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SIMPLIFAI – THE SINGLE LEG SQUAT MOVEMENT PATTERN SCALE FOR INDIVIDUALS WITH FEMOROACETABULAR IMPINGEMENT SYNDROME

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RESUMO

INTRODUÇÃO: Avaliar o padrão de movimento do agachamento unipodal em pacientes com síndrome do impacto femoroacetabular (SIFA) é considerado importante na prática clínica. No entanto, a avaliação cinemática do agachamento unipodal desses pacientes requer alto investimento financeiro e de tempo. **OBJETIVO:** o objetivo principal desta tese foi desenvolver e testar uma escala para a avaliação visual do agachamento unipodal em indivíduos com SIFA. **MÉTODOS**: Três estudos foram desenvolvidos neste projeto: (I) "Revisão sistemática sobre validade convergente e discriminativa de métodos visuais para a avaliação de agachamentos unipodais", (II) "Desenvolvimento e confiabilidade da escala de padrão de movimento unipodal para indivíduos com impacto femoroacetabular (SimpliFAI)" e (III) "É hora de simplificar? Qualidade de vida e estado sintomático estão correlacionados com os escores do SimpliFAI após artroscopia de quadril para tratar a síndrome do impacto femoroacetabular". **RESULTADOS:** Nossas descobertas indicam que os métodos atuais de avaliação visual do agachamento unipodal apresentam validade discriminativa insuficiente para desfechos secundários e grupos. A SimpliFAI é a primeira escala para a avaliação visual do agachamento unipodal desenvolvida especificamente para pacientes com SIFA. A SimpliFAI apresenta validade e confiabilidade adequada para a avaliação de pacientes com SIFA tratados apenas com cirurgia ou quando avaliados em conjunto com indivíduos assintomáticos. O escore da escala SimpliFAI parece estar associado à qualidade de vida e função em pacientes com SIFA 4 meses após a artroscopia de quadril. O escore da escala SimpliFAI foi capaz de discriminar pacientes com SIFA com diferentes estados sintomáticos após a cirurgia, mas não deve ser usado isoladamente para inferir o estado sintomático. Por outro lado, o ângulo de amplitude de movimento de adução do quadril - uma medida comument utilizada em pesquisas e na prática clínica - não foi associado à qualidade de vida e função e não foi capaz de discriminar diferentes estados sintomáticos após a cirurgia no mesmo grupo de pacientes. **CONCLUSÃO**: Nossos resultados indicam que a SimpliFAI é uma ferramenta válida, confiável e de baixo custo que pode auxiliar os clínicos na avaliação de pacientes com SIFA durante a reabilitação e também na alta. Além disso, parece que a SimpliFAI é mais útil do que a análise da amplitude de movimento de adução do quadril nessa população.

Descritores (DeCS): Quadril; Agachamento unipodal; Artroscopia; Fisioterapia; Qualidade de vida.

ABSTRACT

***INTRODUCTION**: Assessing the movement pattern of the single leg squat of patients with femoroacetabular impingement (FAI) syndrome is considered important in clinical practice. However, the kinematic assessment of the single leg squat of these patients requires high financial and time investment. **OBJECTIVE:** the main objective of this thesis was to develop and test a scale for the visual assessment of the single leg squat in individuals with FAI syndrome. **METHODS:** Three studies were developed in this project: (I) "A systematic review on convergent and discriminative validity of visual methods for the assessment of single leg squats", (II) "Development and reliability of the single leg movement pattern scale for individuals with femoroacetabular impingement (SimpliFAI)", and (III) "Is it time to simplify? Quality of life and symptomatic state are correlated to SimpliFAI scores after hip arthroscopy to treat FAI syndrome". **RESULTS:** Our findings indicate that current methods of visual assessment of the single leg squat present insufficient discriminative validity for secondary outcomes and groups. The SimpliFAI is the first scale for the visual assessment of the single leg squat developed specifically for patients with FAI syndrome. SimpliFAI presents adequate validity and reliability for the assessment of patients with FAI syndrome treated with surgery alone or when assessed together with asymptomatic individuals. The score from the SimpliFAI scale seems to be associated with quality of life and function in patients with FAI syndrome 4 months after hip arthroscopy. The score from the SimpliFAI scale was capable of discriminating patients with FAI syndrome with different symptomatic states after surgery, but it should not be used in isolation to infer symptomatic state. On the other hand, the hip adduction range of motion angle – a common measure used in research and clinical practice – was not associated with quality of life and function and was not capable of discriminating different symptomatic states after surgery in the same group of patients. **CONCLUSION:** Our results indicate that the SimpliFAI is a valid, reliable, low-cost tool that can help clinicians in the assessment of patients with FAI syndrome during rehabilitation and also at discharge. Also, it seems that the SimpliFAI is more useful than the analysis of hip adduction range of motion in this population.*

***Medical Subject Headings:** Hip; Single-Leg Squat; Arthroscopy; Physical Therapy; Quality of life.*

RESUMO EXPANDIDO

Introdução

Avaliar o padrão de movimento do agachamento unipodal em pacientes com síndrome do impacto femoroacetabular (SIFA) é considerado importante na prática clínica. No entanto, a avaliação cinemática do agachamento unipodal desses pacientes requer alto investimento financeiro e de tempo.

Objetivos

Realizar uma revisão sistemática sobre a validade discriminativa e convergente de métodos de avaliação visual do agachamento unipodal a respeito de desfechos primários e secundários. Desenvolver uma escala para avaliar visualmente o padrão de movimento do agachamento unipodal de pacientes com SIFA e testar suas propriedades de medida. Comparar o escore da escala desenvolvida e o ângulo de amplitude de movimento da adução do quadril entre pacientes com SIFA tratados com cirurgia com estados sintomático aceitável e não aceitável e indivíduos assintomáticos, e explorar a associação entre o escore da escala desenvolvida e o ângulo de amplitude de movimento de adução do quadril com a qualidade de vida e função de pacientes com síndrome de IFA 4 meses após a cirurgia.

Metodologia

A Revisão sistemática foi conduzida de acordo com as diretrizes COSMIN. As seguintes bases de dados foram utilizadas para seleção de estudos: Cinahal, Cochrane, Embase, Pubmed, Sportdiscuss e Web Of Science. Estudos que avaliaram populações com disfunções musculoesqueléticas do membro inferior e/ou indivíduos assintomáticos, utilizaram avaliações visuais do padrão de movimento do agachamento unipodal, e analisaram validade discriminativa e/ou validade convergente a respeito de desfechos primários e secundários foram incluídos. Não foi possível realizar uma análise quantitativa de dados devido alta heterogeneidade entre estudos. Os resultados dos estudos foram resumidos de forma qualitativa para obtenção de uma classificação geral da validade das propriedades de medida de cada método de avaliação visual do agachamento unipodal. Para o desenvolvimento da escala de foi realizado um estudo transversal de desenvolvimento de instrumento. O construto, a estrutura e a confiabilidade da escala foram desenvolvidos com base em procedimentos teóricos, analíticos e empíricos que foram auxiliados pelas diretrizes do COSMIN para o desenvolvimento de instrumentos com propriedades de medida adequadas. Dados de 30 indivíduos com SIFA tratados com artroscopia de quadril e 15 indivíduos assintomáticos foram usados para esses procedimentos. Dois fisioterapeutas usaram o instrumento desenvolvido para avaliar os vídeos de agachamento unipodal de um grupo de pacientes com SIFA tratados com artroscopia de quadril (grupo SIFA, n=30) e de um grupo de pacientes com SIFA tratados com artroscopia de quadril e indivíduos assintomáticos (Grupo misto, n=30). A confiabilidade inter e intra-examinadores do instrumento desenvolvido foi avaliada por meio do coeficiente de correlação intraclasse (CCI). A consistência interna do instrumento desenvolvido foi avaliada por meio da análise alfa de Cronbach. Para testar a validade clinica desta escala sessenta e oito pacientes tratados com artroscopia de quadril e 42 indivíduos assintomáticos foram avaliados. Todos os indivíduos foram submetidos a uma avaliação por vídeo do agachamento unipodal. Um fisioterapeuta analisou vídeos do agachamento unipodal e usou a SimpliFAI para avaliar a qualidade do movimento. O sistema de inteligência artificial Kinebot foi usado para avaliar amplitude de movimento da adução do quadril durante o agachamento unipodal. A pontuação total do questionário iHOT-33 foi utilizada para avaliar a qualidade de vida e a função

relacionadas ao quadril e para classificar os pacientes que apresentam um estado sintomático aceitável ou inaceitável após a cirurgia. Correlações de Spearman foram realizadas para avaliar a associação entre o escore SimpliFAI e o ângulo de amplitude de movimento da adução do quadril com a qualidade de vida relacionada ao quadril e a função de pacientes tratados com artroscopia do quadril. Os testes de Kruskall-Wallis foram realizados para avaliar o escore SimpliFAI e a amplitude de movimento da adução do quadril entre os grupos de estados sintomáticos aceitáveis, não aceitáveis e assintomáticos. Em caso de diferença significativa entre os grupos, análises de características do operação do receptor (COR) foram realizadas para avaliar a capacidade discriminativa do método de avaliação.

Resultados e discussão

Nossos achados indicam que os presentes métodos de avaliação visual do agachamento unipodal apresentam validade discriminativa insuficiente para desfechos secundários mas podem ser válidos para discriminar desfechos primários com evidências suportando o uso da Escala Crossley para discriminar pacientes com dor não relacionada a artrose com diferentes níveis de dor e qualidade de vida. Entretanto, esses resultados devem ser interpretados com cautela devido ao nível de evidência muito baixo dos estudos. A presente revisão sistemática ressalta a escassez de evidências de boa qualidade metodológica suportando a validade discriminativa e convergente de métodos de avaliação visual do agachamento unipodal. A escala desenvolvida foi entitulada SimpliFAI e é a primeira escala para avaliação visual do agachamento unipodal desenvolvida especificamente para pacientes com SIFA, apresentando adequada validade e confiabilidade para avaliação de pacientes com SIFA tratados com cirurgia ou quando avaliados em conjunto com indivíduos assintomáticos. Nossos achados tambem sugerem que a melhor qualidade de movimento do agachamento unipodal avaliado pelo escore SimpliFAI está associada a melhor qualidade de vida e função em pacientes com SIFA tratados com artroscopia de quadril. Além disso, pacientes com estado sintomático aceitável após artroscopia apresentaram melhor qualidade do padrão de movimento do agachamento unipodal avaliado pela SimpliFAI em comparação com pacientes com estado sintomático não aceitável. No entanto, a SimpliFAI apresentou baixa capacidade de discriminar pacientes com estado sintomático inaceitável de pacientes com estado sintomático aceitável após artroscopia. A amplitude de movimento da adução do quadril não foi associada à qualidade de vida.

Considerações finais

Nossos resultados indicam que a SimpliFAI é uma ferramenta válida, confiável e de baixo custo que pode auxiliar os clínicos na avaliação de pacientes com SIFA durante a reabilitação e também na alta. Além disso, parece que a SimpliFAI é mais útil do que a análise da amplitude de movimento de adução do quadril nessa população.

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CHAPTER I

1 INTRODUCTION

1. INTRODUCTION

Femoroacetabular impingement (FAI) syndrome is a hip dysfunction characterized by the premature and symptomatic contact between the femur and acetabulum due a morphological alteration of these structures (GRIFFIN et al., 2016). This premature contact often occurs during an excessive and combined range of motion of hip flexion, adduction, and internal rotation, resulting in hip pain, structural damage such as chondrolabral injuries, and quality of life and function impairments (DIAMOND et al., 2015; AGRICOLA et al., 2020). Also, FAI syndrome is known as a risk factor for the development of hip osteoarthritis, a major cause of disability worldwide (CROSS et al., 2014; KOWALCZUK et al., 2015).

When conservative treatment is not effective, hip arthroscopy is indicated as the main option of treatment for individuals with FAI syndrome (KEMP et al., 2020). Hip arthroscopy is an emerging procedure, with more than 50.000 surgeries performed in the United States per year and presenting a 7-fold increase in the number of procedures performed in Europe between 2002 and 2013 (PALMER et al., 2019). However, 54% of patients with FAI syndrome treated with hip arthroscopy do not achieve an acceptable symptomatic state 1 to 2 years after surgery, raising doubts about the processes of assessment and treatment of these individuals (ISHØI et al., 2021).

It is hypothesized that movement pattern alterations such as excessive hip flexion, adduction and internal rotation could result in articular impingement positions and overload hip structures that are still vulnerable after hip arthroscopy, such as the acetabular labrum and chondral surface, resulting in persisted pain and limitations (CHARLTON et al., 2016; CANNON et al., 2020). The single leg squat task is characterized by an intense demands to the hip and has been considered a useful test to screen for movement patterns that may contribute to the progression of FAI syndrome (CHEATHAM et al., 2018; MALLOY et al., 2019). The single leg squat task tends to show greater differences in movement pattern between patients with FAI syndrome and asymptomatic individuals than the double-leg squatting task for example (MALLOY; NEUMANN; KIPP, 2019) and seems to be useful in the identification of movement pattern alterations in patients one to two years after hip arthroscopy (CHARLTON et al., 2016).

Movement patterns in the single leg squat of patients with FAI syndrome treated with hip arthroscopy are commonly assessed through tridimensional (3D) and bidimensional (2D) kinematic analysis (KING et al., 2018). 3D and 2D kinematic analyses are excellent tools to assess human movement, however these methods require high financial investment, and the

reduction and interpretation of data is considerably time-consuming. These issues may turn these methods unfeasible in daily clinical practice of physiotherapists and other health professionals (LOPES et al., 2018).

Visual assessments are a practical and low-cost alternative to assess movement patterns in clinical practice. Recent studies focused on the development of visual scales for the assessment of different functional tasks, such as the unilateral drop landing and single leg squat (CROSSLEY et al., 2011; HARRIS-HAYES et al., 2014; PADUA et al., 2009). Visual assessment scales for the analysis of the single leg squat commonly present adequate reliability (RESSMAN et al., 2019). Also, previous studies have demonstrated the potential of these scales to identify risk of an anterior cruciate ligament injury in athletes and movement pattern alterations in individuals with chronic hip pain (PADUA et al., 2015; VASILJEVIC et al., 2020). However, none of these methods of visual assessment was developed specifically for patients with FAI syndrome, limiting its applicability in this clinical scenario.

Ideally, a scale for the visual assessment of the single leg squat must be easy to apply and demonstrate adequate psychometric properties. The clinical value of such scale, indicated by the association of the scale score with patient reported outcomes and/or the capacity of the scale to discriminate individuals in different clinical states would also need to be confirmed. These associations and the discriminative performance should preferably be stronger or at least equivalent to the results obtained through currently used instruments. For quantitative analyses, 2D hip angle adduction seems to be the most used kinematic outcome to assess individuals with hip pain (CHARLTON et al., 2016; HARRIS-HAYES et al., 2018, 2020a; MALLOY et al., 2019), and understanding how a qualitative scale performs in comparison to this parameter could potentially affect how clinicians evaluate this movement. The development of a scale for the visual assessment of the single leg squat in individuals with FAI syndrome may optimize the assessment and better inform clinical decisions in the treatment of FAI syndrome.

Individuals with FAI syndrome treated with hip arthroscopy are commonly discharged from rehabilitation 4 months after surgery (CONNOR et al., 2020; KEMP et al., 2012) but not all of them reach an acceptable symptomatic state, with some presenting with persisted pain and impaired function (ISHØI et al., 2021). The significance of assessing movement pattern at this stage after surgery is not clear in the literature but it is possible that persisted symptoms are accompanied with alterations in the single leg squat movement pattern. Identifying the specific movement pattern of these patients and whether this movement pattern is associated or not to variables of clinical importance is needed to elucidate the utility of the visual assessment of the

single leg squat movement in patients with FAI at the discharge stage of rehabilitation after hip arthroscopic surgery.

1.1 OBJECTIVES

1.1.1 General objective

Develop and test a scale for the visual assessment of the single leg squat in individuals with FAI syndrome.

1.1.2 Specific objectives

- Construct a conceptual framework for the visual assessment of the single leg squat in individuals with FAI syndrome;
- Assess the internal consistency of the developed instrument;
- Investigate the inter-rater and intra-rater reliability of the developed instrument when assessing patients with FAI syndrome treated with hip arthroscopy;
- Explore the correlation between the score of the developed instrument and hip related quality of life and function in patients with FAI syndrome treated with hip arthroscopy;
- Explore the correlation between hip adduction range of motion angle and hip related quality of life and function in patients with FAI syndrome treated with hip arthroscopy;
- Investigate the capacity of the developed instrument to discriminate asymptomatic individuals with no history of FAI syndrome from patients with FAI syndrome treated with hip arthroscopy;
- Investigate the capacity of the hip adduction range of motion angle in the single leg squat to discriminate asymptomatic individuals with no history of FAI syndrome from patients with FAI syndrome treated with hip arthroscopy;
- Investigate the capacity of the developed instrument to discriminate patients with FAI syndrome that do not reach an acceptable symptomatic state 4 months after hip arthroscopy;
- Investigate the capacity of the hip adduction range of motion angle in single leg squat to discriminate patients with FAI syndrome that do not reach an acceptable symptomatic state 4 months after hip arthroscopy.

PROJECT STRUCTURE

This Master's thesis was developed according to the norms of the Graduate Program in Rehabilitation Sciences of the Federal University of Santa Catarina (Nº 04/PPGCR/2021 – UFSC). The thesis is structured according to the Scandinavian model (scientific study model). Its structure is divided into 7 chapters. The first and second chapter contemplated the general introduction and methods of the research, respectively. The chapters III, IV and V present the original scientific studies that are result from the specific aims of this research. At the end, final considerations (Chapter VI) regarding the studies are presented and a list of scientific contributions (Chapter VII) associated to this master's thesis is provided.

This research was conducted through collaborations among the Federal University of Santa Catarina (UFSC), Fisiolab Institute, University of the State of Santa Catarina (UDESC) and the Center of Orthopaedics and Rehabilitation (CORE). The research was approved by the ethical committee of the University of the State of Santa Catarina (CAAE: 96023618.0.0000.0118).

2.1 RESEARCH CHARACTERIZATION

The methods used in this research include the development, validation and testing of a new instrument of analysis and for that it includes theorical, empirical and analytical procedures aimed at analysing the conceptual framework supporting the instrument, the items' selection, and validity and reliability assessments (BOATENG et al., 2018; DAVIS et al., 1996; PASQUALI et al., 1998).

Three studies were developed in this project aiming to provide scientific evidence about the construct validity and measurement properties of a scale for the visual assessment of the movement pattern of patients with FAI syndrome. The studies are entitled:

I. "A systematic review on convergent and discriminative validity of visual methods for the assessment of single leg squats";
II. "Development and reliability of the single leg movement pattern scale for individuals with femoroacetabular impingement (SimpliFAI)";
III. "Is it time to simplify? Quality of life and symptomatic state are correlated to *SimpliFAI* scores after hip arthroscopy to treat FAI syndrome".

A flowchart was created for better understanding of the specific studies objectives and its relationship with the research main objective.

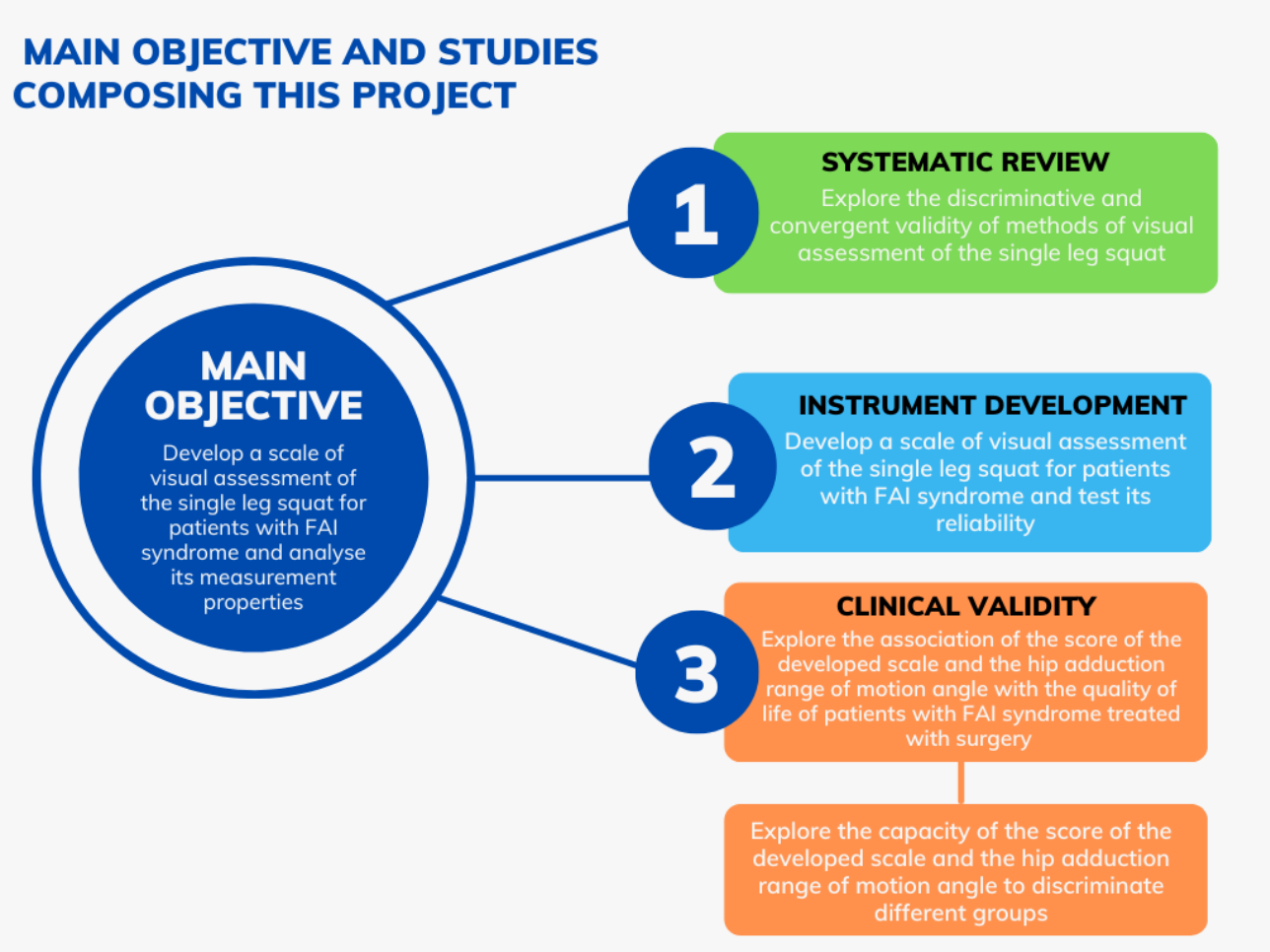

Figure 1 – Flowchart with research main objective and studies composing this project.

