive external rotation. The FAI syndrome patients' hip extensors, adductors and flexors were weaker compared to controls. **Manuscript 2.** The second study aimed to compare hip ROM and muscle strength in patients with different femoral versions (FV) and to predict FV based on ROM measurements. **Methods:** Thirty-one young patients with hip pain were evaluated and submitted to biplane radiographs to quantify FV. The 62 hips evaluated were divided into normal, anteverted and retroverted FVs. Hip ROM and muscle strength were assessed using goniometry and manual dynamometry, respectively. **Results:** The anteverted hips had a greater internal rotation ROM, while retroverted hips had a greater external rotation ROM. All three groups had a different hip rotation index, this being a strong and independent predictor of FV. Patients with anteverted hips were weaker compared to patients with retroverted hips for the 30° external rotation, abduction, and adduction. **Manuscript 3.** The third study aimed to assess the prognostic ability of baseline characteristics in FAI syndrome patients and determine their impact on the health outcome of these patients. **Methods:** This study is a cohort of one hundred and forty-five patients with FAI syndrome, evaluated between 2013 and 2019. These patients were re-evaluated using the Hip Assessment Instrument iHOT-33 1 to 8 years after the initial evaluation. Fifteen variables were investigated regarding their prognostic ability. The iHOT-33 cut-off point of acceptable satisfactory status for the patient (PASS) was set at 67 points, while the iHOT-33 delta score was defined as the final score minus the initial score. **Results:** Eighty-one patients reach the PASS. Only the initial iHOT-33 score was a predictor of reaching PASS $\geq$ 67. The initial iHOT-33 score, normal FV and body mass index were able to predict the delta iHOT-33 score. **Conclusion:** Hip ROM and muscle strength were different in FAI syndrome patients and controls and different in patients with different FV. The hip rotation index was a strong predictor of FV. Only iHOT-33 proved to be an acceptable prognostic factor for achieving PASS $\geq$ 67. On the other hand, the initial iHOT-33, the normal FV and the body mass index were able to predict the iHOT-33 delta score.

Key words: Hip; range of motion; strength; femoroacetabular impingement, prognostic, patient reported outcome

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LISTA DE ABREVIATURAS E SIGLAS

ABD	Abduction or abductors
ADD	Adduction or adductors
ADM	Amplitude de movimento articular
BMI	Body mass index
CI	Confidence interval
CG	Control group
ER	External rotation or external rotators
EXT	Extension or extensors
FADDR	Flexion adduction internal rotation hip impingement test
FAI	Femoroacetabular impingement
FLEX	Flexion or flexors
FV	Femoral Version
HOS	Hip outcome score
ICC	Intraclass correlation coefficient
IFA	Impacto Femoroacetabular
iHOT-33	Instrumento de avaliação do quadril e International hip Outcomes Tool
IMC	Índice de massa corporal
IR	Internal rotation or internal rotators
MCID	Mínima diferença clinicamente importante e Minimal clinical important difference
mHHS	Modified Harris hip score
MVIC	Maximal voluntary contraction
OR	Odds ratio
PASS	Estado satisfatório aceitável para o paciente e Patient's acceptable symptom state
PROMs	Resultados reportados pelo paciente e Patient-reported outcome measure
RCT	Randomized controlled trial
ROM	Range of motion
SD	Standard deviation
VF	Versão femoral

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1 CONTEXTUALIZAÇÃO

A dor no quadril em adultos jovens é uma condição desafiadora que leva à incapacidade funcional comprometendo a realização de atividades físicas e de lazer.¹ A causa mais comum de dor persistente no quadril de adultos jovens é a síndrome do Impacto Femoroacetabular (IFA)¹ descrita como uma desordem do quadril relacionada ao movimento.² O impacto entre as estruturas ósseas do quadril é associado a duas anormalidades morfológicas, chamadas de CAME (retificação da transição entre a cabeça e o colo do fêmur) e Pincer (aumento da cobertura acetabular), que podem estar presentes individualmente ou simultaneamente. Estas anormalidades morfológicas levam ao contato anormal das estruturas do quadril provocando danos na cartilagem, levando ao desenvolvimento do processo degenerativo precoce do quadril.³

Além das anormalidades morfológicas clássicas associadas ao IFA, a versão femoral (VF) tem sido reconhecida como uma fonte potencial de dor no quadril em adultos jovens.⁴ VF é definida como o ângulo formado entre o eixo medio-lateral através dos côndilos femorais e o eixo transversal do colo femoral no plano transversal.⁵ A VF normal varia entre 8° e 20° na maioria dos estudos.^{4,6-8} Aumento da VF ou anteversão tem sido associado com a anteriorização excessiva da cabeça femoral levando à sobrecarga labral mais do que ao IFA propriamente dito.^{9,10} Por outro lado, a redução da VF ou retroversão tem sido associada ao risco aumentado de impacto precoce femoroacetabular.⁵

O principal sintoma dos pacientes com síndrome do IFA é a dor no quadril relacionada à posição e/ou ao movimento, sendo o diagnóstico realizado através da análise de sintomas, sinais clínicos e achados de imagem. A localização mais comum da dor é nas regiões anterior, lateral e/ou posterior do quadril, e o teste mais utilizado para auxiliar no diagnóstico é o teste de impacto.¹¹ Além disto, a redução na amplitude dos movimentos de rotação interna e flexão do quadril é comumente encontrada em pacientes com síndrome do IFA.¹² Esses sinais e sintomas, associados à redução da força muscular, prejudicam as atividades de vida diária dos pacientes com síndrome do IFA, como sentar, agachar e caminhar, e também a prática de atividades esportivas.¹²

Duas revisões sistemáticas apresentaram resultados conflitantes ao comparar a ADM do quadril em indivíduos saudáveis e pacientes com síndrome do

IFA. Enquanto Diamond et al.¹² demonstraram que pacientes com síndrome do IFA apresentam redução da ADM na direção do impacto (flexão e rotação interna), Freke et al.¹³ não encontraram nenhuma diferença na ADM de quadril ao comparar indivíduos saudáveis e pacientes com síndrome do IFA. Uma possível explicação para as divergências da literatura pode estar relacionada à presença de alterações da VF em pacientes com síndrome do IFA. Pacientes com anteversão femoral tendem a apresentar maiores valores de rotação interna do quadril, enquanto os pacientes com retroversão apresentam maior rotação externa do quadril.⁸ Estudos prévios demonstraram uma correlação entre a ADM rotacional do quadril e as alterações da VF.^{7,8,10} O impacto da VF na ADM de pacientes com síndrome do IFA, bem como seu potencial diagnóstico e prognóstico, precisa ser estabelecido.

Além da ADM de quadril, a força muscular também é afetada na presença de IFA. As revisões sistemáticas^{12,13} corroboram o fato de que pacientes com síndrome do IFA apresentam déficits de força dos músculos responsáveis pelos movimentos do quadril em comparação a indivíduos saudáveis. No entanto, parece não existir consenso sobre a magnitude da redução de força e sobre os grupos musculares mais afetados. Além disso, o efeito da VF na força muscular de quadril foi muito pouco investigada.¹⁴ Considerando que o aumento ou a diminuição da VF podem alterar o braço de alavanca e o comprimento dos músculos que cruzam o quadril, é plausível que alterações da VF afetem a capacidade de geração de torque muscular.

Tratamentos conservador e cirúrgico têm sido propostos na literatura para melhora da dor e funcionalidade de pacientes com síndrome do IFA. O tratamento conservador consiste na educação do paciente, modificações nas atividades diárias e esportivas e fisioterapia. Já o tratamento cirúrgico de escolha tem sido a artroscopia. O número de artroscopias para correção das anormalidades morfológicas relacionadas à síndrome do IFA cresceu muito nos últimos anos.^{2,15} Uma revisão sistemática atual¹⁵ demonstrou que a artroscopia do quadril tem um pequeno efeito positivo comparado à intervenção fisioterapêutica após 8 a 12 meses das respectivas intervenções. No entanto, considerando o resultado de longo prazo, a evidência da literatura é limitada para sugerir qualquer diferença entre os tratamentos.

Resultados reportados pelo paciente (PROM) têm um papel fundamental em avaliar a resposta a um tratamento específico baseado na perspectiva do paciente. Determinar quando um paciente atingiu uma melhora clinicamente importante após um tratamento é a informação mais importante que o PROM pode fornecer.¹⁶ A

mínima diferença clinicamente importante (MCID) e estado satisfatório aceitável para o paciente (PASS) têm sido preconizados na literatura para definir valores específicos que representam a melhora clínica dos pacientes. Considerando que perceber melhora e estar satisfeito têm impactos diferentes nos pacientes, o PASS tem vantagem de mensurar um valor alvo no qual os pacientes frequentemente estão satisfeitos com seu estado físico.¹⁷

Um dos questionários amplamente utilizado na literatura para pacientes com síndrome do IFA, o instrumento de avaliação do quadril iHOT-33, apresenta propriedades psicométricas satisfatórias reportadas na literatura.¹⁸ Alguns autores têm apresentado valores alvo de PASS variando entre 58 e 67 para o iHOT-33.^{17,19} No entanto, a avaliação de fatores prognósticos baseada no PASS parece ainda não ter sido apresentada na literatura. Além disso, embora estudos já tenham abordado o papel de fatores como idade, sexo, IMC, degeneração articular no prognóstico de pacientes com síndrome do IFA,^{20,21} fatores como a força muscular, a ADM, e a VF não parecem ter sido ainda testados em suas propriedades prognósticas.

Considerando o protagonismo que a Fisioterapia tem assumido na reabilitação de pacientes com síndrome do IFA, seja na condução do tratamento conservador ou na abordagem pós-cirúrgica, a avaliação fisioterapêutica é de suma importância na tomada de decisões. Portanto, a otimização dos métodos utilizados pelo fisioterapeuta na avaliação realizada no ambiente clínico é um fator determinante para decisões cada vez mais assertivas. Nesse sentido, a presente tese é composta por 3 estudos que versam sobre aspectos da avaliação clínica de pacientes com síndrome do IFA e suas potenciais repercussões para a atuação dos fisioterapeutas na reabilitação de pacientes com síndrome do IFA.

REFERÊNCIAS

1. Dick AG, Houghton JM, Bankes MK. An approach to hip pain in young adult. *BMJ*. 2018; 361:k1086. 8
2. Griffin DR, Dickenson EJ, O'Donnell J et al. The Warnick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med*. 2016; 50(19):1169-1176.
3. Agricola R, Waarsing J, Arden N, et al. Cam impingement of the hip -a risk factor for hip osteoarthritis. *Nat Rev Rheumatol*. 2013; 9:630-34.
4. Lerch TD, Todorski IAS, Steppacher SD, Schmaranzer F, Werlen SF, Siebenrock KA, Tannast M. Prevalence of Femoral and Acetabular Version Abnormalities in Patients with Symptomatic Hip Disease. *Am J Sports Med*. 2018; 46(1): 122-134.
5. Audenaert EA, Peeters I, Vigneron L, Baelde N, Pattyn C. Hip Morphological Characteristics and Range of Internal Rotation in Femoroacetabular Impingement. *Am J Sports Med*. 2012; 40(6):1329-36.
6. Botser IB, Ozoude GC, Martin DE, Siddiqi AJ, Kuppuswami S, Domb BG. Femoral Anteversion in the Hip: Comparison of Measurement by Computed Tomography, Magnetic Resonance Imaging, and Physical Examination. *Arthroscopy*. 2012; 28(5): 619-627.
7. Ejnisman L, Philippon MJ, Lertwanich P, Pennock AT, Herzog MM, Briggs KK, Ho CP. Relationship Between Femoral Anteversion and Findings in Hips With Femoroacetabular Impingement. *Orthopedics*. 2013; 36: e293-e300.
8. Kraeutler MJ, Chadayammuri V, Garabekyan T, Mei-Dan O. Femoral Version Abnormalities Significantly Outweigh Effect of Cam Impingement on Hip Internal Rotation. *J Bone Joint Surg*. 2018; 100:205-10.
9. Siebenrock KA, Steppacher SD, Haefeli PC, Schwab JM, Tannast M. Valgus hip with high antetorsion causes pain through posterior extraarticular FAI. *Clin Orthop Relat Res*. 2013; 471:3774-3780.
10. Uding A, Bloom NJ, Commean PK, Hillen TJ, Patterson JD, Clohisy JC, Harris-Hayes M. Clinical Test to Determine Femoral Version Category in People with Chronic Hip Joint and Asymptomatic Controls. *Musculoskelet Sci Pract*. 2019; 39:115-122.
11. Reiman MP, Goode AP, Hegedus EJ, Cook CE, Wright AA. Diagnostic accuracy

- of clinical tests of the hip: a systematic review with meta-analysis. *Br J Sports Med.* 2013;47(14):893-902.
12. 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):230-42.
 13. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med.* 2017; 50(19):1118.
 14. Marostica AD, Pizzolatti ALA, Adam GP, Codonho D, Canella RP, Ganev GG. Is femoral version associated with changes in hip muscle strength in females with symptomatic femoroacetabular impingement? *Rev Bras Ortop.* 2019; 54:422-427.
 15. Kemp JL, Mosler AB, Hart H, et al. Improving function in people with hip-related pain: a systematic review and meta-analysis of physiotherapist-led interventions for hip-related pain. *Br J Sports Med.* 2020; 54(23):1382-1394.
 16. Kivlan BR, Martin RL, Christoforetti JJ et al. The Patient Acceptable Symptomatic State of the 12-Item International Hip Outcome Tool at 1 year Follow-Up of Hip Preservation Surgery. *J Arthrosc Related Surg.* 2019; 35(5):1457-1462.
 17. Maxwell S, Pergaminelis N, Renouf J, Tirosh O, Tran P. Identification of a Patient Acceptable Symptomatic State Score for the International Hip Outcome Tool in People Undergoing Hip Arthroscopy. *Arthrosc.* 2018; 35(11):3024-3029.
 18. Impellizzeri FM, Jones DM, Griffin D, et al. Patient-reported outcome measures for hip-related pain: a review of the available evidence and a consensus statement from the International Hip-related Pain Research Network, Zurich 2018. *Br J Sports Med.* 2020; 54(14):848-857.
 19. Ishoi L, Thorborg K, Orum MG, Kemp JL, Reiman MP, Per Hölmich. How Many Patients Achieve an Acceptable Symptom State After Hip Arthroscopy for Femoroacetabular Impingement Syndrome? A Cross-sectional Study Including PASS Cutoff Values for the HAGOS and iHOT-33. *Orthopaedic J Sports Med.* 2021; 9(4):1-9.
 20. Sogbein OA, Shah A, Kay J, Memon M, Simunovic N, Belzile EL, Ayeni OR. Predictors of Outcomes After Hip Arthroscopic Surgery for Femoroacetabular Impingement: A Systematic Review. *Orthop J Sports Med.* 2019; 19(6):1-19.
 21. Cvetanovich GL, Weber AE, MD, Kuhns BD et al. Arthroscopic Surgery for Femoroacetabular Impingement With Capsular Management Factors Associated

With Achieving Clinically Significant Outcomes. *Am J Sports Med.* 2017; 46(2):288-296.

2 OBJETIVOS

Artigo 1

Comparar a ADM e força muscular de quadril em pacientes com síndrome do IFA e sujeitos assintomáticos;

Artigo 2

Comparar a força muscular e ADM de quadril em adultos jovens com dor no quadril com diferentes VF e verificar se a avaliação clínica pode prever a VF;

Artigo 3

Avaliar a habilidade prognóstica de características basais para o desfecho futuro de saúde de pacientes com síndrome do IFA.

3 ARTIGO 1

HIP MUSCLE WEAKNESS AND REDUCED JOINT RANGE OF MOTION IN PATIENTS WITH FEMOROACETABULAR IMPINGEMENT SYNDROME: A CASE-CONTROL STUDY

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Short title:

Hip strength and range of motion in FAI patients

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ABSTRACT

Background: Femoroacetabular impingement (FAI) syndrome is a hip joint motion-related clinical disorder characterized by abnormal contact between the hip joint structures. Abnormal hip morphology and joint pain may impair the hip joint range of motion (ROM) and muscle function. However, FAI effects on hip joint ROM and muscle strength remain controversial.

Objectives: The purpose of this study was to compare hip joint ROM and muscle strength between FAI syndrome patients and healthy controls.

Methods: Twenty FAI syndrome male patients and 20 healthy male controls (CG) matched for age (FAI=28±6 years; CG=27±5 years), body mass (FAI=81±12 kg; CG=80±13 kg) and height (FAI=177±6 cm; CG=178±6 cm), participated in the study. Hip joint ROM for flexion, internal rotation and external rotation were assessed through goniometry. Maximal isometric strength for hip flexion, extension, abduction and adduction were evaluated through hand-held dynamometry.

Results: Hip joint ROM was significantly lower in FAI syndrome patients compared with CG for passive flexion (-4%; Effect Size-ES=0.65), active internal rotation (-42%; ES=1.60), active external rotation (-28%; ES=1.46) and passive external rotation (-23%; ES=1.63). FAI patients' hip extensors (-34%; ES=1.46), hip adductors (-33%; ES=1.32), and hip flexors (-25%; ES=1.17) were weaker compared to the CG subjects.

Conclusions: FAI syndrome patients presented both hip muscle weakness and reduced joint ROM compared to match CG.

Keywords: FAI; hip pain; Physical Therapy; muscle strength.

BULLET POINTS

- Femoroacetabular impingement (FAI) syndrome patients had losses in hip muscle strength
- Flexion and rotation movements are reduced in FAI syndrome patients
- Reduced hip strength and motion should be considered during rehabilitation programs

INTRODUCTION

Femoroacetabular Impingement (FAI) syndrome is a hip joint motion-related clinical disorder with a triad of symptoms (i.e., pain related to position or movement), clinical signs, and imaging findings.¹ FAI is characterized by the abnormal contact between the acetabular border and the cervicocephalic femur junction. This abnormal contact causes cartilage damage, and has been related to the early onset of hip degenerative disease.^{2,3} Moreover, it seems plausible that the both altered bone morphology and the hip pain may impair the joint mobility, the muscle strength and the patient's functional capacity.

Two systematic reviews provide conflicting conclusions regarding the effect of FAI on hip range of motion (ROM).^{4,5} Diamond et al.⁴ showed that FAI patients present a decreased ROM at the hip joint impingement directions, whereas Freke et al.⁵ found that hip joint ROM did not differ between symptomatic FAI and healthy subjects. The different methods used to assess the hip ROM (goniometry, inclinometer, 3D kinematic system, simulate 3D tomography, MRI-generated bony models),⁶⁻⁹ and the poor methodological quality of some studies might explain the divergent conclusions on these two systematic reviews.

