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AMIR CURCIO DOS REIS

Estudo das características biomecânicas do tronco, quadril, joelho, tornozelo e pé associado à intervenção com biofeedback em mulheres com dor femoropatelar durante diferentes atividades funcionais

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Segunda Qualificação de Doutorado apresentada ao Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Nove de Julho como parte dos requisitos para obtenção do título de Doutor em Ciencias da Reabilitação

Orientador: Prof. Dr. Paulo Roberto Garcia Lucareli

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DEDICATÓRIA

Aos meus pais, Joaquim Abrantes e Ana Maria, por todo carinho e dedicação que me oferecem a cada dia. Por abdicarem de seus próprios projetos de vida para que eu pudesse realizar os meus sonhos, sempre me apoiando e incentivando com atitudes e gestos de muito amor. Meu eterno amor e gratidão a vocês.

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A mente que se abre a uma nova ideia jamais voltará ao seu tamanho original.

Albert Einstein

PREFACIO

Essa tese de Doutorado aborda o tema referente à dor femoropatelar em mulheres fisicamente ativas. A Universidade Nove de Julho possui algumas regras específicas para a elaboração da defesa da tese que, para melhor entendimento da banca, será explicada durante esse prefácio. Segundo essas regras o aluno deve dividir a tese em 3 capítulos: 1: contextualização; 2: Métodos e 3: Resultados

No primeiro capítulo é apresentado um panorama geral da literatura a respeito do assunto abordado. No nosso caso foi abordado a etiologia da dor femoropatelar, assim como a sua incidência, opções de tratamento conservador e/ou cirúrgico, novas perspectivas de tratamento e algumas perguntas que ainda não estão totalmente respondidas na literatura. Ao final desse capítulo são apresentados, ainda, os objetivos dessa tese que, segundo as regras da Universidade, devem ser respondidos em forma de artigo.

No segundo capítulo é apresentado os métodos utilizados em cada um dos artigos escritos pelo aluno durante a sua formação. Na presente qualificação encontram-se 3 artigos escritos, um deles já submetido à revisa Gait & Posture (artigo 2) e os outros dois aguardando considerações da banca de qualificação para breve submissão.

O terceiro e último capítulo, os resultados, deve ser os artigos escritos durante a formação do aluno dentro da Universidade. Todos eles já encontram-se já na língua inglesa e após as considerações da banca serão submetidos à uma revisa de alto impacto na áres, tão logo as considerações e as correções do aluno forem feitas.

RESUMO

A dor femoropatelar (DFP) constitui uma das principais afecções dos membros inferiores, sobretudo de mulheres fisicamente ativas. Sua etiologia é multifatorial e está diretamente ligada à desarranjos biomecânicos que envolvem o membro inferior, sendo o valgo dinâmico do joelho uma das principais alterações ligadas à ela. Dentre as características biomecânicas, destacamos a movimentação excessiva de adução e rotação medial do quadril durante atividades em cadeia cinética fechada, sobretudo o agachamento unipodal. Além do agachamento unipodal, o valgo dinâmico é descrito em outras atividades consideradas de baixo impacto, como a subida de escadas, descida de escadas, marcha, corrida e step downs tests, entretanto, quando se busca informações comparativas entre atividades de alto *versus* baixo impacto, há ima importante lacuna na literatura. Além disso, o comportamento cinemático do pé tem sido frequentemente associado à dor femoropatelar, entretanto, estudos que avaliem especificamente a cinemática durante as atividades funcionais por meio de um modelo multisegmentar também são escassos na literatura. Em relação ao tratamento, não existe um consenso sobre a melhor conduta, mas o biofeedback cinemático tem se tornado uma ferramenta cada vez mais útil. Sua aplicação pode intervir de forma direta nas articulações de interesse. Sendo assim, essa tese de Doutorado foi dividida em 3 estudos, com os seguintes objetivos: 1: Avaliar através de variáveis cinéticas e cinemáticas, se a fase de alto impacto do *single leg triple hop test* (SLTHT) promove mais alterações biomecânicas no membro inferior do que a fase de baixo impacto; 2: Comparar a cinemática do pé de mulheres com dor femoropatelar e o pé pronado com as assintomáticas durante a execução do do *step down anterior e lateral*; e 3: Avaliar se os resultados da redução de 20% da adução de quadril ou um aumento de 20% da inclinação anterior do tronco através do biofeedback cinemático apresentam resultados diferentes quando dado o biofeedback verbal para menor adução do quadril e maior flexão anterior do tronco, assim como avaliar se essas estratégias são capazes de melhorar a dor de forma imediata das mulheres com dor femoropatelar durante o agachamento unipodal.

Palavras-chave: Joelho; cinemática; biofeedback; dor femoropatelar

ABSTRACT

Patellofemoral pain (PFP) is one of the main diseases of the lower limbs, especially physically active women. The etiology is multifactorial and is directly linked to biomechanical disorders in the lower limb. Dynamic knee valgus is one of the major lower limb misalignment linked to PFP. Among the biomechanical characteristics in dynamic knee valgus, we highlight the excessive movement of hip adduction and internal rotation during closed kinetic chain activities, especially the squat. In addition to squat, dynamic valgus is described in other activities considered as low impact, such as stair climbing, and descending, walking and step downs tests, however, when we look for comparative information between high and low impact activity there is a gap in the literature. Furthermore, the kinematic behavior of the foot has been frequently associated with patellofemoral pain, however, studies evaluating the kinematic specifically during the functional activities through a multisegmented model are also scarce in the literature. Regarding treatment, there is no consensus about best approach, but the kinematic biofeedback has become an increasingly useful tool. The application can intervene directly in the joints of interest. Therefore, this PhD thesis was divided into 3 studies, with the following objectives: 1: Assess through kinetic and kinematic variables, the phase of high-impact single leg triple hop test (SLTHT) promotes more biomechanical changes in lower limb the phase of the low impact; 2: Compare the women foot kinematics with patellofemoral pain and pronated foot with asymptomatic during the implementation of the previous step down and side; and 3: To assess whether the 20% reduction results hip adduction or an increase of 20% of the anterior trunk tilt through kinematic biofeedback display different results when given the verbal biofeedback to lower hip adduction and most anterior trunk flexion and to evaluate whether these strategies are able to improve the pain immediately of women with patellofemoral pain during the squat.

Key words: Knee; kinematic; biofeedback; patellofemoral pain

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LISTA DE ABREVIATURAS

DFP: Dor femoropatelar

FPI: Foot Posture Index

NPRS: Numerical pain ratins scale

3D: Três dimensões

UNINOVE: Universidade Nove de Julho

SLTHT: Single leg triple hop test

GCM: *Gait conventional model*

FRS: Força de reação ao solo

OFM: Oxford foot model

CG: Control group

PFPG: Patellofemoral pain group

SDL: Step down lateral

HFTLF: Retropé em relação ao laboratório

HFTBA: Retropé em relação à tibia

FFTBA: Antepé em relação à tíbia

FFHFA: Antepé em relação ao retropé

SLSHB: Single leg squat hip biofeedback

SLSHV: Single leg squat hip verbal

SLSTB: Single leg squat tronco biofeedback

SLSTV: Single leg squat tronco verbal

SLSU: Single leg squat usual

FPS: Frames por segundo

AKPS: Anterior knee pain scale

ASIS: Anterior superior inferior spine

SD: Standard deviation

ROM: Range of motion

CCF: Cadeia cinética fechada

1. CONTEXTUALIZAÇÃO

A dor femoropatelar (DFP), ou dor anterior no joelho, constitui uma das condições musculoesqueléticas mais comuns dentre todas as lesões relacionados à articulação do joelho, podendo caracterizar, nos adolescentes e adultos jovens, até 40% de todas as afecções ortopédicas nessa articulação.[1-3] É frequentemente descrita como dor localizada na região anterior do joelho ou ao redor da patela, sem nenhuma outra lesão associada. Seu principal sintoma constitui na crepitação e no processo álgico durante atividades que envolvam descarga de peso, como o agachamento, subida de escadas, descida de escadas e corrida. Além disso, sintomas ao ficar sentado por tempo prolongado, agachar ou realizar força isométrica máxima do quadríceps também podem estar frequentemente presentes.[2]

Sua prevalência ainda não é totalmente esclarecida[4] mas acredita-se que seja em torno de vinte e duas pessoas acometidas a cada mil por ano, sendo as mulheres, em média, duas vezes mais acometidas do que os homens, sobretudo aquelas fisicamente ativas.[5, 6] No que diz respeito àqueles que praticam atividade física, sua incidência gira em torno de 17%[7] e 25%[8].

Ainda não há um consenso a respeito da real causa da DFP, pois a literatura atual aponta que existem vários fatores que podem contribuir para o surgimento da dor,[9] dentre eles, o desalinhamento biomecânico do membro inferior e do tronco durante atividades funcionais tem sido cada vez mais relacionado à dor anterior no joelho, especialmente quando os pacientes executam movimentos em cadeia cinética fechada, tais como a subida e descida de escadas, agachamentos e saltos.[10, 11]

Powers[12] afirma que, ao realizar tais atividades, por um descontrole do membro inferior, dentre outras características, existe uma cascata de movimentos lesivos à articulação femoropatelar que tem início na articulação do quadril: adução e rotação medial, seguido de uma abdução do joelho e rotação lateral da tíbia, o que produz uma força de cisalhamento na articulação femoropatelar e diminui a área de contato da patela com o fêmur, sobrecarregando, assim, a cartilagem retropatelar e gerando sintomas dor ao paciente.

A esse descontrole do membro inferior durante as atividades mencionadas, chamamos de valgo dinâmico do joelho,[13] que tem sido frequentemente relacionado à dor femoropatelar[4, 14-22] entretanto, um fato que chama atenção é que esse desarranjo tem sido frequentemente comparado entre mulheres com e sem dor femoropatelar durante atividades que envolvem pouco impacto. A literatura é escassa de informações a respeito das diferenças encontradas durante atividades de alto e baixo impacto em mulheres com dor femoropatelar.

Dentre as atividades de alto impacto, o *single leg triple hop test* é frequentemente utilizado na prática clínica para avaliar a estabilidade do joelho após períodos de reabilitação,[23, 24] é considerado uma importante tarefa funcional por apresentar uma fase de menor impacto, chamada de fase de preparação, e uma fase de alto impacto, chamada de fase de aterrissagem.[25]

Estudos tem avaliado a força muscular de mulheres com DFP. Alguns afirmam existir a fraqueza da musculatura do quadríceps,[26] outros dos abdutores do quadril[27-29] ou até mesmo alguns que afirmam não existir déficit muscular dessas estruturas,[26] não permitindo uma relação de causa e efeito para a DFP em relação à força muscular. Estudos coorte que avaliem essas características devem ser realizados.

No que diz respeito à cinemática angular, não é apenas a movimentação excessiva da articulação do quadril que está associada à presença da DFP. Segundo o último consenso sobre o DFP,[7] os segmentos do tronco e do tornozelo/pé (fatores distais) também estão diretamente ligados à DFP. De acordo com esse estudo, os mecanismos do tronco vão influenciar na dor femoropatelar devido ao déficit de movimento no plano sagital. Por outro lado, a cinemática do pé, pouco abordada nos estudos que avaliam essa doença, pode contribuir para o surgimento da dor femoropatelar pela existência de excessivo movimento de eversão do retropé e rotação interna da tíbia, que sobrecarregarão a articulação femoropatelar, entretanto, as chamadas características distais ainda precisam ser melhor estudadas e correlacionadas com a dor.[30]

Ainda em relação aos fatores distais, para avaliar a postura estática pé, o *foot posture índex* (FPI) tem se tornado uma importante ferramenta. Este índice avalia estaticamente e de uma forma simples, os três planos anatômicos do pé e fornece um *score* que o qualifica em: normal, pronado, hiper-pronado ou supinado.[31, 32]

Novos estudos tem relacionado, também, o posicionamento do tronco como um dos fatores predisponentes de dor no joelho em mulheres com DFP. Segundo Bazett-Jones et al (2013)[33] quando indivíduos acometidos pela dor femoropatelar realizam o agachamento com aumento da flexão do tronco, há o deslocamento anterior do centro de massa, diminuindo o momento extensor no joelho, o que diminui o stress na articulação femoropatelar, melhorando a dor de mulheres acometidas pela dor femoropatelar.