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CHAPTER II

STUDY I – A SYSTEMATIC REVIEW ON CONVERGENT AND DISCRIMINATIVE VALIDITY OF VISUAL METHODS FOR THE ASSESSMENT OF SINGLE LEG SQUATS

ABSTRACT

Background: Visual assessments of the single leg squat are widely used in clinical practice and have shown to be reliable. However, the construct of such instruments that support their utility in clinical practice is not clear. The aim of this study was to systematically review the literature on the convergent and discriminative validity of visual methods for the assessment of the single leg squat in individuals with lower limb disorders or asymptomatic individuals. Methods: Systematic review conducted in accordance with the COSMIN guidelines. The following data sources were used for study selection: CINAHL, Cochrane, Embase, Pubmed, SPORTDiscus and Web of Science. Studies that (i) evaluated populations with musculoskeletal lower limb disorders or asymptomatic individuals, (ii) utilized visual methods for the assessment of movement pattern in the single leg squat, and (iii) analysed discriminative and/or convergent validity regarding primary and/or secondary outcomes, were included. Studies results were qualitative summarized to obtain an overall classification of the measurement properties validity of each method of visual assessment. Results: Ten studies were included involving three different methods of visual assessment of the single leg squat (Crossley scale, Whatman score, and Medial knee displacement method). All studies analysed discriminative validity. None of the studies analysed convergent validity. The quality of evidence of the analysed studies ranged between moderate and very low quality. The Crossley scale was the only method that presented sufficient discriminative validity regarding primary outcomes. All methods presented insufficient discriminative validity regarding secondary outcomes. Conclusion: Our findings indicate that current methods of visual assessment of the single leg squat present insufficient discriminative validity for secondary outcomes and groups. However, these methods might be valid to discriminate patient centred primary outcomes with current evidence supporting the use of the Crossley scale to discriminate non arthritic hip pain patients with different levels of pain and different levels of hip related quality of life. Results should be interpreted with caution due the very low quality of evidence from studies. The present systematic review underlines a paucity of good quality evidence supporting discriminative and convergent validity of visual methods of assessment of the single leg squat.

Keywords: Clinical assessment, Visual analysis, Single leg squat, Screening

RESUMO

Introdução: Avaliações visuais do agachamento unipodal são amplamente utilizadas na prática clínica. No entanto, a literatura apresenta uma escassez de evidências científicas sobre propriedades de medidas que suportam a utilidade desses métodos na prática clínica. O objetivo deste estudo foi realizar uma revisão sistemática sobre a validade discriminativa e convergente de métodos de avaliação visual do agachamento unipodal a respeito de desfechos primários e secundários. Métodos: Revisão sistemática conduzida de acordo com as diretrizes COSMIN. As seguintes bases de dados foram utilizadas para seleção de estudos: Cinahal, Cochrane, Embase, Pubmed, Sportdiscuss e Web Of Science. Estudos que avaliaram populações com disfunções musculoesqueléticas do membro inferior e/ou indivíduos assintomáticos, utilizaram avaliações visuais do padrão de movimento do agachamento unipodal, e analisaram validade discriminativa e/ou validade convergente a respeito de desfechos primários e secundários foram incluídos. Não foi possível realizar uma análise quantitativa de dados devido alta heterogeneidade entre estudos. Os resultados dos estudos foram resumidos de forma qualitativa para obtenção de uma classificação geral da validade das propriedades de medida de cada método de avaliação visual do agachamento unipodal. Resultados: Dez estudos foram incluídos

envolvendo três diferentes métodos de avaliação visual do agachamento unipodal (Escala Crossley, Pontuação Whatman, Metodo de deslocamento medial do joelho). Todos os estudos analisaram validade discriminative. Nenhum dos estudos analisou validade convergente. A qualidade de evidência dos estudos various entre moderada e muito baixa. A Escala Crossley, Pontuação Whatman e o Metodo de deslocamento medial do joelho apresentaram validade discriminativa insuficiente em relação a desfechos secundários. A escala Crossley foi o único método que apresentou validade discriminativa suficiente em relação a desfechos primários. Conclusão: Nossos achados indicam que os presentes métodos de avaliação visual do agachamento unipodal apresentam validade discriminativa insuficiente para desfechos secundários mas podem ser válidos para discriminar desfechos primários com evidências suportando o uso da Escala Crossley para discriminar pacientes com dor não relacionada a artrose com diferentes níveis de dor e qualidade de vida. Entretanto, esses resultados devem ser interpretados com cautela devido ao nível de evidência muito baixo dos estudos. A presente revisão sistemática ressalta a escassez de evidências de boa qualidade metodológica suportando a validade discriminativa e convergente de métodos de avaliação visual do agachamento unipodal.

Palavras-chaves: Avaliação clínica, Análise visual, Agachamento unipodal, Triagem

1. INTRODUCTION

Visual assessment of movement is widely implemented in the clinical setting and in injury prevention (RESSMAN et al., 2019). Its use is generally justified on the need to screen for movement pattern features that are associated to the origin or aggravation of a disfunction (MØRTVEDT et al., 2020). The output of such analyses has been used to offer insight on the patient's physical capacities, assisting on the development of rehabilitation and training programs that are focused on the specific deficits presented (WARNER et al., 2019). Advantages of such visual scales over outcomes obtained through quantitative kinematic systems include the reduced financial and time investments required (LOPES et al., 2018). On the other hand, a common weakness among available qualitative scales is the current lack of information regarding their measurement properties (RESSMAN et al., 2019).

The COnsensus-Based Standards for the selection of health Measurements INstruments (COSMIN) initiative created a consensus statement on definitions of measurement properties such as reliability, validity, and responsiveness (MOKKINK et al., 2018). Ideally, instruments should be reliable, reflect a clear construct and have a satisfactory performance when used in clinical research for hypothesis-testing (TERWEE et al., 2007). Among the properties that can define an instrument performance, the discriminative and convergent validity are those that can define the clinical utility of a scale (MOKKINK et al., 2018). The convergent validity can inform on the association between the output of the scale and another outcome that measures a

similar/related construct (MOKKINK et al., 2018). For example, the association between movement pattern and quality of life (primary outcome) or movement pattern and muscle strength (secondary outcome). The discriminative validity of a tool can inform on its ability to discriminate groups with different health or injury risk status (MOKKINK et al., 2018). For example, how valid a tool is in identifying individuals with different levels of pain or individuals that are more likely to experience injury.

There has been a large body of the literature aimed at confirming the concurrent validity of visual scales against objective quantitative parameters derived from video-based kinematic assessments, with often satisfactory results with regards to angular excursions (RESSMAN et al., 2019). These results, in conjunction with the confirmation of inter-rater and intra-rater reliability of such scales (RESSMAN et al., 2021) have encouraged their use in clinical practice and injury prevention screening programs and, among the tasks evaluated in the clinical and sports medicine context, the single leg squat is arguably the one that has received the greatest attention (MACLACHLAN et al., 2015).

The single leg squat indeed presents some unique characteristics that support its use in movement screening. Functional balance and movement patterns such as excessive hip adduction, pelvic drop, knee abduction, foot pronation can be screened during the single leg squat performance (RESSMAN et al., 2019). These movement patterns were previously associated with different lower limb disorders, such as patellofemoral pain, FAI syndrome, anterior cruciate ligament injury, tibial stress fractures and iliotibial pain (ADEREM et al., 2015; BOTHA et al., 2014; MILNER et al., 2010; XIE et al., 2023). There are in the literature at least 2 scales that have been developed to assess the movement pattern during the single leg squat (CROSSLEY et al., 2011; WHATMAN et al., 2012) and these are considered a cost-effective alternative to more complex kinematic analyses of this task (RESSMAN et al., 2019).

A recent systematic review and meta-analysis has shown that the currently available methods for the visual assessment of the single leg squat are reliable and a feasible alternative for the assessment of patients with lower limb disorders and asymptomatic individuals (RESSMAN et al ., 2019). However, while the available visual scales seem to be reliable, their clinical utility as based on the measurement properties defined by the COSMIN guidelines is not clear. Information with regards to how the results from a visual assessment of the single leg squat could help in the management of lower limb injuries and rehabilitation are controversial (BAHR, 2016; CROSSLEY et al., 2011; WHATMAN et al., 2021).

For these scales to be considered useful in clinical practice, the score outcome should offer relevant insights that directly impact the patient well-being (patient centered primary

outcomes) or parameters that may assist on the decision-making process in rehabilitation programs (secondary outcomes). Understanding how clinical outcomes or physical function status relate to the scores of these scales is fundamental to build their construct validity and, in this context, the distinction between primary and secondary outcomes can better define the usefulness of such scales. In this systematic review we aimed to answer the following question: Do methods of visual assessment of the single leg squat present discriminative and/or convergent validity regarding primary and secondary outcomes? In order to answer that question we used the COSMIN guidelines to perform a systematic review able to provide a comprehensive overview and evidence-based recommendations regarding the previously cited measurement properties (MOKKINK et al., 2018).

2. METHODS

The current systematic review was conducted in accordance with the COSMIN guidelines (MOKKINK et al., 2018). The study protocol was registered on the international prospective register of systematic reviews – PROSPERO (ID: CRD42022320876).

2.1 Eligibility criteria

Studies were eligible for inclusion when meeting the following criteria:

1. Population: Individuals with musculoskeletal lower limb disorders and/or asymptomatic individuals. Studies including individuals with neurological impairments and/or amputee individuals were excluded.

2. Construct: The test was a measure of movement pattern of the single leg squat defined as "functions associated with control over and coordination of complex voluntary movements" based on the International Classification of Functioning, Disability and Health (ICF) body function domain (BRANCHE, 2008).

3. Instrument: The instrument was a scale or test that visually assess the quality of movement of the single leg squat. Studies using quantitative methods (i.e., 2D and 3D kinematic analysis) to assess the single leg squat were excluded.

4. Measurement property: the study reported discriminative/known-groups validity (capacity of the visual assessment of the single leg squat score to discriminate groups regarding primary and secondary outcomes and groups with different characteristics) and/or the study reported convergent validity (association between the visual assessment outcome with primary and secondary outcomes).

We considered primary outcomes as clinical important outcomes that directly measure how patients feels (patient-centred) (MCLEOD et al., 2019) such as Patient Reported Outcomes Scores, symptomatic state and success of treatment. Secondary outcomes were considered as outcomes that are not patient-centred, but could be associated with primary outcomes, such as muscle strength, muscle activity and range of motion (MCLEOD et al., 2019). Studies were excluded if they were not available in full-text and published in languages other than English.

2.2 Study selection and data extraction

Appropriate truncation and word combinations were elaborated and adapted for the following electronic databases: CINAHL, COCHRANE, EMBASE, PUBMED, SPORTDISCUS AND WEB OF SCIENCE. Exclusion filters were used to exclude randomised controlled trials, systematic reviews, and conference abstracts. The reference lists of included studies were manually searched by two authors (DG and GVC), independently. Identified publications were imported to Mendeley software (Mendeley 2.30.0, Elsevier, London, United Kingdom) for management and removal of duplicates. All electronic databases were searched from the starting coverage date through September 10, 2022. Search strategies are available in Appendix 1

Two authors (DG and GVC) independently screened titles and abstracts using the Rayyan application (OUZZANI et al., 2016). Full texts were reviewed for eligibility. A senior author (HDBF) was consulted as needed to resolve disagreements by consensus. Data extraction was performed by two authors (DG and GVC) independently using a data extraction form. The following data items were extracted: (1) Sample characteristics, (2) Method of visual assessment, (3) Type of validity (convergent or discriminative), (4) statistical methods used, and (5) results on measurement properties.

2.3 Risk of bias assessment

Two authors (DG and GVC) independently assessed the methodological quality of studies using the Box 9 (Hypothesis testing for construct validity) of the COSMIN risk of bias checklist (MOKKINK et al., 2018). Studies evaluating discriminative and/or convergent validity were rated on a 4-point scale (very good, adequate, doubtful, and inadequate) based on standards specified to each measurement property. Overall rating was determined based on the "worst score counts" rule (MOKKINK et al., 2018).

2.4 Data synthesis and analysis

Generic hypotheses were developed by the research team and used to synthesize and analyse the data as suggested by the COSMIN initiative. Hypotheses were based on previous evidence from the literature, suggestions by the COSMIN initiative and experience from the review team (MOKKINK et al., 2018). The results of each study was contrasted to the generic hypotheses and then results were classified as either sufficient (+), indeterminate (?) or insufficient (-) (according to the effect/evidence for discriminative and convergent validity) (MOKKINK et al., 2018). Sufficient results were confirmed if the results from the study was in accordance with the generic hypotheses. Indeterminate results were confirmed if no hypothesis was developed by the research team. Insufficient results were confirmed if the results from the study were not in accordance with the developed hypothesis.

Regarding the generic hypotheses developed for convergent validity, we expected correlations > 0.50 between visual assessments scores and secondary outcomes and > 0.40 between visual assessments scores and primary outcomes. The direction of correlations between the score of a visual assessment and primary and secondary outcomes is expected to follow a rationale where better movement quality is associated with better primary and secondary outcomes. For example, if higher scores of a visual assessment indicate better movement quality, it is expected a positive correlation between the score of visual assessment and muscle strength and a negative correlation between the score of visual assessment and pain. Therefore, a sufficient result was confirmed if the outcomes analysed by the visual assessment method presented a correlation > 0.50 (secondary outcome) or > 0.40 (primary outcome) with a direction following the previously described rationale. For this analysis, only studies documenting Pearson or Spearman correlation coefficients were included.

For discriminative validity, we expected a standardized mean difference (SMD) > 0.5 of primary outcomes between groups and a SMD > 0.8 of secondary outcomes between groups. Lower values of correlation and SMD for primary outcomes compared to secondary outcomes were adopted since primary outcomes are commonly multifactorial and can be influenced by several aspects. The direction of differences between groups is expected to follow a rationale where (i) a group classified with better movement quality will present better primary and secondary outcomes compared to a group classified with worse movement quality or (ii) a group with a lower limb dysfunction will present worse movement quality compared to an asymptomatic group. For example, if groups are divided into good and poor movement quality, it is expected that the group with good movement quality presents higher values of muscle strength and lower values of pain. If the visual assessment of the single leg squat was used to

compare the movement pattern between a group with knee pain and an asymptomatic group it is expected that the group with no symptoms present better movement quality. Therefore, a sufficient result was confirmed if the group comparison presented a SMD > 0.5 (primary outcomes) or > 0.8 (secondary outcomes) where the difference between groups followed the previously described rationale. The SMD for secondary outcomes was used for studies that compared the difference between the score of a method of visual assessment between groups with different characteristics. Studies with insufficient data that did not allow for the calculation of SMD were not considered in the analysis.

When homogeneity across studies allowed, the results of the hypothesis testing for a given outcome were quantitatively pooled to obtain an overall classification of the measurement properties validity of each method of visual assessment (MOKKINK et al., 2018). If quantitative pooling was not possible, the results were qualitative summarized to obtain an overall classification of the measurement properties validity of each method of visual assessment using the following criteria: For the evidence of validity to be rated sufficient (+) or insufficient (-), 75% of the summarized generic hypotheses tested had to be confirmed or rejected, respectively (MOKKINK et al., 2018). If this threshold was not met, the evidence was considered inconsistent (±). If the pooled results were all indeterminate, the overall evidence of validity was also considered indeterminate (?). In case of inconsistent results, subgroups based on comparable characteristics (methods of visual assessment and primary and secondary outcomes measuring similar constructs) were categorized.

2.5 Grading the quality of evidence

Evidence quality was graded for each method of visual assessment. The modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used to grade the quality of evidence as high, moderate, low or very low (MOKKINK et al., 2018). Four factors were used to grade the quality of evidence: (1) risk of bias (methodological quality assessed by the COSMIN risk of bias checklist), (2) inconsistency (unexplained inconsistency of results), (3) imprecision (total sample size of available studies) and (4) indirectness (evidence from different populations). Publication bias was not assessed. When concerns regarding one of the four factors were found the quality of evidence was downgraded. No grading was given in case the overall evidence was indeterminate or inconsistent without explanation for inconsistency.

3. RESULTS

3.1 Study selection

The searches resulted in 738 studies (Figure 1). After removal of duplicates, 340 studies were identified and screened for eligibility, resulting in 36 studies selected for full-text reading. Finally, we included 10 studies.

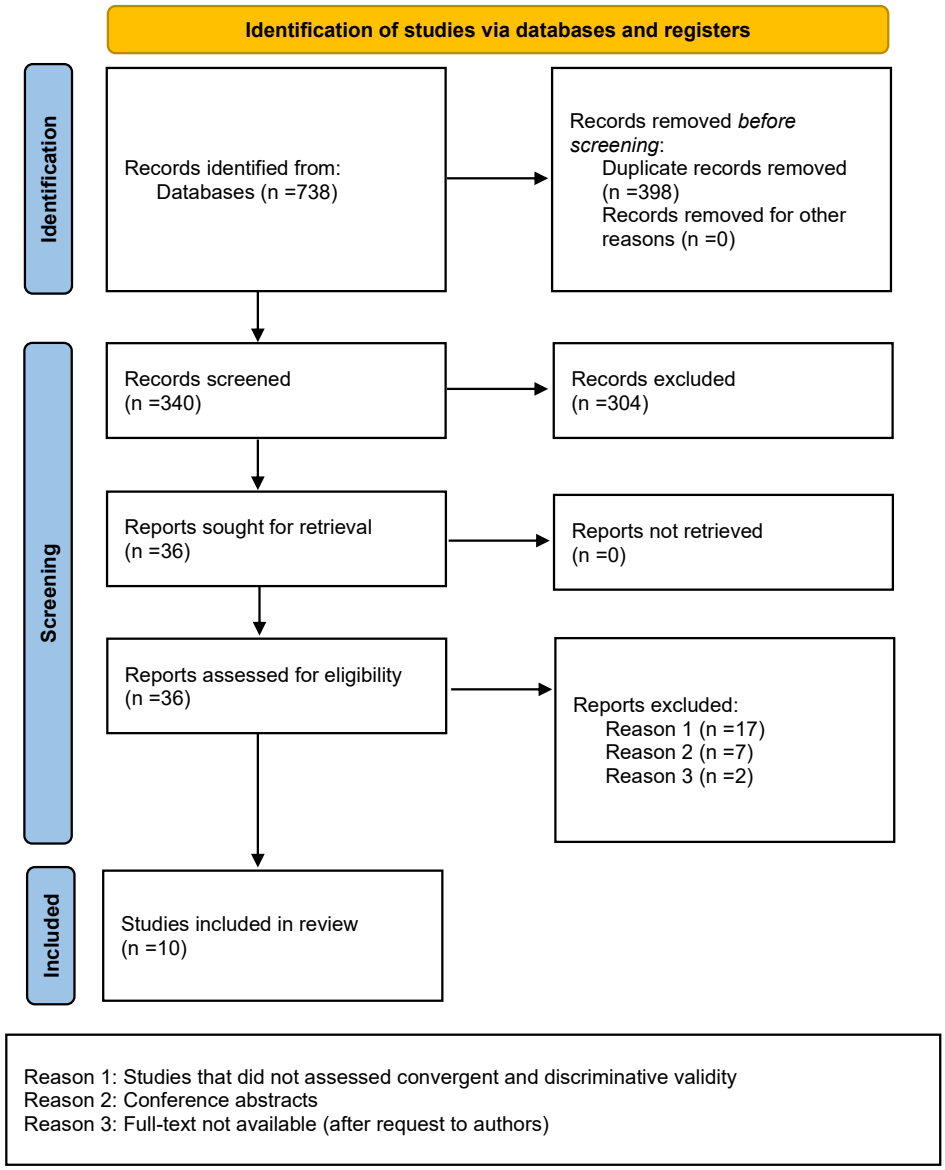

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart diagram of study selection.

3.2 Included studies

All ten studies addressed the discriminative validity of single leg squat visual assessment methods. There were no studies analysing convergent validity for the visual assessment of the single leg squat. Characteristics of the included studies are presented in table 1.

3.3 Methods of visual assessment

3.3.1 Crossley scale

Five studies used the scale of visual assessment of the single leg squat developed by Crossley and colleagues (CROSSLEY et al., 2011; GIANOLA et al., 2017; HALL et al., 2015; HOLLMAN et al., 2014; MCGOVERN et al., 2019). The original scale contain five criteria regarding overall impression, posture of the trunk over the pelvis, posture of the pelvis, hip posture and movement and knee posture and movement (CROSSLEY et al., 2011). Based on these criteria the quality of movement of the single leg squat was rated as poor, fair or good. To be considered good, the participant needed to achieve all the requirements for four of the five criteria for all five consecutive trials of the single leg squat. Performance was considered poor when the participant did not meet all the requirements for at least 1 criterion for all trials. Those participants that could not be rated as poor or good were rated as fair.

3.3.2 Medial knee displacement

Three studies (CARROLL et al., 2021; MAUNTEL et al., 2013; WEBB et al., 2021) used the visual assessment of medial knee displacement to assess the movement quality during the single leg squat. The method is basically characterized by classifying participants into a good or bad movement pattern groups if their patella deviated medially to second toe ≥3 times during the single leg squat.

3.3.3 Whatman score

Two studies used the Whatman score to visually assess the single leg squat movement quality (BARTHOLOMEW et al., 2019; WHATMAN; et al., 2021). The Whatman score is a seven-item checklist to rank lower extremity functional tests based on lower limb positioning and balance, with high scores indicating poor functional ability. Each item can be rated as no segment oscillation (0 points) or yes for segment oscillation with minor (1 point), moderate (2 points) or marked severity (3 points).

Variations were found across studies that use the same method of visual assessment of the single leg squat with regards to the number of repetitions and depth of the squat and final scoring.

Table 1. Characteristics of included studies

Author, year	Method of visual assessment	Population	Type of validity	Outcome	Sample	Age ±SD	Study design
Bartholomew, 2019	Whatman score	PFP, PFJOA and asymptomatic	Discriminative	Groups (individuals with PFP vs asymptomatic and individuals with PFJOA vs asymptomatic)	82	n/a*	Cross-sectional
Crossley, 2011	Crossley scale	Asymptomatic	Discriminative	Hip EMG onset timing, hip muscle strength, trunk resistance	21	24±5	Cross-sectional
Whatman, 2021	Whatman score	Individuals with and without history of knee articular injury	Discriminative	Groups (individuals with knee articular injury vs individuals without knee articular injury)	115	n/a*	Cross-sectional
Carrol, 2021	MKD	Healthy active individuals	Discriminative	Foot posture, ankle ROM	65	25±5	Cross-sectional
Webb, 2021	MKD	Elite figure skaters	Discriminative	Groups (male vs female)	40	23±4	Cross-sectional
Gianola, 2017	Crossley scale	Physically active and non-physically active individuals	Discriminative	Groups (Physically active vs non-physically active)	70	25±2	Cross-sectional
Hall, 2015	Crossley scale	Patients after ACLR	Discriminative	IKDC, hop distance, hip muscle strength	33	28±?	Cross-sectional
Mauntel, 2013	MKD	Physically active individuals	Discriminative	Hip EMG, hip EMG coactivation, hip ROM	40	n/a*	Cross-sectional
Hollman, 2014	Crossley scale	Physically active woman	Discriminative	Hip EMG, hip muscle strength	41	n/a*	Cross-sectional
McGovern, 2019	Crossley scale	Patients with nonarthritic hip pain	Discriminative	HOS, hip ROM	45	28±10	Cross-sectional

SD: standard deviation, PFP: patellofemoral pain, PFJOA:Patellofemoral joint osteoarthritis, EMG: electromyography, MKD: medial knee displacement, ROM: range of motion, ACLR: anterior cruciate ligament reconstruction, IKDC: International Knee Documentation Committee, HOS: Hip Outcome Score. * Mean age (SD) not available for total sample.