Freke et al.⁵ reviewed six studies on FAI patients' muscle weakness, and concluded that hip muscle strength is overall impaired in FAI patients. However, studies comparing FAI patients with a control subjects have presented no consensus on the most affected muscle groups.¹⁰⁻¹³ For instance, while Casartelli et al.¹⁰ showed that FAI patients had significantly lower isometric voluntary strength for the hip abductors, adductors, flexors and external rotators, Diamond et al.¹² showed that only the hip abductors were weaker in FAI patients compared to asymptomatic subjects. These inconsistent results might be related to the different positions used during the strength tests, as well as the different evaluation tools (manual dynamometer or isokinetic dynamometer).

Knowing which movements and muscle groups are the most affected by FAI syndrome is imperative for developing effective physical therapy treatment programs. Considering the abovementioned literature divergences, high methodological quality

studies are required. In addition, studies with FAI patients have greater practical applicability when using evaluation procedures that can be reproduced by physical therapists in the clinical setting. Therefore, the purpose of this study was to compare hip joint ROM and muscle strength between FAI syndrome patients and a CG.

METHODS

Study design

A cross-sectional, case-control study was performed to identify possible deficits in hip ROM and muscle strength in FAI syndrome patients compared to their matched CG. All volunteers were submitted to a clinical evaluation protocol conducted by two physical therapists, who presented at least 10 years of clinical practice and more than 500 FAI patients that they assessed using the methods applied in this study. Hip joint ROM for flexion, internal rotation and external rotation were assessed through goniometry. Maximal isometric strength of the hip flexors, hip extensors, hip abductors and hip adductors was evaluated through hand-held dynamometry.

The study was conducted according to the revised Helsinki declaration. Ethical approvals for the study were obtained from the Federal University of Rio Grande do Sul (Porto Alegre, RS, Brazil) ethics committee (reference number 1.871.372). All subjects agreed to participate by signing an informed consent form.

Subjects

Twenty FAI syndrome male patients and 20 healthy male controls (CG) were assessed in this study. Male patients were selected due to the larger prevalence of FAI morphology in this population.¹⁴ Sample size calculation was determined based on hip adductor muscle weakness detected in FAI patients compared with matched controls.¹⁰ Power analysis indicated that a sample size of 20 subjects/group was required to detect significant hip adductors strength differences between FAI and CG (effect size $d=0.8$; $\alpha=0.05$; power=0.8).

FAI syndrome patients were obtained from a local Physical Therapy Center. An orthopedic surgeon diagnosed FAI syndrome patients based on a symptoms triad, clinical signs and image findings.¹ To be included, patients should present: (1) motion-

related or position-related pain symptoms at the hip or groin; (2) positive hip impingement test (FADDIR) and limited ROM; and (3) an anteroposterior radiograph of the pelvis and a lateral neck view with a “pistol grip” or CAM deformity and/or Pincer morphology (an over covered acetabular rim). Data collection occurred prior to the surgical treatment, and patients did not received any kind of physiotherapeutic intervention before evaluations. The modified Harris Hip Score (mHHS),¹⁵ the Hip Outcome Score (HOS),¹⁶ and the International Hip Outcomes Tool (iHOT-33 – Brazilian adapted version)¹⁷ were used to assess the patients’ functionality. These questionnaires were applied only to FAI patients, and were chosen because they evaluate different syndrome domains. While mHHS emphasizes the presence of pain, HOS emphasizes functionality in daily activities. The iHOT-33 takes into account biopsychosocial aspects. In all three questionnaires, results close to 100 indicate an excellent result, where the hip problem does not affect the assessed domain. Patients with other lower limb injuries (e.g. ACL rupture, muscle strain, meniscal tear, tendinopathy) were excluded from the study, as well as patients with rheumatologic or neurological diseases.

CG subjects were recruited from the university community. To rule out the presence of intra-articular pathology (osteoarthritis - OA, labral lesions and FAI), all subjects were subjected to the flexion-adduction-internal rotation (FADDIR) test.¹⁸ This test, performed by the physical therapist, was chosen due to its potential for the determination of intraarticular pathology nonexistence (its screening ability with a sensitivity of 99 and a negative likelihood ratio of 0.15).¹⁹

Range of motion (ROM) evaluation

Hip joint ROM was assessed using a goniometer for flexion (active and passive), internal rotation (only active) and external rotation (active and passive). Goniometry was chosen to assess hip ROM because it is a widely used and clinician-friendly tool, and is a reliable and valid method to assess FAI patients’ ROM.⁸ According to Nussbaumer et al.,⁸ who used goniometry and clearly described the positioning during the ROM tests, goniometer-based assessments considerably overestimate hip ROM due to uncontrolled pelvic rotation and pelvic tilt. We tried to solve some of these

problems by using a bilateral movement, so that the patient could not compensate with a pelvic tilt or pelvic rotation during internal rotation ROM measurements. Therefore, the subjects' positions were chosen to favor pelvis stabilization (FIGURE 1). For hip flexion, the contralateral leg was maintained fully extended to reduce the posterior pelvic tilt. For external rotation, the contralateral leg was maintained fully extended in neutral position to control the pelvic inclination. For internal rotation, the movement was performed bilaterally to neutralize the pelvic inclination, and the subject maintained the hip and knee flexed in 90° throughout the test. We did not measure passive internal rotation ROM because it is not possible for the physical therapist to force passive bilateral ROM at the same time that he/she is measuring hip ROM with a goniometer. We chose not to use help from another evaluator during the tests because we wanted the tests to be easily reproducible in the clinical setting.

Nussbaumer et al.⁸ have already demonstrated that passive hip joint goniometry was reliable between days (intra-rater reliability). Healthy subjects hip ROM inter-rater reliability was previously established in our laboratory using the same methodology here presented and was considered excellent for hip rotations and satisfactory for hip flexion.²⁰ The inter-rater intraclass correlation coefficient (ICC) values were superior to 0.84 for hip flexion and hip rotations.²⁰

Hip extension, hip abduction and hip adduction ROM tests were not included due to difficulties in obtaining a good testing position with the pelvis stabilized, which increases measurement errors and/or data dispersion. In addition, hip flexion and hip rotations appeared to be good representatives of hip mobility related to the morphological abnormalities that cause FAI.

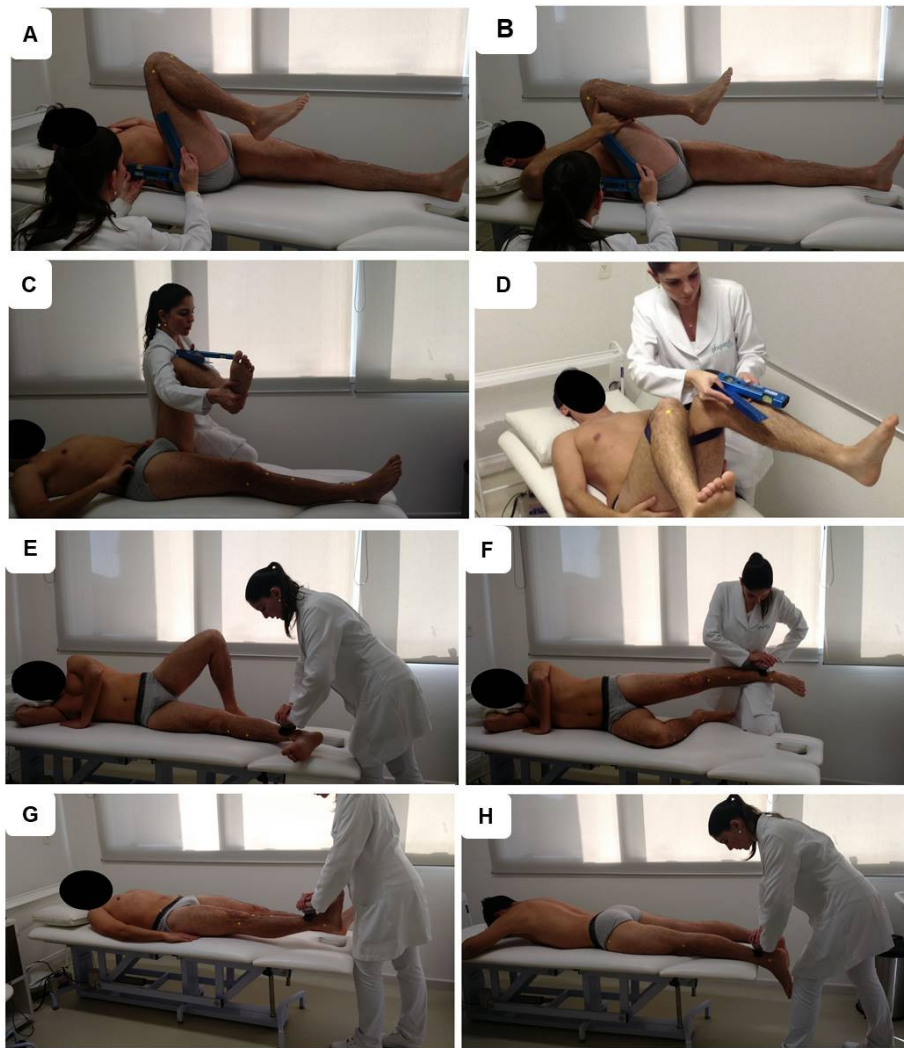


FIGURE 1. Subjects' positions during hip range of motion assessments (A to D) and isometric muscle strength measurements (E to H). Active flexion (A), Passive flexion (B), Passive external rotation (C) and Active internal rotation (D) were measured with a goniometer. Hip adductors (E), hip abductors (F), hip flexors (G) and hip extensors (H) strength measurements with a hand held dynamometer.

Muscle strength evaluation

Maximal isometric hip strength was assessed through hand-held dynamometry (MICROFET – Hoogan Scientific, Salt Lake City, USA). Hip flexors, extensors, abductors and adductors were evaluated in different positions (FIGURE 1). In all tests,

the dynamometer was placed distally (close to the ankle joint), with a great lever arm to favor the evaluators' stabilization. The evaluator hold the dynamometer pad 5 cm proximal to the lateral (hip abduction) and medial (hip adduction) malleoli. For the hip flexors and extensors, a horizontal line was drawn from the lateral malleolus to the anterior (hip flexors) or posterior (hip extensors) part of the leg and the dynamometer was placed proximal to this line.

For each muscle group, subjects completed two maximal voluntary isometric contraction (MVICs) trials. If the difference between the two MVICs was higher than 10%, another trial was performed. Subjects were asked to perform maximal efforts with the following sequence: 2 sec to build up to maximal force, 2 sec of isometric contraction, and 2 sec to relax. The between-trials rest interval was set at 120 sec. Additional measurements were taken if poor stabilization occurred or if participants failed to achieve a maximum effort. Participants received standardized verbal encouragement to produce maximal effort by the physical therapist, who used the following expression: "Come on, full effort, full effort!" The highest effort of the two valid measures was converted to torque value (Nm) by multiplying the force in Newtons by the lever arm length (distance between approximate joint axis of rotation and the point of force application). Normalized to body mass (Nm/kg) data were analyzed.

Thorborg et al.²¹ and Pua et al.²² have shown good to excellent reliability for intra-rater hip strength measurements, but did not evaluate the inter-rater reliability. However, their methodology used to determine this intra-rater reliability differs from the one used in the present study. Healthy subjects hip muscle strength intra-rater and inter-rater reliability was previously established in our group using the same methodology here presented. Our results agreed with those of the abovementioned studies for the intra-rater reliability, and added new information for the inter-rater reliability. ICC was considered excellent (intra-rater superior to 0.89, inter-rater superior to 0.90) for all tested muscle groups.²⁰

Statistical analysis

The symptomatic (for unilateral FAI patients) or the most symptomatic (for bilateral FAI patients) hip was used for analysis. Since CG subjects presented no

differences for the between-legs comparison, data from the right leg were used for analysis. Data normal distribution was assessed using the Shapiro Wilk test. Independent t-tests were used to compare FAI and CG for age, body mass, height, ROM, and strength. Cohen's "d" effect size was used to determine differences on the hip ROM and strength values between the two groups. Effect size results were interpreted based in the following classification: trivial (<0.2), small (>0.2), moderate (>0.6), large (>1.2), very large (>2.0).^{23,24}

RESULTS

All twenty subjects from each group completed the evaluation session. The two groups were matched for age (FAI = 28.1 ± 6.0 year, CG = 27.0 ± 5.0 years, $p=0.232$), body mass (FAI = 81.5 ± 12.1 kg, CG = 80.0 ± 13.1 kg, $p=0.367$) and height (FAI = 1.77 ± 0.06 m, CG = 1.78 ± 0.06 m, $p=0.416$). All FAI patients' questionnaires presented reduced values compared to the full score. The mean $\pm$ SD values for the questionnaires were 45.5 ± 14.3 for iHOT-33, 73.8 ± 13.8 for MMHS, and 80.6 ± 19.4 for HOS.

FAI patients presented significantly smaller hip ROM for passive flexion, passive and active external rotation, and active internal rotation compared to CG (TABLE 1). Active flexion was similar between the two groups. The effect size was considered large for hip internal and external rotation and moderate for hip flexion (TABLE 1).

FAI patients were weaker (smaller relative strength) compared to CG subjects for hip flexors, hip extensors, and hip adductors (TABLE 2). Hip abductors relative strength was similar between FAI patients and CG. The effect size was considered large for hip extensors and hip adductors, moderated for the hip flexors and small for the hip abductors (TABLE 2).

TABLE 1. Range of motion of femoroacetabular impingement (FAI) patients and control group (CG) subjects [mean $\pm$ SD (95% CI)].

	FAI	CG	$\Delta\%$	p-value	Effect size
Active flexion (degrees)	115.8 $\pm$ 7.7 (112-119)	120.4 $\pm$ 7.8 (117-124)	-4%	0.065	0.60
Passive flexion (degrees)	131.2 $\pm$ 8.4 (127-135)	136.7 $\pm$ 8.2 (133-141)	-4%	0.044	0.65
Active external rotation (degrees)	35.4 $\pm$ 8.5 (31-39)	49.3 $\pm$ 8.5 (45-53)	-28%	<0.001	1.46
Passive external rotation (degrees)	51.8 $\pm$ 12.2 (46-58)	68.1 $\pm$ 9.9 (63-73)	-23%	<0.001	1.63
Active internal rotation (degrees)	17.3 $\pm$ 7.1 (15-21)	29.8 $\pm$ 8.4 (26-34)	-42%	<0.001	1.60

TABLE 2. Hip strength relative to body mass (Nm/kg) of femoroacetabular impingement (FAI) patients and control group (CG) subjects [mean $\pm$ SD (95% CI)].

	FAI	CG	$\Delta\%$	p-value	Effect size
Extension (Nm/kg)	1.59 $\pm$ 0.50 (1.36- 1.81)	2.40 $\pm$ 0.61 (2.11- 2.68)	-34%	<0.001	1.46
Flexion (Nm/kg)	1.55 $\pm$ 0.41 (1.35- 1.74)	2.08 $\pm$ 0.48 (1.85- 2.30)	-25%	<0.001	1.17
Adduction (Nm/kg)	1.21 $\pm$ 0.44 (1.0- 1.41)	1.80 $\pm$ 0.45 (1.58- 2.01)	-33%	<0.001	1.32
Abduction (Nm/kg)	1.42 $\pm$ 0.36 (1.25- 1.58)	1.60 $\pm$ 0.37 (1.42- 1.77)	-12%	0.112	0.51

DISCUSSION

Our results on hip ROM disagree from those reported by Freke et al.,⁵ who suggested that no differences in hip ROM existed between FAI patients and CG asymptomatic subjects. Our results for internal rotation ($\sim 17^\circ$ for FAI and $\sim 30^\circ$ for CG) were a little smaller than Nussbaumer et al.⁸ results ($\sim 26^\circ$ for FAI and $\sim 34^\circ$ for CG). For hip flexion, while using the same position as Nussbaumer et al.,⁸ we tried to neutralize the lumbopelvic movement by placing a lumbar cushion at the lumbar region. Although this lumbar cushion limited pelvic tilt, our results ($\sim 116^\circ$ for FAI and $\sim 120^\circ$ for CG) for hip flexion were superior than those described in some studies.^{8,25} The reason for this difference is not completely clear. However, these studies present hip flexion ROM values inferior to those described by normative ROM studies.²⁶ For external rotation, our values ($\sim 35^\circ$ for FAI and $\sim 49^\circ$ for CG) are like those from Nussbaumer et al.⁸ ($\sim 36^\circ$ for FAI and $\sim 45^\circ$ for CG).

The losses in hip ROM confirmed the initial hypothesis presented by Ganz et al.^{3,27} that FAI syndrome patients had reduced hip flexion and internal rotation. Hip internal rotation reduction, frequently cited in different FAI studies,^{6,7,9} seems to be highly related to the morphological abnormality at the femoral-neck junction, which blocks the internal rotation especially when the hip is flexed by 90° .²⁷ The hip external rotation reduction, however, cannot be explained by the presence of CAM morphological abnormality. It appears that this hip ROM limitation is more related to a movement restriction caused by skeletal soft tissues (e.g. joint capsule, ligaments and muscle fiber length).^{28,29,30} Joint effusion should be considered an intervenient factor on FAI patients hip ROM,³¹ as well as kinesiophobia (i.e. fear of movement). Therefore, the reduced hip ROM observed in FAI patients might be related to several factors, and physical therapists should investigate the main movement restriction factors in each patient (e.g., soft tissues adaptation to disuse, effusion, pain, or kinesiophobia) to offer an individualized and assertive treatment.

Our results for the hip strength measurements agree with those reported by Freke et al.⁵ FAI patients were weaker than the CG, and our effect size results showed that strength losses in FAI patients' hip muscle groups are clinically relevant, and not only statistically significant as traditionally reported by clinical trials through the "p-

values". Interestingly, we were unable to show a consistent loss on the hip abductors strength in FAI patients (no between-groups statistical difference with a small effect size). Casartelli et al.¹⁰ showed that patients with symptomatic FAI presented muscle weakness for all hip muscle groups (except for internal rotators and extensors) using hand-held and isokinetic dynamometers, while Diamond et al.¹² showed that only hip abduction strength was lower in FAI patients compared to controls when testing with a hand-held dynamometer. Apparently, the testing method and the subject's positioning are strong intervening factors for detecting FAI patients muscle weakness. FAI patients' pain or discomfort at some positions, their restricted ROM and kinesiophobia may negatively affect muscle strength evaluation.

Muscle strength reduction has been demonstrated in patients with hip and knee disorders,^{32,33} and associated with muscle weakness and generalized reduced muscle mass in the affected lower limb of patients with unilateral hip OA.³² Muscle weakness mechanisms are multifactorial, and include reduced muscle mass, presence of muscle inhibition and decreased muscle quality, which are common to disuse situations.³⁰ It is interesting to note that many of the FAI patients end up leaving their sports/exercise practice at a life stage when they are physically active or even athletes. Considering that FAI patients remain for many years with pain (e.g., FAI syndrome patients in our study had a mean pain symptom of ~50 months), pain-induced neuromuscular inhibition³⁴ might partly explain the strength losses. In addition, FAI abnormal morphologies have been related with the early onset of hip OA,^{2,27} which is known to cause muscle inhibition. However, to date there appears to be no study assessing muscle inhibition in FAI patients.