Dutton,[34] divide de forma didática os fatores que podem estar relacionados à presença da DFP. Os fatores locais seriam a fraqueza do quadríceps e/ou vasto medial oblíquo e o encurtamento das estruturas musculares ao redor da articulação do joelho, como o próprio quadríceps, gastrocnêmios, banda iliotibial e isquiotibiais; em relação aos fatores distais (tornozelo/pé), as principais características seriam a pronação excessiva do retropé ou pé plano, que vão predispor o fêmur a aumentar a rotação medial durante as atividades em cadeia cinética fechada. A fraqueza da musculatura abdutora e rotadora lateral seriam características relacionadas aos fatores proximais.

Dentro desse contexto, pode-se afirmar que a dor femoropatelar pode ser relacionada com vários fatores como possíveis causadores da síndrome.[26]

As estratégias de tratamento são diversas: há intervenções conservadoras que visam a estabilização segmentar lombopélvica;[35] as que abordam o fortalecimento da musculatura do quadríceps;[34] alguns que abordam predominantemente o fortalecimento da musculatura abdutora e rotadora lateral do quadril;[36, 37] alongamento da banda iliotibial, tensor da fascia lata, isquiotibiais e quadríceps;[38] e taping patelar.[39]

Apesar das diferentes abordagens terapêuticas para a DFP, uma recente revisão sistemática[37] nos informa que a abordagem com melhores resultados é aquela em que é dado ênfase ao fortalecimento da musculatura abdutora e rotadora lateral do quadril, associado ao fortalecimento muscular do quadríceps e o controle neuromuscular.

Uma das formas utilizadas para mensurar a melhora desses pacientes após o tratamento é a *Numerical Pain Ratins Scale* (NPRS), que consiste em uma medida reprodutível e validada para avaliar a intensidade da dor nas afecções musculoesqueléticas. Ela consiste em uma linha de 10 cm de comprimento, onde o zero representa a ausência de dor e o dez representa a pior dor imaginável. O paciente é questionado em relação à sua dor antes e depois do tratamento para efeitos comparativos.[40, 41]

Apesar de ser variado e com diferentes resultados, o tratamento conservador é aquele que surte os melhores resultados no tratamento da dor femoropatelar pré e pós tratamento[42] entretanto, em último caso, se a abordagem conservadora não surtir os efeitos desejados, a abordagem cirúrgica pode ser indicada,[43] que consiste geralmente em uma das seguintes opções: realinhamento patelar através do *release* lateral, *resurfacing* ou, em último caso, artroplastia de joelho.[4]

O biofeedback biomecânico tem se caracterizado como uma importante ferramenta para o tratamento das mulheres com dor femoropatelar, uma vez que seu principal objetivo é facilitar o movimento normal do segmento após uma lesão[44] dando a oportunidade ao paciente de conseguir melhorar os movimentos durante atividades funcionais, envolvendo a mensuração dos movimentos, controle postural e das forças produzidas pelo corpo.[45]

Dentre os diferentes recursos que podem ser utilizados para o biofeedback biomecânico, temos as plataformas de força, eletrogoniômetros, sensores de movimento e câmeras baseadas na mensuração das três dimensões do movimento, sendo essa última, usada sobretudo, para promover um biofeedback visual do movimento executado.[45]

As câmeras com base na mensuração 3D tem sido utilizadas na reabilitação ortopédica para promover o biofeedback visual e avaliar a melhora do movimento e ativação muscular. Kim e colaboradores[46] fizeram uso do biofeedback visual através de câmeras de vídeo para intervir em pessoas com dor no ombro e conseguiram melhorar a ativação do serratil anterior e diminuir a ativação do trapézio superior nesses pacientes a partir do uso do biofeedback[46]

Salsich e colaboradores[13] avaliaram a influência imediata da melhor movimentação de quadril na dor de mulheres com DFP através de um biofeedback verbal. Para isso selecionou 20 mulheres com dor femoropatelar que apresentavam valgo dinâmico do joelho e solicitou que elas agachassem em 3 condições: 1 – agachamento usual; 2 – agachamento corrigido (através de um feedback verbal para que a paciente não deixasse o joelho “ir para dentro”) e, 3 – agachamento exagerado (através de um feedback verbal para que a paciente realizasse mais valgo de joelho durante o agachamento). Ao final da análise concluiu que a mudança da cinemática quadril (melhora do valgo dinâmico) não alterou a dor no joelho das voluntárias de forma imediata, entretanto, segundo os próprios autores, um dos principais viés da pesquisa foi a forma como foi dada a instrução às voluntárias (biofeedback verbal). Segundo eles, caso haja um outro tipo de biofeedback para o melhor controle do movimento (além do biofeedback verbal) os resultados podem ser melhores.

Por outro lado, Powers e colaboradores[47] fizeram uso apenas do biofeedback verbal e avaliaram a influência da flexão anterior do tronco na pressão femoropatelar. Foram selecionados 24 voluntários que correram em 3 situações distintas: 1 – flexão do tronco usual (onde não foi dada nenhuma informação ao paciente); 2 – flexão do tronco confortável (onde era solicitado ao o voluntário que corresse com aumento da flexão do tronco, desde que de uma forma confortável) e, 3 – extensão (solicitado que o paciente fizesse a corrida com o tronco em extensão confortável). Ao final do experimento foi concluido que a flexão confortável do tronco diminui o stress na articulação femoropatelar, o que pode ser uma estratégia de tratamento interessante para pessoas que sofrem de DFP.

Davis *et. al*[48] selecionou 10 corredores com dor femoropatelar e os submeteu a um treinamento de biofeedback cinemático com o objetivo de diminuir a adução do quadril durante a prática da corrida por um período de 8 sessões e observou que o treinamento proporcionou melhora de 23% na adução do quadril durante a prática da corrida e em 18% durante uma atividade não treinada (agachamento unipodal), promovendo melhora dos sintomas durante a avaliação pós tratamento e até um mês de acompanhamento, diferentemente do estudo reportado por Salsich e colaboradores,[13] entretanto, esse estudo constituiu em um tratamento de 8 sessões e não apenas uma sessão unica.

Frente à esse cenário, essa tese foi dividida em 3 diferentes estudos, com os seguintes objetivos:

Estudo 1 – Avaliar através de variáveis cinéticas e cinemáticas, se a fase de alto impacto do SLTHT promove mais alterações biomecânicas no membro inferior do que a fase de baixo impacto.

Estudo 2 – Comparar a cinemática do pé de mulheres com dor femoropatelar e pé pronado com as assintomáticas durante a execução do do *step down anterior e lateral*

Estudo 3 – Avaliar se os resultados da redução de 20% da adução de quadril ou um aumento de 20% da inclinação anterior do tronco através do biofeedback cinemático apresentam resultados diferentes quando dado o biofeedback verbal para menor adução do quadril e maior flexão anterior do tronco, assim como avaliar se essas estratégias são capazes de melhorar a dor de forma imediata das mulheres com dor femoropatelar durante o agachamento unipodal.

2. MÉTODOS

Artigo 1

Does high-impact functional activity increase lower limb misalignment in women with patellofemoral pain during the different phases of the single leg triple hop test?

Desenho do estudo

Estudo transversal

Local de Realização do Estudo

O trabalho foi desenvolvido no Núcleo de Apoio à Pesquisa em Análise de Movimento do Programa de Pós-Graduação Stricto Sensu em Ciências da Reabilitação da Universidade Nove de Julho – UNINOVE, Campus Vergueiro, localizado na cidade de São Paulo.

Aspectos Éticos

O presente protocolo de pesquisa foi aprovado pelo "*Comitê de Ética e Pesquisa"* da Universidade Nove de Julho – UNINOVE, seguindo a resolução 196/96. Para a realização de todos os procedimentos foi exigida a leitura e assinatura do Termo de Consentimento Livre e Esclarecido dos participantes.

Cálculo da amostra

O tamanho da amostra foi calculado com base no valor máximo da flexão do joelho, que de acordo com estudos prévios, são associados ao o desalinhamento biomecânico do membro inferior.[49] Sendo assim, para um α=.05, β=.10 (90% de poder), uma diferença média entre os grupos de 11 graus e um desvio padrão de 10, foram necessários 17 participantes no estudo.

Participantes

Foram selecionadas 17 mulheres com DFP. As voluntárias tinham entre 18 e 35 anos e tinham histórico de dor anterior no joelho por pelo menos 3 meses antes da avaliação. Para serem consideradas aptas a participar da pesquisa elas deveriam reportar os sintomas em pelo menos duas das seguintes atividades:[50] subida e descida de escadas, sentar por tempo prolongado, ajoelhar, saltar, agachar, fazer força isométrica máxima do quadríceps ou dor à palpação da faceta lateral da patela.

Um fisioterapeuta experiente no tratamento de lesões musculoesquelética foi o responsável por fazer todas as avaliações e julgar se as voluntárias estavam aptas ou não a participar da pesquisa. Todas aquelas que foram selecionadas para o estudo eram consideradas fisicamente ativas, ou seja, praticavam algum tipo de atividade fisica pelo menos uma vez por semana.[51] Como critério de exclusão foram adotadas as seguintes características: gravidez, alterações cardíacas ou neurológicas reportadas pelas próprias voluntárias, lesões na coluna, quadril ou pé, artrite reumatóide, cirurgias prévias nos membros inferiores, instabilidade femoropatelar, lesões ligamentares ou meniscais, osteoatrose ou tendinppatias nos membros inferiores. Aquelas que apresentassem discrepância dos membros inferiores maior do que 1cm também eram excluídas da pesquisa (distância entre a espinha iláaca ântero superior e o maléolo medial).

Instrumentação

Oito câmeras SMART-D® BTS (Milan, Italia) com uma frequência de 100 Hz foram utilizadas para capturar as trajetórias dos marcadores durante os saltos. As câmeras eram conectadas a um computador e à uma plataforma de força de 400 Hz (Kistler 9286, New York, USA) que ficava localizada de forma camuflada no centro da área de coleta. Essa plataforma era conectada ao mesmo computador que foi utilizado para a coleta dos dados cinemáticos através de um conversor analógico-digital, que promoveu a sincronização dos dados cinéticos e cinemáticos.

Baseado em estudos prévios, frequências de 100 Hz para os dados cinemáticos[25,52-55] e de 400 Hz para os dados cinéticos[25, 52, 55-58] são considerados suficientes para avaliar as variáveis do nosso estudo.

Procedimentos

Após a triagem a partir dos critérios de inclusão e exclusão foi marcada uma avaliação inicial para a realização do *single leg triplo hop test* (SLTHT) no laboratório de análise do movimento humano da Uninove Campus Vergueiro. Antes de realizarem o salto as voluntárias eram questionadas sobre a média da dor no joelho durante os últimos 15 dias através de uma escala numérica para mensuração da dor, a NPRS.[40, 41]

Foram coletadas as medidas antropométricas para a coleta da análise do movimento humano: peso corporal, altura, distância entre as espinhas ilíacas ântero-superiores, diâmetro do joelho, diâmetro do tornozelo e torção tibial[27]. Para essas mensurações foram utilizadas uma balança, fita métrica, paquímetro (para a mensuração da distância entre as espinhas ilíacas, profundidade do joelho e do tornozelo) e um goniômetro, respectivamente.

Antes de realizarem os saltos as voluntárias realizaram um aquecimento prévio na esteira em uma velocidade de 6 km/h durante 10 minutos. Depois do aquecimento eram instruidas a realizar alguns saltos triplos progressivos (SLTHT) com a máxima distância possível, a fim de se familiarizarem com a tarefa, até que se sentissem aptas a realizar a atividade.