3.4 Analysed outcomes and generic hypotheses tested

3.4.1 Groups

Four studies used methods of visual assessment of the single leg squat to discriminate pre-defined groups with different characteristics. Bartholomew (2019) analysed three different groups, patients with patellofemoral pain, patients with patellofemoral joint osteoarthritis and asymptomatic individuals. Whatman (2021) analysed a group of patients with a history of intra-articular knee injury and a group with no history of intra-articular knee injury. Webb (2021) analysed female and male groups of elite figure skaters. Gianolla (2017) analysed physically active and non-physically active individuals. The following generic hypotheses emerged for group comparisons:

I) Asymptomatic individuals present better movement quality (SMD between group scores >0.8) compared to patients with patellofemoral pain and patients with patellofemoral joint osteoarthritis. Patients with patellofemoral pain present better movement quality compared to patients with patellofemoral joint osteoarthritis (SMD between group scores >0.8).

II) Patients with no history of intra-articular knee injury present better movement pattern (SMD between group scores >0.8) compared to patients with history of intra-articular knee injury.

III) Male elite figure skaters present better movement quality (SMD between group scores >0.8) when compared to female elite figure skaters.

IV) Physically active individuals present better movement quality (SMD between group scores >0.8) compared to non-physically active individuals.

3.4.2 Electromyography

Three studies analysed electromyography (EMG) outcomes. Crossley (2011) analysed the anterior gluteus medius and posterior gluteus medius onset timing EMG activity (defined as the point at which EMG activity increased above the baseline activity) during the single leg squat. Mauntel (2013) analysed the mean EMG amplitude of the gluteus maximus, gluteus medius, hip adductors, medial hamstrings, biceps femoris, vastus medialis, vastus lateralis and medial gastrocnemius during the single leg squat. Hollman (2014) analysed gluteus maximus

and gluteus medius EMG activation during the single leg squat. The following hypotheses were developed for EMG related outcomes:

V) Patients classified as having a good movement quality present faster onset timing regarding EMG activity (SMD between groups >0.8) when compared to patients classified with a poor movement quality.

VI) Patients classified as having a good movement quality present higher EMG amplitude (SMD between groups >0.8) when compared to patients classified with a poor movement quality.

VII) Patients classified as having a good movement quality present higher EMG activation (SMD between groups >0.8) when compared to patients classified with a poor movement quality.

3.4.3 Hip muscle strength

Three studies analysed hip muscle strength outcomes, all of them using hand-held dynamometry. Crossley (2011) analysed hip external rotation and abduction strength, Hall (2015) analysed hip abduction muscle strength, and Hollman (2014) analysed hip abduction and extension muscle strength. The following hypothesis was developed for hip muscle strength:

VIII) Patients classified as having a good movement quality present higher values of muscle strength for all muscle groups (SMD between groups >0.8) when compared to patients classified with a poor movement quality.

3.4.4 Range of motion

Three studies analysed range of motion outcomes. Carrol (2021) analysed non weight bearing and weight bearing ankle dorsiflexion range of motion using a goniometer. Mauntel (2013) analysed passive range of motion for the hip external rotators, hip internal rotators, hamstrings, iliotibial band, iliopsoas and femoral anteversion using a digital inclinometer. Mcgovern (2019) analysed hip internal rotation range of motion (method of assessment not described). The following hypothesis was developed for range of motion:

IX) Patients classified as having a good movement quality present higher values of range of motion for all directions (SMD between groups >0.8) when compared to patients classified with a poor movement quality.

3.4.5 Patient reported outcomes

Two studies analysed patient reported outcomes. Hall (2015) analysed knee self-reported function and symptoms through the International Knee Documentation Committee (IKDC). McGovern (2019) analysed hip related self-reported function and quality of life through the Hip Outcomes Score (HOS). The following hypotheses were developed for patient-reported outcomes:

X) Patients that underwent ACLR classified as having a good movement pattern present higher values on the IKDC (SMD between groups >0.5) when compared to patients that underwent ACLR classified as having a poor movement pattern.

XI) Patients with non-arthritic hip pain classified as having good movement pattern will present higher values in the HOS when (SMD between groups >0.5) compared to patients with non-arthritic hip pain classified as having poor movement pattern.

Four studies analysed outcomes that could not be grouped. Carrol (2021) analysed the foot posture using the Foot Posture Index (FPI-6). We hypothesized that individuals classified with a good movement pattern present higher values on the FPI-6 (SMD between groups >0.5) compared to individuals classified with a poor movement pattern. Crossley (2011) analysed trunk resistance measured by the trunk side flexion strength test. We hypothesized that individuals classified with a good movement pattern present higher values on the trunk side flexion strength test (SMD between groups >0.5) compared to individuals classified with a poor movement pattern. Hall (2015) analysed single leg function measured by the single leg forward hop for maximum distance test. We hypothesized that individuals classified with a good movement pattern present greater distance in the single leg forward hop for maximum distance test (SMD between groups >0.5) compared to patients classified with a poor movement pattern.

3.5 Data synthesis

COSMIN risk of bias assessment and hypothesis testing for each study are presented in Table 2. Summarized results through qualitative synthesis are presented in table 3. It was not possible to summarize the results of the study from Hall (2015) due to insufficient data. Therefore, this study was not included in the analysis.

Table 2. COSMIN risk of bias assessment and hypothesis testing of included studies

Author, year	Method	COSMIN Risk of bias	Results
Crossley, 2011	Crossley scale	Doubtful	Hypotheses confirmed for anterior gluteus medius onset timing (+), hip abduction torque (+), trunk side resistance (+). Hypotheses not

			confirmed for hip external rotation torque (-) and posterior gluteus medius onset timing (-)
Hollman, 2014	Crossley scale	Doubtful	Hypotheses not confirmed for hip abduction strength (-), hip extension strength (-), EMG activation gluteus maximus (-) and EMG activation gluteus medius (-)
McGovern, 2019	Crossley scale	Doubtful	Hypothesis not confirmed for hip internal rotation range of motion (-)
McGovern, 2019	Crossley scale	Doubtful	Hypotheses confirmed for visual analog scale of pain (+), HOS daily living subscale (+), and HOS sport related subscale (+)
Gianola, 2017	Crossley scale	Doubtful	Hypothesis not confirmed for different groups – no difference between physically active and non-physically active groups (-)
Carrol, 2021	MKD	Doubtful	Hypotheses not confirmed for foot posture index (-), non-weightbearing knee flexed dorsiflexion (-), non-weightbearing knee extended dorsiflexion (-), and weightbearing dorsiflexion (-)
Mauntel, 2013	MKD	Very good	Hypotheses not confirmed for EMG activation of gluteus maximus (-), gluteus medius (-), hip adductors (-), hamstrings (-), quadriceps (-) medial gastrocnemius (-), biceps femoris (-), vastus medialis (-), vastus lateralis (-) and for passive range of motion of the hip external rotators (-), hip internal rotators (-), iliotibial band (-), hip adductors (-), iliopsoas (-), femoral anteversion (-), hamstrings (-), dorsiflexion flexed (-) and dorsiflexion straight (-). Hypothesis confirmed for talar glide (+)
Webb, 2021	MKD	Doubtful	Hypotheses not confirmed for different groups – no difference between elite men figure skaters and elite women figure skaters for both right (-) and left leg (-)
Bartholomew, 2019	Whatman score	Doubtful	Hypotheses not confirmed for different groups – no difference between asymptomatic individuals and patients with PFP (-) and no difference between asymptomatic individuals and patients with PFJOA (-)
Whatman, 2021	Whatman score	Adequate	Hypotheses not confirmed for different groups – no difference between asymptomatic individuals and patients with history of intra-articular knee injury for apparent knee valgus (-), mediolateral oscilation (-), patella medial to the first toe (-), patella medial to the second toe (-) and pelvic position (-)

(+) and (-) signs indicates that the study results are in line or not in line, respectively, with the hypothesis previously defined by the research team. PFP: Patellofemoral pain, PFJOA: Patellofemoral joint osteoarthritis, HOS: Hip outcome score, EMG: Electromyography.

3.5.1 Discriminative validity for secondary outcomes

The Crossley scale (based on three studies) and MKD method (based on two studies) presented insufficient rating regarding discriminative validity for secondary outcomes. The quality of evidence for these summarized results was very low for the Crossley scale and moderate for the MKD method.

3.5.2 Discriminative validity for primary outcomes

Based on one study, the Crossley scale showed sufficient rating regarding the discriminative validity for primary outcomes. The quality of evidence was very low.

3.5.3 Discriminative validity for groups

The Crossley scale (based on one study), MKD method (based on one study) and Whatman score (based on two studies) presented insufficient rating regarding discriminative validity for groups. The quality of evidence for these summarized results was very low for the Crossley scale and MKD method, and moderate for the Whatman score.

Table 3. Summarized results and quality of evidence for method of visual assessment

Method of visual assessment	Type of validity	Summary result	Overall rating	Quality of evidence
Crossley scale	Discriminative validity for secondary outcomes	3 hypotheses confirmed (+) and 9 hypotheses not confirmed	Insufficient	Very low
	Discriminative validity for primary outcomes	3 hypotheses confirmed (+)	Sufficient*	Very low
	Discriminative validity for groups	1 hypothesis not confirmed (-)	Insufficient*	Very low
MKD	Discriminative validity for secondary outcomes	1 hypothesis confirmed (+) and 22 hypotheses not confirmed (-)	Insufficient	Moderate
	Discriminative validity for primary outcomes	Not tested in the literature	-	-

	Discriminative validity for groups	2 hypotheses not confirmed (-)	Insufficient*	Very low
Whatman score	Discriminative validity for secondary outcomes	Not tested in the literature		
	Discriminative validity for groups	6 hypotheses not confirmed (-)	Insufficient	Moderate
	Discriminative validity for primary outcomes	Not tested in the literature		

Summarized results were rated as sufficient (or insufficient) if 75% of results were sufficient (or insufficient). If less than 75% of the results were sufficient or insufficient, the results were considered inconsistent. * Indicates that the overall rating was based on one study.

4. DISCUSSION

This is the first study to summarize the discriminative and convergent validity of visual methods for the assessment of the single leg squat with regards to primary and secondary outcomes in individuals with musculoskeletal lower limb disorders and in asymptomatic individuals. Three different methods of visual assessment of the single leg squat were found in the literature and analysed according to the COSMIN guidelines. Our findings showed that the discriminative validity of visual methods for the assessment of the single leg squat is insufficient, especially with regards to its capability to discriminate groups or secondary outcomes. However, the Crossley scale showed sufficient discriminative validity for primary outcomes. Of concern, most studies analysed presented a very low quality of evidence.

The tools described in the literature for the visual assessment of the single leg squat (i.e. the Crossley scale, Whatman score, and the MKD method) were not developed according to the current best practices recommended regarding the creation of valid instruments (BOATENG et al., 2018; TERWEE et al., 2007, 2017). A clear construct, target population, and context of use seems to be missing, which may result in poor content validity and negatively impact the comprehensibility, relevance, and ability of the scale to include key concepts related to the construct investigated (TERWEE et al., 2017). An instrument with poor content validity is likely to not present utility in clinical practice (TERWEE et al., 2017).

The recommended procedures when using the scales to analyse the single leg squat are also not clear. Comparisons across studies and the and clinical validity of the instruments are

compromised by the lack of a standard procedure. A high heterogeneity across studies that used the same method is observed, with differences including the number of squat trials analysed, the rating criteria, and the control of confounding factors such as speed and depth of the squat. Also, while some studies recorded the movement and allowed the evaluator to watch the video multiple times some conducted real time analyses. These aspects are expected to influence how the targeted movement pattern features, such as dynamic balance and knee, hip and pelvic range of motion will present and be ranked (Bazett-Jones et al., 2022; Talarico et al., 2019). To ensure appropriate comparisons across studies and assure the validity of such measurements, a standardized assessment of the single leg squat with regards to speed, depth and number of repetitions during research and clinical practice is required.

The observed discriminative validity for primary outcomes of the Crossley scale is based on one study ranked with very low-quality of evidence (MCGOVERN et al., 2019). In this study, the Crossley scale was able to discriminate non arthritic hip pain patients with different levels of pain and different scores in the Hip Outcome Score: patients with a better movement pattern in the single leg squat presented less pain and better hip related quality of life. The main methodological issues that contributed to increased bias in this study were imprecision (sample size < 50 subjects) and inadequate description of subgroups characteristics. Future studies with adequate methodological quality should investigate if the Crossley scale is able to discriminate primary outcomes in individuals with hip pain.

None of the studies included in this systematic analysed the convergent validity of the visual methods. Without the convergent validity of such tools, their construct remains unclear. Understanding how the scores of movement pattern relate to the scores of other, related primary and secondary outcomes would helping to inform if these scales are meaningful for clinical practice (MOKKINK et al., 2018). Future studies should focus on exploring the convergent validity of visual methods of assessment of single leg squat, especially patient-reported outcomes, muscle strength, muscular activation, and articular range of motion which are outcomes of particular interest in the context of lower limb disorders.

Overall, we cannot confirm the clinical utility of the available methods of visual assessment of the single leg squat due to the lack of discriminative and convergent validity. Adequate inter and intra-rater reliability for these methods of visual assessment of the single leg squat has been confirmed (RESSMAN et al., 2019). However, to prove a method of assessment useful, not only it has to be reliable but also should have the ability to influence future interventions for the individual that is being assessed. Except for the study conducted by McGovern et al (2019) using the Crossley scale, methods of visual assessment of the single leg

squat analysed in this review did not present the capability to discriminate relevant groups or were associated to important outcomes for asymptomatic or injured individuals. Therefore, these methods can be used to screen the movement pattern of an individual, but it is unclear how they can help to guide decisions throughout rehabilitation or training.

This study has limitations. We wanted to adopt a broad approach, including different types of outcomes in our review, but given the small number of studies found, heterogeneity became substantial and limited the summarization of findings, with often only one study supporting a given hypothesis. The results of this review should be interpreted with caution given the absence of high-quality studies confirming the discriminative and convergent validity of visual methods for the assessment of the single leg squat. The generic hypotheses tested in this review were established by our research team and were developed according to the COSMIN guidelines recommendations. It is possible that different hypotheses would emerge if an independent team had been consulted, possibly influencing the present results and conclusions.

5. CONCLUSION

Our findings indicate that current methods of visual assessment of the single leg squat present insufficient discriminative validity for secondary outcomes and groups. However, these methods might be valid to discriminate patient-centred primary outcomes with current evidence supporting the use of the Crossley scale to discriminate non arthritic hip pain patients with different levels of pain and different levels hip related quality of life. The present systematic review underlines a paucity of evidence of good methodological quality supporting discriminative and convergent validity of visual methods of assessment of the single leg squat.

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CHAPTER III

STUDY II - DEVELOPMENT AND RELIABILITY OF THE SINGLE LEG MOVEMENT PATTERN SCALE FOR INDIVIDUALS WITH FEMOROACETABULAR IMPINGEMENT SYNDROME (SIMPLIFAI)

ABSTRACT

Background: Assessing the movement pattern of the single leg squat of patients with femoroacetabular impingement (FAI) syndrome is considered important in clinical practice. However, the kinematic assessment of the single leg squat of these patients require high financial and time investment, and/or are reduced to a single 2D variable at a specific frame of interest to minimize these costs, generally turning the use of these methods unfeasible in clinical practice. The aim of this study was to develop a scale to visually assess the single leg squat movement pattern of patients with FAI syndrome and test its measurement properties. Methods: This was an instrument development cross-sectional study. The construct, structure and reliability of the scale were developed based on theorical, analytical and empirical procedures that were assisted by the COSMIN guidelines. Data from 30 individuals with FAI syndrome treated with hip arthroscopy and 15 asymptomatic individuals was used for these procedures. Two physical therapists used the developed instrument to rate single leg squat videos from a group with patients with FAI syndrome treated with hip arthroscopy (FAI group, n=30) and a group of patients with FAI syndrome treated with hip arthroscopy and asymptomatic individuals (Mixed group, n=30). Inter and intra-rater reliability of the developed instrument was assessed using the intra-class correlation coefficient (ICC). Internal consistency of the developed instrument was assessed using the Cronbach alpha analysis. Results: The developed scale was entitled "SIngle leg squat Movement Pattern scaLe of Individuals with FemoroAcetabular Impingement syndrome" (*SimpliFAI*). The *SimpliFAI* scale demonstrated adequate content validity and internal consistency for the FAI (Cronbach alpha= 0.88) and mixed groups (Cronbach alpha= 0.81). Also, the SimpliFAI scale demonstrated good inter (ICC= 0.84) and intra-rater reliability (ICC=0.90) for the FAI group. For the mixed group the SimpliFAI scale presented moderate and good inter-rater (ICC= 0.68) and intra-rater (ICC= 0.79) reliability, respectively. Conclusion: SimpliFAI is the first scale for the visual assessment of the single leg squat developed specifically for patients with FAI syndrome, presenting adequate validity and reliability for the assessment of patients with FAI syndrome treated with surgery alone or when assessed together with asymptomatic individuals.

Keywords: Hip pain, Rehabilitation, Screening, Movement quality

RESUMO

Introdução: Avaliar o padrão de movimento do agachamento unipodal de pacientes com síndrome do impacto femoroacetabular (SIFA) é considerado importante na prática clínica, uma vez que existe a hipótese de que padrões específicos de movimento identificados durante essa tarefa podem contribuir para dor persistente no quadril e prejuízos funcionais. No entanto, os métodos atualmente disponíveis para avaliação do agachamento unipodal desses pacientes (análises cinemáticas tri e bidimensionais) requerem alto investimento financeiro e de tempo, geralmente inviabilizando o uso desses métodos na prática clínica. Portanto, o objetivo deste estudo foi desenvolver uma escala para avaliar visualmente o padrão de movimento do agachamento unipodal de pacientes com SIFA e testar suas propriedades de medida. Métodos: Este foi um estudo transversal de desenvolvimento de instrumento. O construto, a estrutura e a confiabilidade da escala foram desenvolvidos com base em procedimentos teóricos, analíticos e empíricos que foram auxiliados pelas diretrizes do COSMIN para o desenvolvimento de instrumentos com propriedades de medida adequadas. Dados de 30 indivíduos com SIFA tratados com artroscopia de quadril e 15 indivíduos assintomáticos foram usados para esses procedimentos. Dois fisioterapeutas usaram o instrumento desenvolvido para avaliar os vídeos de agachamento unipodal de um grupo de pacientes com SIFA tratados com artroscopia de

quadril (grupo SIFA, n=30) e de um grupo de pacientes com SIFA tratados com artroscopia de quadril e indivíduos assintomáticos (Grupo misto, n=30). A confiabilidade inter e intra-examinadores do instrumento desenvolvido foi avaliada por meio do coeficiente de correlação intraclasse (CCI). A consistência interna do instrumento desenvolvido foi avaliada por meio da análise alfa de Cronbach. Resultados: A escala desenvolvida foi intitulada Escala do padrão de movimento do agachamento unipodal de indivíduos com síndrome do impacto femoro acetabular (SimpliFAI). A escala SimpliFAI demonstrou adequada validade de conteúdo e consistência interna para os grupos SIFA (alfa de Cronbach= 0,88) e misto (alfa de Cronbach= 0,81). Além disso, a escala SimpliFAI demonstrou boa confiabilidade inter (ICC= 0,84) e intra-avaliador (ICC=0,90). Para o grupo misto, a escala SimpliFAI apresentou moderada e boa confiabilidade inter (ICC= 0,68) e intra-avaliador (ICC= 0,79), respectivamente. Conclusão: A SimpliFAI é a primeira escala para avaliação visual do agachamento unipodal desenvolvida especificamente para pacientes com SIFA, apresentando adequada validade e confiabilidade para avaliação de pacientes com SIFA tratados com cirurgia ou quando avaliados em conjunto com indivíduos assintomáticos.

Palavras-chaves: Dor no quadril, Reabilitação, Triagem, Qualidade de movimento

1. INTRODUCTION

Femoroacetabular impingement (FAI) syndrome is a hip dysfunction characterized by morphological alterations and the premature and symptomatic contact between the femur and acetabulum (GRIFFIN et al., 2016). This premature contact occurs with a combination of excessive hip flexion, adduction, and internal rotation and results in hip pain, chondrolabral injuries and limitations on the patient ability to complete functional tasks (DIAMOND et al., 2015; KEMP et al., 2020). FAI syndrome has detrimental effects on quality of life and is a risk factor for hip osteoarthritis, a major cause of disability worldwide (CROSS et al., 2014; KOWALCZUK et al., 2015).

Movement pattern alterations during dynamic tasks are commonly present in individuals with FAI syndrome and can persist even after hip arthroscopy (ALRASHDI et al., 2021; KING et al., 2018a; YARWOOD et al., 2022). It is hypothesized that hip adduction and internal rotation deviations during functional or athletic movements that require hip flexion can be prejudicial for patients with FAI syndrome, overloading hip structures and contributing to persistent hip pain and functional impairments (CANNON et al., 2020; CHARLTON et al., 2016). Interestingly, one to two years after arthroscopy surgery correcting the bone deformities, patients with FAI syndrome still present with greater hip adduction during the single leg squat test compared to asymptomatic individuals (CHARLTON et al., 2016).

The single leg squat test is frequently applied to assess individuals with FAI syndrome in research and clinical practice (CHEATHAM et al., 2018; MALLOY et al., 2021a; MALLOY et al., 2019). The test is characterized by squatting with one leg following a predefined number

of repetitions associated or not to a range of motion restriction (BAZETT-JONES et al., 2022). This task places intense demands on the hip and requires aspects commonly impaired in individuals with FAI syndrome for its performance, such as lower limb strength, coordination and balance (FREKE et al., 2018, 2016; GOMES et al., 2022; MALLOY et al., 2021; MALLOY et al., 2019). Also, the single leg squat was identified as a better test to discriminate biomechanical differences at the hip in individuals with FAI syndrome when compared to the double-leg squat (MALLOY et al., 2019).

Three-dimensional quantitative kinematic analyses are the gold standard in the assessment of movement and can provide reliable parameters in the evaluation of the single leg squat (NAKAGAWA et al., 2014; VAN DER STRAATEN et al., 2019). However, high financial and time investments are required to conduct such analyses, which might make them unfeasible in daily clinical practice (LOPES et al., 2018). In an attempt to overcome these limitations and include the assessment of movement patterns in clinical practice, 2D video recording with the quantitative analysis of one or two selected frames has been proposed as an reliable alternative to the full 3D movement analysis (HERRINGTON et al., 2017; SCHURR et al., 2017). However, the utility of this method for patients with FAI syndrome in clinical practice is still unclear, since parameters extracted from this kind of assessment are not associated to clinically important outcomes of patients treated with hip arthroscopy (CHARLTON et al., 2016). Also, we believe this approach – based on specific "photographs" extracted from selected frames – might leave important features of the movement pattern unnoticed.