FAI syndrome patients experience disability and functional limitations while performing daily living movements that have high hip ROM demands (e.g., putting pants or tying shoelaces),³⁵ which can worsen during demanding physical activities.^{36,37} Since hip ROM and muscle strength losses have an important role in functional limitations and disability, improvements in these outcomes have been recommended in physiotherapy programs.³⁸⁻⁴⁰ There is a consensus that muscle strengthening plays a key role in these patients' recovery in both conservative and surgical treatments, but ROM recovery is a controversial point.³⁸⁻⁴⁰ As part of the hip ROM limitation is related

to the bone structure and to the joint lesions (labrum and cartilage), one could argue that full ROM recovery might not be achievable with conservative treatment. However, apparently surgical intervention also does not guarantee hip ROM increase.⁵ Therefore, further high-quality methodology studies are needed to clarify the best procedures for the recovery of the FAI patients' hip ROM.

A crucial limitation of this study was that evaluators were not blinded to the subjects' group allocation. In addition, the CG subjects' evaluation used to exclude hip pathology was performed based on clinical exams. A health-lifestyle questionnaire could have been used for the CG to better describe their health status; and the hip morphology imaging analysis would have helped to eliminate any chance of morphological abnormality in the control subjects. The ROM measurements were made only for hip flexion and rotational movements due to the difficulty in obtaining a good pelvis stable position for testing the hip abduction and adduction ROM. The poor stability during tests also prevented the strength tests for hip internal and external rotators through the hand-held dynamometer. Despite our limitations to test ROM and strength for all hip movements and muscle groups, we used a reliable testing procedure easily executable in the clinical setting.

CONCLUSION

FAI syndrome patients presented hip muscle weakness and reduced ROM. These deficiencies may be detected in the clinical setting using simple and reliable tests with a goniometer and a hand-held dynamometer. Hip adduction, hip flexion and hip extension strength training, as well as hip internal and external rotation mobility training to increase hip ROM, should be emphasized during FAI syndrome patients' rehabilitation programs.

REFERENCES

1. Griffin DR, Dickenson EJ, O'Donnell J et al. The Warnick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *BJSM* 2016; 50(19):1169-1176. <https://doi.org/10.1136/bjsports-2016-096743>.
2. Agricola R, Waarsing J, Arden N, et al. Cam impingement of the hip -a risk factor for hip osteoarthritis. *Nat Rev Rheumatol.* 2013; 9:630-34. <https://doi.org/10.1038/nrrheum.2013.114>.
3. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res.* 2008; 466(2):264-272. <https://doi.org/10.1007/s11999-007-0060-z>
4. 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):230-42. <https://doi.org/10.1136/bjsports-2013-093340>.
5. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *BJSM.* 2017; 50:1118. <https://doi.org/10.1136/bjsports-2016-096152>.
6. Kemp JL, Schache AG, Makdissia M, Pritchard MG, Sims K, Crossley KM. Is hip range of motion and strength impaired in people with hip chondrolabral pathology? *J Musculoskelet Neuronal Interact.* 2014; 14(3):334-42.
7. Kubiak-Langer M, Tannast M, Murphy SB, et al. Range of motion in anterior femoroacetabular impingement. *Clin Orthop Relat Res.* 2007; 458:117-24. <https://doi.org/10.1097/BLO.0b013e318031c595>.
8. Nussbaumer S, Leunig M, Glatthorn JF, Stauffacher S, Gerber H, Maffiuletti NA. Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskelet Disord.* 2010; 31;11:194. <https://doi.org/10.1186/1471-2474-11-194>.
9. Tannast M, Kubiak-Langer M, Langlotz F, Puls M, Murphy SB, Siebenrock KA.

- Noninvasive three-dimensional assessment of femoroacetabular impingement. *J Orthop Res*. 2007; 25(1):122-31. <https://doi.org/10.1002/jor.20309>.
10. Casartelli N, Maffiuletti N, Item-Glatthorn JF. Hip muscle weakness in patients with symptomatic femoroacetabular impingement. *Osteoarthr Cartil*. 2011; 19(7):816-21. <https://doi.org/10.1016/j.joca.2011.04.001>.
 11. Casartelli NC, Leunig M, Item-Glatthorn JF, Lepers R, Maffiuletti NA. Hip flexor muscle fatigue in patients with symptomatic femoroacetabular impingement. *Int Orthop*. 2012; 36(5):967-73. <https://doi.org/10.1007/s00264-011-1385-5>.
 12. Diamond LE, Wrigley TV, Hinman RS, Hodges PW, O'Donnell J, Takla A, Bennell KL. Isometric and isokinetic hip strength and agonist/antagonist ratios in symptomatic femoroacetabular impingement. *J Sci Med Sport*. 2015; 19(9):696-701. <https://doi.org/10.1016/j.jsams.2015.10.002>.
 13. Nepple JJ, Goljan P, Briggs KK, Garvey SE, Ryan M, Philippon MJ. Hip strength deficits in patients with symptomatic femoroacetabular impingement and labral tears. *Arthroscopy*. 2015; 31(11):2106-2111. <https://doi.org/10.1016/j.arthro.2015.04.095>.
 14. Mascarenhas VV, Rego P, Dantas P, Moraes F, McWilliams J, Collado D, Marques H, Gaspar A, Soldado F, Consciência JG. Imaging prevalence of femoroacetabular impingement in symptomatic patients, athletes, and asymptomatic individuals: A systematic review. *Eur J Radiol*. 2016; 85(1):73-95. <https://doi.org/10.1016/j.ejrad.2015.10.016>.
 15. Guimarães RP, Alves DPL, Azuaga TL, Ono NK, Honda Emerson, Polesello GC et al. Tradução e adaptação transcultural do Harris Hip Score modificado por Byrd. *Acta Ortop Bras*. 2010; 18(6):339-342.
 16. Oliveira LP, Cardinot TM, Carreras LDC, Queiroz MC, Polesello GC. Tradução e adaptação cultural do Hip Outcome Score para a língua portuguesa. *Rev Bras Ortop*. 2014; 49(3):297-304.
 17. Polesello GC, Godoy GF, Trindade CAC, Queiroz MC, Honda E, Ono NK. Tradução e adaptação transcultural do instrumento de avaliação do quadril MHOT. *Acta Ortop Bras*. 2012; 20(2):88-92.
 18. Reiman MP, Thorborg K. Clinical examination and physical assessment of hip

- joint-related pain in athletes. *Int J Sports Phys Ther*. 2014;9(6):737-755. PMID: 25383243.
19. Reiman MP, Goode AP, Hegedus EJ, Cook CE, Wright AA. Diagnostic accuracy of clinical tests of the hip: a systematic review with meta-analysis. *Br J Sports Med*. 2013;47(14):893-902. <http://doi:10.1136/bjsports-2012-091035>.
 20. Torresan A. *Reprodutibilidade intra e interavalador na avaliação funcional do quadril – Intra and inter reability in hip functional assessment* [thesis]. Porto Alegre, RS, Brazil: Federal University of Rio Grande do Sul; 2017. <http://www.lume.ufrgs.br/handle/10183/172134>.
 21. Thorborg K, Petersen J, Magnusson SP et al. Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports*. 2010;20(3):493-501. <https://doi.org/10.1111/j.1600-0838.2009.00958.x>.
 22. Pua YH, Wrigley TV, Cowan SM et al. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. *Arch Phys Med Rehabil*. 2008;89(6):1146-1154. <https://doi.org/10.1016/j.apmr.2007.10.028>.
 23. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Hillsdale: Lawrence Erlbaum; 1988.
 24. Armijo-Olivo S. The importance of determining the clinical significance of research results in physical therapy clinical research. *Braz J Phys Ther*. 2018, 22(3):175-176. <http://doi:10.1016/j.bjpt.2018.02.001>.
 25. Philippon MJ, Briggs KK, Yen YM, Kuppersmith DA. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg Br*. 2009; (1(1): 16-23. <http://doi:10.1302/0301-620X.91B1.21329>.
 26. Roach KE and Miles TP. Normal Hip and Knee Active Range of Motion: The Relationship to Age. *Phys Ther*. 1991; 71:656-665.
 27. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res*. 2003; 417:112-120. <https://doi.org/10.1097/01.blo.0000096804.78689.c2>.

28. Martin HD, Savage A, Braly BA, Palmer IJ, Beall DP, Kelly B. The function of the hip capsular ligaments: a quantitative report. *Arthroscopy*. 2008; 24(2):188-95. <https://doi.org/10.1016/j.arthro.2007.08.024>.
29. van Arkel JR, Amis AA, Cobb JP. The capsular ligaments provide more hip rotational restraint than the acetabular labrum and the ligamentum teres: an experimental study. *Bone Joint J*. 2015; 97-B(4):484–91. <https://doi.org/10.1302/0301-620X.97B4.34638>.
30. Narici MV, Maganaris CN. Plasticity of the muscle-tendon complex with disuse and aging. *Exerc Sport Sci Rev*. 2007; 35(3):126-34. <https://doi.org/10.1097/jes.0b013e3180a030ec>.
31. Hebert C, Smyth MP, Woodard E, Bills CC, Mihaiko MJ, Mihaiko WM. Effects of hip joint transverse plane range of motion with a modeled effusion and capsular tear: a cadaveric study. *Clin Biomech* (Bristol, Avon). 2017; 42:115-119. <https://doi.org/10.1016/j.clinbiomech.2017.01.016>.
32. Loureiro A, Mills PM, Barrett RS. Muscle weakness in hip osteoarthritis: a systematic review. *Arthritis Care Res* (Hoboken). 2013; 65(3):340-52. <https://doi.org/10.1002/acr.21806>.
33. Prins MR, van der Wurff P. Females with patellofemoral pain syndrome have weak hip muscles: a systematic review. *Aust J Physiother*. 2009; 55(1):9-15. [https://doi.org/10.1016/S0004-9514\(09\)70055-8](https://doi.org/10.1016/S0004-9514(09)70055-8).
34. Freeman S, Mascia A, McGill S. Arthrogenic neuromusculature inhibition: a foundational investigation of existence in the hip joint. *Clin Biomech*. 2013;28(2):171-7. <https://doi.org/10.1016/j.clinbiomech.2012.11.014>.
35. Hyodo K, Masuda T, Aizawa J, Jinno T, Morita S. Hip, knee, and ankle kinematics during activities of daily living: a cross-sectional study. *Braz J Phys Ther*. 2017; 21(3): 159-168. <http://doi:10.1016/j.bjpt.2017.03.012>.
36. Bizzini M, Nötzli HP, Maffiuletti NA. Femoroacetabular impingement in professional ice hockey players: a case series of 5 athletes after open surgical decompression of the hip. *Am J Sports Med*. 2007; 35(11):1955-59. <https://doi.org/10.1177/0363546507304141>.
37. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical

- presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc.* 2007; 15(8):1041-47. <https://doi.org/10.1007/s00167-007-0348-2>.
38. [Wall PD](#), [Fernandez M](#), [Griffin DR](#), [Foster NE](#). Nonoperative treatment for femoroacetabular impingement: a systematic review of the literature. *PM R.* 2013; 5(5):418-26. <https://doi.org/10.1016/j.pmrj.2013.02.005>.
39. Enseki KR, Martin R, Kelly BT. Rehabilitation after arthroscopic decompression for femoroacetabular impingement. *Clin Sports Med.* 2010; 29(2):247-55. <https://doi.org/10.1016/j.csm.2009.12.007>.
40. 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. <https://doi.org/10.1007/s00167-013-2664-z>.

4 ARTIGO 2

DO FEMORAL VERSION ABNORMALITIES PLAY A ROLE IN HIP FUNCTION OF PATIENTS WITH HIP PAIN?

Artigo submetido à *Clinical Biomechanics*

(Qualis A1, Fator de impacto 2.063)

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DECLARATIONS

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Ethical approval

The study was conducted according to the Helsinki declaration of 1975, and revised in 2000. The study was approved by the University of Calgary Ethics Committee (REB 18-1711), and all patients gave written informed consent to participate in this study.

Authors' contribution

VB participated in the conception, design, data acquisition, data analysis and interpretation, drafting and revision of the manuscript.

WH participated in the conception, design, data analysis and interpretation, drafting and revision of the manuscript.

KJ participated in the conception, design, data acquisition, data analysis and interpretation, drafting and revision of the manuscript.

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MAV participated in the conception, design, data acquisition, data analysis and interpretation, drafting and revision of the manuscript.

BMB participated in the conception, design, data analysis and interpretation, drafting and revision of the manuscript.

ABSTRACT

Background: A high prevalence of femoral version (FV) abnormalities has been observed in hip pain patients, with impact on hip range of motion and muscle strength that should be elucidated.

Methods: Cross-sectional study. Thirty-one patients with hip pain (16 men and 15 female) were subjected to Biplanar X-Rays to quantify FV using three-dimensional measurement methods. The 62 hips were divided into normal version ($10-20^\circ$, $n=18$), anteverted ($>20^\circ$, $n=19$), and retroverted ($<10^\circ$, $n=25$). Hip joint range of motion for flexion, internal rotation, and external rotation was assessed through digital goniometry, while maximal isometric hip strength (flexion, extension, internal rotation, external rotation at 0° and 30° , abduction, adduction) was evaluated through hand-held dynamometry.

Findings: All three hip groups had similar flexion range of motion. Anteverted hips had a greater range of internal rotation, while retroverted hips had greater range of external rotation ($p=0.001$). All three groups had a different hip rotation index (calculated as internal rotation minus external rotation): retroverted $>$ normal $>$ anteverted ($p<0.001$). Patients with anteverted hips were weaker compared to patients with retroverted hips in external rotation at 30° ($p<0.001$), abduction ($p=0.006$) and adduction ($p<0.001$) and were weaker in hip extension ($p=0.018$) compared to patients with normal version. A strong correlation between FV group and rotation index was found ($r_s=0.76$, $p<0.001$).

Interpretation: Hip range of motion and muscle strength differed in patients with different FVs. The hip rotation index was a strong FV predictor and may be used in clinical practice to determine FV abnormalities.

Key Words: Femoral version, hip muscle strength, hip range of motion, hip pain.

1. INTRODUCTION

Young adults with hip pain display a challenging condition that may lead to severe pain and disability, affecting work, leisure, and sporting activities [8]. One of most common causes of persistent hip pain in young adults is femoroacetabular impingement (FAI) syndrome [8]. FAI syndrome is a hip joint motion-related clinical disorder with a triad of symptoms, clinical signs, and imaging findings [17]. The impingement that occurs between the femoral neck-head junction and the acetabulum causes cartilage damage, pain, and predisposes the hip to early onset of osteoarthritis [16]. The number of arthroscopic surgeries for FAI correction has increased rapidly in the past years [17]. Current evidence supports that FAI surgical intervention is superior to conservative management in the short term [18], but muscle strength is not fully recovered at return to sport after hip arthroscopy in FAI patients compared to healthy subjects [19]. According to a recent systematic review [20], a typical physiotherapy intervention ranges from 3 weeks to 5 months, and the effects of these strength interventions range from non-significant to large positive effect after a 12-week intervention period comprising targeted strengthening and functional retraining exercises [20]. It is possible that the lack of an organized hip strength-training program during rehabilitation has influenced these results. Therefore, additional research is needed to determine the best care for FAI syndrome patients and the long-term effects of these interventions [25].

Ever since the clinical introduction of the FAI concept [15], CAM (flattening or convexity at the femoral head-neck junction) and Pincer (focal or global over-coverage of the femoral head by the acetabulum) morphological abnormalities have been the focus of attention. However, femoral version (FV) has been recognized as a potentially important factor in the development of hip pain [23]. FV is defined as the angle between the medial-lateral axis across the posterior distal femoral condyles and the femoral neck axis measured in the transverse plane (Figure 1A) [1]. Normal range of VF has been reported between 0° and 30° [35,38]; however, the range between 8° and 20° seems to encompass the majority of the studies' results [e.g., 3,9,21,23,27].

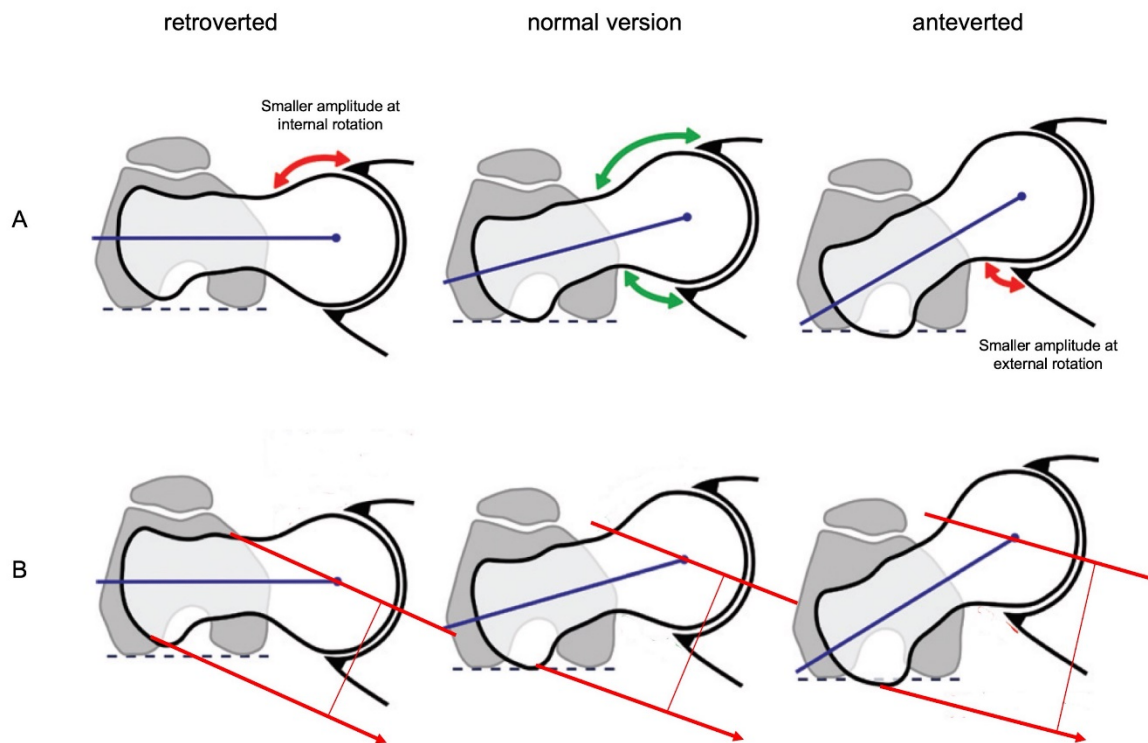


Figure 1. Schematic diagrams of the left femur and acetabulum showing different femoral version (FV) profile. FV is defined as the angle between the medial-lateral axis across the posterior distal femoral condyles and the femoral neck axis measured in the transverse plane [1].