Seguindo o modelo convencional de análise de marcha (GCM),[59, 60]que tem sido frequentemente utilizado para a análise cinemática do salto,[25, 57, 58, 61-65] 23 marcadores foram colocados nos seguintes pontos anatomicos das voluntárias: espinhas ilíacas ântero-superiores, espinhas ilíacas ântero-inferiores (com um terceiro marcador auxiliar na mesma base rigida), centro da patela, epicôndilos femorais laterais, terço médio das pernas, maléolo lateral, segundo metatarso, calcâneo, articulações acromiclavicular, processo espinhoso da sétima vertebra cervical, processo xifoide e ângulo inferior da escapula direita. Todos esses marcadores foram utilizados tanto para a coleta estática como a coleta dinâmica.

Uma vez colocados os marcadores, foi realizada uma coleta estática, seguida de três coletas dinâmicas do SLTHT com um intervalo de dois minutos entre cada um dos *trials* a fim de evitar a fadiga. A coleta foi feita apenas no lado sintomático e, caso a dor fosse bilateral, apenas o lado com maiores sintomas era escolhido para análise.

Frente à dificuldade de fornecer um calçado para cada voluntária da pesquisa, optamos por fazer com que as voluntárias realizassem a tarefa descalça. A fim de evitar movimentos compensatórios com membros superiores e troncos, todas foram instruídas a realizar o salto com as mãos cruzadas na região anterior do tronco, abaixo do processo xifóide, para que não houvesse obstrução dos marcadores do tronco.

Para melhor avaliação do ciclo da atividade, o SLTHT foi separado em fase de preparação (momento em que a voluntária prepara-se para executar o primeiro salto) e fase de aterrissagem (momento em que a voluntária toca o pé no solo durante o primeiro salto, até o momento da máxima flexão do joelho), que foram capturadas em *trials* diferentes e de forma randomizada através de um envelope opaco para cada voluntária.

Para a coleta da fase de preparação as voluntarias foram colocadas no centro da plataforma de força e foram instruidas a realizar o SLTHT com a máxima distância possível. Já para a aterrissagem, durante os *trials* de familiarização foi computada a distância que cada uma das voluntárias atingiram durante o salto. Essa distância foi utilizada para posicionar as voluntárias no volume de coleta para que elas aterrisassem no centro da plataforma de força durante a transição do primeiro para o segundo salto do SLTHT.

Processamento dos Dados

Os dados cinemáticos foram convertidos para o formato C3D através do Matlab (MathWorks, Inc, Natick, MA) e um Toolkit Biomecanico BTK 0.1.10.[66] A marcação do ciclo e o seu processamento foi realizado através do Software Vicon Nexus[67](VICON, Oxford, UK) e o Modelo Plug in Gait foi aplicado. Assim como em estudos prévios que avaliam tarefas dinâmicas, a trajetória dos marcadores foi filtrada usando um filtro Butherworth 12 Hz com filtro passa baixa de quarta ordem e atraso de fase zero.[68] A cinemática angular foi calculada através de um Sistema de coordenadas[59] e reportadas levando em consideração o *trial* estático para quantificar os movimentos de um segmento em relação ao outro, assim como ao laboratório. Os dados cinemáticos, a força de reação ao solo e as medidas antropométricas foram utilizadas para calcular o momento interno articular do quadril, joelho e tornozelo, baseado em cálculos de dinâmica inversa no software Vicon Nexus®. Os dados cinéticos foram normalizados de acordo com o peso corporal das voluntárias.

Durante a fase de preparação do SLTHT, o início do ciclo (0%) foi considerado no instante em que a força de reação do solo (FRS) diminuiu em relação ao peso corporal. Já o fim do movimento (100%) foi considerado quando ela atingiu zero (instante em que o pé perdeu o contato com o solo. Durante a aterrissagem o ciclo iniciou no instante em que o pé tocou o solo e terminou no instante em que o pé perdeu o contato com a plataforma durante a transição do primeiro para o segundo salto do SLTHT. Para cada uma dessas fases, o valor máximo alcançado por cada articulação (tronco, pelve, quadril, joelho e tornozelo) nos três planos de movimento foram utilizados para análise. Os momentos internos do quadril, joelho e tornozelo foram obtidos no momento da maior flexão do joelho.

Análise Estatistica

O teste de Kolmogorov Smirnov foi utilizado para testar a normalidade dos dados cinéticos e cinemáticos. A estatistica descritiva foi feita através da média e desvio padrão para todas as variáveis. A média dos 3 *trials* realizados foi utilizada para a estatística. Os dados foram comparados entre os grupos usando análise multivariada (MANOVAs) para a cinemática e outra análise para a cinética. No caso de efeitos multivariados significantes, análise univariada foi testada para cada variável significativa. O valor de P considerado estatisticamente significante foi $P<0.05$ para todas as análises intergrupos. As análises intragrupo foram comparadas usando o teste t pareado com a correção de Bonferroni. Dessa forma o P foi considerado significante quando $<.005$ para os dados cinemáticos e <0.008 para os dados cinéticos. A relevância clinica dos resultados foi confirmada pelo cálculo do *effect size* (Cohen d) das diferenças encontradas nos testes. Foram considerados os seguintes efeitos: 0-0.49 pequeno; 0.50-0.79 médio; e, maior do que 0.80 alto.[69] Todo o processo estatístico foi feito usando o software SPSS, versão 20.0(SPSS Inc Chicago, IL).

Artigo 2

Kinematic analysis of the ankle/foot complex mobility of women with PFPS during weight bearing functional tests

Desenho do estudo

Estudo transversal, tipo caso controle

Local de Realização do Estudo

O trabalho foi desenvolvido no Núcleo de Apoio à Pesquisa em Análise de Movimento do Programa de Pós-Graduação Stricto Sensu em Ciências da Reabilitação da Universidade Nove de Julho – UNINOVE, Campus Vila Maria, localizado na cidade de São Paulo.

Aspectos Éticos

O presente protocolo de pesquisa foi aprovado pelo "*Comitê de Ética e Pesquisa*" da Universidade Nove de Julho – UNINOVE, seguindo a resolução 196/96. Para a realização de todos os procedimentos foi exigida a leitura e assinatura do Termo de Consentimento Livre e Esclarecido dos participantes.

Participantes

Este estudo avaliou 50 mulheres que foram divididas em dois grupos: grupo controle (GC; n=16), constituiído por voluntárias assintomáticas e grupo dor femoropatelar (GDPF; n=34).

As mulheres do GDFP deveriam ter um score entre 6 e 9 no *Foot Posture Index* (FPI), o que as caracteriza como pés pronados.[31] Os demais critérios de inclusão e exclusão foram os mesmos adotados no estudo 1.[50]

Assim como no estudo 1, as voluntárias também foram questionadas sobre a intensidade da sua dor através da NPRS[40] nos últimos 15 dias e deveriam ter um escore mínimo de 3 antes de entrarem na pesquisa.

Procedimentos

A colocação dos marcadores para análise cinemática seguiu as recomendações do *Oxford Foot Model* (OFM).[70] Para familiarização, logo após a colocação dos marcadores as voluntárias realizaram algumas vezes as atividades que seriam avaliadas: *step down anterior* (SDA) e *step down lateral* (SDL). Para a realização do SDA o membro avaliado foi posicionado com os dedos próximos ao limite anterior do step e o não testado em extensão de joelho, com o calcanhar logo à frente do step (assumindo uma posição de flexão do quadril, extensão do joelho e dorsiflexão do tornozelo). Para o SDL o membro avaliado foi posicionado com a borda medial do pé próxima ao limite lateral do step e o não testado foi posicionado bem na borda lateral do step (assumindo um quadril em posição neutra, extensão de joelho e dorsiflexão do tornozelo) (figura 1).

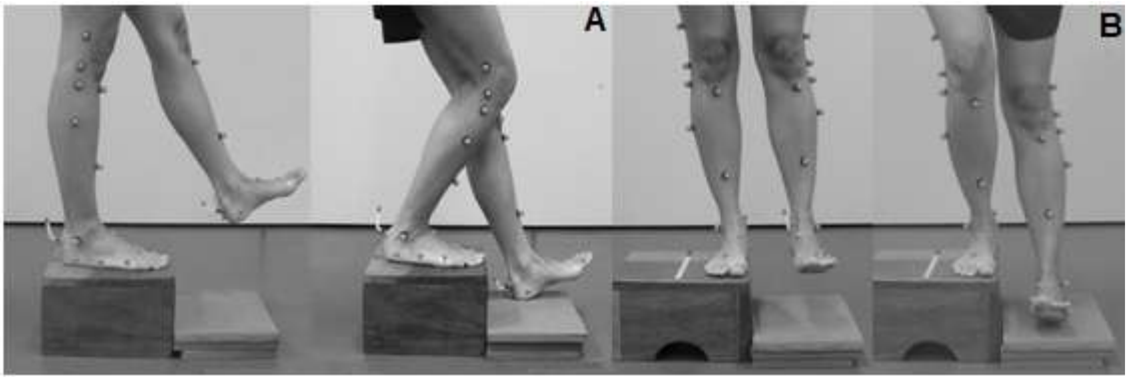

Figura 1. Representação da posição adotada para avaliação durante o step down anterior (A) e o step down lateral (B).

Para ambas as tarefas as voluntárias foram instruidas a agachar de forma lenta (em um tempo de dois segundos), até que o calcanhar tocasse o solo, quando deveriam retornar à posição inicial (em outros dois segundos).

Para padronizar o posicionamento de todas elas durante o teste, elas foram instruídas a iniciar a atividade com o joelho em extensão e agachar até aproximadamente 60 graus de flexão do joelho (blocos de EVA foram utilizados caso necessário). As tarefas foram realizadas em um total de nove vezes com o intervalo que cada voluntária julgasse necessário entre cada uma delas a fim de evitarmos os efeitos da fadiga.

Processamento dos dados

A nomeação dos marcadores, reconstrução e marcação do ciclo foram realizados no software Vicon-Nexus 1.8.5®. Um filtro Woltring de 8hz foi utilizado para diminuir o ruído dos marcadores causado por possível movimentação durante a atividade. Primeiramente os marcadores foram reconstruídos e nomeados, em seguida o ciclo foi marcado à partir da máxima extensão do joelho, até a sua máxima flexão para caracterizar o início (0%) e o final (100%) do ciclo, respectivamente.

Após esse procedimento a amplitude de movimento foi calculada baseada nos movimentos realizados durante os nove testes para cada voluntária. Os valores foram calculados para os seguintes seguimentos: retropé em relação ao laboratório (HFTLF); retropé em relação à tíbia (HFTBA); antepé em relação à tíbia (FFTBA); antepé em relação ao retropé (FFHFA); e, joelho no plano sagital.

Análise estatística

Os dados demográficos e a amplitude de movimento foram testados em relação à sua normalidade através do teste de Shapiro Wilk. O teste T independente foi utilizado para comparar as características da amostra. Os dados cinemáticos foram comparados entre grupos usando a análise multivariada (MANOVA) e quando os efeitos multivariados estavam presentes, análises univariadas eram realizadas. O nível de significância foi considerado $P<0.05$ para todas as variáveis. Toda análise estatistica foi realizada no software SPSS versão 20.0 (SPSS Inc., Chicago, IL). A relevância clínica dos resultados foi confirmada pelo cálculo do *effect size* (Cohen d) das diferenças encontradas nos testes. Foram considerados os seguintes efeitos: 0-0.49 pequeno; 0.50-0.79 médio; e, maior do que 0.80 alto (Cohen, 1988).

Artigo 3

Influence of kinematic and verbal biofeedback on pain in women with patellofemoral pain syndrome during single leg squats

Desenho do estudo

Estudo transversal

Local da realização do estudo

O trabalho foi desenvolvido no Núcleo de Apoio à Pesquisa em Análise de Movimento do Programa de Pós-Graduação Stricto Sensu em Ciências da Reabilitação da Universidade Nove de Julho – UNINOVE, Campus Vila Maria, localizado na cidade de São Paulo.

Aspectos Éticos

O presente protocolo de pesquisa foi aprovado pelo "*Comitê de Ética e Pesquisa*" da Universidade Nove de Julho – UNINOVE, seguindo a resolução 196/96. Para a realização de todos os procedimentos foi exigida a leitura e assinatura do Termo de Consentimento Livre e Esclarecido dos participantes.