Qualitative, visual assessments can be more comprehensive and may better reflect the construct around movement pattern in the context of FAI syndrome when compared to 2D kinematic assessments based on one or two frames. Indeed, previous studies have focused on subjective scales/methods to assess the single leg squat in clinical practice (BARTHOLOMEW et al., 2019; CARROLL et al., 2021; AGEBERG et al., 2014; CROSSLEY et al., 2011; GIANOLA et al., 2017; HALL et al., 2015; HOLLMAN et al., 2014; MCGOVERN et al., 2019; WEBB et al., 2021; WHATMAN et al., 2021). However, the scales used in these studies were not developed for the assessment of patients with FAI syndrome. Failing to identify a specific target population and to follow the current recommendations with regards to instrument validity can result in poor comprehensibility, lack of relevance, and on the exclusion of key concepts in the development of a new instrument (BOATENG et al., 2018; TERWEE et al., 2017). Most methods available for the visual assessment of the single leg squat fail to report a clear description of construct, target population, context of use, and requirements for data collection

(CARROLL et al., 2021; CROSSLEY et al., 2011; WHATMAN et al., 2012). These limitations harm the validity of these scales and, while some of them have been proved reliable, the construct and content validity are considered to be the most important measurement properties when selecting the most appropriate instrument in research and in clinical practice (MOKKINK et al., 2018).

In this study, we aimed to develop a scale for the visual assessment of the single leg squat and to assess its measurement properties. The development was focused on individuals with FAI syndrome and guided by the COSMIN recommendations (MOKKINK et al., 2018; TERWEE et al., 2017). Specifically, we identified the theorical ground, defined the construct and structure of a scale aimed at the analysis of movement pattern in individuals with FAI syndrome, and analysed the content validity and reliability of the newly developed instrument.

2. METHODS

2.1 Study design

An instrument development, cross-sectional study was jointly conducted by the Federal University of Santa Catarina, the University of the State of Santa Catarina, the Fisiolab Institute and the Core Centre of Orthopaedics and Rehabilitation (CORE). This study was approved by the local ethical committee with the protocol number of CAAE 96023618.0.0000.0118 (Brazil). All individuals provided written informed consent before participating in the study.

2.2 Participants

Patients with hip pain were recruited through the orthopaedic service of the CORE clinic and the Fisiolab Institute between January 2019 and December 2021. Patients had undergone hip arthroscopy and were assessed four months after surgery. Asymptomatic individuals aged between 18 and 60 years were also recruited. Detailed information about diagnosis, screening, surgical procedure and rehabilitation are presented in the Supplementary material (Appendix II) along with the inclusion criteria for participation in the study.

Fourty-five individuals with FAI syndrome treated with hip arthroscopy and 15 asymptomatic individuals participated in the study. In the development of the construct of the scale, data from 34 of the 45 participants was available and was used as input. In the remaining analysis of validity and reliability, all participants with FAI syndrome were included. To test the instrument reliability, participants were randomly grouped into a *FAI group*, which

comprised 30 participants that had been diagnosed with FAI syndrome and treated with hip arthroscopy, and a *mixed-group*, with the remaining 15 FAI syndrome participants treated with surgery and 15 asymptomatic individuals (n=30).

2.2.1 Participant-related data collection

In the clinical setting, the movement pattern of individuals with FAI syndrome was assessed through a video analysis of the single leg squat performance. The detailed description of the test and recording setup is presented as supplementary material (Appendix II). Hip related quality of life and function were assessed on the same day using the iHOT-33 questionnaire (MOHTADI et al., 2012) . Patients that underwent bilateral surgery had their most affected side (self-reported) analysed. Asymptomatic individuals were evaluated in a non-clinical setting using the exact same procedures to test and record the single leg squat. One video per subject containing three repetitions of the single leg squat was used for the analysis of the measurement properties of the developed scale.

2.3 Scale development procedures

The scale development included theorical, analytical and empirical procedures that were assisted by the COSMIN guidelines for the development of instruments with adequate measurement properties (MOKKINK et al., 2018; TERWEE et al., 2017). The steps used to develop the scale are outlined in the following subsections:

2.3.1 Scale construct: theorical ground and structure

The construct and structure of the scale were developed based on (1) a systematic review in the literature regarding the methods used for the visual assessment of the single leg squat (study I), (2) the current guidelines and literature regarding the screening of patients with FAI syndrome (CHARLTON et al., 2016; GRIFFIN et al., 2016; KEMP et al., 2020; KING et al., 2018; MALLOY et al., 2019; MALLOY et al., 2021; MCGOVERN et al., 2018) and (3) on the experience of the authors (D.G, M.P.C, G.V.C) at the Instituto Fisiolab, a physiotherapy service in Florianopolis, Brazil, specialized in the biomechanical assessment of individuals with hip pain.

The COSMIN methodology for systematic reviews of patient-reported outcomes (MOKKINK et al., 2018) was used to conduct the systematic review. We investigated the construct validity of the different methods of visual assessment of the single leg squat available in the literature until August of 2022. The structure of available scales for the visual assessment

of the single leg squat and their utility in clinical practice were carefully analysed by two investigators (D.G and G.V.C), gathering important information for the development of the scale.

To further assist the development of the scale and its structure, recorded videos of the single leg squat of patients with FAI syndrome four months after hip arthroscopy were analysed by D.G. to identify movement-related criteria that could potentially discriminate patients with different symptomatic states after surgery and potentially be integrated to the scale. Participants were split into two groups according to their symptomatic state based on the iHOT-33 questionnaire. Patients with a score ≥67 points were allocated to the acceptable symptomatic state group (n=21) while patients with a score <67 point were allocated to the non-acceptable symptomatic state group (n=13) (Ishøi et al., 2021). Based on the careful inspection of the videos D.G developed parameters that could potentially reflect movement related differences in the single leg squat between the acceptable and non-acceptable symptomatic state groups were identified and listed. These parameters were presented and discussed with H.D.B.F. and M.P.C. - two PhD researchers with approximately 10 years of experience in the field of musculoskeletal assessment and rehabilitation.

Based on the above procedures the construct was defined and a preliminary version of the scale was proposed. The first version of the scale presented 7 questions that aimed to assess movement quality of the single leg squat with a dichotomous response (yes or no). A dichotomous response for item scoring was used since scales used to visually assess the single leg squat with ≤3 points rating allow for more reliable results than scales that use ≥4 points rating (RESSMAN et al., 2019). The three first items/questions referred to the general movement quality and the remaining four to the control of specific body segments.

2.3.2 Scale content validity development

Content validity is the degree to which the content of an instrument is an adequate reflection of the construct to be measured (TERWEE et al., 2017). The following procedures were performed to develop the content validity and improve the relevance, comprehensiveness and comprehensibility of the scale:

2.3.2.1 Questionnaire application with hip specialist physiotherapists

An online questionnaire about the relevance, comprehensiveness and comprehensibility of the developed scale was created and answered by hip specialist physiotherapists. Thirteen specialists with a minimum of 5 years in the speciality were invited to participate and seven agreed to collaborate in this phase. Participants were recruited through social media. The

questionnaire was created in Google forms (Google, 2018) and sent via email. Along with the questionnaire the clinicians received a YouTube video (https://www.youtube.com/watch?v=HS6k6PQbHUU) developed by our research team. The video presented the developed scale and information about its objective, the materials and setup needed to apply the scale and the standardized procedures required for the single leg squat test. The physiotherapists were oriented to watch the video before filling the questionnaire. The questionnaire was composed by three multiple choice questions regarding the readability of the scale items, its application in clinical practice and its structure. After each question, an open field was provided for the physiotherapists to make suggestions. After the completion of the questionnaire, the physiotherapists sent their answers back to the responsible researcher via email for full consideration. The complete version of the questionnaire is available in the Supplementary material (Appendix III)

2.3.2.2 Focus group discussion

A focus group discussion was performed with five of the seven hip specialist physiotherapists that filled the questionnaire. The number of participants selected for the focus group was based on the number and comprehensiveness of questions, available time for discussion, physiotherapists experience, and objective of discussion as we aimed to preclude adequate participations by all members included (STALMEIJER et al., 2014; TANG et al.,, 1995; WONG L, 2008). Mean (standard deviation) time of experience rehabilitating patients with hip pain was 13 (8) years. Four physiotherapists identified themselves as male and one as female. The focus group discussion was performed through an online video meeting platform (Zoom Video Communications, 2011). The same researcher that analysed the online questionnaire answers planned and conducted the focus group discussion based on the questionnaire answers and suggestions. During the focus group participants were asked three main questions about the: (1) relevance and readability of the first three items of the scale, (2) relevance and readability of the four last items of the scale, (3) feasibility of application of the scale. The focus group discussion was recorded (with participants consent) and transcribed.

The video-recorded data was transcribed abridgedly and analysed by D.G. using Microsoft Word and Excel (Microsoft Corporation, 2018). Participants names were pseudonymized. The constant comparative method (BOEIJE, 2002; GLASER, 1965) was used to identify patterns and differences among participants responses. Responses were grouped in dimensions by their similarity and turn into categories. The transcript was revised for emerging ideas. All categories were compared and analysed aiming to identify possible commonalities

and differences in the responses that could contribute to the scale development. Preliminary findings were discussed with another researcher (H.B.F.). Illustrative quotes were extracted to preserve original meaning.

2.3.2.3 Scale presentation at the Brazilian Congress of Biomechanics

The first version of the developed scale was submitted to the Brazilian Congress of Biomechanics as a conference abstract entitled *"Development of the single leg squat movement pattern scale for individuals with femoroacetabular impingement syndrome (SimpliFAI)".* The conference abstract underwent a review process by the scientific committee and was accepted for oral presentation and elected as one of the five best abstracts in the Clinical Biomechanics section to be presented in the congress. Suggestions made after the presentation were considered for improvements in the developed scale. The conference abstract is available in the Supplementary material (Appendix IV)

2.2.3 Scale reliability assessment

Two physiotherapists (7 and 10 years of experience in musculoskeletal disorders) were recruited through social media to rate the single leg squat videos from the FAI (n=30) and mixed (n= 30) groups using the developed scale. The two physiotherapists did not participate in the scale development and did not receive any information about the scale that was not contained in the scale documentation.

Raters were sent an email containing an Excel sheet with the developed scale and documentation on how to use the scale and assess the single leg squat videos. The Excel sheet contained 30 tabs, with each tab consisting of a blank scale and a link to the single leg squat video of one of the participants. Raters were oriented to watch the video in full-screen and were able to pause, rewind and watch the video many times as preferred. In the first-round both rater 1 and rater 2 analysed the sample of videos from the FAI group (n=30). Four weeks later, in the second-round, rater 1 analysed the same sample of videos from the hip arthroscopy group (with a new randomized order) while rater 2 analysed the videos from the mixed group (n=30). Four weeks later in the third round, rater 1 and rater 2 (with a new randomized order) analysed the videos from the mixed group. Inter and intra-rater reliability was evaluated for the for the FAI (n=30) and mixed group (n=30). Videos were presented in a randomized order and an interval of 4 weeks was respected for the intra-rater assessment.

Cronbach alpha analysis was used to test the internal consistency of the scale for the FAI (n = 30) and mixed (n = 30) groups. A value of alpha between 0.70 and 0.95 was used as

an indicator of adequate internal consistency (TERWEE et al., 2007). Values of alpha of each one of the seven items of the scale was dropped at a time were analysed in order to define the final version of the scale. Additionally, in order to understand the impact of each item on the reliability of the scale and inform what could be changed in its structure to improve clarity we conducted an item per item inter-rater reliability analysis for the mixed group (n = 30) using the Unweighted Cohens Kappa (k) (MCHUGH et al., 2012). Agreement was interpreted as follows; < 0 indicates no agreement; between 0.01 - 0.20 as none to slight agreement; 0.21-0.40 as fair; 0.41-0.60 as moderate; 0.61-0.80 as substantial and 0.81-1 as almost perfect (MCHUGH et al., 2012).

The scale inter and intra-rater reliability for the FAI and mixed groups was calculated using intraclass correlation coefficients (ICC) with 95% confidence intervals. We used a two-way random effect single measurement model (ICC2,1) for ICC calculation (KOO et al., 2016). Reliability was classified as low (ICC<0.5), moderate (ICC between 0.5 and 0.75), good (ICC between 0.75 and 0.9), or excellent (ICC>0.9) (Koo et al., 2016). Also, the standard error measurement (SEM) and smallest detectable change (SDC) were calculated. The SEM was calculated with the following formula $\left(SD\ x\ \sqrt{1} - ICC\right)$ (Weir et al., 2005). The SDC was calculated at an individual level $\left(SDCindividual = 1.96\ x\ \sqrt{2}\ x\ SEM\right)$ and at a group level $\left(SDCgroup = \frac{SDCindividual}{\sqrt{n}}\right)$(TERWEE et al., 2007). The SDCgroup can be used to compared results between groups in research studies. The SDCindividual can be used clinically to evaluate change within an individual.

3. RESULTS

3.1 Scale theorical ground and construct

In patients with FAI syndrome, anterior mechanical impingement results from simultaneous hip flexion, adduction and internal rotation (CANNON et al., 2020). The combination of hip adduction and internal rotation during functional or athletic movements that require hip flexion are considered an undesired movement pattern for patients with FAI syndrome. This specific movement pattern is hypothesized to favour the symptomatic bony impingement and consequent chondrolabral damage, inflammation, gluteal inhibition, and capsular fibrosis, perpetuating the cyclical progression of FAI syndrome (CANNON et al., 2020). Therefore, assessment of the movement pattern of patients with FAI syndrome could add important information for the rehabilitation process of these patients.

The developed scale was entitled as Single leg squat movement pattern scale for individuals with Femoroacetabular impingement syndrome (SimpliFAI) (Table 1). The scale construct was described as follows: *"The SimpliFAI measures the single leg squat movement pattern quality of patients with FAI syndrome possibly indicating functional and symptomatic state of these patients. The movement pattern assessment includes topics regarding overall movement quality and segmental movement quality."*

Three questions regarding overall movement quality (movement fluidity, balance and cadence control) and four questions regarding segmental movement quality (trunk, hip, knee and foot control) were included in the SimpliFAI. For each question a dichotomous answer (yes or no) was made available. Each question regarding overall movement quality answered with a yes response is scored with 2 points, while each question regarding segmental movement quality answered with a no response is scored with 1 point. Therefore, the SimpliFAI presents a worse possible score of 0 and a best possible score of 10. The scale was developed with the aim of providing a tool to assess and discriminate the single leg squat movement pattern of patients with FAI syndrome with different symptomatic states.

Table 1. Preliminary version of the SimpliFAI tool.

Item	During the single leg squat...	Yes	No	Score
1.Balance	Is the patient able to maintain hands on hips AND not touch the contralateral foot on the floor?			2 points for each Yes response
2.Fluidity	Is the patient able to maintain the ascent and descent phases of movement smooth AND without tremor and hesitation?			
3. Cadence*	Is the patient able to follow the cadence competently			
3.Trunk control	Does the trunk excessively deviates/shift laterally?			
4.Hip control	Does the patella pass medially to the second toe (knee valgus)?			1 point for each No response
5.Knee control	Does the knee swing side to side in an unsteady and repetitive way?			
6.Foot control	Does the medial or lateral edge of the foot loose contact with the floor repetitively?			
	Total SimpliFAI Score			

*This item was later excluded from the SimpliFAI scale. See the per-item reliability and internal consistency sections for details. **The final version of the SimpliFAI is presented in the Appendix V, supplementary material.**

3.2 Questionnaire application with hip specialist physiotherapists

Regarding the difficulty of understanding of the SimpliFAI items, 71% of the hip specialist physiotherapists considered it *extremely easy* and 29% considered it *easy*. Regarding the difficulty of application of the SimpliFAI in clinical practice 57% of the hip specialist physiotherapists considered the application as *extremely easy* and 43% as *easy.* One specialist stated that the cadence item could hinder the assessment by the clinician when using the SimpliFAI. Furthermore, 43% of the hip specialist physiotherapists indicated that the SimpliFAI did not comprehend all important movement related factors potentially associated to hip pain, and suggested the inclusion of an item for the assessment of pelvic control in the SimpliFAI.

3.3 Focus group discussion

The focus group discussion lasted 71 minutes. The results are described along the line of the identified categories regarding the three main questions asked. Five categories were identified: (1) Relevance and readability of the cadence and balance items, (2) Readability problems in the Fluidity item, (3) Relevance and readability of the trunk, hip, knee and foot control items, (4) possible inclusion of an item regarding pelvic control, and (5) feasibility of the SimpliFAI application.

3.3.1 Relevance and readability of the Cadence and Balance items

All participants indicated that the “Balance” item is relevant and easy to understand and could be useful in research and clinical practice. While the majority of participants indicated that the “Cadence” item is relevant and easy to understand, one participant indicated that this item could hinder the comprehension of the SimpliFAI scale in clinical practice. Illustrative quotes are summarized in Table 2.

3.3.2 Readability problems in the Fluidity item

All specialists indicated limitations in the readability of the “Fluidity” item. They highlighted in their statements that the terms “insecurity” and “tremor” present in the item description hindered interpretation of the SimpliFAI. Some of the participants suggested the exclusion of the “insecurity” term and stated that the “Fluidity” item needed rewriting for better clarity. Illustrative quotes are summarized in Table 2.

3.3.3 Relevance and readability of the Trunk, Hip, Knee and Foot control items

All participants agreed that the items related to the trunk, hip, knee and foot control are relevant and easy to understand. Illustrative quotes are summarized in table 2.

3.3.4 Possible inclusion of an item regarding pelvic control

Participants disagreed about the possible inclusion of an item regarding pelvic control in the SimpliFAI. Three participants indicated that the inclusion of a pelvic control item is not required since other items already in the scale are closely associated to pelvic control (i.e. trunk and hip control) and make up for the absence of a pelvic control item. Additionally, concern was raised to difficulty in visually distinguishing a clinical important pelvic drop. However, two participants indicated that the inclusion of a pelvic control item would be important. They stated that this specific item is important for patients with FAI syndrome and could be an important aspect of the scale in research since several studies explore pelvic control in these patients. Illustrative quotes are summarized in Table 2.

3.3.5 Feasibility of the scale application

All participants indicated that the application of the scale was feasible regarding the required equipment and the test setup, warm-up and familiarization processes. One of the participants indicated that the procedures described for the application of the SimpliFAI would require effort and were time consuming for the context of the clinical practice. However, the same participant stated that the described procedures were all necessary for a reliable measure of movement pattern.

Table 2. Categories and illustrative quotes of focus group discussions

Category	Participant	Illustrative quote
Relevance and readability of cadence and balance items	#1	*"I think that these items are easy to use and understand in clinical practice and are relevant for the assessment of patients with FAI syndrome."*
	#2	*"About the three first items, I think that they are essential and easy to understand. They can be useful for other researchers and for clinical practice. It seems pretty reliable."*
	#3	*"I really appreciate the scale. It seems really easy to use in the daily clinical practice, and maybe can be useful for me and other clinicians to evaluate the progress and rehabilitation discharge of these patients."*
Readability problems in the Fluidity item	#1	*"The only thing that is not clear when using the scale – because it depends a lot of the assessor perception – is the "insecurity" term. What do we consider as insecurity? Since*

		this depends a lot from the assessor interpretation it could result in great (undesirable) variability on the scale responses."
	#3	*"About the insecurity, I think that you could exclude this term. Other items such as the cadence control and balance already reflect insecurity. So, I think you could exclude this term from the item."*
	#4	*'We should be cautious with subjective items such as fluidity. The cadence item is more objective since we have the sound. The balance item is quite subjective, but is easy to tell whether the patient put his foot on the ground or not. Items that are too qualitative can be a problem, such the fluidity."*
	#1	*"Fluidity reminds me of a continuous movement. Without pauses. Without accelerations and deaccelerations. I think that the question in the fluidity item can be improved."*
Relevance and readability of the Trunk, Hip, Knee and Foot control items	#3	*"These items are excellent. Very clear. I have nothing to add to those items, the description and everything is great."*
Possible inclusion of an item regarding pelvic control	#4	*"The pelvic drop it is a little bit harder to assess and judge, sometimes more experience is required to do so, and sometimes the experience does not help at all too. Also, who says that the pelvic drop is a problem? ...For what the scale is aimed at, I think it is good. If the pelvic drop is present or not, the difference between having the pelvic drop or not is based on a 5 to 7 degrees difference. It is not possible to assess it visually"*
	#1	*"I also think that you should include the pelvis as an item. I would use something like "if the pelvis alignment deviates the horizontal plane". Also, it was said before: "who says that this (pelvic drop) is a problem?", but if we think this way, who says that the valgus is a problem? But the valgus is on the scale. Your scale is not detecting if the movement pattern alteration is a problem. The scale is trying to detect a valgus, if the valgus is a problem or not that is another thing. I would include an item related to pelvic control, I think it is important and relevant."*
	#3	*"When the pelvic drop is something that we should take into account, the trunk inclines laterally. The other items kind of make up for the absence of the pelvic control item. So, if the pelvic drop is important, probably you are going to see a trunk inclination, a dynamic valgus, and thinking about the*

		purpose of your scale I think that it is good just as the way it is."
	#2	*"The literature talks a lot about pelvis related data instead of trunk data. I understand that your scale is for clinical practice use, however, we should also understand that the scale is going to be used in research."*
Feasibility of the SimpliFAI application	#1	*"I think that for the test to be reliable, the process, materials and purpose are adequate. The scale uses as few materials as possible. Is it easy to apply in the clinical routine? No, it takes effort and time. If you add that (SimpliFAI assessment) to a typical hip clinical assessment, which includes time spent for manual dynamometry, time spent for goniometry, time spent for video recording... when all those things are added together, the assessment will probably take more than one hour. You have this difficulty, but if you cut-off any part of the process maybe the scale is not going to be reliable."*
	#5	*"I think it is pretty good and cheap. There is nothing that will be too expensive. Everything can be adapted. You can use a chair to limit the range of motion of the individuals squat as suggested (reference to video). It is extremely easy to apply in clinical practice with suggested materials and environment. I would also suggest adapting the scale for the online use, I think that adaptation is possible."*

Based on the focus group discussion the fluidity item description was adapted to: *Does the patient presents a continuous and fluid movement, without sudden accelerations.*

3.4 Per-item reliability

Rater agreement per item was classified as: none to slight (k= 0.20) for cadence control, almost perfect (k= 1) for balance, fair (k= 0.40) for movement fluidity, moderate (k= 0.56) for trunk control, fair (k= 0.29) for hip control, substantial (k= 0.61) for knee control, and moderate (k= 0.44) for foot control. Since the cadence control was pointed as an item that could hinder the use of the SimpliFAI during questionnaire answers and presented none to slight between rater agreement, authors discussed the possibility of exclusion of the item. After discussion, authors agreed on excluding this item from the SimpliFAI and further analyses.