In A Left: reduced femoral version with small internal rotation ROM. Middle: normal femoral version with physiologic internal and external rotation ROM. Right: increased femoral version with small external rotation ROM. In B superior view of the hip, with direction vectors for the line of action the gluteus maximus (GM). The moment arm for each hip position are represented in red. The increased GM moment arm in the anteverted hip compared to normal and retroverted hip is illustrated. The GM vector length represents different muscle lengths, where anteverted hips had shorter muscle length compared to normal and retroverted hips. (Adapted from Sutter et al. 2012 with permission from the Radiological Society of North America) [27].

Reduced FV (i.e., retroverted hips) has been reported to add a risk of early collision between the head-neck junction and the acetabulum, predisposing the hip to pain and a reduced range of motion (ROM) [1]. On the other hand, increased FV (i.e., anteverted hips) has been associated with hip dysplasia, labral tears, and joint instability [3,9]. One mechanism thought to cause hip pain is related to the excessive anteriorization of the femoral head leading to an acetabular rim overload rather than an impingement mechanism [33,38]. From a clinical point of view, knowledge about FV is essential for clinicians, considering both conservative and surgical treatments. The high prevalence of FV abnormalities (52%) in patients scheduled for hip preservation surgery [23], and studies showing poor results after hip arthroscopy in patients with abnormal FV [10,11], highlights the importance of FV evaluation in patients scheduled for hip surgery. In a conservative approach of young patients with hip pain, FV also plays a role in clinical outcomes. Knowing the FV profile of patients undergoing hip rehabilitation could help physical therapists to choose better exercise strategies to avoid the impingement between hip structures during rehabilitation, thereby reducing hip stresses.

FAI syndrome patients usually present with reduced hip internal rotation (IR) while in a flexed position (hip at 90° from full extension) [7]. However, FAI syndrome patients with retroverted hips have an even smaller IR ROM compared to those with anteverted hips [21]. Previous studies reported a significant correlation between hip rotational ROM with FV [9,21,38], leading to the idea that FV could be predicted by ROM measurements in clinical settings [38], but this hypothesis has not been tested using appropriate research designs. In addition to hip ROM adaptations, increased or decreased FV may alter the muscles' moment arms (Figure 1B) and muscle architecture (shifting the optimum length due to serial sarcomere adaptations) crossing the hip, leading to changes in hip muscle strength. Muscle weakness has been demonstrated in FAI syndrome patients [4,7,13], but the role of FV in hip muscle strength is poorly understood [26].

Determining the FV effects on hip ROM and strength may help in gaining a better understanding of FAI syndrome and other hip-related injuries, and in establishing guidelines for clinical practice. Therefore, the purpose of this study was to compare hip

ROM and muscle strength in patients with hip pain and different FVs. Additionally, we wanted to determine if clinical assessment tools for measuring hip ROM can predict FV in patients with hip pain.

2. METHODS

2.1 Study design

A cross-sectional study was performed to determine FV and possible deficits in hip ROM and strength in patients presenting to a surgeon with hip pain. All patients were subjected to biplanar X-rays to quantify the FV angle using three-dimensional measurement methods. A physiotherapist with 10 years of experience in hip evaluation assessed hip joint ROM and maximal isometric strength through digital goniometry and hand-held dynamometry, respectively. To reduce the potential for bias, the evaluator was blinded to the patients' FV profile.

Patients were assessed in a single visit to the XXXX at the XXXX, from March to July 2019. The study was approved by the XXX's Ethics Committee (REB 18-1711) and all patients signed an informed consent form.

2.2 Participants

Only patients with hip pain assigned to surgical treatment were assessed for eligibility in this study. They were diagnosed by a single orthopedic surgeon specialized in hip surgery as having intra-articular hip pathology based on symptoms, clinical signs, and imaging findings [17], and were assigned to surgical treatment. Although some patients in our study had CAM morphology abnormalities, we did not analyze the influence of this morphological aspect because previous studies found no correlation between CAM morphology and hip IR ROM [21,38]. The International Hip Outcomes Tool (iHOT) [28] was used to assess the patients' ability to live an active lifestyle and it contains four domains: symptoms and functional limitations, sports and recreational activities, job-related concerns, and social, emotional, and lifestyle concerns. Results close to 100 indicate that the hip disorder does not affect the assessed domain.

Patients with other lower limb injuries were excluded from the study, as well as patients with rheumatologic or neurological diseases. Patients with uncontrolled

cardiovascular or respiratory disease, active malignancy, or chronic infections were also excluded from the study. In addition, pregnant females were not included in the study.

2.3 Femoral Version Assessment

Following acceptance into the study, biplanar X-ray images were obtained using an EOS X-Ray Imaging Acquisition System (EOS Imaging Inc., Paris, France). One experienced technician performed all X-ray exams. Two high-quality orthogonal X-ray images in the coronal and sagittal planes were acquired with low dose radiation. The radiation dose for these imaging procedures is reported to be less than that of a conventional computed-radiographic image [6]. For this procedure, patients were positioned and remained standing during a five-minute period, and both antero-posterior (AP) and lateral (orthogonal) images were acquired simultaneously. Based on this pair of registered X-ray images, three-dimensional models were generated, and anatomical measurements, including the FV angle were computed (SterEOS Software). The EOS FV technique has shown an excellent inter-observer [intraclass correlation coefficient (ICC) = 0.983 – 0.998] and intra-observer (ICC = 0.982 to 0.998) reliability [31], with an average difference between FV measurements between EOS and computed tomography of $4.9^{\circ} \pm 3.8^{\circ}$ [32]. These results showed that EOS measurements of FV can be comparable to the gold standard method, computed tomography.

After the biplanar X-ray analysis, hips were grouped in accordance with their FV values (Figure 2) into hips with normal version (between 10° and 20°), hips with increased FV ($>20^{\circ}$, anteverted), and hips with decreased FV ($<10^{\circ}$, retroverted) [21]. We decided to divide FV values into these 3 categories based on the recommendations of a recent study by Krautler et al. [21], since there is no generally agreed consensus regarding cut-offs for FV [3,21,23,38].

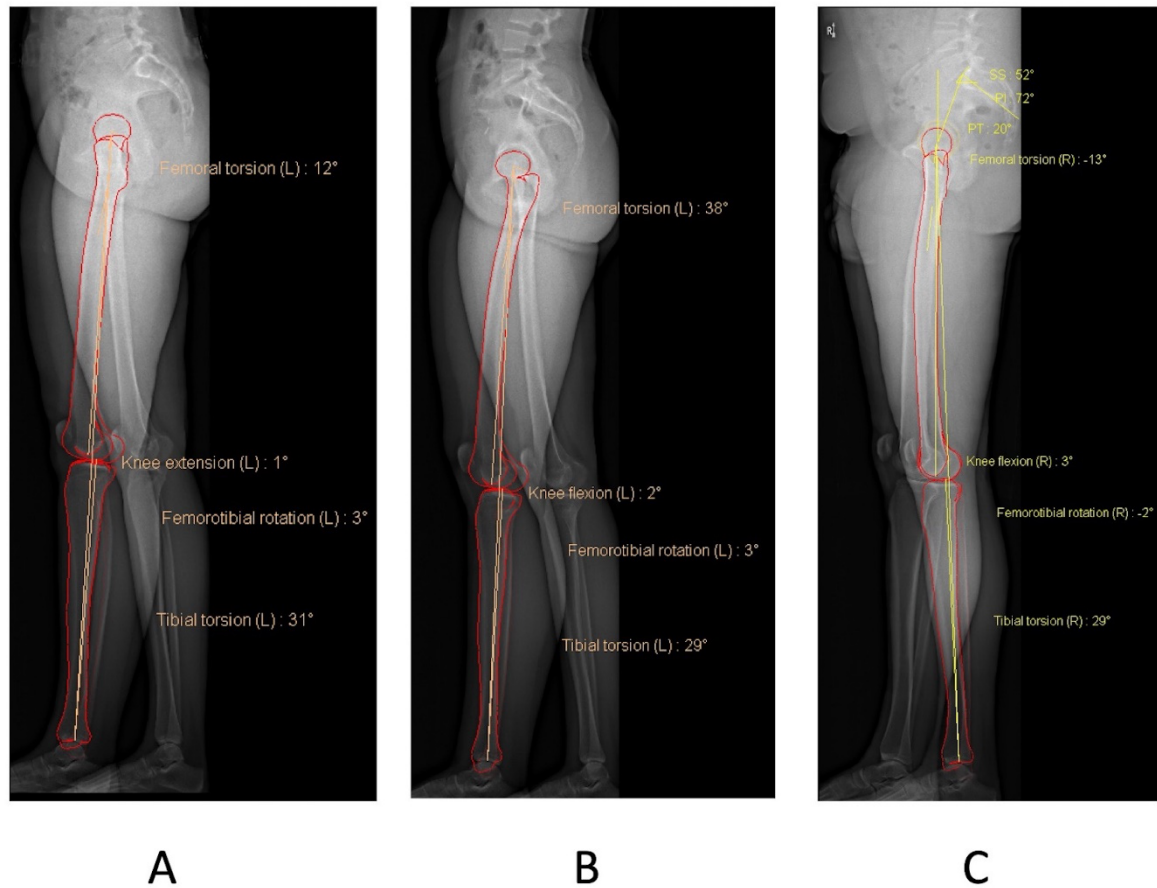


Figure 2. EOS system femoral version measurements: (A) normal version, (B) anteverted hip, (C) retroverted hip.

2.4 Range of Motion Assessment

Hip joint ROM was assessed using a digital goniometer (Medigauge, Columbia, USA) for flexion (FLX - active and passive), internal rotation (IR - only active) and external rotation (ER - active and passive), as previously described [12]. Neutral position was considered when the hip was fully extended regarding FLX and EXT, with no hip IR or ER for rotation (patella pointing to the roof) and with no ABD or ADD (lower limb aligned with the hip in the frontal plane). For hip FLX and ER, patients were positioned in supine using a neutral position in the contralateral leg. For IR, patients were in supine with both hips and knees flexed at 90°, and the movement was performed bilaterally and simultaneously. This position for IR ROM assessment was

chosen to maximize pelvis stabilization. We did not measure passive IR ROM because it was not possible for the evaluator to produce the passive bilateral ROM while measuring the hip ROM with the goniometer at the same time. However, an advantage of the simultaneous bilateral ROM evaluation in the chosen test position was that the gravitational force did not exert an influence helping or hindering the hip movement during IR. Healthy subjects' hip ROM inter-rater reliability was previously established in our laboratory using the same method as used here and was considered excellent for hip rotation and satisfactory for hip flexion (ICC values greater than 0.84 for all measures) [37].

Considering that IR ROM is expected to be higher in anteverted hips and ER ROM higher in retroverted hips [3,21,38], we calculated a “rotation index”, defined by the subtraction of the active IR from the active ER ROM values.

2.5 Strength Assessment

Maximal isometric torque generated by the hip muscles strength was assessed through hand-held dynamometry (MICROFET – Hoogan Scientific, Salt Lake City, USA). The term “muscle strength” is used throughout the text for simplification purposes. Muscle strength for hip FLX, extension (EXT), abduction (ABD), adduction (ADD), IR and ER was evaluated in different positions (Figure 3). The evaluator held the dynamometer pad 5 cm proximal to the lateral (for IR and ABD) or medial (for ER and ADD) malleoli, and for FLX and EXT a line from the lateral malleoli to the anterior part of tibia for FLX and to the posterior for EXT were drawn. For FLX, EXT, ABD and ADD, we used the methodology introduced by Frasson et al. [12]. For ER and IR, we used a prone position with the knee flexed at 90° (Figures 2E and 2F). Also, measurements of ER strength were done in two positions: 0° (0° was considered when foot sole was pointing to the roof) and 30° of ER (measured with a goniometer) to assess the FV influence on strength at different muscle lengths (Figure 3). In all tests, the dynamometer was placed distal on the leg close to the ankle joint, thereby providing a great lever arm for the evaluator, thus maximizing the evaluator's stability.

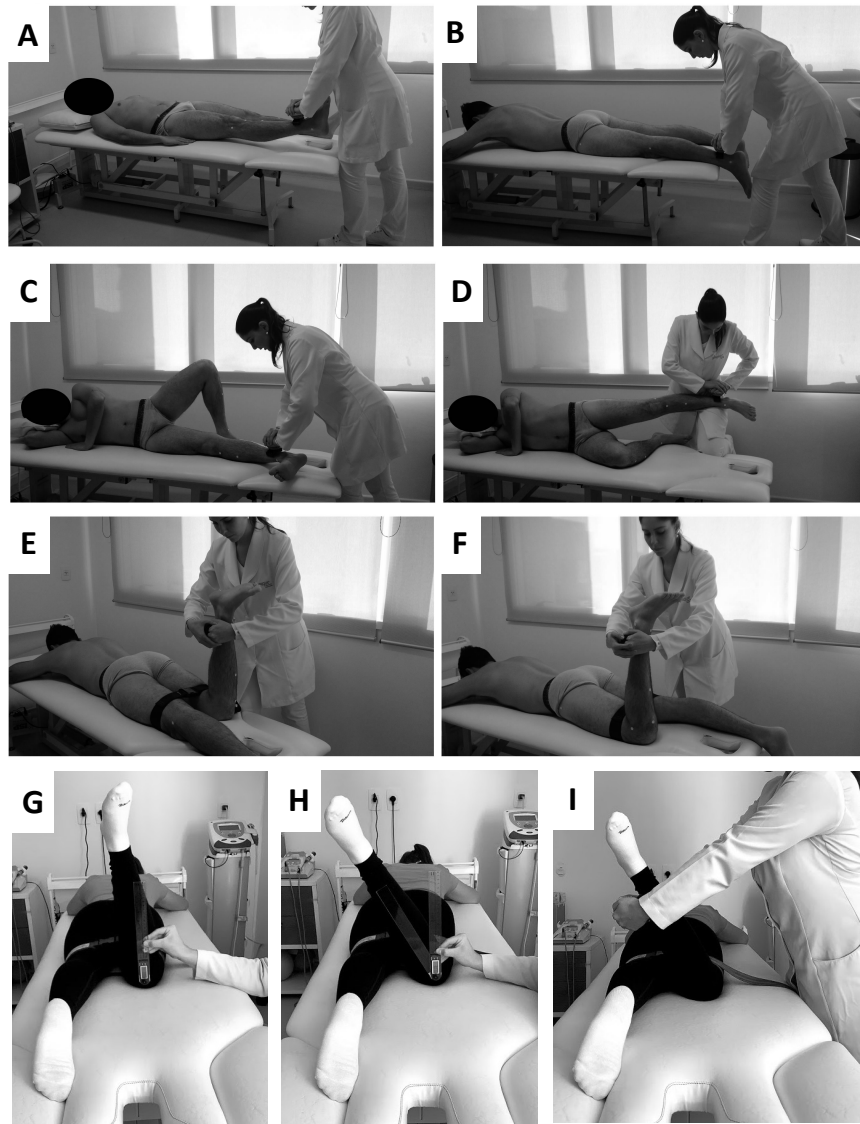


Figure 3: Positions of the subjects during the isometric muscle strength measurements (A---F). Hip flexors (A) and extensors (B) hip adductors (C), and abductors (D), hip external (E), and internal rotators (F). ER strength was done in two positions: 0° (G) and 30° (H, I) of ER measured with a goniometer.

For each muscle group, patients completed 2 maximal voluntary isometric contractions (MVICs). If the difference between the 2 MVICs was greater than 10%, a third trial was obtained. Participants received standardized verbal encouragement to produce maximal effort contractions in the following way: 2 seconds to build up to maximal force, 2 seconds of MVIC, and 2 seconds to relax. A rest of 120 s was strictly

enforced between trials. Additional measurements were taken if the evaluator felt unstable during the measurement or if participants failed to achieve a maximum effort. The highest valid force measurement was converted to a hip joint torque by multiplying the force measured by the dynamometer (in Newtons) with the lever arm length in meters measured with a metric tape. For FLX, EXT, ABD and ADD, the distance in meters between the hip joint axis of rotation and the point 5 cm superior to the lateral malleoli was used with the knee extended. For ER and IR, the knee was flexed, so the distance between the knee articular line and the point 5 cm superior to the lateral malleoli was used. Torques were normalized to body mass (Nm/kg) and were used for data analysis. Healthy subjects hip muscle strength intra- and inter-rater reliability were previously established in our group using this method. ICC was considered excellent (intra-rater superior to 0.89, inter-rater superior to 0.90) for all tested muscle groups [37].

2.6 Statistical Analysis

We projected that with 54 observations in three groups ($n = 18$ per group) the study would have 80% power to detect a mean difference ≥ 0.95 standard deviation units (d statistic) with a two-tailed type I error of 0.05. Normal distribution was assumed when standard deviation was less than half the mean. Results were summarized using means, standard errors (SEs) and confidence intervals for quantitative variables and as counts and frequencies for categorical variables. Since a patient contributed with information from both hips and their hip results may have fallen into different FV groups, we accounted for this in the statistical analysis by considering clustered data. To accomplish this, hip FV groups were compared using the Generalized Estimating Equations (GEE) technique, and by presenting the estimated means and their respective 95% confidence intervals. All models were adjusted for the potential confounding effect of sex. Between-group differences were identified using the adjusted Sidak post-hoc test where means not sharing any letter are significantly different at the 5% level of significance. To predict FV based on ROM and hip muscle strength, we used an ordinal logistic regression model. Strength of correlation was

assessed using Spearman's correlation coefficient. A p-value smaller than 0.05 was considered statistically significant. All analyses were conducted using IBM-SPSS (version 25.0).

3. RESULTS

Forty-eight patients assigned to surgical treatment were assessed for eligibility by an orthopedic surgeon specialized in hip surgery. Thirty-one patients with hip pain (16 men, 15 women; n = 62 hips) were included in this study (Figure 4). They were 29 ± 1.17 years old, with body mass of 79 ± 2.56 kg, and were 1.74 ± 0.01 m of height. Nineteen patients had symptoms in both hips, 7 only in the right and 5 only in the left hip. The iHOT scores ranged from 11.1 to 80.7 points, with a mean ($\pm$ SEs) of 40.3 ± 2.3 points.