Cálculo Amostral

A amostra foi calculada de acordo com o estudo de Salsich (2012)[13] para encontrar uma diferença de 3.5 graus na adução do quadril, com um desvio padrão estimado em 5.9, um alfa de 0.05 e um poder de 80%. Sendo assim, a amostra requerida foi de 44 voluntárias.

Participantes

Foram recrutadas 44 mulheres fisicamente ativas[51] com idade entre 18 e 35 anos, que apresentassem valgo dinâmico do joelho visual.[13] Os demais critérios de inclusão e exclusão seguiram os mesmos adotados nos estudos 1 e 2. Uma vez triadas a partir dos critérios, as voluntárias compareceram ao laboratório de análise do movimento da

UNINOVE para a avaliação da interferência de 4 tipos de agachamento na dor femoropatelar, realizados de forma randomizada: 1: agachamento unipodal com biofeedback cinemático do quadril (SLSHB); 2: agachamento unipodal com biofeedback verbal do quadril (SLSHV); 3: agachamento unipodal com biofeedback cinemático do tronco (SLSTB) e; 4: agachamento unipodal com biofeedback verbal do tronco (SLSTV). Todos esses agachamentos foram realizados levando em consideração um agachamento prévio da voluntária, que foi chamado de agachamento usual (SLSU).

Instrumentação

Para a aquisição dos dados da cinemática, foi utilizado o sistema Vicon®, constituído por 8 câmeras de infra vermelho de frequência de até 120 frames por segundo (fps) e resolução de 1MP.

As câmeras eram conectadas a um computador dedicado para o tratamento do sinal de vídeo. Este possui placas com diversas funções: circuito de temporização/ controle; circuito gerador de coordenadas e circuito de interface para as câmeras.

Uma vez armazenados na memória de vídeo os dados foram transferidos para um segundo computador. Neste, um software próprio, Vicon-Nexus® foi utilizado para processamento e reconstrução da imagem 3D dos marcadores através de um modelo biomecânico e diversos algoritmos matemáticos.

Procedimentos

Após triagem a partir dos critérios de inclusão e exclusão, foi solicitado às voluntárias que realizassem 4 agachamentos unipodais enquanto eram filmadas por um dos pesquisadores, a fim de avaliar se existia valgo dinâmico do joelho.[13] Essa análise foi feita de forma independente por dois profissionais, que deveriam concordar entre si. Caso houvesse divergência entre eles, um terceiro pesquisador era acionado para desempate.

Uma vez confirmado o valgo dinâmico e definitivamente incluídas na pesquisa, as voluntárias foram encaminhadas para a avaliação cinemática. Foi preenchida, inicialmente, uma ficha com dados pessoais tais como nome, idade, data de nascimento, telefone, duração dos sintomas, membro inferior dominante (definido através do questionamento pela preferência em chutar uma bola o mais distante possível) e lado de predominância da dor. Depois disso, devidamente vestidas com *short* e top, elas foram submetidas ao protocolo de mensurações antropométricas necessárias para a realização do exame tridimensional do movimento, composto de: altura, peso, distância entre as espinhas ilíacas ântero-superiores, comprimento dos membros inferiores, diâmetro dos joelhos, diâmetro dos tornozelos e torção tibial.[27] Por último, respondiam a um questionário traduzido e validado no Brasil destinados a avaliar a funcionalidade dos membros inferiores: *Anterior Knee Pain Scale* (AKPS),[40] além de assinalarem a intensidade da sua dor no joelho nas últimas duas semanas em uma escala, também destinada à quantificar a dor em pacientes com DFP, a NRPS[40] antes da análise cinemática.

Vinte e três marcadores esféricos retro-reflexivos (12mm de diâmetro) foram então fixados com fita dupla face nos seguintes pontos anatômicos: articulações acrômio claviculares, sétima vértebra cervical, ângulo inferior da escapula direita, décima vértebra torácica, espinhas ilíacas póstero-superiores (com um terceiro marcador em uma base rígida), espinhas ilíacas antero-superiores, região lateral das coxas, base lateral das patelas, epicôndilos femorais laterais, lateral das tíbias, maléolo lateral, calcâneos e região entre o segundo e terceiro dedos dos pés. Este conjunto de marcadores foi baseado no modelo Helen Hayes, usado para estimar a posição dos centros articulares e calcular a cinemática tridimensional das articulações da pelve, quadril, joelho e tornozelo,[59, 60] que serviram de referência para o sistema de captura de análise do movimento. Esses marcadores foram utilizados tanto para a coleta estática quanto a coleta dinâmica. Após a colocação dos marcadores as voluntárias realizaram quantos agachamentos unipodal achassem necessário para familiarização com a atividade.

Intervenção

SLSU

Uma vez familiarizadas com a atividade, uma coleta de um *trial* estático foi realizada e, consecutivamente, 3 agachamentos unipodais usuais.[17, 71, 72] Para a padronização do posicionamento de todas as voluntárias elas executaram os agachamentos com os membros superiores cruzados na região anterior do tórax (abaixo do processo xifóide, para não obstruir os marcadores do tronco). A atividade foi realizada durante um período total de 4 segundos,[73] sempre iniciando e terminando com completa extensão do joelho. No caso de desequilibrio ou má execução, uma nova chance era dada para a voluntária, até o máximo de 10 tentativas. Se mesmo assim ela não conseguisse executar o teste ela era considerada inapta a participar do estudo.

Para a execução do SLSU não foi dado nenhuma outra informação adicional à paciente. Nessa atividade foi coletado o pico do movimento de flexão do tronco e adução do quadril, que foram usados posteriormente durante os demais agachamentos: SLSTB, SLSHB, SLSTV e SLSHV. As voluntárias realizaram essas tarefas 3 vezes, com intervalo que julgassem suficiente entre cada uma das tentativas, a fim de evitar os efeitos da fadiga.

Após a realização do SLSU, foi randomizada, através de um envelope opaco contendo os quatro tipos de agachamento (SLSTB, SLSTV, SLSHB, SLSHV), a ordem que cada uma das voluntárias realizaria os demais agachamentos. Essa randomização foi feita um total de 45 vezes, sempre após a execução do SLSU de cada voluntária, por um integrante do laboratório que não fazia parte da pesquisa.

Durante todos os tipos de agachamento, foi dado, também, um biofeedback auditivo à paciente por meio do software Vicon Nexus, que era ativado quando o joelho atingia 60° de flexão[13] indicando que ela já poderia voltar à posição inicial com total extensão do joelho.

SLSTB e SLSHB

Durante os agachamentos com o biofeedback cinemático, o Sistema Vicon foi programado no modo "*Kinematic Fit*" e a angulação de flexão do tronco ou adução do quadril foram projetados em tempo real à frente das voluntárias, em uma televisão de 42 polegadas, à uma distância de 5 metros do local de onde estavam sendo realizadas as atividades.

Para a projeção da angulação do tronco para as voluntárias, o segmento do tronco era selecionado no modelo biomecânico e, na aba "*communications*", era selecionado o eixo Y de movimento do tronco em relação ao laboratório. Uma vez selecionado o eixo Y, no modo "*Threshold*" eram colocados os parâmetros da chamada linha alvo, que utilizava a média do pico de flexão do tronco adquirida durante o SLSU, acrescida de 20%. Esses dados eram colocados no campo "*Upper Threshold*". Assim, caso a voluntária apresentasse 20 graus de flexão do tronco durante o SLSU, no SLSTB o valor referente à linha alvo era de 24 graus de flexão do tronco e durante o agachamento era solicitado então que a voluntária realizasse a atividade aumentando a flexão do tronco, a ponto de fazer com que a linha referente à flexão do tronco cruzasse a linha alvo.

O mesmo foi feito durante o biofeedback cinemático da adução do quadril, entretanto, os parâmetros da linha alvo colocados no modo "*Threshold*" eram referentes à 20% a menos do pico de adução de quadril alcançado durante o SLSU (ou seja, caso a voluntária apresentasse dez graus de adução do quadril, no campo "*Lower Threshold*" era colocado o valor de 8 graus) e durante o agachamento era solicitado então que a voluntária realizasse a atividade diminuindo a sua adução de quadril, a ponto de não deixar a linha referente à adução cruzar a linha alvo.

SLSTV e SLSHV

Durante os agachamentos com o biofeedback verbal, não houve nenhuma projeção à frente da voluntária. Para a execução do SLSTV foi dado o seguinte comando verbal: "durante o seu agachamento, incline o seu tronco para frente de uma forma confortável à medida que você flexiona o joelho". Durante o SLSHV o comando dado foi: "não deixe a sua pelve cair e nem o seu joelho ir de encontro ao outro durante o agachamento"

Para o biofeedback verbal, a fim de mantermos a padronização de cada agachamento, o biofeedback auditivo referente à angulação de 60 graus de flexão do joelho continuou sendo dado às pacientes, também por meio do software Vicon Nexus.

Entre cada uma das diferentes tarefas foi solicitado à paciente que demarcasse a intensidade da sua dor em uma escala de 10 cm durante aquele exercício específico, para posterior análise estatística, a fim de sabermos qual das atividades reduziria mais a dor durante o agachamento.

Os dados cinemáticos que foram analisados eram coletados durante todo o processo de treinamento das voluntárias. Caso ela desequilibrasse durante o *trial* ou não conseguisse executar a tarefa por algum outro motivo, o *trial* era cancelado e dava-se início a uma nova tentativa.

Processamento dos Dados

Após a coleta dos dados, a reconstrução, nomeação e processamento dos dados foi realizado no software Vicon Nexus (VICON, Oxford, UK).[67] Assim como em prévios estudos que avaliam tarefas dinâmicas, os dados foram filtrados a partir de um filtro Butterworth de quarta ordem e atraso de fase zero de 12 hz passa baixa. A cinemática articular foi calculada a partir de um sistema de coordenadas[59, 60] e foram reportadas em relação ao trial estático para quantificar os movimentos de um segmento em relação ao outro e em relação ao laboratório.

Para análise dos dados, o ciclo da atividade foi considerado do momento em que o joelho iniciou a flexão (0% do ciclo) até o instante em que ele voltou para a sua posição inicial de extensão (100% do ciclo). A média da amplitude de movimento dos três *trials* foi utilizada para análise estatística.

Analise Estatistica

As estatísticas descritivas foram apresentadas em média e desvio padrão. Todos os dados apresentaram distribuição normal ou aproximadamente normal, confirmadas através da inspeção visual de histogramas. Análises de variância (ANOVA) de medidas repetidas foram realizadas para verificar as interações entre as variáveis dependentes em cada tarefa analisada (SLSU, SLSTV, SLSTB, SLSHV e SLSHB). A esfericidade dos dados foi avaliada através do teste de Mauchly, e se violada, os graus de liberdade foram corrigidos através do teste de Greenhouse-Geisser. Diante de resultados significantes da ANOVA, análises de post hoc de Bonferroni foram utilizadas para verificar as interações significantes entre as tarefas analisadas. A significância estatística para todos os testes foi fixado em P <0,05. Todas as análises estatísticas foram realizadas utilizando o programa SPSS versão 20.0 (IBM Corporation, Armonk, NY). Foram considerados os seguintes efeitos: 0-0.49 pequeno; 0.50-0.79 médio; e, maior do que 0.80 alto (Cohen, 1988).

3. RESULTADOS

ARTIGO 1:

- ARTIGO JÁ SUBMETIDO À JOURNAL OF SPORTS SCIENCE -

Does high-impact functional activity increase lower limb misalignment in women with patellofemoral pain during the different phases of the single leg triple hop test?