3.5 Internal consistency

An adequate internal consistency of SimpliFAI was observed, with a Cronbach alfa coefficient (range) of 0.88 (0.74 to 0.92) and 0.81 (0.71 to 0.92) for the FAI and mixed groups, respectively. Additionally, the exclusion of one of the six items that integrate the SimpliFAI did not result in improved internal consistency (Table 3). Therefore, no changes in the scale were needed to optimize internal consistency.

Table 3. Cronbach alfa coefficient changes if an item from SimpliFAI was dropped.

SimpliFAI item excluded	FAI group (n = 30)	Mixed group (n= 30)
- Balance	0.85	0.82
- Fluidity of movement	0.85	0.78
- Trunk control	0.87	0.79
- Hip control	0.85	0.81
- Knee control	0.86	0.76
- Foot control	0.86	0.74

3.6 SimpliFAI reliability measures

SimpliFAI inter and intra-rater reliability (ICC2,1), standard error measurement (SEM), and smallest detectable change (SDC) at group and individual level for both hip FAI and mixed groups are presented in Table 4.

Table 4. SimpliFAI inter and intra-rater reliability for the FAI and mixed groups

Reliability	Group	ICC* (95% CI)	SEM	SDC_{Group}	$SDC_{Individual}$
Inter-rater	FAI (n = 30)	0.84 (0.66 to 0.92)	1	1	3
	Mixed (n = 30)	0.68 (0.43 to 0.83)	1	1	3
Intra-rater	FAI (n = 30)	0.90 (0.80 to 0.95)	1	1	3
	Mixed (n = 30)	0.79 (0.54 to 0.90)	1	1	3

* ICC (2,1) for absolute agreement, single measures. CI: Confidence interval.

4. DISCUSSION

SimpliFAI is the first scale developed specifically for the visual assessment of the single leg squat of patients with FAI syndrome. Our results indicate that SimpliFAI is a valid and reliable tool for the assessment of the single leg squat movement pattern in individuals with FAI syndrome. The final version of the SimpliFAI with the associated documentation can be found as supplementary material (Appendix V).

Other methods/scales for the visual assessment of the single leg squat are available in the literature (CROSSLEY et al., 2011; MCGOVERN et al., 2019; WHATMAN et al., 2015) but their content validity, considered one of the most important measurement properties of an instrument (BOATENG et al., 2018; TERWEE et al., 2017) is not clear. The steps used to develop the SimpliFAI, described in detail in this manuscript, are essential to warrant a clear and defined construct, target population, context of use and theorical framework. Additionally, the questionnaire application and focus group discussion with specialists allowed the development of a scale that is relevant, comprehensive, and comprehensible (BOATENG et al., 2018; TERWEE et al., 2017). These aspects are of great importance for the SimpliFAI, since they are considered the three main criteria for a good content validity (TERWEE et al., 2017).

The systematic review performed by our research team as part of the development process of the SimpliFAI indicated that previous methods/scales of visual assessment of the single leg squat do not present adequate discriminative and convergent validity regarding clinical outcomes, raising questions about the usefulness of these scales in clinical practice. These results can be partially explained by the fact that previous scales/methods of visual assessment of the single leg squat were not developed according to the best practices for a quality development of instrument and processes that ensure adequate content validity (BOATENG et al., 2018; TERWEE et al., 2007). The fact that SimpliFAI development followed these processes open possibilities for future studies to investigate cross-cultural, discriminative and convergent validity and other measurement properties to explore the clinical relevance of the SimpliFAI within its context of use.

Changes in the description of the items from the preliminary to the final version of the SimpliFAI considered the opinion and suggestions of target users aiming to improve its comprehensibility and turn the scale understandable to this population. The only major disagreement between specialists during focus group discussion and questionnaire answers was about the inclusion of an item regarding pelvic control. Hip and pelvic kinematics are potentially associated during single leg activities (BAZETT-JONES et al., 2022; NEUMANN et al., 2010). Also, the assessment of the hip joint contemplates movements in both thigh and pelvis segment (NEUMANN et al., 2010). Prior evidence indicates that subjects visually rated as having the patella medial to the second toe during the single leg squat (criteria used in the hip control item) are likely to present increased 3D peak hip adduction compared to those who do not fulfil this criterion (WHATMAN et al., 2013). The hip adduction angle is associated with function and pain in patients with hip pain (HARRIS-HAYES et al., 2018). Therefore, the

presence of the hip control item in the SimpliFAI possibly makes up for the absence of an item regarding pelvic control in the scale.

The SimpliFAI presents adequate internal consistency, suggesting that the different items in the scale are appropriately related and measure the same proposed construct (TERWEE et al., 2007). Internal consistency is an important property associated to the structure of an instrument (TERWEE et al., 2017), and an internally consistent scale is considered to reflect a well-defined construct and properly developed items (TERWEE et al., 2007). The balance item in scale is the only item that, if dropped, would not decrease the internal consistency of the scale (Table 3). Single leg balance, however, has been proved to be an important parameter in the evaluation of patients with FAI syndrome (FREKE et al., 2016). Also, by dropping the balance item, changes in the alpha value would be minimal and probably do not have an important impact in the internal consistency of the SimpliFAI, and, therefore, we opted to not exclude this item. To our knowledge, this is the first internally consistent scale for the visual assessment of the single leg squat to include items associated to overall movement quality (movement fluidity and balance) and items regarding segmental movement quality (trunk, hip, knee and foot control).

SimpliFAI was also shown to be reliable for intra-rater and inter-rater assessments. This study provides the standard error measurement and smallest detectable change values when assessing a group of patients with FAI syndrome treated with hip arthroscopy and a group of patients with FAI syndrome treated with hip arthroscopy and asymptomatic individuals. These parameters can help physiotherapists and researchers to distinguish true effects from measurement error. The SDC_{group} can be used to compare results between groups (research studies) and the $SDC_{individual}$ can be used clinically to evaluate change within an individual (TERWEE et al., 2007). The reliability of SimpliFAI was shown to be good, except for the inter-rater assessment of the mixed group, for which SimpliFAI demonstrated moderate reliability. In research, an average group change of 1 point in the SimpliFAI scale can be interpreted as a true effect if deemed significant. When assessing both FAI and mixed groups, a minimal change of 3 points is needed, to ensure that the observed changes in the scale score are real and not a product of measurement error of the instrument (Table 4). A recent systematic review on available methods to visually assess the single leg squat found a moderate inter and intra-rater reliability (RESSMAN et al., 2019). Moreover, studies regarding other scales of visual assessment of the single leg squat previously reported in literature do not provide standard error measurement and smallest detectable change values (CROSSLEY et al., 2011b; RESSMAN et al., 2021; WHATMAN et al., 2012), which harms the applicability of these

instruments in clinical practice. Therefore, SimpliFAI seems to present better estimates of reliability when compared to other methods for the visual assessment of the single leg squat.

The use of a sample of patients with FAI syndrome treated with surgery in the development of this scale might have resulted in different outcomes with regards to the scale measurement properties compared to a sample not treated with surgery. However, patients treated with hip arthroscopy still present symptoms and functional impairments related to FAI syndrome (KIERKEGAARD et al., 2022; WÖRNER et al., 2019). Also, the construct and content of the scale would likely not change if we had included patients with FAI that had not undergone surgery, therefore, we do not believe this has affected the outcomes of this study. Future studies should investigate the validity and reliability of the SimpliFAI when assessing other populations, including patients with FAI syndrome before and after treated conservatively. While SimpliFAI presents adequate reliability, other measurement properties not investigated in this study, such as discriminative, convergent and cross-cultural validity and responsiveness are important for the use of the scale in clinical practice and should be explored by future studies.

5. CONCLUSION

SimpliFAI is the first scale for the visual assessment of the single leg squat developed specifically for patients with FAI syndrome, presenting adequate validity and reliability for the assessment of patients with FAI syndrome treated with surgery alone or when assessed together with asymptomatic individuals.

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CHAPTER IV

STUDY III – IS IT TIME TO SIMPLIFY? QUALITY OF LIFE AND SYMPTOMATIC STATE ARE CORRELATED TO SIMPLIFAI SCORES AFTER HIP ARTHROSCOPY TO TREAT FAI SYNDROME

ABSTRACT

Background: The hip adduction range of motion during the single leg squat is an outcome of interest in the assessment of movement pattern in individuals with femoroacetabular impingement. Recently, the SimpliFAI scale has been proposed as a valid and reliable alternative to assess the single leg squat movement pattern in patients with FAI syndrome. However, the clinical utility of this tool remains unclear. The aim of this study was to compare the SimpliFAI score and hip adduction range of motion angle among patients that reach and do not reach an acceptable symptomatic state after hip arthroscopy to treat FAI syndrome, and asymptomatic individuals. The association between the SimpliFAI score and the hip adduction range of motion angle with the quality of life and function of patients with FAI syndrome 4 months after surgery is also explored. Methods: Sixty-eight patients treated with hip arthroscopy and 42 asymptomatic individuals were screened. All subjects underwent a video assessment of the single leg squat. A physiotherapist blind to groups analysed videos of the single leg and used the SimpliFAI to rate movement quality. A markerless motion capture tool based on artificial intelligence (Kinebot, Brazil) was used to assess the hip adduction range of motion during the single leg squat. The total score of the iHOT-33 questionnaire was used to assess hip related quality of life and function, and to classify patients presenting an acceptable or non-acceptable symptomatic state after surgery. Spearman-rank correlations were performed to assess the association between the SimpliFAI score, and hip adduction range of motion with hip related quality of life and function of patients treated with hip arthroscopy. Kruskall-Wallis tests were performed to assess differences in the SimpliFAI score and hip adduction range of motion across groups. In case of significative difference between groups, receive operator characteristic (ROC) analyses were performed to assess the discriminative capacity of the method of assessment. Results: No association was identified between the hip adduction range of motion angle and the iHOT-33 score in patients treated with hip arthroscopy ($p = 0.079$, $r = -0.23$, 95% CI = -0.47 to 0.03). A positive and moderate correlation ($p = 0.011$, $r = 0.32$, 95% CI = 0.07 to 0.54) was identified between the SimpliFAI and IHOT-33 scores in patients treated with hip arthroscopy. No difference was identified regarding the hip adduction range of motion angle among asymptomatic individuals, patients with acceptable, and patients with non-acceptable symptomatic states [$H(2) = 4.29$, $p= 0.116$)]. The SimpliFAI score was higher in patients with an acceptable symptomatic state compared to patients with a non-acceptable symptomatic state with a moderate effect size of difference ($p= 0.047$, $r= 0.34$). No differences in the SimpliFAI score were found between the asymptomatic and acceptable symptomatic state groups ($p=0.675$) and between the asymptomatic and non-acceptable symptomatic state groups ($p=0.103$). ROC analysis indicated that the SimpliFAI presents poor capability (AUC=0.67) to discriminate patients with a non-acceptable symptomatic state from patients with an acceptable symptomatic state after surgery. Conclusion: Our findings suggest that better movement quality of the single leg squat assessed by the SimpliFAI score is associated with better quality of life and function in patients with FAI syndrome treated with hip arthroscopy. Also, patients with an acceptable symptomatic state after arthroscopy presented better single leg movement pattern quality assessed by the SimpliFAI compared to patients with a non-acceptable symptomatic state. However, the SimpliFAI presented poor ability to discriminate patients with a non-acceptable symptomatic state from patients with acceptable symptomatic state after arthroscopy. The hip adduction range of motion angle was not associated with quality of life and function in patients treated with hip arthroscopy and did not discriminate patients with different symptomatic states after surgery.

Keywords: Hip pain, Hip surgery, Rehabilitation, Screening

RESUMO

Introdução: A escala SimpliFAI é uma ferramenta válida e confiável para avaliar o padrão de movimento do agachamento unipodal de pacientes com síndrome do impacto femoroacetabular (SIFA) tratados com artroscopia de quadril. No entanto, a utilidade clínica da escala SimpliFAI não é clara. Além disso, não há evidências que indiquem porque devemos usar a escala SimpliFAI em vez de outros métodos de análise de movimento ao avaliar pacientes com SIFA tratados com cirurgia na prática clínica. Portanto, o objetivo deste estudo foi comparar o escore da SimpliFAI e o ângulo de amplitude de movimento da adução do quadril entre pacientes com SIFA tratados com cirurgia com estados sintomático aceitável e não aceitável e indivíduos assintomáticos, e explorar a associação entre o escore SimpliFAI e o ângulo de amplitude de movimento de adução do quadril com a qualidade de vida e função de pacientes com síndrome de IFA 4 meses após a cirurgia. Métodos: Sessenta e oito pacientes tratados com artroscopia de quadril e 42 indivíduos assintomáticos foram avaliados. Todos os indivíduos foram submetidos a uma avaliação por vídeo do agachamento unipodal. Um fisioterapeuta analisou vídeos do agachamento unipodal e usou a SimpliFAI para avaliar a qualidade do movimento. O sistema de inteligência artificial Kinebot foi usado para avaliar amplitude de movimento da adução do quadril durante o agachamento unipodal. A pontuação total do questionário iHOT-33 foi utilizada para avaliar a qualidade de vida e a função relacionadas ao quadril e para classificar os pacientes que apresentam um estado sintomático aceitável ou inaceitável após a cirurgia. Correlações de Spearman foram realizadas para avaliar a associação entre o escore SimpliFAI e o ângulo de amplitude de movimento da adução do quadril com a qualidade de vida relacionada ao quadril e a função de pacientes tratados com artroscopia do quadril. Os testes de Kruskall-Wallis foram realizados para avaliar o escore SimpliFAI e a amplitude de movimento da adução do quadril entre os grupos de estados sintomáticos aceitáveis, não aceitáveis e assintomáticos. Em caso de diferença significativa entre os grupos, análises de características do operação do receptor (COR) foram realizadas para avaliar a capacidade discriminativa do método de avaliação. Resultados: Não foi identificada associação entre a amplitude de movimento da adução do quadril e o escore do iHOT-33 em pacientes tratados com artroscopia do quadril (p=0,079, r=-0,23, IC95%=-0,47 a 0,03). Foi identificada correlação positiva e moderada (p=0,011, r=0,32, IC95%=0,07 a 0,54) entre os escores SimpliFAI e IHOT-33 em pacientes tratados com artroscopia de quadril. Não foi identificada diferença quanto ao ângulo de amplitude de movimento da adução do quadril entre indivíduos assintomáticos e pacientes com estado sintomático aceitável e não aceitável [H(2) = 4,29, p= 0,116)]. A pontuação do SimpliFAI foi maior em pacientes com um estado sintomático aceitável em comparação com pacientes com um estado sintomático não aceitável com diferença de tamanho de efeito moderado (p= 0,047, r= 0,34). Não foram encontradas diferenças no escore do SimpliFAI entre os grupos assintomático e estado sintomático aceitável (p=0,675) e entre os grupos assintomático e estado sintomático não aceitável (p=0,103). A análise ROC indicou que o SimpliFAI apresenta baixa capacidade (AUC=0,67) de discriminar pacientes com estado sintomático não aceitável de pacientes com estado sintomático aceitável após a cirurgia. Conclusão: Nossos achados sugerem que a melhor qualidade de movimento do agachamento unipodal avaliado pelo escore SimpliFAI está associada a melhor qualidade de vida e função em pacientes com SIFA tratados com artroscopia de quadril. Além disso, pacientes com estado sintomático aceitável após artroscopia apresentaram melhor qualidade do padrão de movimento do agachamento unipodal avaliado pela SimpliFAI em comparação com pacientes com estado sintomático não aceitável. No entanto, a SimpliFAI apresentou baixa capacidade de discriminar pacientes com estado sintomático inaceitável de pacientes com estado sintomático aceitável após artroscopia. A amplitude de movimento da adução do quadril não foi associada à qualidade

de vida e função em pacientes tratados com artroscopia de quadril e não discriminou pacientes com diferentes estados sintomáticos após a cirurgia.

Palavras-chaves: Dor no quadril, Cirurgia de quadril, Reabilitação, Triagem

1. INTRODUCTION

Femoroacetabular impingement (FAI) syndrome is a major cause of hip pain and reduced quality of life. It is characterized by a symptomatic and premature contact between the femur and acetabulum that is associated with an alterations in the shape of these structures (GRIFFIN et al., 2016). Hip arthroscopy surgery is one of the main options of treatment for these patients (KEMP et al., 2020). Patients with FAI syndrome treated with hip arthroscopy present improvements in quality of life and function (GOHAL et al., 2019). However, 54% of patients with FAI syndrome treated with hip arthroscopy do not achieve an acceptable symptomatic state 1 to 2 years after surgery.

These patients commonly exhibit movement pattern alterations when compared to asymptomatic individuals (BRISSON et al., 2013; LAMONTAGNE et al., 2011; RYLANDER et al., 2013, 2011). Assessing the movement pattern of patients with FAI syndrome treated with hip arthroscopy is considered important in clinical practice (CANNON et al., 2020). It is hypothesized that movement pattern alterations such as excessive hip flexion, adduction and internal rotation could reproduce articular impingement positions and overload hip structures that are still vulnerable after surgery, such as the acetabular labrum and chondral surface, possibly provoking pain and limitations (CANNON et al., 2020; CHARLTON et al., 2016).

The single leg squat is considered one of the most useful tests to screen altered movement patterns that may contribute with the progression of FAI syndrome It is characterized by intense demands on the hip, and is a test able to identify movement pattern alterations in patients 1 to 2 years after arthroscopy (CHARLTON et al., 2016; CHEATHAM et al., 2018; MALLOYet al., 2019). Three-dimensional kinematic assessments are the gold standard in movement analysis and are commonly used in research to assess the movement pattern of the single leg squat of patients with FAI syndrome, specially using the hip adduction range of motion parameter (HARRIS-HAYES et al., 2018; MALLOY et al., 2021; MALLOY et al., 2019). However, high financial and time investments are required to conduct such analyses, which might make them unfeasible in daily clinical practice (LOPES et al., 2018). In an attempt to overcome these limitations and include the assessment of movement patterns in clinical practice, 2D video recording with the quantitative analysis of one or two selected frames has

been proposed as an alternative to the full 3D movement analysis (SCHURR et al., 2017). However, when using this method to assess patients FAI syndrome treated with hip arthroscopy the clinical validity of these parameters is not clear, since there is no evidence regarding the association of the analysed parameters and clinical important outcomes for these patients, such as patient satisfaction, pain, quality of life and function (CHARLTON et al., 2016). Moreover, we believe that this approach – based on specific parameters extracted from selected frames – might leave important features of the movement pattern unnoticed, reducing the clinical value of this method in the assessment of patients with FAI syndrome.

For that reason, our research group developed the SimpliFAI scale, a tool to visually assess the movement pattern of the single squat of patients with FAI syndrome. The SimpliFAI scale was created following best practices and recommendations for development of measurement instruments and aims to assess several important movement features for patients with FAI syndrome. It allows the clinician to analyse the full movement during the single leg squat. A previous study showed that the SimpliFAI scale presents adequate validity and reliability for the assessment of patients with FAI syndrome treated with hip arthroscopy. However, it is still unclear how the SimpliFAI scale could help clinicians throughout decision making for the rehabilitation of patients with FAI syndrome treated with surgery. Understanding the association between the movement pattern assessed by the SimpliFAI and quality of life and function of patients with FAI syndrome treated with surgery, could help clinicians to tailor assessment and rehabilitation programmes for these patients. Additionally, given the high number of individuals that do not reach an acceptable symptomatic state after surgery, finding parameters that may help to distinguish patients with different symptomatic conditions can provide insight into the factors contributing to persisted symptoms.

The aim of this study was to (i) compare the SimpliFAI score and the hip adduction range of motion angle between patients with FAI syndrome treated with surgery with acceptable and non-acceptable symptomatic states and asymptomatic individuals, and to (ii) explore the association between the SimpliFAI score and the quality of life and function of patients with FAI syndrome 4 months after surgery, and the association between the hip adduction range of motion angle and the quality of life and function of the same group of patients. The concomitant analysis of the SimpliFAI and the hip adduction range of motion can inform clinicians which method might be more worthwhile for the assessment of these patients.

2. METHODS

2.1 Study design

This was a cross-sectional study jointly conducted by the Federal University of Santa Catarina, the University of the State of Santa Catarina, the Fisiolab Institute and the Core Centre of Orthopaedics and Rehabilitation (CORE). This study was approved by the local ethical committee with the protocol number of CAAE 96023618.0.0000.0118 (Brazil). All individuals provided written informed consent before participating in the study.

2.2 Participants

Patients with hip pain were recruited through the orthopaedic service of the CORE clinic. These patients were assessed by an experienced hip surgeon between January 2019 and December 2021. The surgeon has already performed approximately 2000 hip arthroscopies throughout his 15 years of practice. Patients were elected for surgery if they presented an Alpha angle >55° and/or a Lateral Center Edge angle >39°, Tonnis angle <0°, Hip pain (for more than 3 months), positive FADIR test and reported no improvement of symptoms after conservative treatment. Specific imaging methods used, and performance description of the FADIR test are described elsewhere (GOMES et al., 2021). Patients diagnosed with FAI syndrome and considered electable for the hip arthroscopy procedure were referred to a clinical setup at the Fisiolab Institute for a pre-surgical assessment. Patients underwent a clinical assessment with a physical therapist and received additional information about the surgical procedure and post-operative phase.

One to seven days after the surgical procedure patients were referred to the Fisiolab institute for a post-surgical assessment conducted by a physical therapist. In that opportunity patients were instructed about their actual condition and about the performance and execution of home-based exercises with an emphasis on motor control, lower limb muscle strengthening, hip range of motion, trunk resistance and cardiorespiratory fitness. Patients received a handbook with images, descriptions, sets and repetitions of the exercises. Two weeks, six weeks and three months after hip arthroscopy patients were referred to the same clinical setup where a physical therapist assessed the clinical evolution and progressed the proposed exercises. Four months after hip arthroscopy the patients were referred to the Fisiolab institute again and underwent a video assessment of the movement pattern of the single leg squat and completed the iHOT-33 questionnaire. Inclusion criteria were: aged between 18 and 60 years and hip arthroscopy surgery as treatment of FAI syndrome 4 months ago. Patients were excluded if they had

undergone another hip surgery in the last two years, presented previous history of perthes disease, hip dysplasia (Lateral center edge angle <25°) or any kind of neurological sequel.

Asymptomatic individuals were recruited and analysed at the University of the State of Santa Catarina. These individuals referred to a clinical setup and answered the Lower Extremity Functional Scale (LEFS) questionnaire (DINGEMANS et al., 2017). Asymptomatic participants were included if they were ≥18 years old, did not present any history of pain that prevented their participation in physical and daily activities in the last 6 months, performed physical activity at least 3 times a week with a minimum duration of 20 minutes per session, present no history of surgery in the spine and/or lower limbs in the last 2 years, scored >75 points in the LEFS. The cut-off score of the LEFS used to include the participants was based in a normative data study that assessed 291 healthy individuals where the inter-quartile inferior limit was 75 points for this sample (DINGEMANS et al., 2017). The exact same procedure for the video assessment of the single leg squat used with patients with FAI syndrome was applied to asymptomatic participants. Patients age, mass, height and lower limb-dominance (self-reported kicking limb) was also assessed.