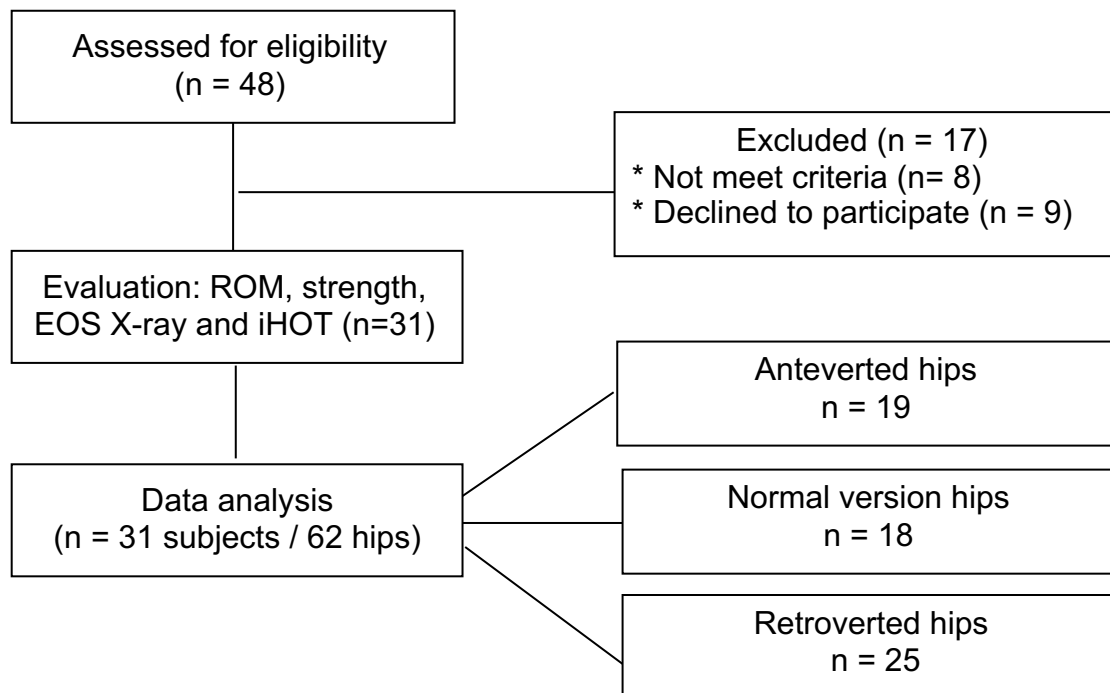


Figure 4. Flowchart of the study (FV = femoral version). Anteverted hips = $FV > 20^\circ$, normal version hips = FV between 10° to 20° , retroverted hips = $FV < 10^\circ$.

Retroverted hips (54 ± 2) had significantly greater hip passive and active ER ROM compared to anteverted (40 ± 2) and normal version (44 ± 2) hips ($p < 0.001$; Table 1). Anteverted hips (22 ± 2) had greater active IR ROM compared to retroverted (14 ± 2) and

normal version (16 ± 2) hips ($p=0.001$). Active and passive FLX was similar between groups ($p=0.097$ and 0.113 , respectively). The rotation index was the greatest for retroverted (41 ± 3), intermediate for the normal (28 ± 3), and smallest for the anteverted (15 ± 3) hips, respectively ($p<0.001$; Table 1).

Table 1. Hip ROM for the different hip version groups. Mean $\pm$ SE (95% confidence interval).

ROM	Retroverted ($<10^\circ$)	Normal 10° to 20°	Anteverted ($>20^\circ$)	p-value
FLX active	108 ± 3 (103 – 113)	113 ± 2 (108 – 117)	115 ± 2 (109 – 118)	0.097
FLX passive	126 ± 2 (121 – 130)	129 ± 2 (125 – 133)	132 ± 2 (128 – 137)	0.113
ER active	54 ± 2^a (50 – 57)	44 ± 2^b (41 – 47)	40 ± 2^b (35 – 44)	< 0.001
ER passive	68 ± 2^a (64 – 72)	60 ± 1^b (57 – 63)	58 ± 2^b (54 – 62)	< 0.001
IR active	14 ± 2^a (10 – 17)	16 ± 2^a (12 – 20)	22 ± 2^b (18 – 27)	0.001
Hip Rotation Index	41 ± 3^a (36 – 46)	28 ± 3^b (22 – 34)	15 ± 3^c (9 – 22)	< 0.001

ROM = range of motion (in degrees), FLX = flexion, ER = external rotation, IR = internal rotation, Hip Rotation Index = ER active – IR active. ^{a,b,c} Means not sharing any letter are significantly different by the adjusted Sidak post-hoc test at the 5% level of significance.

Muscles in anteverted hips were weaker compared to those in retroverted hips for ER at 30° (retroverted = 0.53 ± 0.018 / anteverted = 0.41 ± 0.028), ABD (retroverted = 1.02 ± 0.057 / anteverted = 0.76 ± 0.075) and ADD (retroverted = 1.23 ± 0.061 / anteverted = 1.02 ± 0.068), and weaker than the muscles in the normal version hips for EXT (normal = 1.87 ± 0.130 / anteverted = 1.61 ± 0.146), Table 2). There was no difference in hip muscle strength between groups for IR, ER at 0° and FLEX.

Table 2. Muscle strength for the different hip version groups. Mean $\pm$ SE (95% confidence interval).

Strength	Retroverted ($<10^\circ$)	Normal (10° to 20°)	Anteverted ($<20^\circ$)	p-value
ER	0.63 ± 0.018 (0.59-0.66)	0.62 ± 0.023 (0.57 – 0.66)	0.57 ± 0.042 (0.49 – 0.66)	0.519
ER 30	0.53 ± 0.018^a (0.49 – 0.56)	$0.49 \pm 0.024^{a,b}$ (0.44 – 0.53)	0.41 ± 0.028^b (0.36 – 0.47)	< 0.001
IR	0.45 ± 0.031 (0.39 – 0.51)	0.47 ± 0.029 (0.42 – 0.53)	0.43 ± 0.030 (0.37 – 0.49)	0.100
ABD	1.02 ± 0.057^a (0.90 – 1.13)	$0.91 \pm 0.066^{a,b}$ (0.78 – 1.04)	0.76 ± 0.075^b (0.61 – 0.90)	0.006
ADD	1.23 ± 0.061^a (1.11 – 1.35)	$1.06 \pm 0.057^{a,b}$ (0.95 – 1.17)	1.02 ± 0.068^b (0.89 – 1.16)	< 0.001
FLX	1.57 ± 0.074 (1.42 – 1.71)	1.68 ± 0.083 (1.51 – 1.84)	1.51 ± 0.147 (1.22 – 1.79)	0.173
EXT	$1.81 \pm 0.097^{a,b}$ (1.62 – 2.00)	1.87 ± 0.130^a (1.62 – 2.13)	1.61 ± 0.146^b (1.32 – 1.89)	0.018

ER = external rotators, ER 30 = external rotators at thirty degrees of external rotation, IR = internal rotators, ABD = abductors, ADD = adductors, FLX = flexors, EXT = extensors. Muscle strength = normalized to body mass (Nm/kg). ^{a,b,c} Means not sharing any letter are significantly different by the adjusted Sidak post-hoc test at the 5% level of significance.

Rotation index was the only variable found to differentiate among all hip version groups using GEE followed by pairwise post-hoc comparisons. We also found a strong correlation between version group and rotation index ($r_s=0.76$, $p<0.001$). Using the values observed on the rotation index, we estimated via ordinal logistic regression the probability of belonging to a specific version rotation group (Figure 5).

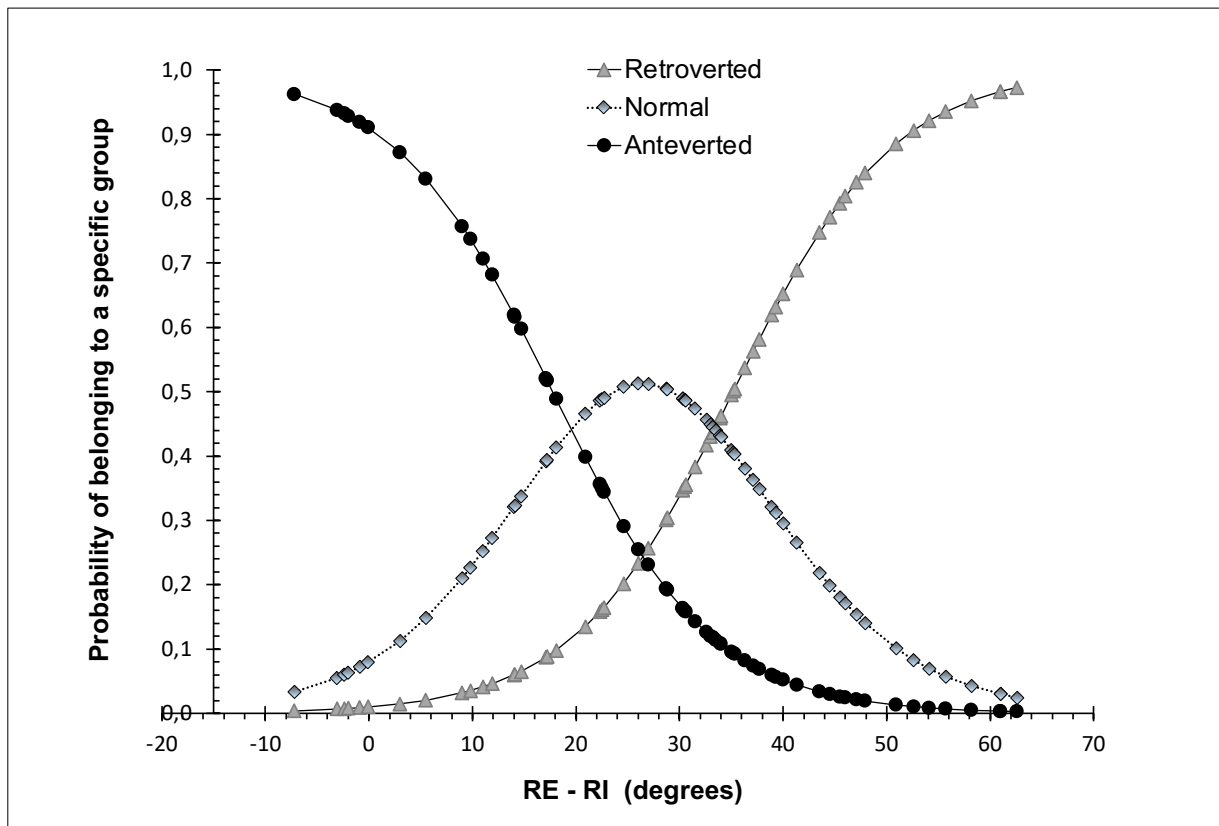


Figure 5. Relationship between hip rotation index and probability of belonging to a specific femoral version group.

4. DISCUSSION

The primary result of this study is that hip ROM and hip muscle strength differ between groups of patients with different FV. Additionally, we demonstrate that the rotation index is a strong predictor of FV in patients with hip pain.

Prediction of FV

Previous studies have found low to moderate correlations ($r=0.21$ to 0.69) between hip rotation ROM and FV [9,35,38]. In addition, Souza & Powers [35] and Uding et al. [38] investigated if hip rotation ROM could be used to predict FV in healthy individuals and patients with chronic hip pain, respectively. Souza & Powers [35] found that a rater can be 95% confident that the true value of FV falls within 11.8° of the clinically measured value, thus classification of persons as having abnormal FV only

would be possible in extreme cases. Uding et al. [38] proposed that a 20° difference between hip IR and ER ROM would be suggestive of abnormal FV. However, two limitations should be highlighted in Uding's findings. First, retroversion was defined as values smaller than 0.45° and anteversion was defined as values greater than 19.01° [38], i.e., cut-off values different from those used in our study and in other recent studies [3,21,23]. Second, although Uding et al. [38] suggested that clinical ROM testing might be used to screen for FV abnormalities, this proposition has not been tested with regression or probability analyses.

Therefore, to the best of our knowledge, the present study is the first to support the prediction of FV through clinical ROM testing with a solid statistical base. The rotation index defined in our study proved to be an independent predictor of FV in patients with hip pain. According to our results, the probability of being anteverted if the rotation index is less than 11° is greater than 70%, and if the rotation index is greater than 40°, there is a >70% chance for being retroverted (Figure 5). Using the rotation index, clinicians can predict the FV of a patient quickly, simply, and inexpensively.

From a clinical practice point of view, knowledge regarding FV abnormalities helps to improve physical therapy rehabilitation programs, by choosing exercises for anteverted or retroverted hips with limited ER or IR hip ROM, respectively. In addition, FV assessment in athletic population should be another application of our prediction model. Sports with high hip IR ROM demands, such as Hockey, could be a source of hip pain and labral tears in people with retroverted hips due to the mechanical abutment between the anterolateral femoral head-neck junction and the anterior acetabular rim [2]. Conversely, activities that demand excessive hip ER ROM, such as classical ballet, could result in repetitive stresses on the posterior acetabular labrum and articular cartilage due to posterior abutment between the posterolateral femoral head-neck junction and the posterior acetabular rim [2].

4.1 ROM

Our results, as well as those reported in some previous studies [1,21,38], support the role of FV on hip rotational ROM in patients with hip-related pain. According to our results, there was an increase of IR in anteverted hips and an increase of ER in

retroverted hips. The maximization of IR in anteverted hips and ER in retroverted hips was previously shown by Kraeutler et al. [21], who also confirmed, using a multivariate linear regression analysis, that FV was the strongest independent predictor of IR ROM at 90° of hip flexion ($b = 0.45$, 95% CI = 0.30 to 0.59, $t = 5.83$, $p < 0.001$). Results from Uding et al. [38] also agree with our results, and Kraeutler et al. [21] showed a moderate correlation between FV and IR at neutral FLX/EXT and measured at 90°. Additionally, both studies showed that CAM morphology is not an important factor determining hip IR ROM in patients with chronic hip pain. Kraeutler et al. [21] found no correlation ($r = -0.06$, $P = 0.61$) between alpha angle and hip IR at 90° FLX, while Uding et al. [38] showed that removing participants with CAM morphology from the analysis, did not significantly change the correlations between rotation ROM and FV. Based on these results, FV should be considered a primary determinant of hip rotation ROM, but not CAM morphology. Therefore, although some of our patients should have CAM morphology, we did not analyze the influence of this morphological abnormality on hip ROM.

The increased ER in retroverted and increased IR in anteverted hips might be explained by the femoral morphology that maximizes ER/IR hip ROM, as the excursion from the neutral position to the maximal ER/IR is larger in retroverted/anteverted hips (Figure 5A). Analyzing the ER and IR ROM together, there is a shift in ROM towards the IR direction for anteverted hips and towards the ER direction for retroverted hips. In addition, we expected that retroverted hips would not flex as much as anteverted hips because of the reduction of anterior hip space due to abnormal FV. However, there was only a trend ($p=0.052$) supporting this hypothesis. We chose not to use two clinicians for ROM testing because we wanted to determine the reproducibility and validity of our testing that is relevant to a clinical setting with a single clinician. Therefore, one possible explanation for the lack of significance could be the difficulty of controlling lumbopelvic tilt during the hip FLX ROM testing.

4.2 Strength

Two systematic reviews pointed out the presence of muscle weakness in FAI syndrome patients compared to healthy controls [7,13]. However, it did not become

clear in these reviews which muscle groups were the most affected, and to what degree weakness was present in patients with hip pain. The methods used for testing strength (isometric or isokinetic) and the patient's positioning during testing are factors that might cause difficulties in comparing between-studies results. Nevertheless, our findings add to the literature by showing that FV affects the strength of hip joint muscles.

The torque generated by muscles (in this study simplified as "muscle strength") is determined by a combination of muscle length and muscle moment arm (defined here by the perpendicular distance between the muscle's line of action and the instantaneous center of joint rotation). According to this definition, muscle moment arm takes into consideration both muscle moment arm length and muscle line of action. A recent study showed that patients with hip dysplasia had significant adaptations in the muscle moment arm length, while the muscle line of action was affected to a lesser extent [34]. The decreased muscle moment arm length found in their hip abductor muscle indicates a mechanical disadvantage for this muscle group [29].

Increased or decreased FV may alter both muscle length and muscle moment arm at the hip joint, causing changes in muscle strength. The influence of FV on muscle length and moment arm is illustrated schematically in Figure 1B. Marostica et al. [26] evaluated hip isokinetic strength in patients with FV abnormalities and found no correlation between muscle strength and FV. Our results disagree with those reported by Marostica et al. [26], as we showed that muscle strength was different for ADD, ABD, ER at 30° and EXT between the three FV groups defined in this study. One possible explanation for the difference in our results compared to Marostica et al. [26] is related to the method used for hip strength evaluation. In isometric testing, used in our study, a constant moment arm is obtained during strength measurements, while in isokinetic testing (used in Marostica's study) the lever arm varies during dynamic strength measurements. More specifically, the maximal muscle strength measured (i.e. peak torque) during isokinetic testing may have been obtained at a different hip angle (i.e. different lever arm) than that measured during isometric testing, especially when we have different FV groups.

ER strength at 0° and 30° of ER may potentially be a good indicator of muscle length and muscle moment arm changes caused by FV. The evaluation of strength

curves (maximal muscle force capacity as a function of joint angle) [22] helps to explain the interaction between muscle length and muscle moment arms. In the neutral position, anteverted hips have a shortened gluteus maximus muscle and a greater moment arm length compared to retroverted hips (Figure 1B). One might speculate that the combination of a small muscle length and a large moment arm length in anteverted compared to retroverted hips leads to similar ER strength. However, when gluteus maximus is shortened (30° of ER compared to neutral position), the anteverted hips showed a greater reduction (-28%) in strength than the retroverted (-15%). The greater reduction in strength in the anteverted hips may be related to an excessive decrease in gluteus maximus muscle length (which is already decreased in the neutral position), while the moment arm length increased from zero to 30° of ER. This dependence of hip rotator muscle strength regarding hip test position (and, consequently, muscle length) has been shown previously [5], and clinicians should be aware of this issue when performing hip strength tests.

Another factor in strength measurement in patients with hip pain could be pain-induced neuromuscular inhibition [14], which **could** explain the lower hip strength found in our study in patients with different FV compared to a previous study with healthy subjects and a similar methodology to assess hip strength [12]. Even though we think that muscle inhibition plays a role in reducing the maximal strength capacity and possibly leading to muscle mass losses as previously shown for patients with hip osteoarthritis [24], the differences between FV groups seems to be better understood from a combination of muscle length and muscle moment arm adaptations.

4.3 Limitations

This study has some limitations. First, we were unable to measure hip ABD and ADD ROM due to the difficulty in obtaining a stable pelvic position. Second, strength tests were performed only isometrically. Finally, we did not control leg dominance in the FV groups. Nevertheless, despite our ROM and strength testing limitations, we used a reliable and practical testing procedure that can be easily performed in a clinical setting by a single practitioner. Findings are limited to adults with hip pain, thus further studies with other populations are needed. In the next steps, it would be important to

assess the intrinsic properties of the hip musculature (e.g., muscle moment arms and muscle architecture), with special attention for evaluating all range of the ER moment-angle relationship (i.e. strength measured at 3 to 5 different angles). It also would be interesting to assess the influence of pain in strength obtained in different joint angles to identify a possible effect of angle specific muscle inhibition that may occur at different FV groups. These would be helpful to elucidate the mechanisms responsible for the strength differences between anteverted and retroverted hips, as well as verifying the impact of the FV on functional performance in patients with hip pain.