Abstract

Objective: Determine if the high-impact (landing) phase of the single-leg triple hop test promotes more biomechanical abnormalities of the lower limb than the low-impact (preparation) phase in women with patellofemoral pain. **Methods:** Seventeen women with and 17 women without patellofemoral pain, aged between 18 and 35, performed the single-leg triple hop test. Three-dimensional hip and knee kinematic and kinetic data were collected and compared across groups and phases using multivariate analyses of variance and t-tests with Bonferroni corrections, respectively. **Results:** In both phases, the patellofemoral pain group exhibited greater frontal and transverse plane biomechanical abnormalities (hip adduction, contralateral pelvic drop, hip internal rotation, ankle eversion, hip abduction moment, knee abduction moment) compared to the control group. In both groups, several biomechanical abnormalities (hip adduction, contralateral pelvic drop, hip internal rotation, eversion moment) were greater in the preparation phase compared to the landing phase, with the exception of ankle eversion, which was greater in the landing phase. **Conclusion:** Women with patellofemoral pain demonstrated greater misalignment of the lower limb compared to women without patellofemoral pain. The high impact (landing) phase did not increase misalignment of the lower limb when compared to the low-impact (preparation) phase of the single-limb triple hop test.

Keywords: knee; biomechanics; knee pain; jump

1. Introduction

Patellofemoral pain (PFP) is one of the most common lower limb diseases among women aged 18 to 35 years[3, 29]. It characterizes between 25% and 40% of knee pain complaints in this population and is often associated with activities that increase compressive forces in the patellofemoral joint.[46, 49]Symptoms are exacerbated upon initiation of physical activity[50] and during closed kinetic chain activities, such as climbing and descending stairs, squatting, running, jumping, and activities that place greater demand on the quadriceps[8, 25]

PFP has been attributed, in part, to misalignment of the lower limb during weight bearing. It has been reported,[15, 38, 39, 41]that excessive ipsilateral trunk inclination, hip adduction and medial rotation, knee abduction, and ankle pronation occur during these activities, decreasing the contact area of the patellofemoral joint and increasing patellofemoral joint stress, thereby leading to overload and pain.[38, 39]

Recent studies involving the kinematic and kinetic assessment of women with PFP have indicated that lower extremity misalignment has been observed during low-impact activities, such as gait,[3]climbing and descending stairs[7, 8, 31], squatting[32, 33], and the preparation phase of the Single leg triple hop test (SLTHT),[6] as well as in activities that place greater demand on the muscles, such as running,[13]vertical jumps[27], and progressive jumps.[6, 14]

Among the activities associated with lower extremity misalignment, the single-leg triple hop test SLTHT, which is often used in clinical practice to assess the dynamic stabilization of the knee after periods of rehabilitation, [19, 35]is important as it contains different phases, which place different demands on the knee joint. One of these phases is the preparation phase[6], which is considered a relatively low-impact activity. Another phase is known as the landing phase, which is characterized as a high-impact activity.

During the execution of the test, the individual is instructed to jump as far as possible using one lower limb. The distance reached by the asymptomatic and symptomatic lower limbs is compared.[1, 17, 20, 21]

Bley et Al.[6] compared the kinematic differences of the lower limbs in women with and without PFP during the preparation phase of the SLTHT (phase considered low impact by the authors), while Dos Reis et Al.[14] compared these characteristics in women with and without patellofemoral pain during the landing phase (phase considered high impact), however, the kinematic differences between these two phases in women with PFP have not been reported in the literature.

It is important that the kinematic differences between high and low impact phases are studied so that clinicians understand the different demands imposed on the lower limb joints and can intervene directly, taking each phase into account separately during rehabilitation.

Therefore, the aim of the present study was to determine if the high-impact phase of the SLTHT promotes more biomechanical abnormalities of the lower limb than the low-impact phase, using kinetic and kinematic variables. The hypothesis of the authors was that there would be an increase in misalignment of the lower limb in women with PFP when compared to controls, and during the landing phase of the SLTHT (high-impact) compared to the preparation phase (low-impact).

2. Methods

2.1 Participants

In total, 34 women (17 pain-free and 17 with PFP) participated in the present study and were divided into two groups: patellofemoral pain group (PFPG) and control group (CG). All volunteers were fully informed about the procedures involved and consented to participate. This study was approved by the local Ethics Committee.

The sample size was calculated based on the maximal knee flexion values found in a previous study, which indicated that the maximal values found in the sagittal plane of this joint during the drop landing are associated with the misalignment of the lower limb[36]. Therefore, given that α=.05, β=.10 (90% power), the mean difference was 11 degrees between the groups and the standard deviation was 10, at least 17 participants were required.

All the women who participated were aged between 18 and 35 years and had a history of anterior knee pain for at least three months prior to the assessment. They also reported increased symptoms while performing two or more of the following activities:[45]climbing and descending stairs; bending; kneeling; jumping; sitting for a prolonged period; exerting maximal isometric quadriceps force against resistance, or palpating the lateral facet of the patella.

All volunteers were recruited from a physiotherapy clinic, by a professional with experience in knee rehabilitation. All the women were considered physically active, practicing physical activity at least once a week[5]. If the volunteers exhibited any of the following, they were excluded from the research: pregnancy; neurological disorders; ankle, hip or lumbosacral injuries; rheumatoid arthritis; heart problems or previous surgery in the lower limbs; patellar instability, ligament or meniscal problems, osteoarthritis or tendinopathies. Finally, women with a discrepancy in lower limb length of more than one centimeter (distance between the medial malleolus and anterior superior iliac spine, measured using a tape measure) were also excluded.

2.2 Procedures

After screening by inclusion and exclusion criteria, the volunteers were scheduled for the initial assessment and performance of the SLTHT in the laboratory of human movement analysis. Before performing the jump, the volunteers were questioned regarding their average pain during the previous 2 weeks, using a visual analogue scale.[10, 11] The following variables were measured for the anthropometric assessment: body mass using a weight bearing scale; height using a tape measure; distance between the anterior superior iliac spines, width of the knee and ankle using a paquimeter, and tibial torsion with a goniometer[13].

Prior to performing the jump, all volunteers walked on a treadmill, at two meters per second, for ten minutes. After the warm-up, they were familiarized with the activity and then performed several attempts of the SLTHT, until they felt comfortable performing the exercise.

Following the conventional gait model (CGM),[12, 23] which has been used in kinematic assessments of jumping, [6, 14, 24, 27, 28, 51-53] twenty-three (23) spherical reflective markers were placed on the volunteers in the following positions: anterior superior iliac spines; posterior superior iliac spines (with a third auxiliary marker in a rigid base), center of the patella; lateral femoral epicondyles; middle third of both legs; lateral malleolus; second metatarsal; calcaneus; acromioclavicular joints; spinous process of the seventh cervical vertebrae; spinous process of the tenth thoracic vertebrae; xiphisternum and right scapula. These markers were used during both static and dynamic data collection. Markers located on the anterior superior iliac spines (ASIS) tend to suffer interference from clothing or excessive motion of the skin due to the greater quantity of soft tissue around the abdomen. To minimize possible positioning errors during capture, we used a pointer with two collinear markers to identify the ASIS, and then a cluster with three markers, placed in the posterior region of the pelvis during the capture of walking trials.

Once the markers were in place the static standing trial commenced, followed by three dynamic trials of the SLTHT. An interval of two minutes was allowed between each jump to avoid fatigue. The symptomatic limb was tested, unless the patient exhibited bilateral pain, in which case the limb with greater pain symptoms was assessed. Since it was difficult to standardize the footwear for every volunteer, the SLTHT was performed barefoot. The volunteers were instructed to perform the exercise with their arms folded on the anterior region of the trunk, under the xiphoid process.[6]

The preparation phase and landing phase of the SLTHT were captured in separate trials. Prior to each collection, the volunteers were randomized to determine whether the preparation phase or landing phase would be collected first. For the preparation phase collection, the volunteers were placed in the center of the force platform and instructed to perform the SLTHT, jumping the greatest distance possible. For the landing phase we used the distance obtained for each volunteer during the practice to position them in such a way that the transition from the first to the second hop was made in the center of the force platform (Figure 1).

2.3 Instrumentation

Eight SMART-D® BTS cameras (Milan, Italy) with a frequency of 100 Hz were used to capture the trajectory of the markers during the jumps. The cameras were inter-connected to a computer and placed around a force platform of 400Hz (Kistler 9286, New York, USA), which was positioned in the center of the collection area. The platform was inter-connected to the same computer as used for the kinematic collection through a digital-analogical converter, enabling synchronization of the kinetic and kinematic data. Based on previous studies, frequencies of 100Hz for kinematics[4, 6, 9, 22, 43]and 400Hz for kinetics[1, 4, 6, 27, 28, 43] were sufficient to assess the variables of the present study.

2.4 Data Analysis

Raw camera data were converted into C3D format using Matlab software (MathWorks, Inc, Natick, MA) and the Biomechanical Toolkit BTK 0.1.10[2]. The cycle marking and processing were carried out using Vicon Nexus software[47](VICON, Oxford, UK) and the Plug-in Gait model. Similar to previous studies that assessed dynamic tasks, the marker trajectories were filtered using a fourth order Butterworth 12Hz low pass filter and a zero phase delay[18]. The kinematics were calculated using a system of coordinates[12]and reported relative to the static trial in order to quantify the movements of one segment in relation to another, as well as to the laboratory. The kinematics, ground reaction force, and anthropometric measurements were used to calculate the internal joint moment of the hip, knee and ankle, based on the inverse dynamics equations of the Vicon Nexus® software. The kinetic data were normalized according to body mass.

During the preparation phase of the SLTHT, the beginning of the cycle of movement (0%) was defined as the moment the GRF decreased in relation to the body weight. The movement ended (100%) when it reached zero (the moment the foot left the ground). During the landing phase, the cycle started when the foot touched the force plate (0%) and ended (100%) when the foot left the platform during the transition phase from the first to the second jump of the SLTHT (Figure 1). For each phase, the peak joint angles (maximum value) of the trunk, pelvis, hip, knee, and ankle in all three planes of movement were obtained. Hip, knee, and ankle internal moments were assessed when the knee reached maximal flexion. Moments were normalized by body weight and expressed in Nm/kg.

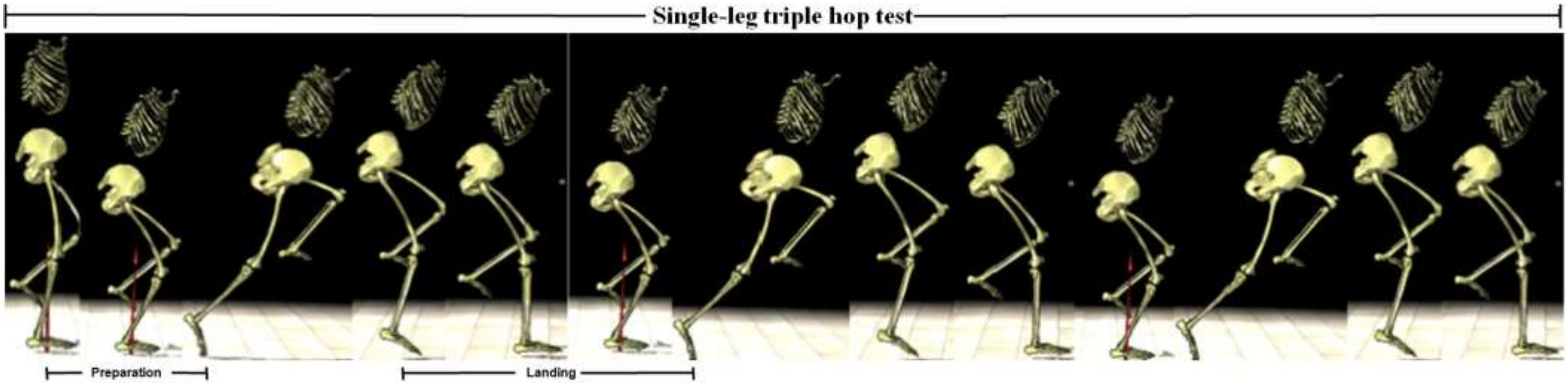

Figure 1: Preparation and landing phase of the single leg triple hop test in woman with patellofemoral pain

2.5 Statistical Analysis

The Kolmogorov-Smirnov test (with the Lilliefors correction factor) was used to test the normality of the kinematic and kinetic data. Descriptive statistics are displayed using the mean and standard deviation (SD) for all variables. The average of three trials was used for the statistical analysis of the kinematic and kinetic data. The kinematic and kinetic variables were compared between the groups using two separate multivariate analyses of variance (MANOVAs). If there were significant multivariate effects, univariate effects were tested for all significant variables. The significance level was $P<0.05$ for all intergroup analysis. For the intragroup analyses, variables were compared using the paired t-test and Bonferroni correction, so the significance level was $p<0.005$ for kinematic and $p<0.008$ for kinetic data. Cohen's d effect size measures were calculated and defined as low if the value was between 0.2 and 0.5, medium between 0.6–0.8, and strong if>0.8[37]. All statistical comparisons were conducted using SPSS, version 20.0(SPSS Inc Chicago, IL).