2.3 Outcomes measures

The main outcome measures of this study were the final score of the SimpliFAI scale, and the hip adduction range of motion assessed by the Kinebot system. Both outcomes are used to estimate the movement pattern of the single leg squat.

2.4 Procedures

2.4.1. Video assessment of the single leg squat

Squat depth was limited to 60° of knee flexion through the use of a tactile support. The support was positioned behind the tested leg of the subject and had its height adjusted to slightly touch the patient's gluteal fold when the 60° of knee flexion was reached.

Subjects were orientated to perform the gesture with the hands-on waist, with the non-tested knee flexed, and to squat until the tactile support touched their gluteal folds. After a gesture demonstration by the researcher, the subjects performed 3 repetitions of the single leg squat as a familiarization and warm-up process. Then, a metronome mobile app (Pro Metronome, ©2014 EUMLab) was used to impose a cadence of 45 bpm per minute for the single leg squat performance. The researcher demonstrated the gesture again, now squatting following the cadence imposed by the metronome. The subjects performed more three

repetitions to get familiarized with the imposed cadence. After those three repetitions, subjects were instructed to perform three repetitions of the single leg squat whenever they were ready a video was recorded.

2.4.2. SimpliFAI score

The SimpliFAI is a scale of visual assessment of the single leg squat developed specifically for patients with FAI syndrome (ref). This tool uses 6 questions regarding overall and segmental movement quality and presents a minimum score of 0 (worst possible outcome) and a maximum score of 8 (best possible outcome). The SimpliFAI scale has appropriate psychometric properties for the assessment of the hip arthroscopy and asymptomatic populations and presents minimal detectable change value of 1 point for groups and 3 points for individuals. The assessment of videos of the single squat using the SimpliFAI were performed by a physiotherapist blind to the hip arthroscopy and asymptomatic groups.

2.4.3. Hip adduction range of motion angle

The Kinebot system (Brazil, 2019) was used to assess the hip adduction angular amplitude (femur related to pelvis). The Kinebot is a markerless motion capturing system that works through artificial intelligence. Using our described methods, we assessed the agreement between the Kinebot system and the 2D kinematic assessment using Kinovea for a sample of 42 asymptomatic individuals, and obtained an intraclass correlation coefficient (ICC) of 0.86. The maximal and minimal angles of the hip in the frontal plane were extracted for each repetition from the waveform generated by the Kinebot system. Hip adduction range of motion angle for each one of the three repetitions was calculated and the mean value across the three repetitions was used for this study.

2.4.4. Quality of life and symptomatic state

The questionnaire iHOT-33 was used to assess the quality of life, function and symptomatic state of patients with FAI syndrome. This 33-item questionnaire encompass questions relating to Symptoms and Functional Limitations, Sports and Recreational Activities, Job-Related Concerns, Lifestyle Concerns and Psychological Concerns and through a visual analogue scale for each question it estimates the quality of life of patients with hip pathology (MOHTADI et al., 2012). The total score is calculated as a simple mean of the responses – ranging from 0 to 100, with 100 representing the best possible quality-of-life score – and was used to measure the quality of life and function of patients with FAI syndrome treated with

surgery in this study. It has appropriate psychometric properties in the hip arthroscopy population and presents a minimal important change value of 10 points (KEMP et al., 2013). We also used the cut-off score proposed by Ishoi (2021) to group patients with acceptable and non-acceptable symptomatic states after surgery. Patients with a score ≥67 points were included in the acceptable symptomatic state group while patients with a score <67 points were included in the non-acceptable symptomatic state group.

2.5 Sample size calculation

Sample size was estimated for one way ANOVA with three groups using GPower version 3.1.5 (University of Kiel, Germany) and considering the main outcome measure of this study, the SimpliFAI score. Alpha was set at 0.05 and power at 0.90. Effect sizes were based on a difference across groups of 2 points with a standard deviation of 2 points. This value reflects the standard deviation and is greater than the smallest detectable difference observed in the previous study (Chapter IV). This procedure resulted in a sample size of 63 subjects (minimum of 21 per group). The sensitivity of such sample size was then checked for the analysis of the hip adduction range of motion across groups and deemed satisfactory. Specifically, a critical effect size f =0.46 was observed. This magnitude of effect has been reported in the literature (CHARLTON et al., 2016) when hip adduction range of motion is compared between asymptomatic individuals and patients treated with hip arthroscopy.

2.6 Statistical analysis

Patient's characteristics were compared between groups using one-way ANOVA tests with tukey post-hoc tests. SimpliFAI score and hip adduction amplitude angle data did not presented a normal distribution (based on Shapiro-wilk tests and visual analysis of histograms). The Spearman rank correlation coefficient was used to explore the association between the hip adduction amplitude angle with the iHOT-33 score, and between the SimpliFAI score and the iHOT-33 in the hip arthroscopy group. For the correlation tests, R_s values of 0 to 0.3 indicated a weak correlation; 0.3 to 0.7 a moderate correlation and 0.7 to 1 a strong correlation (RATNER, 2009).

We used Kruskall-Wallis tests (reported as H value and degrees of freedom) to compare the SimpliFAI score and the hip adduction range of motion angle between the asymptomatic, acceptable symptomatic state and non-acceptable symptomatic state groups. In case of significative differences, Dunn post-hoc tests were used to identify specific differences between

groups. For these comparisons, we used $r = \frac{z}{\sqrt{N}}$ for calculation of the effect size, where Z stands for statistical value of the Dunn post-hoc test and N stands for number of observations (ROSENTHAL, 1994). Values of r ranging from 0.1 to 0.29 were considered small; 0.3 to 0.49 as moderate and larger than 0.5 as large (FRITZ; MORRIS; RICHLER, 2012).

The ability of the parameters (SimpliFAI score and/or hip adduction range of motion angle) to discriminate specific groups was analysed by received operating characteristic (ROC) curves. The area under the curve (AUC) was used to assess discriminative ability and classified as no discriminative ability (AUC=0.5), poor discriminative ability (0.5 < AUC < 0.7), acceptable discriminative ability (0.7 < AUC < 0.8), excellent discriminative ability (0.8 < AUC < 0.9), and outstanding discriminative ability (AUC ≥ 0.9) (MANDREKAR, 2010). The best cut-off value for groups discrimination with highest combined sensitivity and specificity was developed using the Youden index (J= sensitivity + specificity – 1), with a higher index score indicating better combined sensitivity and specificity (YOUDEN, 1950).

All statistical analysis were conducted in the software R (R core team., 2016) with alpha set at 0.05.

3. RESULTS

Sixty-eight patients treated with hip arthroscopy and 42 asymptomatic individuals were screened. From the hip arthroscopy group, 36 and 23 patients were identified as presenting an acceptable symptomatic state and non-acceptable symptomatic state, respectively. The IHOT-33 data of 9 patients that were treated of hip arthroscopic surgery was not available and these subjects were excluded from further analyses based on symptomatic state. Table 1 describes the age, sex, BMI and iHOT-33 score for the asymptomatic, acceptable and non-acceptable symptomatic state groups.

The non-acceptable symptomatic state group was older compared to the acceptable symptomatic state group (95%CI= 2 to 14 years, p= 0.008) and to the asymptomatic group (95%CI= 5 to 17 years, p= 0.001). Also, the non-acceptable symptomatic state group presented higher BMI compared to the asymptomatic group (95%CI= 0.2 to 3.8, p= 0.018).

Table 1. Characterization of participants. Values are presented as mean (standard deviation)

	Hip arthroscopy patients (n= 68)	Asymptomatic (n= 42)	Patient acceptable symptomatic state (n= 36)	Patient non-acceptable symptomatic state (n= 23)
Age (years)	38 (11)	31 (8)[a]	35 (11)[a]	42 (9)[b]

Sex (male)	56%	54%	53%	48%
BMI (kg/m^2)	24.5 (3.6)	23.5 (2.1)[a]	23.6 (3.1)[ab]	25.4 (3.4)[b]
iHOT-33	-	-	83.9 (7.8)	45.9 (13.4)

BMI; Body mass index. iHOT-33; International Hip Outcome Tool score. Matching superscript letters indicate nonstatistical differences between groups ($p > 0.05$).

In the hip arthroscopy group a positive and moderate correlation ($p=0.011$, $R_s=0.32$, 95%CI=0.07 to 0.54) was identified between the SimpliFAI and IHOT-33 scores, indicating that higher scores (better movement quality) in the SimpliFAI tool were associated with higher scores in the IHOT-33 (better quality of life and function) in patients treated with hip arthroscopy (Figure 1). In the hip arthroscopy group no correlation was identified between hip adduction range of motion angle and the IHOT-33 score ($p=0.079$, $R_s=-0.23$, 95%CI=-0.47 to 0.03).

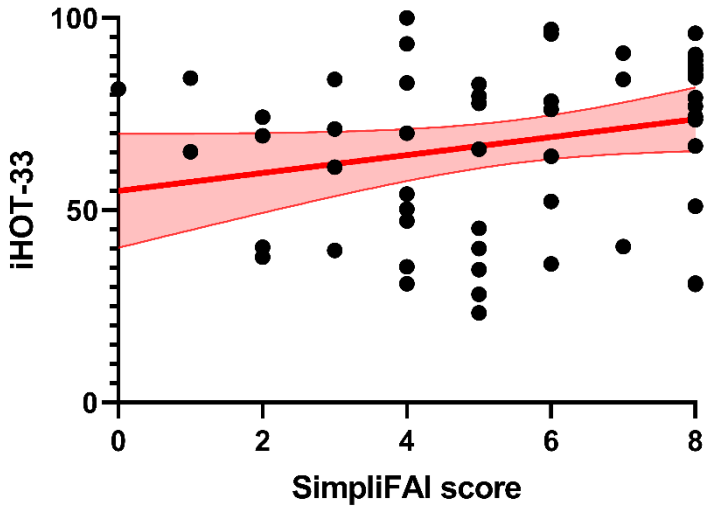

Figure 1. Correlation between the SimpliFAI and iHOT-33 scores in patients treated with hip arthroscopy ($R_s=0.32$, moderate correlation).

Regarding the hip adduction range of motion, no differences were found among asymptomatic individuals and patients with acceptable and non-acceptable symptomatic states [$H(2) = 4.29$, $p= 0.116$)] (Figure 2).

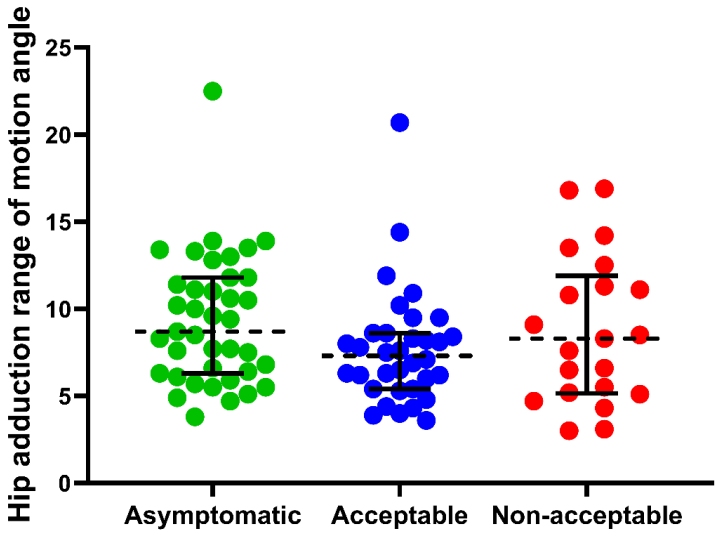

Figure 2. Hip adduction range of motion angle across groups of asymptomatic individuals, patients with acceptable symptomatic state, and patients with a non-acceptable symptomatic state. No differences were identified between groups (p = 0.116).

The SimpliFAI score differed among asymptomatic individuals and patients with acceptable and non-acceptable symptomatic states [H(2) = 6.42, p= 0.040)]. Dunn post-hoc tests indicated that the SimpliFAI score was higher in patients with an acceptable symptomatic state (median= 7, IQR= 4) compared to patients with a non-acceptable symptomatic state (median= 5, IQR= 2) with a moderate effect size of difference (p= 0.047, r_{dunn} = 0.34) (Figure 3). No differences in the SimpliFAI score were found between the asymptomatic (median= 7, IQR= 3) and acceptable symptomatic state groups (p=0.675) and between the asymptomatic and non-acceptable symptomatic state groups (p=0.103).

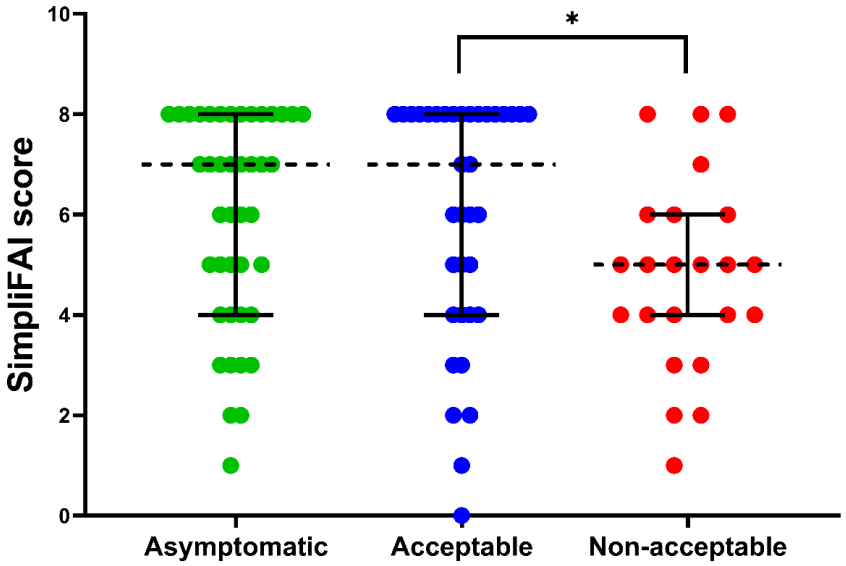

Figure 3. SimpliFAI score between asymptomatic individuals, patients with an acceptable symptomatic state, and patients with a non-patient acceptable symptomatic state. * indicates significative differences between groups (p= 0.047, r_{dunn} = 0.34).

The ROC curve analysis (Figure 4) showed that the SimpliFAI score presents poor ability (AUC= 0.67, 95%CI= 0.53 to 0.81) to discriminate these groups. The Youden index indicated that the best SimpliFAI cut-off value to discriminate patients with a non-acceptable symptomatic state from patients with an acceptable symptomatic state is ≤ 6 points (J = 0.35) with a sensitivity = 0.82 (95%CI = 0.62 to 0.93) and specificity= 0.52 (95%CI = 0.37 to 0.68).

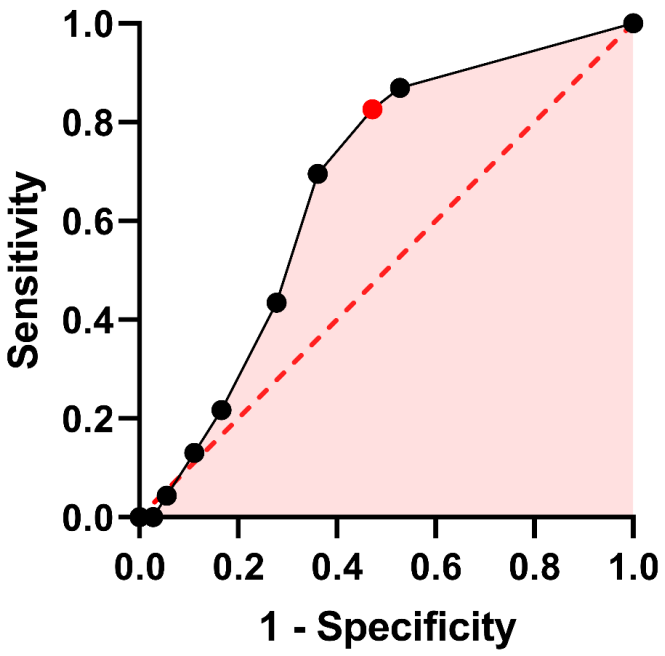

Figure 4. Receiver operator characteristic (ROC) curve for the SimpliFAI score ability to discriminate groups with different symptomatic states. RED dashed line indicates reference line. Red dot refers to the best SimpliFAI cut-off value (6 points) to discriminate groups.

4. DISCUSSION

Our findings indicate that a better movement quality in the single leg squat assessed by the SimpliFAI scale is associated with better quality life and function in patients with FAI syndrome 4 months after hip arthroscopy. Hip adduction range of motion, however, was not associated with quality and function in patients treated with hip arthroscopy and was not able to discriminate patients with different symptomatic states after surgery. These findings highlight the clinical utility of the SimpliFAI scale and support the use of this tool instead of the hip adduction range of motion angle for the assessment of patients with FAI syndrome treated with surgery in clinical practice. However, as it can be expected, the SimpliFAI scale alone shows poor ability to discriminate patients with different symptomatic states after surgery.

The results from our study represent preliminary evidence that the movement pattern of the single leg squat assessed by the SimpliFAI scale could be an important outcome when assessing patients with FAI syndrome treated with hip arthroscopy. A previous study showed that an intervention based on movement pattern training was able to improve pain and function in patients with chronic hip joint pain (HARRIS-HAYES et al., 2018, 2020b). Future clinical trials and longitudinal studies are warranted to support movement quality of the single leg squat as a potential treatment target for patients with FAI syndrome treated with hip arthroscopy. Also, it is important to note that the correlation between the SimpliFAI and the iHOT-33 scores was only moderate.

The strength of the correlation between SimpliFAI and the iHOT-33 is justified by the multifactorial nature of quality of life and function determination in these patients, which includes several aspects such as symptoms and functional limitations and sport, job and emotional related concerns (KEMP et al., 2013; MOHTADI et al., 2012). It is not expected that differences in one single outcome, such as movement pattern, would be closely associated with changes in the iHOT-33 score. In this context, we argue that a moderate correlation is clinically significant.

The fact that quality of life and function of patients with FAI syndrome treated with surgery are better related to the SimpliFAI score than to the hip adduction range of motion might be explained by the stronger construct behind the SimpliFAI. While this scale was developed specifically for the analysis of the single-leg movement pattern in individuals with

FAI, the hip adduction range of motion is a measure that was initially proposed for different populations. Additionally, the SimpliFAI scale is not restricted to segmental parameters/kinematics but also contain items related to full movement quality such as balance, fluidity and instability. These parameters seem to be important for the determination of function in patients with FAI syndrome (DIAMOND et al., 2015; KING et al., 2018a), but are left unnoticed when using specific angles extracted from selected frames in a 2D movement assessment. A broader assessment of the movement pattern of the single leg squat, as instrumented by the SimpliFAI, seems to be in better agreement with the fact that FAI syndrome is a movement-related disorder of the hip (CLOHISY et al., 2009; GRIFFIN et al., 2016).

Patients with an acceptable symptomatic state after surgery presented better movement quality of the single leg squat assessed by the SimpliFAI compared to patients with a non-acceptable symptomatic state. The difference in the SimpliFAI score between patients that reached an acceptable state compared to those that did not was of 2 points. This difference between groups can be considered real and not a product of error measurement: the smallest detectable change value of the SimpliFAI scale for the hip arthroscopy population is 1 point (Study n°2). However, it is not yet clear to us if this difference is clinically important for patients with FAI syndrome treated with hip arthroscopy. Future studies should explore measurement properties of the SimpliFAI scale for this population, such as the minimally clinical important difference, and evaluate its use in clinical practice.

Prior evidence suggests that most outcomes that predict the state of patients after hip arthroscopy are non-modifiable, such as age, sex, chondral injuries and type of surgical procedure (SOGBEIN et al., 2019), making it harder for clinicians to indicate modifiable factors that can be targeted and improved during a rehabilitation process with the aim of meeting patient satisfaction after surgery. Our findings indicate that movement quality of the single leg squat (a modifiable factor) after hip arthroscopy might be associated with patient satisfaction. Prospective studies should explore in the future the capacity of the SimpliFAI score to predict self-reported outcomes of patients with FAI syndrome after hip arthroscopy.

Not surprisingly, the SimpliFAI scale presented poor ability to discriminate patients with different symptomatic conditions 4 months after hip arthroscopy when used in isolation. This result are based in the AUC, a measure commonly used for diagnostic purposes (MANDREKAR, 2010), which is not the purpose of the SimpliFAI scale. The ROC curve analysis also showed that patients with FAI syndrome 4 months after hip arthroscopy with a SimpliFAI score ≤ 6 points tend to present a non-acceptable symptomatic state. However, this cut-off value presents a sensitivity of 81% and a specificity of 52%, indicating that the

SimpliFAI scale tend to wrongly identify patients with an acceptable symptomatic state as patients with a non-acceptable symptomatic state (false positive), and probably can be more useful when identifying patients with an acceptable symptomatic state. A SimpliFAI score > 6 reduces substantially the probability of an individual to have a non-acceptable symptomatic state. Precisely, the negative likelihood ratio is 0.34, indicating. an approximately three-fold reduction in the chance of having a non-acceptable symptomatic state.

Our results indicating that the hip adduction range of motion angle is not able to discriminate patients with different symptomatic states after hip arthroscopy or asymptomatic individuals is in contrast to the results of Charlton (2016) who showed that patients 1 to 2 years after hip arthroscopy presented higher hip adduction range of motion values when compared to controls matched firstly by sex, and subsequently on age, height, hours of weekly physical activity, and nature of occupation. In our study, the comparison to the group of asymptomatic individuals was exploratory, with the data regarding the healthy participants being extracted from a database. Patients with any source of painful hip intra-articular pathology were included in the study by Charlton and therefore the surgical procedure was also unspecific (e.g. labral debridement or repair, chondral debridement, microfracture, femoral and/or acetabular osteoplasty) which might also have had an influence on the outcome (CHARLTON et al., 2016). Our study included only patients that underwent hip arthroscopy as a form of treatment of FAI syndrome, increasing the external validity of our findings to this specific population. Recent studies seem to indicate that improvements in quality of life and function in patients with FAI syndrome after hip arthroscopy are not correlated with changes in hip kinematics (peak angles and angular excursions) during functional gestures (GRANT et al., 2022; KANNAN et al., 2022). These findings combined raise questions about the utility of the hip adduction range of motion when assessing patients with FAI syndrome treated with hip arthroscopy in clinical practice.