5. CONCLUSION

In conclusion, hip ROM and strength were different in anteverted, retroverted and normal version hips. The rotation index was a strong FV predictor, suggesting that it is possible to screen for FV abnormalities using ROM testing in clinical settings. The effects of FV abnormalities on hip ROM and strength should be considered in the decision making of individualized rehabilitation programs in patients with hip pain.

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6. REFERENCES

1. Audenaert EA, Peeters I, Vigneron L, Baelde N, Pattyn C (2012) Hip Morphological Characteristics and Range of Internal Rotation in Femoroacetabular Impingement. *Am J Sports Med* 40(6):1329-36. <http://doi.org/10.1177/0363546512441328>
2. Bedi A, Thompson M, Uliana C, Magennis E, Kelly BT (2013) Assessment of range of motion and contact zones with commonly performed physical exam maneuvers for femoroacetabular impingement: What do these tests mean? *Hip Int* 23-Suppl 9:S27–34. <http://doi.org/10.5301/hipint.5000060>
3. Botser IB, Ozoude GC, Martin DE, Siddiqi AJ, Kuppuswami S, Domb BG (2012) Femoral Anteversion in the Hip: Comparison of Measurement by Computed Tomography, Magnetic Resonance Imaging, and Physical Examination. *Arthroscopy* 28(5): 619-627. <http://doi.org/10.1016/j.arthro.2011.10.021>

4. Casartelli N, Maffiuletti N, Item-Glatthorn JF (2011) Hip muscle weakness in patients with symptomatic femoroacetabular impingement. *Osteoarthr Cartil* 19(7):816-21. <https://doi.org/10.1016/j.joca.2011.04.001>
5. Cibulka MT, Strube MJ, Meier D, Selsor M, Wheatley C, Wilson NG, Irrgang JJ (2010) Symmetrical and asymmetrical hip rotation and its relationship to hip rotator muscle strength. *Clin Biomech* 25:56-62. <http://doi.org/10.1016/j.clinbiomech.2009.09.006>
6. Deschenes S, Charron G, Beaudoin G, Labelle H, Dubois J, Miron M, Parent S (2010) Diagnostic imaging of spinal deformities: reducing patients' radiation dose with a new slot-scanning X-ray imager. *Spine (Phila Pa 1976)* 35(9):989-994. <http://doi.org/10.1097/BRS.0b013e3181bdcaa4>
7. Diamond LE, Dobson FL, Bennell KL, Wrigley TV, Hodges PW, Hinman RS (2015) Physical impairments and activity limitations in people with femoroacetabular impingement: a systematic review. *Br J Sports Med* 49(4):230-42. <http://doi.org/10.1136/bjsports-2013-093340>
8. Dick AG, Houghton JM, Bankes MK (2018) An approach to hip pain in young adult. *BMJ*. 361:k1086. <http://doi.org/10.1136/bmj.k1086>
9. Ejnisman L, Philippon MJ, Lertwanich P, Pennock AT, Herzog MM, Briggs KK, Ho CP (2013) Relationship Between Femoral Anteversion and Findings in Hips With Femoroacetabular Impingement. *Orthopedics* 36: e293-e300. <http://doi.org/10.3928/01477447-20130222-17>
10. Fabricant PD, Bedi A, De La Torre K, Kelly BT. Clinical outcomes after arthroscopic psoas lengthening: the effect of femoral version (2012) *Arthroscopy* 28(7):965-971 <http://doi.org/10.1016/j.arthro.2011.11.028>
11. Fabricant PD, Fields KG, Taylor SA, Magennis E, Bedi A, Kelly BT (2015) The effect of femoral and acetabular version on clinical outcomes after arthroscopic femoroacetabular impingement surgery. *J Bone Joint Surg Am* 97(7):537-543. <http://doi.org/10.2106/JBJS.N.00266>
12. Frasson VB, Vaz MA, Morales AB, Torresan A, Telöken MA, Gusmão PDF, Crestani MV, Baroni BM (2020) Hip muscle weakness and reduced joint range of motion in patients with femoroacetabular impingement syndrome: a case-control study. *Braz*

- J Phys Ther* 24(1):39-45. <http://doi.org/10.1016/j.bjpt.2018.11.010>
13. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM (2017) Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med* 50(19):1118. <http://doi.org/10.1136/bjsports-2016-096152>
 14. Freeman S, Mascia A, McGill S. Arthrogenic neuromusculature inhibition: a foundational investigation of existence in the hip joint (2013) *Clin Biomech* 28(2):171-177. <http://doi.org/10.1016/j.clinbiomech.2012.11.014>
 15. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA (2003) Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res*. 417:112-120. <https://doi.org/10.1097/01.blo.0000096804.78689.c2>
 16. Ganz R, Leunig M, Leunig-Ganz K, Harris WH (2008) The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res* 466(2):264-272. <http://doi.org/10.1007/s11999-007-0060-z>
 17. Griffin DR, Dickenson EJ, O'Donnell J, Agricola R, Awan T, Beck M, Clohisy JC, Dijkstra HP, Falvey E, Gimpel M, Hinman RS, Hölmich P, Kassarian A, Martin HD, Martin R, Mather RC, Philippon MJ, Reiman MP, Takla A, Thorborg K, Walker S, Weir A, Bennell KL (2016) The Warnick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med* 50(19):1169-1176. <http://doi.org/10.1136/bjsports-2016-096743>
 18. Griffin DR, Dickenson E, Wall PDH, Achana F, Donovan JL, Griffin J, Hobson R, Hutchinson CE, Jepson M, Parsons NR, Petrou S, Realpe A, Smith J, Foster NE, FASHIoN Study Group (2018) Hip Arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomised controlled trial. *Lancet* 391:2225-35. [http://doi.org/10.1016/S0140-6736\(18\)31202-9](http://doi.org/10.1016/S0140-6736(18)31202-9)
 19. Hallberg S, Sansone M, Augustsson J. (2020) Full recovery of hip muscle strength is not achieved at return to sports in patients with femoroacetabular impingement surgery. *Knee Surg Sports Traumatol Arthrosc* 28:1276-1282. <http://doi.org/10.1007/s00167-018-5337-0>
 20. Kemp JL, Mosler AB, Hart H, Bizzini M, Chang S, Scholes MJ, Semciw AI, Crossley

- KM. Improving function in people with hip-related pain: a systematic review and meta-analysis of physiotherapist-led interventions for hip-related pain. *Br J Sports Med*. 2020; 54(23):1382-1394.
21. Kraeutler MJ, Chadayammuri V, Garabekyan T, Mei-Dan O (2018) Femoral Version Abnormalities Significantly Outweigh Effect of Cam Impingement on Hip Internal Rotation. *J Bone Joint Sur* 100:205-10. <http://doi.org/10.2106/JBJS.17.00376>
 22. Kulig K, Andrews JGMS, Hay JG. Human Strength Curves (1984) *Exerc Sport Sci Rev* 12(1):417-466.
 23. Lerch TD, Todorski IAS, Steppacher SD, Schmaranzer F, Werlen SF, Siebenrock KA, Tannast M (2018) Prevalence of Femoral and Acetabular Version Abnormalities in Patients with Symptomatic Hip Disease. *Am J Sports Med* 46(1): 122-134. <http://doi.org/10.1177/0363546517726983>
 24. Loureiro A, Mills PM, Barrett RS (2013) Muscle weakness in hip osteoarthritis: a systematic review. *Arthritis Care Res* (Hobo-ken) 65(3):340-352. <http://doi.org/10.1002/acr.21806>
 25. Mansell NS, Rhon DI, Meyer J, Slevin JM, Marchant BG (2018) Arthroscopic Surgery or Physical Therapy for Patients with Femoroacetabular Impingement Syndrome. A randomized controlled trial with 2 year of follow-up. *Am J Sports Med* 46(6):1306-1314. <http://doi.org/10.1177/0363546517751912>
 26. Marostica AD, Pizzolatti ALA, Adam GP, Codonho D, Canella RP, Ganey GG (2019) Is femoral version associated with changes in hip muscle strength in females with symptomatic femoroacetabular impingement? *Rev Bras Ortop* 54:422-427. <http://doi.org/10.1055/s-0039-1694019>
 27. Matsuda DK, Gupta N, Martin HD (2014) Closed Intramedullary Derotational Osteotomy and Hip Arthroscopy for Cam Femoroacetabular Impingement from Femoral Retroversion. *Arthrosc Tech* 3(1):e83-e88. <http://doi.org/10.1016/j.eats.2013.08.013>
 28. Mohtadi NG, Griffin DR, Pedersen ME, Chan D, Safran MR, Parsons N, Sekiya JK, Kelly BT, Werle JR, Leunig M, McCathy JC, Martin HD, Thomas Byrd JW, Philippon MJ, Martin RL, Guanche CA, Clohisy JC, Sampson TG, Kocher MS, Larson CM, Multicenter Arthroscopy of Hip Outcomes Research Network (2012) 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). *J Arthrosc* 28(5):595-605. <http://doi.org/10.1016/j.arthro.2012.03.013>
29. Neumann DA (2010) Kinesiology of the Hip: A Focus on Muscular Actions. *JOSPT* 40(2): 82-94. <https://www.jospt.org/doi/10.2519/jospt.2010.3025>
30. Nussbaumer S, Leunig M, Glatthorn JF, Stauffacher S, Gerber H, Maffiuletti NA (2010). Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskelet Disord* 31;11:194. <http://doi.org/10.1186/1471-2474-11-194>
31. Pomerantz ML, Glaser D, Doan J, Kumar S, Edmonds EW (2015) Three-dimensional biplanar radiography as a new means of accessing femoral version: a comparative study of EOS three-dimensional radiography versus computed tomography. *Skeletal Radiol* 44:255-260. <http://doi.org/10.1007/s00256-014-2031-2>
32. Roskopf AB, Ramseier LE, Sutter R, Pfirrmann CWA, Buck FM (2014) Femoral and tibial torsion measurement in children and adolescents: comparison of 3D models based on low-dose biplanar radiography and low-dose CT. *AJR* 202: W285-W291. <http://doi.org/10.2214/AJR.13.11103>
33. Siebenrock KA, Steppacher SD, Haefeli PC, Schwab JM, Tannast M (2013) Valgus hip with high antetorsion causes pain through posterior extraarticular FAI. *Clin Orthop Relat Res* 471:3774-3780. <http://doi.org/10.1007/s11999-013-2895-9>
34. Song K, Gaffney BMM, Shelburne KB, Pascual-Garrido C, Clohisy JC, Harris MD (2020) Dysplastic hip anatomy alters muscle moment arm lengths, lines of action, and contributions to joint reaction forces during gait. *J Biomech* 18:110. <http://doi:10.1016/j.jbiomech.2020.109968>
35. Souza RB, Powers CM (2009) Concurrent Criterion-Related Validity and Reliability of a Clinical Test to Measure Femoral Anteversion. *JOSPT* 39(8): 586-592. <http://doi.org/10.2519/jospt.2009.2996>
36. Sutter R, Dietrich TJ, Zingg PO, Pfirrmann CWA (2012) Femoral antetorsion: Comparing asymptomatic volunteers and patients with femoroacetabular

- impingement. *Radiol* 263(2): 475-483. <http://doi.org/10.1148/radiol.12111903>
37. Torresan A. Reprodutibilidade intra e interavalador na avaliação funcional do quadril - Intra and inter-rater reliability in hip functional assessment [MSc dissertation]. Porto Alegre, RS, Brazil: Federal University of Rio Grande do Sul; 2017. <https://lume.ufrgs.br/handle/10183/172134>
38. Uding A, Bloom NJ, Commean PK, Hillen TJ, Patterson JD, Clohisy JC, Harris-Hayes M (2019) Clinical Test to Determine Femoral Version Category in People with Chronic Hip Joint and Asymptomatic Controls. *Musculoskelet Sci Pract* 39:115-122. <http://doi.org/10.1016/j.msksp.2018.12.003>

5 ARTIGO 3

PROGNOSTIC FACTORS FOR FEMOROACETABULAR IMPINGEMENT SYNDROME: AN AMBIDIRECTIONAL COHORT STUDY

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(Qualis A1, Fator de impacto 6.206)

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ABSTRACT

Background: Femoroacetabular impingement (FAI) syndrome is a recognized source of hip pain in young adults that impairs the hip muscle function and range of motion. The prognostic ability of hip muscle strength and range of motion has not been studied yet.

Purpose: To assess the prognostic ability of hip muscle strength and range of motion, in addition to a range of baseline characteristics, for the future health outcome in patients with FAI syndrome.

Study Design: Ambidirectional cohort study.

Methods: Patients with FAI syndrome, evaluated between 2013 and 2019 at a private physiotherapy clinic, were enrolled in this cohort. In 2020/2021, patients' health outcome was assessed through the International Hip Outcome Tool (iHOT-33). Fifteen variables were investigated for their prognostic ability with a multivariate forward stepwise regression analysis. The patient's acceptable symptom state (PASS) cutoff for iHOT-33 was established in 67 points, while the iHOT-33 delta score was defined as the difference between the follow up minus the baseline scores.

Results: From 353 FAI syndrome patients who completed the baseline assessment, 145 responded the iHOT-33 follow-up. The mean follow-up time was 5 ± 2 years (minimum = 1, maximum = 8 years). Eighty-one (56%) patients reached a $PASS \geq 67$. Only the initial iHOT-33 score was a good predictor for achieving the $PASS \geq 67$ at the follow up ($AUC = 0.76$). No other variable was able to improve the predictive model. The iHOT-33 delta scores increased 21 ± 22 points (minimum -39.8, maximum 76.9 points). Higher iHOT-33 delta scores were significantly associated with a normal femoral version (β 9.03), a lower body mass index (β -0.99) and a higher initial iHOT-33 score (β -0.44).

Conclusion: The initial iHOT-33 is an acceptable prognostic factor for achieving $PASS \geq 67$, whereas initial iHOT-33, normal femoral version and body mass index were associated with mid- to long-term improvements in iHOT-33 score in FAI syndrome patients.

Clinical Relevance: Physical therapists and medical doctors should consider the initial iHOT-33, femoral version and body mass index as prognostic factors, and use this information to align FAI syndrome patients' expectations with their possible outcome.

Key Terms: Femoroacetabular Impingement Syndrome, prognosis, hip muscle strength, hip range of motion.

What is known about the subject: FAI syndrome patients with low body mass index, a Tönnis grade of 0, and pain relief from preoperative intra-articular hip injections are significantly more likely to achieve positive outcomes after hip arthroscopic surgery.

What this study adds to existing knowledge: The present study showed that the initial iHOT-33 score is the only independent factor that can predict a PASS $\geq$ 67 for iHOT-33 in FAI syndrome patients. In addition, normal femoral version and body mass index were predictors of the patients' iHOT-33 delta score.

INTRODUCTION

Femoroacetabular Impingement (FAI) syndrome is a hip joint motion-related clinical disorder with a triad of symptoms, clinical signs, and imaging findings.⁸ The impingement between bone structures causes cartilage damage, pain, and predisposes the hip to early osteoarthritis onset.⁷ Hip arthroscopy surgery has been often proposed to treat FAI syndrome. According to a recent systematic review, hip arthroscopy had a small positive benefit compared with physiotherapy interventions at 8 and 12 months of follow up.¹⁷ Additionally, physiotherapy-led interventions, focused on targeted strengthening exercise programs with at least 3 months duration, might have the best effect to improve function and strength in young patients with hip-related pain.¹⁷

Patient-Reported Outcome Measures (PROMs) play a prominent role in assessing outcomes after a treatment, considering function and symptoms from the patient's perspective. The International Hip Outcome Tool (iHOT-33) was proposed in 2012²⁰ and has been extensively used in hip-related pain patients due to this tool's adequate reliability, cross-cultural and construct validity.¹⁴ iHOT-33 domains encompass symptoms and functional limitations, sports and recreational activities, job-related concerns, and social, emotional, and lifestyle concerns. This tool's maximum score, which represents the best possible result, is 100 points.

The FASHIoN trial,⁹ one of the largest randomized controlled trials with FAI syndrome, reported that arthroscopy and physiotherapy approaches improve the patients' iHOT-33 scores in ~20 and ~14 points after one year of the interventions, respectively.⁹ Considering 6 points as the minimal clinically important difference (MCID) for iHOT-33,^{16,20} patients have experienced an improvement that they perceive as important when an MCID is achieved post-intervention. However, this improvement does not mean that patients were satisfied with their health status.

A different look at the iHOT-33 scores is through the patient's acceptable symptom state (PASS).¹⁹ This measure establishes a target score at which the patient is highly likely to be satisfied with the physical state of his or her hip joint.¹⁹

The PASS cutoff score varies from 58 to 67 points for iHOT-33.^{15,19} Considering that the mean value for FAI syndrome patients' iHOT-33 score is about 59 and 50 points following arthroscopy and physiotherapy,⁹ respectively, it is likely that a large number of patients did not achieve the PASS with both treatment options.

Prognosis refers to the risk of future health outcomes to improve or worsen in people with a given disease or health condition.¹² A recent systematic review²⁴ showed that young male FAI syndrome patients, with low body mass index ($\text{BMI} < 24.5 \text{ kg/m}^2$), a Tönnis grade of 0, and pain relief from preoperative intra-articular hip injections are significantly more likely to achieve positive outcomes after hip arthroscopic surgery. Considering that FAI syndrome patients have hip muscle weakness and less hip range of motion (ROM) compared to healthy subjects,^{2,4} and that physiotherapy interventions with strengthening exercise programs may be effective to treat these patients,¹⁷ it is reasonable to assume that muscle strength and/or joint mobility could play a role as prognostic factors in this population. However, the prognostic ability of hip strength and ROM in FAI syndrome has not been studied so far.

The aim of the present study was to assess the prognostic ability of hip muscle strength and range of motion, in addition to a range of baseline characteristics, for the future health outcome in FAI syndrome patients. The initial hypothesis was that hip strength, hip internal rotation ROM, normal femoral version (FV), BMI and age would be prognostic factors related to FAI syndrome patients' health improvement. More specifically, patients with better strength, larger hip internal rotation ROM, normal FV, smaller BMI and age should present better PROMs and PASS results.

METHODS

Study design

This is a cohort study with ambidirectional design (i.e., a retrospective and a prospective phase).

Retrospective phase. Information was obtained from data records of FAI

syndrome patients evaluated between 2013 and 2019 at a private physiotherapy clinic (Porto Alegre, Brazil), regarded as a reference center for hip-related disorders' rehabilitation. The research team accessed the clinic's electronic database. Hip ROM, hip strength and iHOT-33 were routinely performed as an initial screening evaluating in FAI syndrome patients. The clinic's physiotherapy director established this routine in 2013, and evaluations were conducted by three physiotherapists properly trained for the procedures and with extensive experience in hip-related disorders.

Prospective phase. Between November 2020 and July 2021, the prospective phase of this study was performed. Patients that completed a minimum of one year post initial screening at the physiotherapy clinic were invited to answer the iHOT-33 questionnaire. All patients received via e-mail, an online link to complete iHOT-33. This assessment was done using the Research Electronic Data Capture (REDCap) platform.^{10,11}

The study was approved by the Federal University of Health Sciences of Porto Alegre's Ethics Committee (#1.871.372). All participants signed an informed consent form agreeing with future use of data for research.