3. RESULTS

Table 1 displays the demographic data of all participants in the present study. There were no differences in demographic data.

TABLE 1: Demographic data of the subjects*

	Control (n = 17)	PFP (n = 17)
Age (y)	23.1 ± 3.3	23.5 ± 1.9
Body mass (kg)	56.2 ± 7.1	55.3 ± 4.8
Height (m)	1.63 ± 0.1	1.65 ± 0.1
Body mass index (kg/m^2)	21.3 ± 2.7	20.2 ± 1.8
VAS (0-10)[ł]	0 ± 0	4.9 ± 1.6
AKPS	99.5 ± 1.2	80.2 ± 5

Abbreviations: PFP, patellofemoral pain; BMI, body mass index; VAS, visual analogue scale

* Data are mean± SD

[ł] Scored from 0 to 10, where 0 is no pain and 10 is the worst imaginable pain, during the previous 2 weeks

The MANOVA tests showed significance differences for the kinematic variables, at [F(20,13) = 70.6, $P< 0.001$; Wilk'sλ= 0.009], and kinetic variables at [F(12,21) = 47.2, $P< 0.001$; Wilk'sλ= 0.04]. The mean kinematic and kinetic values are displayed in Table 2. Table 3 displays the effect sizes (Cohen's d) for all comparisons.

1. Group Comparisons (intergroup analysis)

1.1 Both phases

PFPG compared to CG:

The PFPG presented greater hip adduction, greater contralateral pelvic drop, greater hip Internal rotation, greater ankle eversion, greater trunk flexion, less knee flexion and dorsiflexion; greater hip and knee abduction internal moment, lower knee extensor and plantar flexion moment, during both phases of the SLTHT ($p<0.05$ for all variables) (table2).

1.2 Preparation Phase Only

PFPG compared to CG

The PFPG presented greater contralateral trunk lean and greater hip flexion, greater ankle eversion moment, and lower hip extensor moment ($p<0.05$ for all variables).

1.3 Landing Phase Only

PFPG compared to CG

The PFPG presented greater ipsilateral trunk lean and less hip flexion, and greater ankle inversion moment ($p<0.05$ for all variables).

2 Phase Comparisons (intragroup comparisons)

2.1 Both Groups

Prep compared to Land

The PFPG and CG presented greater hip adduction, contralateral pelvic drop, hip internal rotation, hip flexion, knee flexion, and ankle dorsiflexion, and less trunk flexion and ankle eversion during the preparation phase of the SLTHT; both groups also exhibited lower hip abductor internal moment, lower knee extensor moment, and greater ankle eversion moment during the preparation phase ($p<0.05$ for all variables).

2.2 PFP Group Only

Prep compared to Land

The PFPG presented greater contralateral trunk lean and lower hip extensor moment during the preparation phase ($p<0.05$ for all variables).

2.3 Control Group Only

Prep compared to Land

The CG presented greater ipsilateral trunk lean and greater hip extensor moment during the preparation phase of the SLTHT ($p<0.05$ for all variables). Figure 1 shows the kinematic differences between preparation and landing phase during the SLTHT.

Table 2 **:** Mean (SD) of kinematic and kinetic data of woman from the PFPG and CG during the preparation and landing phase of the single leg triple hop test.

	PREP PHASE		**LAND PHASE**		**PFPG X CG PREP**	**PFPG X CG LAND**	**Prep X Land PFPG**	**Prep X Land CG**
	Mean (95% CI) PFPG	**Mean (95% CI) CG**	**Mean (95% CI) PFPG**	**Mean (95% CI) CG**	**Mean difference**	**Mean difference**	**Mean difference**	**Mean difference**
			Kinematic (values are in degrees) *					
Trunk Flexion[δ,Y,†,£]	14.8 (12.9; 16.8)	9.2 (7.2;11.2)	36.1 (33.6; 38.6)	31.5 (29.0; 34.0)	5.6	4.6	21.3	22.3
Trunk Obliquity[δ,†,£]	[-]5.6 (-7.7; -3.5)	5.6 (3.4; 7.7)	9.5 (8.3; 10.6)	3.5 (2.4; 4.7)	10.0	6.0	15.0	2.1
Pelvic Drop[δ,Y,†,£]	14.8 (13.6; 16.1)	7.6 (6.4; 8.9)	7.0 (6.1; 7.9)	4.2 (3.3; 5.1)	7.2	2.8	7.8	3.4
Hip Flexion[δ,Y,†,£]	80.8 (78.0; 83.7)	72.5 (69.7; 75.4)	54.1 (51.9; 56.3)	58.7 (56.4; 60.9)	8.3	4.6	26.7	13.8
Hip Adduction[δ,Y,†,£]	19.9 (18.1; 21.6)	12.7 (11.0; 14.5)	10.3 (9.2; 11.3)	7.1 (6.1; 8.2)	7.2	3.2	9.6	5.6
Hip Rotation[δ,Y,†,£]	19.5 (17.3; 21.7)	10.5 (8.3; 12.7)	12.9 (11.8; 14.0)	8.8 (7.7; 9.9)	9.0	4.1	6.6	1.7
Knee Flexion[δ,Y,†,£]	63.5 (61.9; 65.1)	66.0 (64.4; 67.6)	48.0 (46.1; 49.8)	57.0 (55.2; 58.8)	2.5	9.0	15.5	9.0
Knee Valgus	7.3 (5.8; 8.9)	6.6 (5.0; 8.1)	8.2 (6.9; 9.6)	7.3 (6.0; 8.7)	0.7	0.9	0.9	0.9
Ankle Dorsiflexion[δ,Y,†,£]	35.3 (32.9; 37.7)	40.6 (38.2; 43.0)	26.9 (24.9; 28.8)	32.2 (30.2; 34.2)	5.3	5.3	8.4	8.4
Ankle Eversion[δ,Y,†,£]	5.8 (4.8; 5.3)	3.9 (3.7; 4.2)	10.3 (8.7; 11.8)	6.5 (5.0; 8.1)	2.1	3.8	4.5	2.6
			Kinetic (values are in N/M^2) *					
IM - Hip Extensor[δ,Y,†]	1.8 (1.3; 2.2)	3.6 (3.2; 4.0)	2.7 (2.4; 2.9)	2.9 (2.6; 3.2)	1.8	0.2	1.1	0.7
IM - Hip Abductor[δ,Y,†,£]	1.6 (1.4; 1.8)	1.1 (0.9; 1.2)	2.2 (2.0; 2.4)	1.8 (1.6;2.0)	0.5	0.4	0.6	0.7
IM - Knee Extensor[δ,Y,†,£]	0.8 (0.7; 1.0)	1.2 (1.0; 1.3)	1.9 (1.7; 2.1)	2.7 (2.5; 2.9)	0.4	0.8	1.1	1.5
IM – Knee Abductor[†,£]	2.6 (2.4; 2.8)	1.0 (0.9; 1.2)	2.1 (1.9; 2.3)	0.9 (0.7; 1.1)	1.6	1.2	0.5	0.1
IM - Plantar Flexor[†,£]	1.9 (1.6; 2.2)	2.3 (2.0; 2.6)	2.0 (1.8; 2.2)	2.4 (2.2; 2.6)	0.4	0.4	0.1	0.1
IM - Ankle Inversor[δ,Y,†,£]	[-]0.6 (-0.8; -0.5)	[-]0.4 (-0.5; -0.3)	0.6 (0.5; 0.7)	0.4 (0.3; 0.5)	0.2	0.2	1.0	1.0

Abbreviations: Prep: preparation phase; Land: landing phase; PFPG, patellofemoral pain group; CG, control group

[δ]Significant difference between preparation X landing in CG

[Y]Significant difference between preparation X landing in PFPG

[†]Significant difference between preparation in PFPG X preparation in CG

[£]Significant difference between landing in PFPG X landing in CG

*For intragroup analysis a significant difference was considered $p<.005$ for kinematic data and $p<.008$ for kinetic data. For intergroup analysis a significant difference was considered $P<0.05$

[-] Negative value is contralateral trunk lean for kinematic variable and eversor moment for kinetic variable

Table 3: Effect Size from kinematic and kinetic data of woman from the PFPG and CG during the preparation and landing phase of the single leg triple hop test§

	Preparation X Landing CG	Preparation X Landing PFPG	Preparation CG X Preparation PFPG	Landing CG X Landing PFPG
		Kinematic		
Trunk Flexion	4.7	4.9	1.4	0.9
Trunk Obliquity	0.7	4.1	2.6	2.6
Pelvic Obliquity	1.4	3.7	8.1	1.5
Hip Flexion	2.3	5.2	1.4	1
Hip Adduction	0.9	2.7	2	1.5
Hip Rotation	0.7	1.5	2	1.8
Knee Flexion	6.5	0.8	0.8	2.4
Knee Valgus	0.6	0.4	0.2	0.5
Ankle Dorsiflexion	3.3	2.3	1.1	1.3
Ankle Eversion	2.3	1.6	3.7	1.2
		Kinetic		
IM - Hip Extensor	0.9	1.5	2	0.4
IM - Hip Abduction	5.5	1.9	1.6	1
IM - Knee Extensor	2	4.3	1.2	2.2
IM – Knee Abductor	3.5	1.1	4.2	3.4
IM - Plantar Flexor	0.7	0.2	0.9	1.1
IM - Ankle Inversor	0.9	0.1	1	1

Abbreviations: CG, control group; PFPG, patellofemoral pain group

§Effect size determined using Cohen's d (0.0 to 0.49 – low; 0.5 to 0.79 - medium, 0.8 or higher - large)

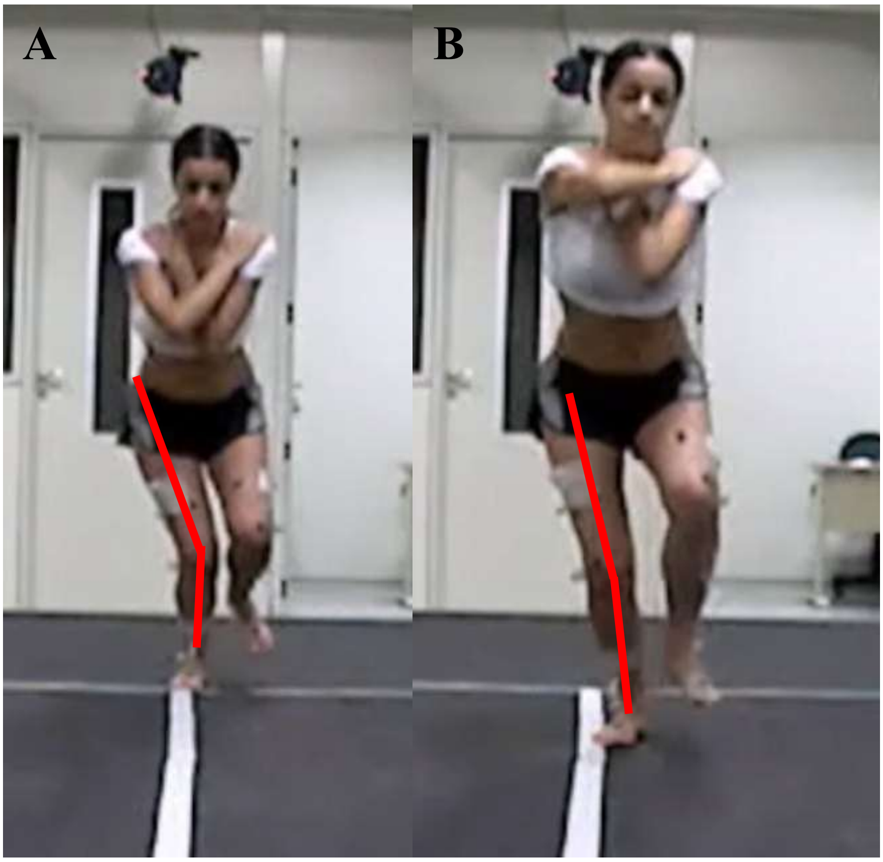

Figure 2: kinematic differences during the preparation (A) and landing (B) phase of the single leg triple hop test in women with patellofemoral pain.