Patients with FAI syndrome not treated with surgery tend to present reduced sagittal plane range of motion, squat depth and speed when compared to asymptomatic individuals (HARRIS-HAYES et al., 2020b; MALLOY et al., 2021a; MALLOY et al., 2019). Based on these results, it has been speculated that patients with FAI syndrome present a “protective” movement pattern during the single leg squat, avoiding hip excessive range of motion that could possibly cause pain (MALLOY et al., 2019). After hip arthroscopic surgery for the treatment of FAI syndrome, we observed a wide variation in movement pattern quality with SimpliFAI scores varying from 0 to 8 (maximum). The association between SimpliFAI scores and the iHOT-33 suggests that movement pattern is relevant for these patients. However, we do not

know whether the impaired movement quality observed in the group with a non-acceptable symptomatic state represents a protective mechanism since speed and depth of the single leg squat were controlled in our study. In fact, we believe movement impairments in this group of patients may reflect a poor general lower limb physical function. Moreover, asymptomatic individuals also presented a wide variation in SimpliFAI scores, indicating that movement pattern impairments in the single leg squat are normal in healthy individuals.

This study has limitations. We did not control the adherence of patients to the proposed exercises or their activities during the study period. Also, subjects were not matched by sex, age or BMI across groups. While sex was distributed similarly across groups, differences in age and BMI were observed and might influence the symptomatic state of patients with FAI syndrome after hip arthroscopy (SOGBEIN et al., 2019). However, there is no evidence in the literature suggesting that higher BMI and age (for the range observed) can influence single leg squat performance. Therefore, it seems unlikely that the association between the movement quality scores and quality of life were confounded by age and BMI.

5. CONCLUSION

Our findings suggest that better movement quality of the single leg squat assessed by the SimpliFAI score is associated with better quality of life and function in patients with FAI syndrome treated with hip arthroscopy. Also, patients with an acceptable symptomatic state after arthroscopy presented better single leg movement pattern quality assessed by the SimpliFAI compared to patients with a non-acceptable symptomatic state. SimpliFAI should not be used in isolation to discriminate patients with a non-acceptable symptomatic state from patients with an acceptable symptomatic state after arthroscopy. Hip adduction range of motion extracted from two-dimensional kinematics was not associated with quality of life and function in patients treated with hip arthroscopy and did not discriminate patients with different symptomatic states after surgery.

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CHAPTER V

5 FINAL CONSIDERATIONS

6. FINAL CONSIDERATIONS

A systematic review of the literature allowed us to observe that most methods of visual assessment of the single leg squat lack clinical utility due to insufficient discriminative and convergent validity. That was specially the case when secondary outcomes are concerned. The Single leg Movement Pattern scale for Individuals with FemoroAcetabular Impingement syndrome (SimpliFAI) proposed in this thesis was developed according to the state of the art guidelines and recommendations for instruments with good measurement properties. The SimpliFAI demonstrated adequate content validity, internal consistency and intra and inter-rater reliability for the assessment of patients with FAI syndrome treated with arthroscopy.

Moreover, the score from the SimpliFAI scale seems to be associated with quality of life and function in patients with FAI syndrome 4 months after hip arthroscopy. The score from the SimpliFAI scale was capable of discriminating patients with FAI syndrome with different symptomatic states after surgery, but should not be used in isolation to infer symptomatic state. Symptomatic state after hip arthroscopic surgery for the treatment of FAI is likely influenced by a multitude of factors but movement pattern seems important, and our results suggest that a carefully developed qualitative tool can be useful in this scenario. On the other hand, the hip adduction range of motion angle – a common measure used in research and clinical practice – was not associated with quality of life and function and was not capable of discriminating different symptomatic states after surgery in the same group of patients.

Our results indicate that the SimpliFAI is a valid, reliable, low-cost tool that can help clinicians in the assessment of patients with FAI syndrome during rehabilitation and also at discharge. Also, it seems that the SimpliFAI is more useful than the analysis of hip adduction range of motion in this population.

CHAPTER VI

6 SCIENTIFIC CONTRIBUTIONS

7. SCIENTIFIC CONTRIBUTIONS

The scientific contributions listed here were resulted from collaborations among the Biomechanics of the Musculoskeletal System Research Group (BSiM), the FisioLab Institute in Florianopolis and the Lower Limb and Trunk Applied Biomechanics project –community-oriented seminar series where health professionals and students are invited to participate in discussions aimed at translating biomechanical concepts and scientific evidence into clinical/exercise practice. This seminar series is conjointly organized by academic and non-academic researchers from the Federal University of Santa Catarina (UFSC), the State University of Santa Catarina (UDESC) and the FisioLab Institute in Florianopolis, Brazil. During this period Diogo Almeida Gomes received a scholarship provided by the Fundação de Amparo a Pesquisa e Inovação do Estado de Santa Catarina (FAPESC).

Peer-reviewed publications

Gomes, D., de Brito Fontana, H., da Costa, G. V., Ribeiro, D. C., Canella, R. P., Ferreira, T., ... & de Castro, M. P. (2022). Differences in hip torque ratios between individuals with femoroacetabular impingement syndrome and asymptomatic individuals: A cross-sectional study. Clinical Biomechanics, 100, 105809.

Gomes, D., Ribeiro, D. C., Ferreira, T., da Costa, G. V., Canella, R. P., & de Castro, M. P. (2022). Knee and hip dynamic muscle strength in individuals with femoroacetabular impingement syndrome scheduled for hip arthroscopy: A case-control study. Clinical Biomechanics, 93, 105584.

Martins, E. C., Steffen, L. B., Gomes, D., Herzog, W., Haupenthal, A., & de Brito Fontana, H. (2022). Looped Elastic Resistance during Squats: How Do Band Position and Stiffness Affect Hip Myoelectric Activity?. Journal of Functional Morphology and Kinesiology, 7(3), 60.

Gomes, D., Ribeiro, D. C., Canella, R. P., Ferreira, T., da Costa, G. V., Okubo, R., & de Castro, M. P. (2021). Association between severity of hip chondrolabral injuries, dynamic hip muscle strength and quality of life: A cross-sectional study in patients with femoroacetabular impingement syndrome scheduled for hip arthroscopy. Clinical Biomechanics, 84, 105348.

Conference abstracts

Martins, EC., Gomes, D., De Brito Fontana, H., Fernandes, DA., Neves, FS. Response to injection can predict outcomes of femoroacetabular impingement, European Alliance of Associations for Reumathology Congress, Copenhagen (2022)

Gomes, D., Canella, R. P., da Costa, G. V., Ferreira, T., de Castro, M. P., De Brito Fontana, H. Development of the Single leg squat movement pattern scale for individuals with femoroacetabular impingement syndrome (SimpliFAI), Brazilian Congress of Biomechanics, Minas Gerais (2021).

Gomes, D., Canella, R. P., da Costa, G. V., Ferreira, T., de Castro, M. P., De Brito Fontana, H. Association between severity of hip chondrolabral injuries, dynamic hip muscle strength and quality of life: A cross-sectional study in patients with femoroacetabular impingement syndrome scheduled for hip arthroscopy. Brazilian Congress of Biomechanics, Minas Gerais (2021).

Accepted abstracts (upcoming conferences)

Gomes, D., da Costa, G. V., de Castro, M. P., De Brito Fontana, H. It is time to SimpliFAI! A reliability analysis of the SIngle leg squat Movement Pattern scaLe for Individuals with FemoroAcetabular Impingement syndrome. Brazilian Congress of Biomechanics, Bauru (2023).

Neumann, F., Gomes, D., Klein, A., Machado, JM., Ruschel, C., De Brito Fontana, H. Avaliação da amplitude de movimento de adução de quadril por sistemas de vídeo para captura de movimento sem marcadores. Brazilian Congress of Biomechanics, Bauru (2023).

Publications under review

Archives of Orthopaedic and Trauma Surgery – IF 3.404

Martins, EC., Gomes, D., De Brito Fontana, H., Fernandes, DA. Does response to preoperative intra-articular anaesthetic injections predict outcomes of femoroacetabular impingement syndrome?

Awards

2021 – Five best abstracts in the section of clinical biomechanics at the Brazilian Congress of Biomechanics – “Development of the Single leg squat movement pattern scale of individuals with FAI syndrome (SimpliFAI).”

2023 – Abstract selected for the International Society of Biomechanics Postgraduate Students Awards, Brazilian Congress of Biomechanics – “It is time to SimpliFAI! A reliability analysis of the SIngle leg squat Movement Pattern scaLe for Individuals with FemoroAcetabular Impingement syndrome.”

Invited presentations

2021 – Assessment of the athlete with FAI syndrome – V symposium of Sports Physiotherapy of the State University of Santa Catarina.

2023 – Running myths: A analysis with more science and less Instagram – I Journey of Sports Physiotherapy of the University of the South of Santa Catarina.

SUPPLEMENTARY MATERIAL

APPENDIX I

Systematic review search strategies

Database	Chave de Busca
CINAHL	("single leg squat" OR "single leg mini squat" OR "single leg loading" OR "single limb squat" OR "single limb mini squat" OR "unilateral squat" OR "small knee bend" OR "single leg step down" OR "single limb step down" OR "lateral step down" OR "forward step down" OR "step down test" OR "step down task" OR "one leg squat" OR "one leg mini squat" OR "one leg loading" OR "one limb squat"OR "one limb mini squat" OR "one leg step down" OR "one limb step down") AND ("visual assessment" OR "visual" OR "visual rating" OR "subjective" OR "visual screening" OR "screening" OR "rating")
EMBASE	("single leg squat"/exp OR "single leg mini squat"/exp OR "single leg loading"/exp OR "single limb squat"/exp OR "single limb mini squat"/exp OR "unilateral squat"/exp OR "small knee bend"/exp OR "single leg step down"/exp OR "single limb step down"/exp OR "lateral step down"/exp OR "forward step down"/exp OR "step down test"/exp OR "step down task"/exp OR "one leg squat"/exp OR "one leg mini squat"/exp OR "one leg loading"/exp OR "one limb squat"/exp OR "one limb mini squat"/exp OR "one leg step down"/exp OR "one limb step down"/exp) AND ("visual assessment"/exp OR "visual"/exp OR "visual rating"/exp OR "subjective"/exp OR "visual screening"/exp OR "screening"/exp OR "rating"/exp)**AND ([article]/lim OR [article in press]/lim)**
SPORTDiscuss (Filter articles)	("single leg squat" OR "single leg mini squat" OR "single leg loading" OR "single limb squat" OR "single limb mini squat" OR "unilateral squat" OR "small knee bend" OR "single leg step down" OR "single limb step down" OR "lateral step down" OR "forward step down" OR "step down test" OR "step down task" OR "one leg squat" OR "one leg mini squat" OR "one leg loading" OR "one limb squat"OR "one limb mini squat" OR "one leg step down" OR "one limb step down") AND ("visual assessment" OR "visual" OR "visual rating" OR "subjective" OR "visual screening" OR "screening" OR "rating")
PubMed	("single leg squat"[All Fields] OR "single leg mini squat"[All Fields] OR "single leg loading"[All Fields] OR "single limb squat" OR "single limb mini squat"[All Fields] OR "unilateral squat"[All Fields] OR "small knee bend"[All Fields] OR "single leg step down"[All Fields] OR "single limb step down"[All Fields] OR "lateral step down" OR "forward step down"[All Fields] OR "step down test"[All Fields] OR "step down task"[All Fields] OR "one leg squat"[All Fields] OR "one leg mini squat" OR "one leg loading"[All Fields] OR "one limb squat"[All Fields] OR "one limb mini squat"[All Fields] OR "one leg step down"[All Fields] OR "one limb step down"[All Fields]) AND ("visual assessment"[All Fields] OR "visual"[All Fields] OR "visual rating" [All Fields] OR "subjective" [All Fields] OR "visual screening" [All Fields] OR "screening" [All Fields] OR "rating" [All Fields]).
The Cochrane Library (Filter articles)	#1=("single leg squat" OR "single leg mini squat" OR "single leg loading" OR "single limb squat" OR "single limb mini squat" OR "unilateral squat" OR "small knee bend" OR "single leg step down" OR "single limb step down" OR "lateral step down" OR "forward step down" OR "step down test" OR "step down task" OR "one leg squat" OR "one leg mini squat" OR "one leg loading" OR "one limb squat"OR "one limb mini squat" OR "one leg step down" OR "one limb step down") #2=("visual assessment" OR "visual" OR "visual rating" OR "subjective" OR "visual screening" OR "screening" OR "rating") #3=(#1 AND #2)
Web of Science (Filter articles)	TS=("single leg squat" OR "single leg mini squat" OR "single leg loading" OR "single limb squat" OR "single limb mini squat" OR "unilateral squat" OR "small knee bend" OR "single leg step down" OR "single limb step down" OR "lateral step down" OR "forward step down" OR "step down test" OR "step down task" OR "one leg squat" OR "one leg mini squat" OR "one leg loading" OR "one limb squat"OR "one limb mini squat" OR "one leg step down" OR "one limb step down") AND TS=("visual assessment" OR "visual" OR "visual rating" OR "subjective" OR "visual screening" OR "screening" OR "rating")

APPENDIX II

Clinical procedures and inclusion criteria (chapter IV)

1. PARTICIPANTS

1.1 Femoroacetabular impingement syndrome patients

Patients with hip pain were recruited through the orthopaedic service of the CORE clinic. These patients were assessed by an experienced hip surgeon between January 2019 and December 2021. The surgeon has already performed approximately 2000 hip arthroscopies throughout his 15 years of practice. Patients were elected for surgery if they presented an Alpha angle >55° and/or a Lateral Center Edge angle >39°, Tonnis angle <0°, Hip pain (for more than 3 months), positive FADIR test and no improvement of symptoms after conservative treatment (self-reported). Specific imaging methods used, and performance description of the FADIR test are described elsewhere (GOMES et al., 2021).

Patients were included in the study if they:

- Were aged between 18 and 60 years;
- Underwent hip arthroscopy surgery as treatment of FAI syndrome 4 months ago.

Patients were excluded if they:

- Had undergone another hip surgery in the last two years;
- Presented previous history of perthes disease, hip dysplasia (lateral center edge angle <25°);
- Any kind of neurological sequel.

1.2 Asymptomatic participants

Data from asymptomatic individuals was collected from a parallel project performed at the State University of Santa Catarina (CAAE: 87478418.50000.0118).

Individuals were included in the study if they:

- Were aged over 18 years;
- Did not presented any history of pain that unable their participation in physical and daily activities in the last 6 months;
- Performed physical activity at least 3 times a week with a minimum duration of 20 minutes per session;
- Present no history of surgery in the spine and/or lower limbs in the last 2 years;

- Score >75 points in the Lower Extremity Functional Scale (LEFS)

Individuals were excluded if they:

- Were aged under 18 years.

One of the inclusion criteria used the LEFS, a scale of functional capacity of the lower limb (DINGEMANS et al., 2017). The cut-off score of the LEFS used to include the participants was based in a normative data study that assessed 291 healthy individuals where the inter-quartile inferior limit was 75 points for this sample (DINGEMANS et al., 2017)

2. PROCEDURES BEFORE AND AFTER HIP ARTHROSCOPY

Patients diagnosed with FAI syndrome and considered electable for the hip arthroscopy procedure were referred to a clinical setup at the Fisiolab Institute for a pre-surgical assessment. Patients underwent a clinical assessment with a physical therapist and received additional information about the surgical procedure and post-operative phase.

One to seven days after the surgical procedure patients were referred to the Fisiolab institute for a post-surgical assessment conducted by a physical therapist. In that opportunity patients were instructed about their actual condition and about the performance and execution of home-based exercises with an emphasis on motor control, lower limb muscle strengthening, hip range of motion, trunk resistance and cardiorespiratory fitness. Patients received a handbook with images, descriptions, sets and repetitions of the exercises. Two weeks, six weeks and three months after hip arthroscopy patients were referred to the same clinical setup where a physical therapist assessed the clinical evolution and progressed the proposed exercises. Four months after hip arthroscopy the patients were referred to the Fisiolab institute again and underwent a video assessment of the movement pattern of the single leg squat and completed the iHOT-33 questionnaire.

3. CLINICAL ASSESSMENTS

Both femoroacetabular impingement patients and asymptomatic individuals underwent through the following procedures.

3.1 Video assessment of the single leg squat

Before the assessment, pieces of white scotch tape were attached to the following anatomical landmarks: superior-anterior iliac spines, medium thighs (2,5 cm above the superior pole of the patella), anterior tibial tuberosities, and anterior central point between the malleoli's (Figure 1).

Figure 1. Anatomical landmarks

Aiming to limit the squat depth to 60° of knee flexion the following procedure was adopted: First, the subject was oriented to maintain a bilateral squat position with 60° of knee flexion (measured with a goniometer) (Figure 2A). In that position, the researcher responsible for data collection measured the distance from the gluteal fold to the ground with a measuring tape. This distance was applied to tactile support. During the gesture, the tactile support was positioned behind the tested leg of the subject. That way, the patients gluteal fold was touched by the tactile support when the patient reached 60° of knee flexion (Figure 2B).

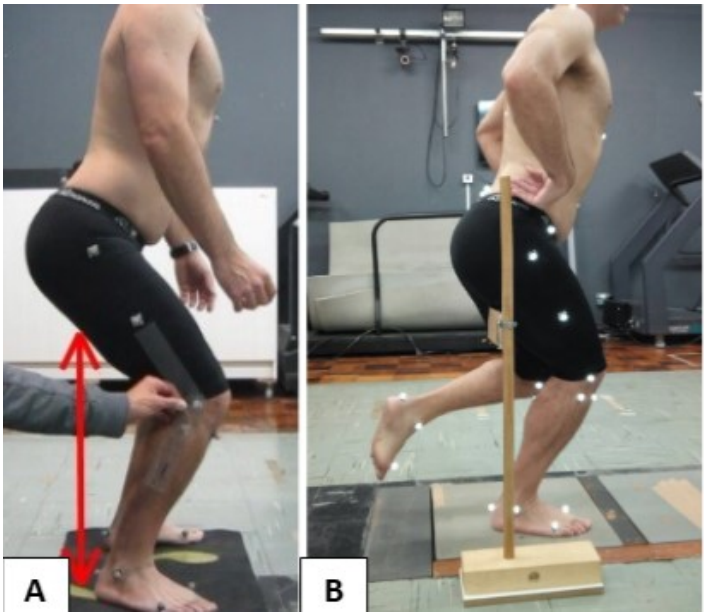


Figure 2. Method used to limit the squat depth during the single leg squat

Subjects were orientated to perform the gesture with the hands-on waist, with the non-tested knee flexed, and to squat until the tactile support touched their gluteal folds. After a gesture demonstration by the researcher, the subjects performed 3 repetitions of the single leg squat as a familiarization and warm-up process. Then, a metronome mobile app (Pro Metronome, ©2014 EUMLab) was used to impose a cadence of 45 bpm per minute for the single leg squat performance. The researcher demonstrated the gesture again, now squatting following the cadence imposed by the metronome. The subjects performed more three repetitions to get familiarized with the imposed cadence. After those three repetitions, subjects were orientated to maintain the foot of the tested leg in the same position (maintaining the alignment with tactile support) and put the foot of the non-tested leg on the ground and wait for perform the single leg squat. Whenever the subjects were ready the researcher instructed them to perform three repetitions of the single leg squat following the rules from the familiarization process (tactile support touch and cadence) for video recording.

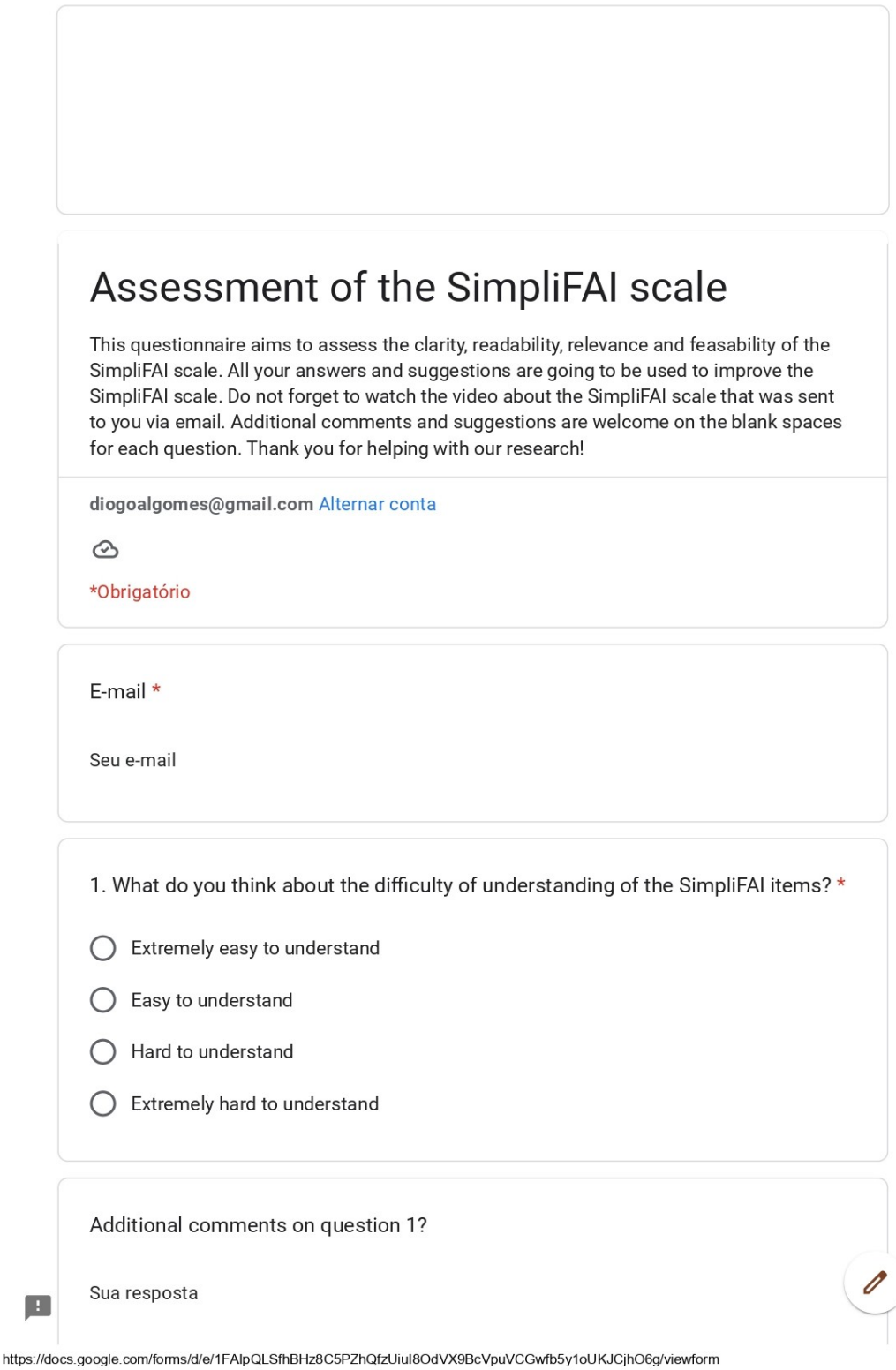
3.2 iHOT-33 questionnaire

After the assessment of the single leg squat, the patients completed the iHOT-33 questionnaire. This questionnaire uses a visual analogue scale to evaluate the quality of life of patients with hip pathology (MOHTADI et al., 2012) and presents a minimum score of zero (worst possible outcome) and a maximum score of 100 (best possible outcome). The Patient-Reported Outcome Measure (PROM) has appropriate psychometric properties in the hip

arthroscopy population and presents a minimal important change value of 10 points (KEMP et al., 2013). Also, a score ≥67 than points is considered an indicator of an acceptable symptomatic state after hip arthroscopy (ISHØI et al., 2021)

APPENDIX III

Questionnaire about the relevance, comprehensiveness and comprehensibility of the SimpliFAI scale.