Participants. From the 523 FAI syndrome patients identified in the clinic's database, 353 were eligible (Figure 1). Patients had been previously evaluated by an orthopedic surgeon and diagnosed with FAI syndrome based on the following criteria: presence of motion-related or position-related pain symptoms at the hip; pain and limited ROM at the Flexion Adduction Internal Rotation (FADDIR) hip impingement test; and radiographic diagnosis of CAM deformity and/or Pincer morphology. Patients with a history of previous hip surgery, diabetes mellitus, neuromuscular, neurological or rheumatological diseases were excluded from the study. Patients that did not complete hip ROM, hip strength and iHOT-33 assessments at the physiotherapy initial appointment were also not included in the study. Contacted patients were assigned into a responder (if they answered the iHOT-33 questionnaire) or non-responder group. Baseline values from both groups were compared to determine the patients' similarity at baseline.

Potential prognostic factors

Fifteen variables were assessed as potential prognostic factors. Thirteen of these factors were evaluated at the physiotherapy clinic during the baseline evaluation: age, sex, BMI, sedentary profile, hip ROM (flexion - FLX, external rotation - ER, internal rotation - IR), FV, hip strength (abduction - ABD, adduction - ADD, IR, ER) and initial iHOT-33. The other two factors (treatment option and time of follow up) were obtained from the patients' evaluation form. Treatment options were: (1) conservative management (physiotherapy) based on education, activity modification advice or/and supervised exercise therapy at the clinic; or (2) hip arthroscopy surgery for FAI syndrome correction. The time of follow up was considered the time between the first assessment at the physiotherapy clinic (baseline assessment) and the final iHOT-33 evaluation in months.

ROM Assessment

Hip joint ROM was assessed using a digital goniometer (Medigauge, Columbia, USA) for FLX, IR and ER, as previously described.⁴ Patients were positioned in the following ways to maximize pelvis stabilization. For hip FLX, the contralateral leg was kept fully extended. For ER, the contralateral leg was kept fully extended in a neutral position. For IR, the movement was performed bilaterally and simultaneously, and the patient kept the hip and knee flexed at 90°. Healthy subjects' hip ROM inter-rater reliability was previously established in our laboratory using the same method and was considered excellent for hip rotations and satisfactory for hip flexion [intraclass correlation coefficient (ICC) values superior to 0.84 for all measures].⁴

Femoral Version Assessment

Femoral version (FV) was clinically assessed using the rotation index, which estimates femoral version based on ROM measurements. In our previous study, we proposed this index calculation by subtracting the ER from the IR ROM values.⁵ The rotation index has been shown to be an independent FV predictor in patients with hip pain: the probability of hip being anteverted or retroverted is greater than 70% if the rotation index is less than 11° or higher than 40°, respectively.⁵ Therefore, a normal FV was considered when the rotation index

was between 11 and 40°, and FV was considered a dichotomous variable (i.e., normal or abnormal) in this study's prediction model.

Strength Assessment

Maximal isometric hip strength was assessed through hand-held dynamometry (MICROFET – Hoogan Scientific, Salt Lake City, USA). Muscle strength for ABD, ADD, IR and ER was evaluated in different positions. For ABD and ADD, we used the methodology introduced by Frasson et al.⁴ For ER and IR, we used a supine position, where the evaluator held the dynamometer pad 5 cm proximal to the lateral (hip IR) and medial (hip ER) malleoli. In all tests, the dynamometer was placed distally on the leg, close to the ankle joint, thereby providing a great lever arm for the evaluator, thus maximizing the evaluator's stability.

For each muscle group, patients completed 2 maximal voluntary isometric contraction (MVIC) trials. If the difference between the 2 MVICs was greater than 10%, a third trial was obtained. Participants received standardized verbal encouragement to produce maximal effort contractions in the following way: 2 seconds to build up to maximal force, 2 seconds of MVIC, and 2 seconds to relax. A 120-s rest time was strictly enforced between trials. Additional measurements were taken if the evaluator felt unstable during the measurement or if participants failed to achieve a maximum effort. The highest valid force measurement was converted to a hip joint torque value by multiplying the force measured by the dynamometer (in Newtons) by the lever arm length (distance in meters between the estimated hip joint's axis of rotation and the point of force application). Torques were normalized to body mass (Nm/kg) and were used for data analysis. Healthy subjects hip muscle strength intra- and inter-rater reliabilities were previously established in our group using this method. ICC was considered excellent (intra-rater superior to 0.89, inter-rater superior to 0.90) for all tested muscle groups.⁴

PROM assessment

Patients completed the iHOT-33 tool at the time of initial screening assessment at the physiotherapy clinic (baseline evaluation) and using the

REDCap on-line platform (follow up evaluation). Participants received standardized guidance on how to complete the instrument. iHOT-33 presents indeterminate structural validity, insufficient measurement error, sufficient reliability, responsiveness, construct validity, cross-cultural validity and internal consistency.¹⁴ The PASS used in this study was $iHOT-33 \geq 67$,¹⁵ and patients that achieved this cutoff value were considered to have a 'favorable result'. The iHOT-33 delta score was calculated by the difference between initial and final iHOT-33 scores.¹⁶

Statistical Analysis

Baseline data for each candidate variable were presented as means and standard deviations for continuous data, and percentages for categorical data. Baseline characteristics were compared between responders and non-responders with T-test for continuous variables and chi-square for categorical variables. Candidate variables entered a multivariate forward stepwise regression analysis. Linear regression was used for iHOT-33 delta score, and logistic regression for the dichotomous measure of achieving or not the PASS (i.e., $iHOT-33 \geq 67$). Variables with the highest p-values were removed one at a time (WALD test), until all remaining variables were significant at $p < 0.10$. Associations within each multivariate model were regarded as significant at $p < 0.05$. The strength of the predictive ability of identified factors in each multivariate model was determined using the odds ratio (OR) for dichotomous measures (PASS) and unstandardized regression coefficients for continuous measure (iHOT-33 delta score). Discrimination for the dichotomous measure was assessed by calculating the area under the receiver operator characteristic (ROC) curve, to evaluate how each variable distinguished patients who achieved the PASS. All analyses were conducted using IBM-SPSS (version 25.0).

RESULTS

From the 523 potential eligible patients, 353 had completed the baseline assessment (Figure 1). One hundred and forty-five patients completed the study after answering the follow up iHOT-33. No statistical difference was found

between responders' and non-responders' baseline characteristics (Table 1).

The mean follow-up time was 58.7 ± 27.2 months (minimum of 12 and maximum of 103 months). One hundred and four patients (71.7% of participants) had arthroscopy surgery after baseline evaluation.

Eighty-one participants (56%) presented a favorable result (i.e., achieved the PASS) on the follow up evaluation. Table 2 shows the univariate statistical significances for the association of baseline characteristics and achieving the PASS observed in the logistic regression. Although multiple variables reached statistical significance in the univariate analysis, only the initial iHOT-33 score was considered statistically significant (OR 1.06, 95% CI 1.03 to 1.8) in the multivariate logistic regression. No other variable was able to improve the predictive model. The ROC analysis showed AUC of 0.76 (95% CI 0.68 to 0.83, Figure 2) with a $p < 0.001$. The initial iHOT-33 scores were 54.5 and 37.2 for patients that achieved the PASS and that did not, respectively.

The average increase in iHOT-33 delta score between evaluations was 20.7 ± 21.8 points (minimum -39.8 and maximum 76.9 points). Table 3 presents the Pearson correlation for all the variables tested in the model, showing that initial iHOT-33 scores, sex, rotation index and ER strength were significantly correlated with iHOT-33 delta values. However, only initial iHOT-33 score (β -0.44), normal FV (β 9.03), and BMI (β -0.99) had the ability to predict iHOT-33 delta score in the multivariate model (Table 4). A normal FV increased in 9 points the iHOT-33 delta score, whereas a decrease of one point in BMI values led to an increase of 1 point in iHOT-33 delta score. This model explained 20% of iHOT-33 delta score variance.

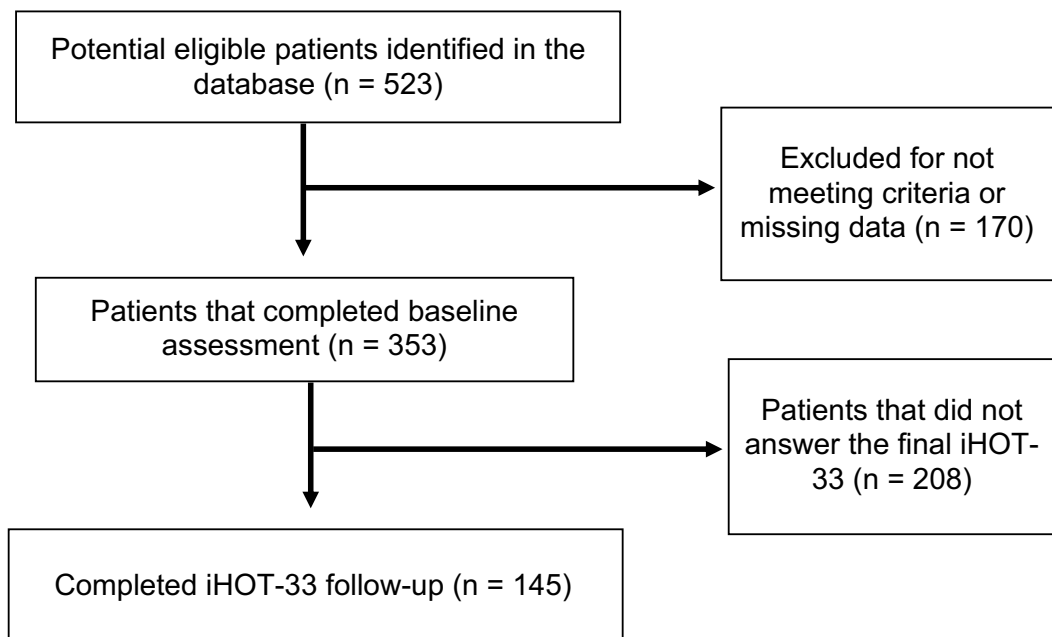


Figure 1. Flow of participants through the study.

Table 1. Baseline characteristics of the participant.

Characteristic	Responders N = 145	Non responders N =208	p value
Age, years	38.2 ± 10.4	37.1± 10.7	0.20
Male sex, no. (%)	99 (68.3)	153 (73.6)	0.28
Body mass index, kg/m ²	24.8 ± 3.3	25.2 ± 3.5	0.15
Sedentary, no. (%)	50 (34.5)	80 (38.5)	0.46
Initial iHOT-33	46.8 ± 19.6	47.6 ± 20.2	0.71
Normal version, no. (%)	111 (76.6)	145 (69.7)	0.16
Hip ROM, degrees			
FLX	115.3 ± 10.7	116 ± 10.6	0.54
ER	39.9 ± 9.3	41.4 ± 9.4	0.14
IR	21.0 ± 9.0	20.9 ± 9.8	0.90
Hip strength, Nm/kg			
ER	0.62 ± 0.27	0.60 ± 0.23	0.46
IR	0.66 ± 0.27	0.68 ± 0.33	0.61
ABD	1.24 ± 0.45	1.28 ± 0.36	0.42
ADD	1.06 ± 0.50	1.11 ± 0.46	0.32
Surgical treatment, no. (%)	104 (71.7)	-----	
Time of follow-up	58.7 ± 27.2	-----	

Values are presented as n (%) or mean ± SD. ABD = abduction; ADD = adduction; BMI = body mass index; ER = external rotation; FLX = flexion; IR = internal rotation; ROM = range of motion; SD = standard deviation.

Table 2. Univariate statistical significances for the association of prognostic factors and iHOT-33 PASS $\geq$ 67 observed in logistic regression.

Variable	Chi-square	P-value
Initial iHOT-33	27.851	0.000
ADD strength	6.510	0.011
ABD strength	5.211	0.022
ER strength	5.102	0.024
ER ROM	4.142	0.042
IR strength	4.090	0.043
FLX ROM	2.957	0.085
Normal version	2.485	0.115
Sedentary	1.913	0.167
Surgical treatment	0.606	0.436
Male sex	0.372	0.542
Age	0.369	0.544
BMI	0.198	0.657
Time of follow up	0.019	0.889
IR ROM	0.000	0.997

ABD = abduction; ADD = adduction; BMI = body mass index; ER = external rotation; FLX = flexion; IR = internal rotation; PASS = patient's acceptable symptom state; ROM = range of motion.

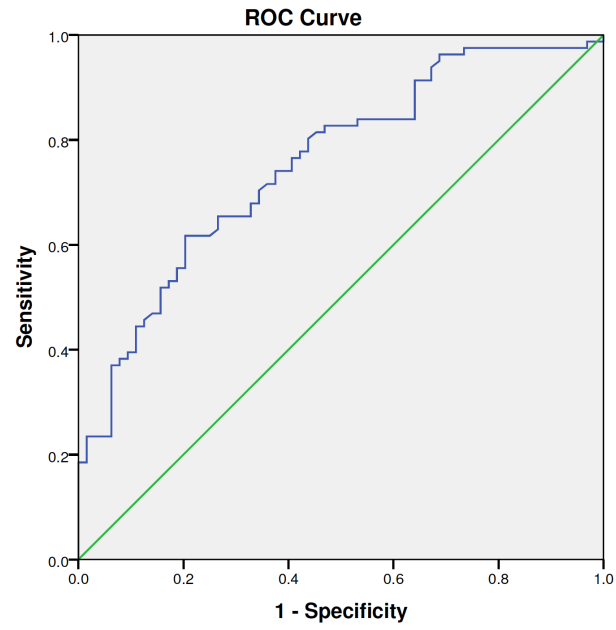


Figure 2. ROC curve for initial iHOT-33 to predict $PASS \geq 67$ (AUC 0.76 95% CI: 0.68-0.83).

Table 3. Correlation between selected variables and iHOT-33 delta score.

Variable	Pearson r
Initial iHOT-33	-0.382**
Male sex	-0.238**
Normal version	0.171*
ER strength	-0.166*
IR strength	-0.152
Sedentary	0.133
ADD strength	-0.131
BMI	-0.109
ABD strength	-0.101
Age	-0.094
Surgical treatment	0.048
FLX ROM	0.040
IR ROM	0.024
ER ROM	-0.010
Time of follow up	0.008

ABD = abduction; ADD = adduction; BMI = body mass index; ER = external rotation; FLX = flexion; IR = internal rotation; ROM = range of motion. ** = $p < 0.01$;

* = $p < 0.05$

Table 4. Prognostic factors for iHOT-33 delta score.

Variables	B	p-value
Initial iHOT-33	-0.440	0.000
Normal version	9.034	0.021
BMI	-0.994	0.047

β = unstandardized regression coefficient; BMI = body mass index.

DISCUSSION

The present study showed that the initial iHOT-33 score is the only independent factor that can predict a favorable result (i.e., iHOT $\geq$ 67) in FAI syndrome patients. In other words, patients who had higher baseline iHOT-33 scores were closer to the cutoff score of 67 points and, therefore, were able to achieve the PASS more frequently than their peers with lower baseline iHOT-33 scores. However, in addition to the baseline iHOT-33 score, normal FV and BMI were predictors of the patients' iHOT-33 delta score. No other variable included in the physiotherapists' initial screening evaluation, such as hip ROM and hip muscle strength, had any prognostic ability.

According with a systematic review, young age, male sex and lower BMI were found to predict a positive outcome after hip arthroscopy in FAI syndrome.²⁴ In our study, which included men and women from 17 to 65 years old, the patients' sex and age played no role in their prognosis. We speculate that the reduced number of patients with more than 50 years (i.e., 14 participants; less than 10% of the sample) makes it difficult to reach a definitive conclusion regarding age's prognostic ability. Nevertheless, the sex distribution (~68% men) allow us to be more assertive that sex was not a prognostic factor in our study. Therefore, despite FAI syndrome women patients present more profound symptomatology with milder morphologic abnormalities, while men have more common combined-

type FAI morphologies and a more extensive intra-articular disease,²¹ prognosis seems to be independent of the patient's sex.

Patients in our sample were submitted to conservative or surgical approaches (~72% treated with hip arthroscopy). The iHOT-33 delta scores for conservative and surgical treatment in our study were 19.07 and 21.40, respectively. Considering that 6 points is the MCID for iHOT-33,^{16,20} these results suggest that both treatment options achieved the MCID. In addition, our findings support the effectiveness of both conservative and surgical treatments, and randomized controlled trials already showed these treatments' efficacy.¹⁷

As found by Sogbein et al.,²⁴ BMI has been described as a predictor factor for FAI syndrome patients undergoing hip surgery. According to Cvetanovich et al.,¹ a BMI below 24.5 was associated with achieving MCID on the hip outcome score - HOS (OR 0.92). If we take the iHOT-33 delta score as an outcome, our results agree with their results, but not if we consider the PASS cutoff value as the outcome. Considering the delta scores, our study showed that every 1 point decrease in BMI increases 1 point in the iHOT-33 delta score. This result agrees with a recent systematic review, which showed that obesity is associated with worse clinical outcomes of hip and knee arthroplasty in terms of pain and complications in osteoarthritis patients.²³ However, achieving the PASS is not related to BMI, and one possible explanation is that achieving a final iHOT-33>67 is highly determined by the iHOT-33 baseline score (discriminative ability of 75%). However, considering that BMI is a modifiable factor, patients should be informed about the possibility of obtaining higher increments in iHOT-33 delta scores with weight loss.

Considering that physical inactivity has been associated with chronic musculoskeletal complains,¹³ it is reasonable to expect that sedentary lifestyle plays a role in FAI syndrome patients' prognosis. According to our results, being sedentary is not a factor related to achieving the PASS nor with iHOT-33 delta score. Fifty patients (34.5%) in our study reported a sedentary lifestyle, with no report of physical exercise neither sports practice. One possible explanation to sedentary lifestyle not being able to predict a favorable result or iHOT-33 delta

scores could be related with the FAI syndrome characteristic. FAI syndrome is a motion related disorder prevalent in young adults, in which pain is related with movement and certain positions.⁸ Therefore, stopping exercise and/or sports can be a way to reduce pain in these patients.

FV has been recognized as a potentially important factor in the development of hip pain.¹⁸ Considering that 52% of the hips scheduled for hip preservation surgery have abnormal FVs,¹⁸ and that patients with abnormal version had less improvement after hip arthroscopy than normal version patients,³ FV may be also an important factor related to health prognosis in FAI syndrome patients. Since the rotation index proved to be an independent FV predictor in patients with hip pain,⁵ we chose this index in the present study to assess patients with normal version and evaluate its prognosis ability. According to our results, 111 (77%) patients presented a rotation index indicative of a normal FV. Additionally, patients with normal FV were associated with a 9-point increase in the iHOT-33 delta score. Therefore, in addition to being a feasible tool to predict FV at the clinical setting,⁵ rotation index proved to be a prognostic factor related to improvements in iHOT-33 after conservative and surgical treatments. The use of this index as a screening test by physiotherapists and medical doctors may influence decision-making regarding the FAI syndrome patients' treatment.