4.DISCUSSION

The present study compared the kinematics of the trunk, pelvis, hip, knee, and ankle, as well as the internal joint moments of the hip, knee, and ankle of women with and without PFP during the preparation and landing phases of the SLTHT. Our hypothesis was that there would be an increase in misalignment of the lower limb in women with PFP when compared to controls, and during the landing phase of the SLTHT (high-impact) compared to the preparation phase (low-impact). However, the analysis conducted did not completely confirm these hypotheses.

Group comparisons

In the preparation phase, the volunteers in the PFPG exhibited greater hip adduction (accompanied by greater hip abduction internal moment); contralateral pelvic drop, hip internal rotation, ankle eversion (accompanied by greater ankle eversion internal moment), trunk flexion and hip flexion (as well as less hip extensor internal moment). They also presented less knee flexion (accompanied by less knee extensor internal moment) and ankle dorsiflexion (with less plantar flexion internal moment). Furthermore, they presented greater knee abduction internal moment compared to the CG.

During the landing phase, the volunteers in the PFPG exhibited greater hip adduction (accompanied by greater hip abduction internal moment), contralateral pelvic drop, hip internal rotation, ankle eversion (accompanied by greater ankle inversion internal moment), trunk flexion, and ipsilateral trunk lean; and less hip flexion, knee flexion and ankle dorsiflexion. They also presented greater knee abduction internal moments compared to the CG.

Some of the results obtained for the PFPG during both phases of the SLTHT are similar to the findings of previous studies, in which dynamic misalignment of the lower limb was common in women with PFP, characterized by excessive movement, particularly in the frontal and transversal planes.[33, 34] Our additional findings pertaining to sagittal plane kinematics in the PFPG (less knee flexion and dorsiflexion in the preparation phase and more knee and hip flexion and dorsiflexion in the landing phase) could have contributed to the greater ranges found in the frontal plane. According to Pollard,[36] healthy women may exhibit a greater range of motion in the frontal plane when they exhibit lower ranges in the sagittal plane. We believe that the lower ROM for knee flexion in women with PFP in both phases of the SLTHT were due to attempts to minimize the pain caused by compressive forces that occur in the patellofemoral joint during activities that demand great ranges of knee flexion.[14, 40]

The preparation and landing phases of the SLTHT place great demands on the knee, hip, and ankle extensors. As the internal hip extensor moment decreases, the demand on the knee extensors increases, which may increase the internal extensor moment in this joint, leading to excessive patellofemoral compression. However, the lower knee extensor moment observed in the PFPG during the preparation phase could be due to an attempt to minimize patellofemoral stress during this task. It could also be associated with the lower knee range of motion among women with PFP during both phases of jumping, including SLTHT.[16, 30, 40, 42]

Despite the kinetic differences found between the groups in the landing phase, it is notable that the contribution of the hip internal extensor moments, knee, and ankle were (proportionally) very similar in both groups. However, we noted that the internal knee extensor moment was slightly lower in the PFPG. During this phase, in which the impact energy is greater, it was expected that women with PFP would adopt strategies that require less knee extensor moment in order to minimize the patellofemoral pain caused by retropatellar compression.

Phase Comparisons

When comparing the kinematics during the different phases of the SLTHT, both groups exhibited greater contralateral pelvic drop; hip flexion, adduction and internal rotation; knee flexion; and ankle dorsiflexion during the preparation phase, whereas trunk flexion and foot eversion were greater during the landing phase. Trunk lean was contralateral during preparation and ipsilateral during the landing phase of the SLTHT for the PFPG, and greater in the preparation phase for the CG, when compared with the landing phase. Our hypothesis that greater lower limb misalignment would be found among the volunteers (CG and PFPG) during the landing phase was not confirmed.

The lower values found in the PFPG and CG during the landing phase compared to the preparation indicated that activities of a greater impact did not contribute to greater misalignment of the lower limb. We believe that the lower hip and knee flexion and dorsiflexion found in the landing phase in the PFPG were due to protection mechanisms against impact pain related to the landing, given that greater knee flexion causes greater patellofemoral stress[40], as well as possibly exacerbating the symptoms during weight-bearing activities[26, 49, 54] such as the SLTHT.

The increase in the trunk angular values during the landing phase may be due to an attempt to cushion the impact during the activity. In our opinion, this can be explained by the need to push for the next jump. We believe that the trunk accumulates energy for the individual to reach the greatest possible distance in the SLTHT, while also minimizing pain symptoms[44].This can also be confirmed by the greater internal extensor hip moment among the volunteers in the PFPG during the landing phase of the SLTHT, when compared with the preparation phase.

The lower values found in the frontal plane during the landing phase in the PFPG may also be related to an attempt to avoid patellofemoral pain. Lower ranges of motion in the sagittal, frontal and transversal planes are capable of minimizing patellofemoral stress.[16, 40]

The results of the present study differ from those reported by Willson and Davis,[48]who compared the kinematic behavior of women with PFP during activities that involved different muscle demands and found no kinematic differences linked to the activity performed. However, they did not assess the SLTHT.

To our knowledge, the present study is the first to compare different phases of the SLTHT among women with and without PFP. Based on the results obtained, the strategies used by patients with and without PFP during periods of high and low impact of the SLTHT are similar, however, during the preparation for the jump the biomechanical alterations found are more pronounced, which should be taken into consideration during treatment of women with PFP.

The present study has some limitations, particularly in relation to the fact that the assessment of the landing phase of the jump was only conducted during the transition from the first to the second jump in the SLTHT. In addition, the fact that the volunteers performed the jump barefoot needs to be considered, since it was difficult to standardize the footwear of all participants. Using different footwear could have affected the results.

The most significant clinical implication of the present study is that, unlike the expected results, the greatest biomechanical abnormalities seem to be associated with low-impact phases of the SLTHT. This finding should be taken into consideration when assessing, treating, and releasing PFP patients. Most professionals are concerned only with assessing biomechanical behavior during the phase of the test with the highest impact. However, despite the results of the present study, it is impossible to infer that the preparation phase is more harmful or dangerous to women with PFP. Consequently, further studies should be undertaken to assess these two phases and investigate more variables, including muscle activity and joint stress during each phase.

5. Conclusions

During a SLTHT, women with patellofemoral pain demonstrated greater misalignment of the lower limb compared to women without patellofemoral pain. The high impact (landing) phase of the SLTHT did not increase misalignment of the lower limb when compared to the low-impact (preparation) phase.

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ARTIGO 2:

- ARTIGO JÁ SUBMETIDO À GAIT & POSTURE JOURNAL -

Kinematic analysis of the ankle/foot complex mobility of women with patellofemoral pain during weight bearing functional tests: a case control study

ABSTRACT

Introduction: Patellofemoral pain syndrome (PFPS) has been frequently associated with abnormalities in the alignment of the lower limbs and trunk, particularly during weight-bearing activities. In this context, proximal and local factors have been widely discussed. Distal factors could also be involved and need to be investigated in more detail.

Objective: To compare the kinematics of the ankle/foot complex in women with pronated feet and patellofemoral pain with the kinematics of asymptomatic women during the execution of anterior and lateral step down tests.

Methods: Fifty women were divided into two groups: control (n=16); and patellofemoral pain (n=34). All volunteers performed the anterior and lateral step down tests (multi-segment biomechanical model). For each session, nine repetitions of each clinical test were performed on the most painful limb of the women with PFPS and the dominant limb of the women in the control group. The mobility of the ankle/foot complex was measured and the range of motion was calculated for all segments. The two groups were compared using multivariate analysis of variance.

Results: Women in the PFP group exhibited less knee flexion and significantly greater mobility of: the hindfoot in relation to the tibia and the laboratory; the forefoot in relation to the tibia; and the forefoot in relation to the hindfoot.

Conclusion: Women with PFPS exhibited greater mobility of the ankle/foot complex during the anterior and lateral step down tests, when compared with asymptomatic women.

Keywords: knee, hip, step down test, anterior knee pain, physiotherapy.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is linked to a process of anterior knee pain and is most prevalent among women aged between 18 and 35 years, regardless of whether they engage in physical activity or not.[1-4] PFPS complaint has often been correlated with abnormalities in the alignment of the trunk and lower limbs, particularly during weight-bearing activities.[1,5-7] This misalignment reduces the contact area between the patella and the femur and consequently increases the pressure exerted on the retropatellar cartilage, causing the algic process.[5] Despite the fact that the etiology of this pain is not well-known, it is clear that local (knee region), proximal (hip and trunk) and distal (ankle and foot)[8,9] factors are directly associated with the syndrome. Proximal and local factors have been widely discussed in the literature, whereas distal factors still require further investigation.[9,10]

Concerning these distal factors, a static measurement is capable of assessing the posture of the foot in an orthostatic position. The Foot Posture Index (FPI) assesses three anatomical planes and provides a score, which ranges from -12 to 12, with the following classifications: values between 0 and 5 are considered normal; values between 6 and 9 are classified as pronated; values between 10 and 12 are considered hyper-pronated; and negative values represent supinated feet.[11] This index is important as it provides a quick and easy method of assessing the feet. However, it only provides a static measure of alignment.[12]

Studies that assessed the three-dimensional kinematics of the lower limb and trunk of individuals with patellofemoral pain during different weight-bearing activities have reported excessive ipsilateral trunk lean, pelvic drop, adduction and medial rotation of the hip, abduction of the knee and pronation of the hindfoot.

[2,6,13-16] In addition, several theoretical studies have correlated the kinematics of the hindfoot with the kinematics of the hip in women suffering from patellofemoral pain,[2, 10, 17] reporting delays in the peak and increase of foot eversion (at the time of the initial contact during gait) and increases in the medial rotation of the tibia, leading to the development of patellofemoral pain.

Witvrouw et al.[9] reported that the influence of hindfoot eversion on the knee of women with PFPS remains unknown. Although there is a probable increase in the medial rotation of the tibia among these individuals, no studies have assessed this phenomenon using a mutli-segmetal model to compare women with pronated feet and PFPS with a control group during a functional test. This type of investigation could provide significant data, since multi-segmental kinematic models enable us to assess the ankle/foot complex in more detail.[18, 19]

Multi-segmental kinematic models enable more detailed assessments of the foot.[18-21] It was recently demonstrated that the Oxford Foot Model is reproducible for the anterior and lateral step down tests.[22] These functional tests involve a high muscular demand and seek to assess the dynamic alignment of the lower limbs and trunk, as well as the dynamic stability of the knee, thereby guiding the treatment of women with knee pain (and PFP) and analyzing the results obtained during rehabilitation programs.[23-25]

Given the importance of understanding the correlation between biomechanical abnormalities in the ankle/foot complex and patellofemoral pain, the aim of the present study was to compare the kinematics of women with patellofemoral pain and pronated feet with the kinematics of asymptomatic women during the execution of anterior and lateral step down tests.

MATERIALS AND METHODS

Participants

This cross-sectional case-control study contained a convenience sample of 50 women, who were divided into two groups: control group (CG; n=16) and patellofemoral pain group (PFPG; n=34).