Assessment of the SimpliFAI scale

This questionnaire aims to assess the clarity, readability, relevance and feasability of the SimpliFAI scale. All your answers and suggestions are going to be used to improve the SimpliFAI scale. Do not forget to watch the video about the SimpliFAI scale that was sent to you via email. Additional comments and suggestions are welcome on the blank spaces for each question. Thank you for helping with our research!

diogoalgomes@gmail.com Alternar conta

*Obrigatório

E-mail *

Seu e-mail

1. What do you think about the difficulty of understanding of the SimpliFAI items? *

- Extremely easy to understand
- Easy to understand
- Hard to understand
- Extremely hard to understand

Additional comments on question 1?

Sua resposta

2. What do you think about the difficulty of application of the SimpliFAI scale in clinical practice (regarding materials, enviroment, time spent)? *

- ◯ Extremely easy to apply
- ◯ Easy to apply
- ◯ Hard to apply
- ◯ Extremely hard to apply

Additional comments on question 2?

Sua resposta

3. Do you think that the scale items comprehend all important movement related factors potentially associated hip pain? *

- ◯ Yes
- ◯ No

Additional comments on question 3?

Sua resposta

Enviar Limpar formu

APPENDIX IV

Conference abstract published in the Brazilian Congress of Biomechanics

Development of the Single leg squat movement pattern scale for individuals with Femoroacetabular impingement Syndrome (SimpliFAI)

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Vol 15 – Supplement ■■ Nov. 2021 ■■ Brazilian Journal of Motor Behavior ■■ ISSN 2446-4902

Background: Femoroacetabular impingement (FAI) syndrome is a clinical hip disorder characterized by the triad: hip pain, positive hip impingement tests and hip morphological alterations identified by imaging findings. Since FAI syndrome is a movement related disorder, biomechanical modifiable factors are critical components in both screening and rehabilitation programs. Previous studies assessed movement patterns during the single leg squat in individuals with FAI syndrome. However, the assessment is typically reduced to kinematic data (often angles) at specific instants in time 7 and does not offer further insight into the movement-pattern impairment in individuals with FAI syndrome. **Aim:** In this study, we took a step back and aimed to develop a qualitative scale to assess movement pattern in individuals with FAI syndrome. **Material and Methods:** This study was approved by the local ethical committee (CAAE 96023618.0.0000.0118). We analyzed 40 individuals with FAI syndrome selected from patients under rehabilitation after hip arthroscopy. Individuals were filmed (frontal plane) while performing the single leg squat, with a limited range of motion of 60° of knee flexion and with a 45-bpm cadence. Videos were analyzed by a physiotherapist who had access to the patient files, including measures of symptom severity based on the iHOT-33 questionnaire scores8. Based on the assessment, the movement features that were shown (research judgment) to better differentiate patients with different iHOT-33 scores were listed and discussed with two external experts. As the last step in the development of the scale (to be tested in the future), its structure is presented to the scientific peers in this conference for feedback. **Results:** The developed scaled is titled Single leg squat movement pattern scale of individuals with FAI Syndrome (SimpliFAI). The first three items of the scale aim to analyze the single leg squat movement quality as whole, emphasizing aspects such as cadence, balance, and fluidity. The final four items are focused on segmental parameters that evaluate the control of the trunk, hip, knee, and foot. The items contained in the scale are presented below and are scored based on dichotomous answers (YES [1pt] or NO [0 pts]). 1. Cadence: Is the individual able to follow the cadence competently? 2. Balance: Is the squat completed with the hands-on hips AND without touching the contralateral foot on the floor? 3. Squat fluidity: Are the ascent and descent phases of squat smooth AND without tremor and hesitation? 4. Trunk control: Does the trunk deviate/ shift laterally during the squat? 5. Hip/pelvis control: Does the hip of the support leg adduct excessively during the squat? 6. Knee control: Does the knee oscillate repetitively in the mediolateral direction during the squat? 7. Foot control: Does the medial or lateral edge of the foot loose contact with the ground during the squat? The SimpliFAI scale may serve as a tool of movement assessment of individuals with FAI syndrome. **Conclusion:** Following steps to the development of this tool include explore its reliability and ability to discriminate symptom severity in individuals with FAI syndrome compared to traditional methods such as the 2D kinematic analysis.

Keywords: Hip pain. Screening. Rehabilitation.

APPENDIX V

SimpliFAI scale

The SimpliFAI tool can be used to visually assess movement quality during the single leg squat task. We suggest the use of SimpliFAI combined to a video recording of the task. and The evaluator must answer each item with "yes or "no". The SimpliFAI score may vary from a minimum of 0 and a maximum score of 8 points, where higher scores indicate better movement quality. (Masters thesis, GOMES et al 2023).

SimpliFAI

Item	During the single leg squat...	Yes	No	Score
1.Balance	*Is the patient able to maintain hands on hips AND NOT touch the contralateral foot on the floor?*			2 points for each Yes response
2.Fluidity	*The patient presents a continuous and fluid movement, without sudden accelerations?*			
3.Trunk control	*Does the trunk excessively deviates/shift laterally?*			1 point for each No response
4.Hip control	*Does the patella pass medially to the second toe (knee valgus)?*			
5.Knee control	*Does the knee swing side to side in a unsteady and repetitive way?*			
6.Foot control	*Does the medial or lateral edge of the foot loose contact with the floor repetitively?*			
SimpliFAI Total Score				

*To calculate the total score, 2 points should be added for each "yes" in questions one (balance) and two (fluidity) and 1 point should be added for each "no" in questions three to six (segmental control).

Access the QR code to watch a video with for more information on how to use the SimpliFAI tool!

ATTACHMENT I

ETHICAL COMITTEE

UNIVERSIDADE DO ESTADO
DE SANTA CATARINA - UDESC

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: VALOR PROGNÓSTICO, SENSIBILIDADE À MUDANÇA E REDUNDÂNCIA DE PARÂMETROS CLÍNICOS, IMAGIOLÓGICOS E BIOMECÂNICOS RELACIONADOS ÀS DISFUNÇÕES DOS MEMBROS INFERIORES

Pesquisador: Marcelo Peduzzi de Castro

Área Temática:

Versão: 3

CAAE: 96023618.0.0000.0118

Instituição Proponente: FUNDACAO UNIVERSIDADE DO ESTADO DE SC UDESC

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.083.697

Apresentação do Projeto:

Trata-se da terceira versão da pesquisa oriunda do CEFID/UDESC em nível de graduação. Pesquisador responsável Dr Marcelo Peduzzi de Castro e equipe de pesquisadores: CARLOS ALBERTO ATHERINOS PIERRI, GUILHERME VINICIUS DA COSTA, HEILIANE DE BRITO FONTANA, TAYLOR FERREIRA, CRISTIANO GOMES SANCHOTENE, RICHARD CANELLA E CAROLINE RUSCHEL.

Desenho do estudo: "A presente investigação configura-se como um estudo prospectivo observacional no qual não haverá qualquer intervenção por parte dos pesquisadores nos participantes". Pesquisa em 3.000 prontuários de pacientes de duas instituições, sendo, o Centro de Ortopedia e Reabilitação (CORE) e o Laboratório de Biomecânica Clínica e Reabilitação Neuromusculoesquelética (LaBClin).

Metodologia proposta e informada no projeto básico: "Os profissionais das instituições parceiras deste projeto (CORE e LaBClin), os quais já demonstraram interesse e anuência em participar do estudo, incluirão na rotina dos serviços a explicação do projeto para os clientes, assim como a entrega do termo de conhecimento livre e esclarecido. Não haverá qualquer tipo de alteração na abordagem oferecida pelo CORE ou LaBClin para os indivíduos que participarem do estudo. Uma vez por mês, um dos pesquisadores envolvidos no projeto acessará o banco de dados das

Endereço: Av.Madre Benvenutta, 2007
Bairro: Itacorubi **CEP:** 88.035-001
UF: SC **Município:** FLORIANOPOLIS
Telefone: (48)3664-8084 **Fax:** (48)3664-8084 **E-mail:** cepsh.udesc@gmail.com

instituições parceiras e extrairá os parâmetros registrados durante o exame físico, dos exames de imagem e avaliações biomecânicas".

Participantes:

Critérios de inclusão: "Qualquer indivíduo, com ou sem disfunção, com idade entre 10 e 80 anos, atendido pelas instituições parceiras deste projeto."

Critério de exclusão: "Indivíduos com disfunção não relacionada ao sistema musculoesquelético, tais como disfunção neurológica ou cardio-respiratória, serão excluídos do estudo".

Metodologia de Análise de Dados descrita no projeto básico: "Como análise principal pretende-se utilizar Neural Networks (redes neurais), visto o potencial que esta abordagem apresenta no sentido de predição. Porém, os modelos estatísticos para tal abordagem ainda estão sendo definidos. Para explorar a presença de sub-grupos de indivíduos (características similares) será utilizada a Análise de Classes Latentes (Hagenaars and Allan L. McCutcheon, 2002). Esse método estatístico estima a probabilidade de agrupamento de casos com base em um conjunto de parâmetros. Os critéiros de informação Akaike e Baysian serão adotados (Hagenaars and Allan L. McCutcheon, 2002). Todos os procedimentos estatísticos serão realizados no IBM SPSS Statistics 20 (IBM Corp., EUA) com um nível de significância de $p<0,05$. Correlações entre os parâmetros clínicos, imagiológicos e biomecânicos serão avaliados por meio do coeficiente de correlação de Pearson".

Cronograma:
Preparação e submissão de artigos científicos 01/06/2021 a 01/12/2021
Registro de dados fase 1 01/04/2019 a 01/06/2021
Registro de dados fase 2 01/06/2021 a 01/05/2023
Registro de dados preliminar 01/01/2019 a 01/04/2019
Preparação e submissão de artigos científicos 01/11/2022 a 01/10/2023
Conclusão das planilhas para extração dos dados dos prontuários
01/01/2019 a 15/01/2019
Articulação com as instituições parceiras 01/01/2019 a 15/01/2019

Tratamento dos dados e processamento estatístico 01/06/2021 a 01/09/2021
Tratamento dos dados e processamento estatístico 01/05/2023 a 01/10/2023

Orçamento, fonte dos recursos, descriminação detalhada: R$100,00 – custeio

Financiamento: próprio

Objetivo da Pesquisa:
Objetivo Primário:

Determinar o valor prognóstico de parâmetros registrados durante o exame físico, de exames de imagem e de avaliações biomecânicas, em indivíduos em recuperação de disfunções da coluna e dos membros inferiores.

Objetivo Secundário:

- Verificar a sensibilidade à mudança de parâmetros clínicos, biomecânicos e imagiológicos em indivíduos em recuperação de disfunções da coluna e dos membros inferiores;

- Verificar a relação entre parâmetros clínicos, biomecânicos e imagiológicos, no sentido de analisar a redundância entre eles;

- Investigar associação entre parâmetros biomecânicos de indivíduos sem qualquer disfunção.

Avaliação dos Riscos e Benefícios:
Riscos:

Riscos aos participantes do estudo e informado no projeto básico: "Os riscos e/ou desconfortos referentes à participação na pesquisa são mínimos. Mesmo que não haja qualquer intervenção nos pacientes ou qualquer forma de influência nos procedimentos adotados pelas instituições parceiras, os dados pertencem ao paciente e são sigilosos, registrados em prontuários. Visando a

não exposição dos dados desses prontuários, o nome do paciente será substituído por um código numérico, preservando assim a sua identidade. Somente o pesquisador responsável terá posse do documento com a identificação do paciente e respectivo código."

Benefícios:

Benefícios descritos no projeto básico: "O projeto não trará benefícios diretos aos participantes. Indiretamente, os participantes poderão se beneficiar quando os resultados do presente estudo forem aplicados à prática clínica. A determinação do valor prognóstico dos parâmetros clínicos, imagiológicos e biomecânicos permite um melhor planejamento do processo de reabilitação e treinamento. A determinação de eventual redundância entre parâmetros, possivelmente permitirá a exclusão da necessidade de alguns exames ou redução do número de parâmetros necessários em cada exame, diminuindo o tempo necessário para os exames e análises, e encargos financeiros para os pacientes e o sistema de saúde. Por fim, a identificação da sensibilidade à mudança dos parâmetros permitirá abordagens melhor direcionadas, possivelmente melhorando as rotinas de avaliação e re-avaliação ao longo da reabilitação e do treinamento de pessoas em recuperação, assim como de pessoas em treinamento visando ganho de performance e prevenção de lesões".

Comentários e Considerações sobre a Pesquisa:
Pesquisa apresenta mérito acadêmico científico ao abordar o "valor prognóstico de parâmetros registrados durante o exame físico, de exames de imagem e de avaliações biomecânicas, em indivíduos em recuperação de disfunções da coluna e dos membros inferiores". de interesse à saúde pública ao compilar dados de 3.000 prontuários e a partir deste resultado propor formas e práticas de reabilitação fisioterápicas as pessoas portadoras de disfunção no sistema musculoesquelético.

Considerações sobre os Termos de apresentação obrigatória:
Folha de rosto: datada, assinada, 3000 participantes;
Declaração de Ciência e Concordância das Instituições Envolvidas – CORE;
Declaração de Ciência e Concordância das Instituições Envolvidas – LaBClin;
Consentimento para fotografias, vídeos e gravações;
Declaração de Fiel Guardião – CORE;
Declaração de Fiel Guardião – LaBClin;
Projeto de Pesquisa Básico (PB) gerado pela Plataforma Brasil;

Projeto de Pesquisa Detalhado (PD) inserido pelo pesquisador;
Termo de Consentimento Livre e Esclarecido (TCLE);
Carta resposta;
Orientação para obtenção do termo de assentimento informado;
Instrumentos de coleta de dados;
Termo de Consentimento Livre e Esclarecido para menores de 18 anos (TCLE).

Recomendações:
Esta relatoria recomenda que os pesquisadores façam a correção ortográfica da frase no TCLE – para menores de 18 anos: "Mesmo assim, os dados QUE gostaríamos de ter acesso pertencem ao(a) seu(ua) filho(a)/dependente e são sigilosos."

Conclusões ou Pendências e Lista de Inadequações:
Pendências geradas após a 2ª análise e atendidas na presente análise:

a)Descrever com clareza a metodologia da coleta dos dados fazer constar que dados são extraídos destes prontuários, incluindo o uso de fotografias, vídeos e ou gravações; = pendência atendida

b)Descrever os procedimentos metodológicos para o atendimento do objetivo: "Investigar associação entre parâmetros biomecânicos de indivíduos sem qualquer disfunção"; = pendência atendida

c)Anexar o TCLE para os responsáveis destes (modelo do CEPSH/UDESC) caso tenha participante menores de 18 anos de idade. = pendência atendida

Em não havendo mais pendências o projeto está apto para Aprovação.

Considerações Finais a critério do CEP:
O Colegiado APROVA o Projeto de Pesquisa e informa que, qualquer alteração necessária ao planejamento e desenvolvimento do Protocolo Aprovado ou cronograma final, seja comunicada ao CEPSH via Plataforma Brasil na forma de EMENDA, para análise sendo que para a execução deverá ser aguardada aprovação final do CEPSH. A ocorrência de situações adversas durante a execução

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da pesquisa deverá ser comunicada imediatamente ao CEPSH via Plataforma Brasil, na forma de NOTIFICAÇÃO. Em não havendo alterações ao Protocolo Aprovado e/ou situações adversas durante a execução, deverá ser encaminhado RELATÓRIO FINAL ao CEPSH via Plataforma Brasil até 60 dias da data final definida no cronograma, para análise e aprovação.
Lembramos ainda, que o participante da pesquisa ou seu representante legal, quando for o caso, bem como o pesquisador responsável, deverão rubricar todas as folhas do Termo de Consentimento Livre e Esclarecido - TCLE - apondo suas assinaturas na última página do referido Termo.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1188858.pdf	10/12/2018 11:34:17		Aceito
Outros	CartaRespostaProspectivo_v2.docx	10/12/2018 11:30:27	Marcelo Peduzzi de Castro	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_de_Consentimento_Livre_e_Esclarecido___menores_ou_dependentes_15242428915699_3526.doc	10/12/2018 11:20:50	Marcelo Peduzzi de Castro	Aceito
Outros	Instrumentodecoleta.xlsx	19/11/2018 19:38:02	Marcelo Peduzzi de Castro	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Orienta__o_para_a_obten__o_do_Termo_de_Assentimento_Informado_15242429069671_3526.doc	19/11/2018 19:29:58	Marcelo Peduzzi de Castro	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLEProjetoProspectivo_v2.doc	19/11/2018 19:28:24	Marcelo Peduzzi de Castro	Aceito
Outros	FielGuardiaoLaBClin.jpg	19/11/2018 19:24:30	Marcelo Peduzzi de Castro	Aceito
Projeto Detalhado / Brochura Investigador	ComiteEticaProjetoProspectivoSensibilidadePrognosticov2.pdf	19/11/2018 19:23:22	Marcelo Peduzzi de Castro	Aceito
Outros	Declaracao_fiel_guardiao_Pierri.pdf	15/08/2018 14:43:55	Marcelo Peduzzi de Castro	Aceito
Outros	ConsentimentoImagensVideos_Prospectivo.doc	15/08/2018 14:42:17	Marcelo Peduzzi de Castro	Aceito
Outros	DeclaraLaBClin.pdf	15/08/2018	Marcelo Peduzzi de	Aceito

Endereço: Av.Madre Benvenutta, 2007
Bairro: Itacorubi **CEP:** 88.035-001
UF: SC **Município:** FLORIANOPOLIS
Telefone: (48)3664-8084 **Fax:** (48)3664-8084 **E-mail:** cepsh.udesc@gmail.com

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Continuação do Parecer: 3.083.697

Outros	DeclaraLaBClin.pdf	14:41:32	Castro	Aceito
Outros	DeclaraCORE.pdf	15/08/2018 14:41:18	Marcelo Peduzzi de Castro	Aceito
Folha de Rosto	FolhadeRosto.pdf	15/08/2018 14:38:06	Marcelo Peduzzi de Castro	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

FLORIANOPOLIS, 14 de Dezembro de 2018

Assinado por:
Renan Thiago Campestrini
(Coordenador(a))

Endereço: Av.Madre Benvenutta, 2007
Bairro: Itacorubi **CEP:** 88.035-001
UF: SC **Município:** FLORIANOPOLIS
Telefone: (48)3664-8084 **Fax:** (48)3664-8084 **E-mail:** cepsh.udesc@gmail.com

ATTACHMENT II

CONSENT FORM FOR RESEARCH PARTICIPATION

UDESC UNIVERSIDADE DO ESTADO DE SANTA CATARINA

cepsh Comitê de Ética em Pesquisa Envolvendo Seres Humanos

GABINETE DO REITOR

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

O(a) senhor(a) está sendo convidado(a) a participar voluntariamente de um projeto de pesquisa intitulado **Valor prognóstico, sensibilidade à mudança e redundância de parâmetros clínicos, imagiológicos e biomecânicos relacionados às disfunções dos membros inferiores**, cujo objetivo é melhorar as estratégias de planejamento da reabilitação, assim como identificar quais os exames e avaliações clínicas são mais importantes.

Os riscos e/ou desconfortos referentes à participação do projeto são mínimos. Não haverá qualquer intervenção ou qualquer forma de influência nos procedimentos adotados pela equipe médica ou equipe de reabilitação que está acompanhando você. Mesmo assim, os dados que gostaríamos de ter acesso pertencem a você e são sigilosos. Para manter o sigilo da informação, o nome do(a) senhor(a) será substituído por um código numérico, preservando assim a sua identidade e garantindo o anonimato. Somente a equipe de pesquisadores terá posse do documento com a identificação do paciente e respectivo código.

O(a) senhor(a) não terá despesas e nem será remunerado pela participação na pesquisa. O(a) senhor(a) poderá se retirar do estudo a qualquer momento, sem qualquer tipo de constrangimento. O projeto não trará benefícios diretos a(o) senhor(a). Indiretamente, você poderá se beneficiar quando os resultados do presente estudo forem aplicados à prática clínica. A determinação do valor prognóstico dos parâmetros clínicos, imagiológicos e biomecânicos permite um melhor planejamento do processo de treinamento, prevenção e reabilitação. A determinação de eventual redundância entre parâmetros, possivelmente permitirá a exclusão da necessidade de alguns exames ou redução do número de parâmetros necessários em cada exame, diminuindo o tempo necessário para os exames e encargos financeiros.

Solicitamos a sua permissão para a equipe de investigadores do projeto ter acesso a sua ficha clínica, assim como aos seus exames de imagem e biomecânicos. Também solicitamos a sua permissão para acessarmos a sua ficha clínica, exames de imagem e biomecânicos de eventuais consultas futuras que o senhor(a) realize, até o término do projeto, previsto para dezembro de 2023. Um dos pesquisadores registrará as informações/medidas referentes ao seu estado de saúde e aos exames que você realizou para posterior análise. Gostaríamos também da sua autorização para o uso de seus dados para a produção de artigos técnicos e científicos. A sua privacidade será mantida através da não-identificação do seu nome.

Este termo de consentimento livre e esclarecido é feito em duas vias, sendo que uma delas ficará em poder do pesquisador e outra com o senhor(a).

Nome do Pesquisador para contato: MARCELO PEDUZZI DE CASTRO
Telefone: (48) 3209-8644 / (48) 991272780
Endereço: Rua Dom Joaquim, 885, 2°andar, Florianópolis, SC, CEP 88010-310

Assinatura do Pesquisador: Marcelo Castro

Comitê de Ética em Pesquisa Envolvendo Seres Humanos – CEPSH/UDESC
Av. Madre Benvenuta, 2007 – Itacorubi – Florianópolis – SC -88035-901
Fone/Fax: (48) 3664-8084 / (48) 3664-7881 - E-mail: cepsh.reitoria@udesc.br / cepsh.udesc@gmail.com
CONEP- Comissão Nacional de Ética em Pesquisa
SEPN 510, Norte, Bloco A, 3ºandar, Ed. Ex-INAN, Unidade II – Brasília – DF- CEP: 70750-521
Fone: (61) 3315-5878/ 5879 – E-mail: conep@saude.gov.br

TERMO DE CONSENTIMENTO

Declaro que fui informado sobre todos os procedimentos da pesquisa e, que recebi de forma clara e objetiva todas as explicações pertinentes ao projeto e, que todos os dados a meu respeito serão sigilosos. Eu compreendo que neste estudo, as medições dos experimentos/procedimentos de tratamento serão feitas em mim, e que fui informado que posso me retirar do estudo a qualquer momento.

Nome por extenso _____

Assinatura _____ Local: _____ Data: _____/_____/_____.