To our knowledge, this is the first study to investigate the prognosis ability of hip strength and ROM in FAI syndrome patients. Considering cross sectional studies' results showing the discriminative ability of hip muscle strength and hip ROM between healthy subjects and FAI syndrome patients, these variables were considered here as candidates with prognosis ability.^{2,6} However, according to our results, hip strength and ROM cannot predict FAI syndrome patients' outcomes. The clinical concept that patients with better strength and mobility will perform better after an orthopedic surgery was not proved here. The modifiable nature of these variables (strength and ROM) might explain their poor prognosis ability. Over the years, patients modified their muscle strength and joint ROM due to exercise and health status. Therefore, strength and ROM at the time of the follow up evaluation should have more impact in the final clinical outcome. It will be interesting to investigate the hip muscles' strength and hip ROM changes of

these patients in the coming years.

Ishoi et al.¹⁵ showed that 46.7% of 137 patients submitted to arthroscopy surgery achieved the PASS score after 12 to 24 months of the procedure. Using the same cutoff (i.e., 67 points), our study showed that 56% of our participants achieved the PASS for iHOT-33. PASS score is a useful way to distinguish patients that report that “are feeling good” (PASS) from those that are “feeling better” (MCID). This information seems to be important for aligning the patients’ expectations with possible health outcomes. However, the PASS has a limitation when considering the initial values, as some patients already had a PASS cutoff score in their initial evaluation (e.g., 26 patients in the current study). Therefore, we cannot have an idea of global improvement looking only at the PASS score, and the iHOT-33 delta score may improve our ability to understand our data behavior. More specifically, the average iHOT-33 score increase between evaluations was ~21 points. This value is higher than the MCID of iHOT-33 (i.e., 6 points),^{16,20} suggesting that both MCID and PASS scores were achieved by the participants, independent of their treatment option (i.e., conservative physiotherapy versus arthroscopy surgery).

This study has some limitations. First, the large time variability between evaluations, ranging from 1 to 8 years, may have brought a variability in the iHOT-33 scores of the follow up evaluation. Second, patients were submitted to different treatment modalities, conservative and surgical approaches. However, the time between evaluations and treatment were not a factor predicting PASS or iHOT-33 delta scores, suggesting that between-evaluations time and treatment did not affect our results. Another limitation was the high number of non-responders in our study (patients that did not answer the follow-up iHOT-33). Despite this, there was no difference in baseline characteristics between responders and non-responders leading us to believe that the responders’ group sample is representative of all patients assessed in the baseline. In the next steps, it would be important to assess the prognostic ability of hip ROM and hip muscle strength over the coming years to test for possible effects of these variables’ modifiable nature in the PASS and iHOT-33 delta scores, as well as in the health status of these FAI syndrome patients.

CONCLUSION

In conclusion, more than half of the FAI syndrome patients had a favorable recovery from one to eight years of follow up and achieved PASS scores. PASS score can be predicted in 75% by the iHOT-33 initial score. The use of iHOT-33, normal FV assessed by the rotation index and BMI at the initial evaluation can predict the iHOT-33 delta score results in FAI syndrome patients. Physiotherapists should consider the initial iHOT-33, FV and BMI as prognostic factors and use this information to align FAI syndrome patients' expectations with their possible outcome.

REFERENCES

1. Cvetanovich GL, Weber AE, MD, Kuhns BD, Alter J, Harris JD, Mather III RC, Nho SJ. MSHip Arthroscopic Surgery for Femoroacetabular Impingement With Capsular Management Factors Associated With Achieving Clinically Significant Outcomes. *Am J Sports Med.* 2017; 46(2): 288-296. PMID: 29161115
2. 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):230-42. PMID: 25246442
3. Fabricant PD, Fields KG, Taylor SA, Magennis E, Bedi A, Kelly BT. The effect of femoral and acetabular version on clinical outcomes after arthroscopic femoroacetabular impingement surgery. *J Bone Joint Surg Am.* 2015; 1;97(7):537-43. PMID: 25834077
4. Frasson VB, Vaz MA, Morales AB, Torresan A, Telöken MA, Gusmão PDF, Crestani MV, Baroni BM. Hip muscle weakness and reduced joint range of motion in patients with femoroacetabular impingement syndrome: a case-control study. *Braz J Phys Ther.* 2020; 24(1):39-45. PMID: 30509854
5. Frasson VB, Herzog W, Johnston K, Vaz MA, Pauchard Y, Baroni BM (2021). Do femoral version abnormalities play a role in hip function of

- patients with hip pain? Submitted to the *Clin Biomech*. June 2021.
6. Freke MD, Kemp J, Svege I, Risberg MA, Semciw A, Crossley KM. Physical impairments in symptomatic femoroacetabular impingement: a systematic review of the evidence. *Br J Sports Med*. 2017; 50(19):1118. PMID: 27301577
 7. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res*. 2008; 466(2):264-272. PMID: 18196405
 8. Griffin DR, Dickenson EJ, O'Donnell J et al. The Warnick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med*. 2016; 50(19):1169-1176. PMID: 2762940
 9. Griffin DR, Dickenson EJ, Wall PDH et al. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomized controlled trial. *Lancet*. 2018; 391:2225-35. PMID: 29893223
 10. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, McLeod L, Delacqua G, Delacqua F, Kirby J, Duda SN. REDCap Consortium, The REDCap consortium: Building an international community of software partners, *J Biomed Inform*. 2019; 95:103208. PMID: 31078660
 11. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde, JG. Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support, *J Biomed Inform*. 2009; 42(2):377-81. PMID: 18929686
 12. Hemingway H, Croft P, Perel P, Hayden JA, Abrams K, Timmis A, Briggs A, Udumyan R, Moons KG, Steyerberg EW, Roberts I, Schroter S, Altman DG, Riley RD; PROGRESS Group. Prognosis research strategy (PROGRESS) 1: a framework for researching clinical outcomes. *BMJ*. 2013; 5;346:e5595. doi: 10.1136/bmj.e5595. PMID: 23386360
 13. Holth HS, Werpen HBW, Zwart A and Hagen K. Physical inactivity is associated with chronic musculoskeletal complaints 11 years later: results from the Nord-Trondelag Health Study. *BMC Musculoskelet Disord*. 2008;

9:159. PMID: 19046448

14. Impellizzeri FM, Jones DM, Griffin D, et al. Patient-reported outcome measures for hip-related pain: a review of the available evidence and a consensus statement from the International Hip-related Pain Research Network, Zurich 2018. *Br J Sports Med.* 2020; 54(14):848-857. PMID: 32066573
15. Ishoi L, Thorborg K, Orum MG, Kemp JL, Reiman MP, Per Hölmeich. How Many Patients Achieve an Acceptable Symptom State After Hip Arthroscopy for Femoroacetabular Impingement Syndrome? A Cross-sectional Study Including PASS Cutoff Values for the HAGOS and iHOT-33. *Orthop J Sports Med.* 2021; 9(4): 1-9. PMID: 33889644
16. Kemp JL, Collins NJ, Roos EM, Crossley KM. Psychometric Properties of Patient-Reported Outcome Measures for Hip Arthroscopic Surgery. *Am J Sports Med.* 2013; 41(9): 2065-2073. PMID: 23835268
17. Kemp JL, Mosler AB, Hart H, et al. Improving function in people with hip-related pain: a systematic review and meta-analysis of physiotherapist-led interventions for hip-related pain. *Br J Sports Med.* 2020; 54(23):1382-1394. PMID: 32376673
18. Lerch TD, Todorski IAS, Steppacher SD, Schmaranzer F, Werlen SF, Siebenrock KA, Tannast M. Prevalence of Femoral and Acetabular Version Abnormalities in Patients with Symptomatic Hip Disease. *Am J Sports Med.* 2018; 46(1):122-134. PMID: 28937786
19. Maxwell S, Pergaminelis N, Renouf J, Tirosh O, Tran P. Identification of a Patient Acceptable Symptomatic State Score for the International Hip Outcome Tool in People Undergoing Hip Arthroscopy. *Arthroscopy.* 2018; 35(11):3024-3029. PMID: 30301632
20. 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). *J Arthrosc.* 2012; 28(5):595-605. PMID: 22542433
21. Nepple JJ, Riggs CN, Ross JR, Clohisy JC, MD. Clinical Presentation and Disease Characteristics of Femoroacetabular Impingement Are Sex-

- Dependent. *J Bone Joint Surg.* 2014; 96(20):1683-9. PMID: 2532019
22. Polesello GC, Godoy GF, Trindade CA, de Queiroz MC, Honda E, Ono NK. Translation and cross-cultural adaptation of the International Hip Outcome Tool (iHOT) into Portuguese. *Acta Ortop Bras.* 2012; 20(2):88-92B. PMID: 24453587
23. Pozzobon D, Ferreira PH, Blyth FM, Machado GC, Ferreira ML. Can obesity and physical activity predict outcomes of elective knee or hip surgery due to osteoarthritis? A meta-analysis of cohort studies. *BMJ Open.* 2018; 27;8(2): e017689. PMID: 2948707
24. Sogbein OA, Shah A, Kay J, Memon M, Simunovic N, Belzile EL, Ayeni OR. Predictors of Outcomes After Hip Arthroscopic Surgery for Femoroacetabular Impingement: A Systematic Review. *Orthop J Sports Med.* 2019; 19(6):1-19. PMID: 31259183

6 CONCLUSÃO GERAL

A literatura a respeito da síndrome do IFA cresceu muito nos últimos anos, de modo que evidências de melhor qualidade têm sido apresentadas acerca das adaptações físicas e funcionais dos pacientes, bem como das diferentes modalidades de tratamento. Estas informações são fundamentais para auxiliar fisioterapeutas e médicos na tomada de decisão clínica para o tratamento de pacientes com síndrome do IFA. A avaliação realizada no ambiente clínico possibilita a detecção de déficits de força, ADM e funcionalidade de pacientes com síndrome do IFA, auxiliando na determinação do prognóstico destes pacientes, e proporcionando a prescrição de estratégias de tratamento individualizadas.

Em nosso primeiro estudo apresentamos evidências relativas à fraqueza muscular e redução da ADM do quadril apresentadas em pacientes com síndrome do IFA comparados a sujeitos assintomáticos. Considerando que a força muscular e ADM têm um papel fundamental relacionado a incapacidade física e funcional, a recuperação da força muscular é prioridade em programas de reabilitação. Por outro lado, a recuperação da ADM de quadril em pacientes com IFA é assunto controverso, já que parte da limitação provavelmente está relacionada à anormalidade óssea apresentada por estes pacientes. Os resultados apresentados sobre os déficits de força e ADM acrescentam à evidência disponível na literatura, no sentido de reduzir a divergência existente. Além disso, o método de avaliação proposto é simples e de fácil uso na prática clínica, utilizando recursos como o dinamômetro manual e o goniômetro.

No segundo estudo, utilizamos a mesma metodologia de avaliação de força e ADM utilizada no primeiro artigo, e investigamos o impacto da VF na força e ADM de adultos jovens com dor no quadril. Nossos resultados confirmaram que a VF tem influência na ADM do quadril. Adicionalmente estabelecemos um método de avaliação capaz de prever a VF através da medida rotacional do quadril, a qual denominamos “índice rotacional”. Também verificamos que a força muscular do quadril sofre modificações devido às diferenças na VF, demonstrando que mudanças anatômicas podem ter impactos sobre a

capacidade funcional dos músculos. Baseado nos nossos resultados é fundamental que os clínicos levem em consideração a VF e seu impacto na ADM e força muscular ao indicar estratégias de tratamento específicas.

Em nosso último estudo investigamos os fatores prognósticos relacionados a pacientes com síndrome do IFA, em especial, fatores relacionados à ADM, força muscular, VF e PROMs. Os resultados apresentados no nosso estudo demonstraram que o iHOT-33 inicial apresenta uma boa capacidade de prever o PASS (ou seja, $iHOT-33 \geq 67$). Além disso, o iHOT-33 inicial, a VF e o IMC apresentam propriedades prognósticas para a variação do escore do iHOT-33 entre as avaliações. Sendo assim, fisioterapeutas e profissionais da saúde devem orientar os pacientes quanto às medidas que auxiliam na obtenção de melhores resultados clínicos, como, por exemplo, a redução da massa corporal. Além disso, considerando o papel prognóstico do iHOT-33 e sua abrangência em aspectos físicos, laborais, esportivos e psicossociais, estratégias de tratamento que abordem todas estas dimensões precisam ser implementadas na prática clínica do fisioterapeuta.

Os artigos apresentados nesta tese reforçam a importância da avaliação em ambiente clínico para pacientes com síndrome do IFA. O impacto desta avaliação vai além da detecção de déficits de força e de ADM, possibilitando a predição da VF e a detecção de fatores prognósticos. É extremamente importante que fisioterapeutas utilizem técnicas válidas e relevantes para a avaliação clínica, possibilitando desenvolver melhores estratégias de tratamento, individualizadas e baseadas nas possibilidades prognósticas de cada indivíduo.

7 IMPACTOS DO TRABALHO

As informações presentes nos artigos apresentam impactos científico, clínico e econômico. Do ponto de vista científico, o primeiro estudo adiciona informações relevantes à literatura atual sobre as características de ADM e força muscular encontradas em pacientes com síndrome do IFA. No segundo estudo, além de apresentarmos o impacto da VF na força e ADM de pacientes com síndrome do IFA, desenvolvemos um índice capaz de prever a VF a partir de medidas simples de ADM rotacional do quadril. No terceiro estudo, mostramos o potencial prognóstico de uma série de medidas comumente realizadas nas avaliações de pacientes com síndrome do IFA.

Do ponto de vista clínico, a metodologia de avaliação proposta nos artigos é simples e fácil de utilizar na prática clínica, sendo capaz de auxiliar fisioterapeutas a detectar déficits de força e ADM em pacientes com síndrome do IFA. Além disso, através desta metodologia os clínicos podem prever a VF de pacientes, a qual tem impacto no prognóstico destes pacientes. Os resultados apresentados auxiliam o fisioterapeuta na educação do paciente com informações de qualidade sobre sua condição clínica. Além disso, o uso da avaliação clínica por parte dos fisioterapeutas reforça o seu papel como agente de saúde, possibilitando destacar sua participação essencial na tomada de decisão acerca da melhor modalidade de tratamento para cada paciente.

Do ponto de vista econômico a utilização deste tipo de avaliação tem potencial de reduzir o uso excessivo de exames de imagem, auxiliando o clínico a identificar pacientes que precisam ou não de exames de imagens, os quais elevam os custos relacionados aos tratamentos de saúde. Além disto, a metodologia de avaliação do paciente com síndrome do IFA no ambiente clínico utilizada em nossos estudos fornece subsídios para uma tomada de decisão mais assertiva pelos fisioterapeutas, e aumenta as chances de um tratamento bem-sucedido, o que, por consequência, apresenta potencial economia de tempo e recursos financeiros com tratamentos equivocados e/ou ineficazes.

ANEXO A – Parecer CEP e Ethics approval

UNIVERSIDADE FEDERAL DE
CIÊNCIAS DA SAÚDE DE
PORTO ALEGRE



PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: AMPLITUDE DE MOVIMENTO, FORÇA E FUNCIONALIDADE EM PACIENTES COM IMPACTO FEMOROACETABULAR: UM ESTUDO RETROSPECTIVO

Pesquisador: Bruno Manfredini Baroni

Área Temática:

Versão: 1

CAAE: 62335216.0.0000.5345

Instituição Proponente: Universidade Federal de Ciências da Saúde de Porto Alegre

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.871.372

Apresentação do Projeto:

O presente estudo busca investigar as adaptações musculoesqueléticas dos pacientes com impacto femoroacetabular (IFA) antes e após a correção cirúrgica. O IFA é caracterizado pelo contato anormal entre as estruturas do quadril localizadas entre a borda acetabular e a junção cêrvico-cefálica do fêmur. A morfologia alterada dos ossos do quadril promove reduções na mobilidade dessa articulação, na capacidade de produção de força muscular e na funcionalidade, e tem sido relacionada com o surgimento precoce da doença degenerativa do quadril. O tratamento cirúrgico tem se mostrado eficaz no alívio da dor e retorno a prática esportiva, em especial em pacientes jovens. A compreensão das alterações neuromusculares associadas ao IFA e sua correção cirúrgica são fundamentais para auxiliar na adoção de estratégias adequadas de tratamento e reabilitação, e podem contribuir para a redução do risco de desenvolvimento precoce da osteoartrite do quadril. A pesquisa será um estudo de coorte retrospectivo. Os dados para o presente estudo serão obtidos através dos prontuários dos pacientes que foram encaminhados à Physique – Centro de Fisioterapia, entre os anos de 2009 e 2016 com diagnóstico de IFA e indicação de tratamento cirúrgico. Após a obtenção dos prontuários, um banco de dados será elaborado com as seguintes variáveis: idade, sexo, data do diagnóstico, data do início dos sintomas, lado acometido, tempo entre início dos sintomas e diagnóstico médico, tipo de impacto (Came ou Pincer), data da cirurgia.

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CERTIFICATION OF INSTITUTIONAL ETHICS APPROVAL

The Conjoint Health Research Ethics Board (CHREB), University of Calgary has reviewed and approved the following research protocol:

Ethics ID:	REB18-1711
Principal Investigator:	Walter Herzog
Co-Investigator(s):	Kelly Johnston
Student Co-Investigator(s):	Viviane Frasson
Study Title:	HIP STRENGTH, RANGE OF MOTION AND FUNCTIONALITY IN PATIENTS WITH HIP PAIN AND ABNORMAL FEMORAL VERSION
Sponsor:	Kinesiology - Administration International Society Of Biomechanics

Effective: December 19, 2018

Expires: December 19, 2019

The following documents have been approved for use:

- telephone recruitment text, 1, November 15, 2018
- Consent- clean copy, 1A, December 17, 2018
- Project Proposal-V.Frasson 2018, November 2, 2018

The CHREB is constituted and operates in accordance with the current version of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS); International Conference on Harmonization E6: Good Clinical Practice Guidelines (ICH-GCP); Part C, Division 5 of the Food and Drug regulations, Part 4 of the Natural Health Product Regulations and the Medical Device Regulations of Health Canada; Alberta's Health Information Act, RSA 2000 cH-5; and US Federal Regulations 45 CFR part 46, 21 CFR part 50 and 56.

You and your co-investigators are not members of the CHREB and did not participate in review or voting on this study.

Restrictions:

This Certification is subject to the following conditions:

1. Approval is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to the CHREB for approval.
3. An annual application for renewal of ethics certification must be submitted and approved by the above expiry date.
4. A closure request must be sent to the CHREB when the research is complete or terminated.