The women in the PFPG scored between 6 and 9 on the Foot Posture Index (FPI), characterizing their feet as pronated,[11] and experienced bilateral anterior knee pain for at least three months, with the symptoms increasing during at least two of the following activities: climbing and descending stairs; squatting; kneeling down; jumping; sitting for long periods; isometric resistance of the quadriceps at 60° of knee flexion and palpation of the lateral or medial aspect of the patella. These activities were labeled anterior knee pain provokers by Thomee.[26]

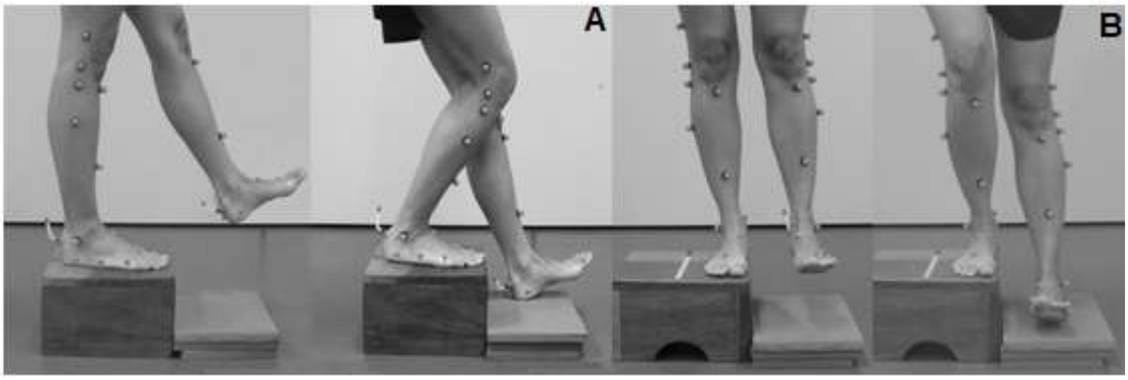
The following exclusion criteria were applied: a history of lower limb surgery; recurrent patellar dislocation or chronic instability; meniscal and/or ligament injuries; unilateral pain; and length discrepancies of more than 1 cm between the lower limbs.

Pain intensity was measured using the Numerical Pain Rating Scale (NPRS).[27] The participants were requested to classify the intensity of their pain in the previous 15 days.

Procedures

The placement of markers was performed in accordance with the OFM protocol.[28] Subsequently, the volunteers performed warm-up exercises and familiarized themselves with the tests that would be carried out on a step (18 cm high, 30 cm long and 30 cm deep).

To perform the anterior step down test, the tested limb was positioned close to the anterior edge of the step and the non-tested limb was suspended immediately in front of the step, assuming hip flexion, knee extension and maximal ankle dorsiflexion. To perform the lateral step down test, the tested limb was positioned close to the lateral edge of the step and the non-tested limb was suspended immediately beside the step, assuming hip and knee extension and



maximal ankle dorsiflexion (Figure 1).

Figure 1. Representation of the adjustments of the patient to perform the single leg step down anterior test (A) and the lateral step down test (B).

For both tasks, the volunteers were requested to squat slowly (over the course of two seconds) until the heel of the non-tested limb touched the ground, and then return immediately to the initial position (again over two seconds).

In order to standardize the test, the participants were requested to begin from maximal extension and squat until they reached approximately 60° of knee flexion in the support leg, while the contralateral foot touched the ground simultaneously. Adjustments related to the height of the volunteers were made using EVA blocks.

The task was repeated nine times, with intervals between attempts. The volunteers were asked if they were ready to perform the test again before beginning the next attempt.

Data processing

The markers were reconstructed, named and processed using Vicon-Nexus 1.8.5® software. A Woltring filter with a cutoff frequency of 8 Hz was used to reduce the noise caused by possible movements during the cycle prior to the application of the OFM model (Vicon Nexus 1.8.5 software). After the reconstruction and labeling of the markers, the movement cycles were recorded using maximal extension and maximal knee flexion as indicators of the start and end of the cycle, respectively. The end of the squat was used as the point of reference.

Finally, the ranges of motion were calculated, based on the movements performed during the nine tests for each lower limb on the three planes. These values were calculated for the following segments: hindfoot in relation to the laboratory (HFTLF); hindfoot in relation to the tibia (HFTBA); forefoot in relation to the tibia (FFTBA); forefoot in relation to the hindfoot (FFHFA) and knee on the sagittal plane.

Statistical analysis

The demographic characteristics and the range of motion data were tested in terms of normality using the Shapiro Wilk test. The independent t-test was used to compare the characteristics of the sample. The kinematic variables were compared between the groups using multivariate analysis of variance tests

(MANOVA). When multivariate effects occurred, univariate effects were tested for the relevant variables. The level of significance was set at P <0.05. Cohen effect size measurements were calculated and defined as follows: 0 – 0.49 = trivial; 0.5 to 0.79 = medium; and 0.8 or higher = large.[29] All of the comparisons were conducted using version 15.0 of SPSS software (SPSS Inc., Chicago, IL).

RESULTS

The women in the PFP group exhibited greater mobility in all of the segments analyzed in both tests, with significant differences recorded between the groups. Table 1 displays comparative demographic data between groups of volunteers ans table 2 displays the comparisons of the mean results for the two groups in the anterior and lateral step down tests.

	CG	**PFPG**
Height (m)	1.63 ± 6.2	1.58 ± 5.8
Mass (kg)	55.6 ± 6.1	57.2 ± 6.8
Age	24.6 ± 4.0	26.5 ± 8.2
FPI	7.5 ± 1.7	8.03 ± 3.2
VAS	0	5.7 ± 1.6
AKPS	100	66.7 ± 10

Table 1 – Comparative demographic data between the groups of volunteers.

Abbreviations: CG: Control Group; PFPG: Patellofemoral pain group; VAS: Visual analogue scale
Data are mean ± SD; AKPS: Anterior knee pain scale

STEP DOWN ANTERIOR		STEP DOWN LATERAL	
Control	**Pain**	**Control**	**Pain**

Sagittal Plane	Mean ± SD	Mean ± SD	ES§	Mean ± SD	Mean ± SD	ES§
Knee (Flexion)*	59.42 ± 8.2	55.75 ± 8.67	0.4	53.47 ± 5.2	48.65 ± 6.08	0.8
HFTFL (Plantar Flexion)*	7.86 ± 3.39	11.33 ± 3.85	0.9	6.40 ± 2.79	7.87 ± 3.31	0.4
HFTBA (Dorsiflexion)*	22.97 ± 5.33	39.15 ± 6.73	2.6	21.69 ± 4.33	36.41 ± 6.05	2.7
FFTBA (Dorsiflexion)*	30.86 ± 5.30	48.78 ± 7.54	2.7	30.10 ± 4.23	42.72 ± 6.42	2.3
FFHFA (Dorsiflexion)*	8.15 ± 3.29	12.89 ± 3.87	1.3	8.17 ± 3.12	10.56 ± 3.88	0.6
Frontal Plane						
HFTFL (Eversion)*	1.63 ± 1.04	19.73 ± 8.69	2.9	1.33 ± 1.07	13.64 ± 6.94	2.4
HFTBA (Eversion)*	17.6 ± 6.77	32.82 ± 13.26	1.4	19.20 ± 6.49	33.45 ± 14.54	1.2
FFTBA (Pronation)*	17.16 ± 6.49	33.68 ± 14.42	1.4	18.36 ± 6.30	35.93 ± 14.66	1.5
FFHFA (Pronation)*	2.82 ± 1.41	10.65 ± 6.62	1.6	2.16 ± 1.41	10.55 ± 6.72	1.7
Transverse Plane						
HFTFL (External Rotation)*	4.33 ± 2.21	8.54 ± 4.22	1.2	5.15 ± 2.66	8.9 ± 4.1	1.0
HFTBA (External Rotation)*	11.67 ± 4.36	23.76 ± 11.59	1.3	11.14 ± 4.26	24.01 ± 10.91	1.5
FFTBA (Abduction)*	13.27 ± 5.20	23.96 ± 9.55	1.3	13.12 ± 5.17	24.28 ± 8.28	1.6
FFHFA (Abduction)*	2.7 ± 1.3	9.11 ± 4.48	1.9	2.63 ± 1.60	9.05 ± 5.38	1.6

Table 2 – Comparison of the mean results for kinematics variables for both groups in the anterior and lateral step down tests.

* $P<0,01$; HFTLF – hindfoot in relation to the laboratory; HFTBA- hindfoot in relation to the tibia; FFTBA – forefoot in relation to the tibia; FFHFA – forefoot in relation to the hindfoot.

§ Effect size determined using Cohen d (0.0 to 0.49 - small, 0.5 to 0.79 - medium, and 0.8 or higher - large)

DISCUSSION

The present study assessed the three-dimensional kinematics of 36 women with PFPS and compared them with 14 asymptomatic women (both with pronated feet) during the anterior and lateral step down tests using a multi-segmental foot model. According to the results obtained, the women with PFPS exhibited greater joint mobility between the segments of the ankle/foot complex, as well as less knee flexion, than the asymptomatic women.

Assessments of foot posture are commonly conducted in clinical diagnoses of PFPS, although their validity, in terms of providing data about the dynamic function of individuals with PFPS, remains unclear. The evidence suggesting that the static posture of the pronated foot is a risk factor for the development of patellofemoral pain is very limited, despite the fact that it is known that the mechanics of movement can be affected by abnormal foot posture and abnormal foot pronation in cases of PFPS.[30] A pronated foot, as defined by the FPI, is considered one of the risk factors for the development of multifactorial syndromes, including PFPS[31, 32] and could be associated with the peak of hindfoot eversion,[33] increases in the contact area, pressure in the midfoot during gait[34] and the orientation of medial forces in the forefoot during the single leg squat.[35] However, prospective studies are required to determine if this relationship is causal.[32, 33]

Although there is a consensus[9] that the exact effect of hindfoot eversion on the knee remains obscure, it remains to be seen if individuals with PFPS exhibit greater general foot mobility and increased medial rotation of the tibia. Barton et al.[36] noted that individuals with PFPS exhibit a more pronated foot posture and increased general foot mobility, in relation to asymptomatic individuals. Albertini et al[37] reported a greater distribution of plantar pressure in the medial region of the foot while descending and climbing stairs. Conversely, Wilson et al.[38] noted regional differences in the plantar distribution of women with PFPS that are not consistent with a reduction in pronation during gait. However, until now, there has not been a kinematic foot measurement that involved a multi-segmental model and effectively analyzed the correlation between the segments in order to compare patients with PFPS with a control group during functional tests. A prospective assessment of these measurement is required to determine if they contribute to a better understanding of the mechanical proximal abnormalities found in cases of PFPS. The present study sought to fill this knowledge gap by performing kinematic analysis using a multi-segmental model of the foot and the Oxford Foot Model protocol.

The results of the present study confirmed a significantly higher mobility of the ankle/foot complex among individual with PFPS, as well as less knee flexion. This could be correlated with attempts to protect and/or compensate for articular pain.[10] These data corroborate the ideas of Barton et al.[36] and Boling et al.,[39, 40] who reported that individuals with greater mobility in the ankle/foot complex and an accentuated navicular drop are more likely to develop PFPS. Barton et al.[2, 10] correlated delays in the peak and increase of foot eversion during the initial contact of individuals with PFPS with an increase in the medial rotation of the tibia during gait, stating that these factors could predispose individuals to the onset of PFPS.

Powers et. al[8] stated that there is evidence of a correlation between hindfoot eversion and rotation of the tibia and hip in cases of PFPS. Peak hindfoot eversion has been positively correlated with peak medial rotation of the tibia and hip in cases of PFPS, which leads to a greater articular load and accentuates the misalignment of the lower limb and joint stress.[41]

Witvrouw et. al[9] confirmed that patients with PFPS produce more hindfoot eversion during gait than asymptomatic individuals. This may be due to the increase in hip adduction,[41] as well as the greater medial rotation of the tibia, which may provide a strong link between PFPS and distal factors. Silva et al[42] recently showed that hindfoot eversion while climbing stairs has the potential to differentiate women with PFPS, although the movement of the hindfoot was analyzed in relation to the laboratory and not in relation to segments of the foot and tibia. Therefore, no prospective studies have identified hindfoot eversion as a predictor of PFPS.

The results of these studies confirmed greater dorsiflexion, eversion and pronation, as well as lateral rotation and abduction of the foot, among women with PFPS in the two step down tests (lateral and anterior). These movements could be correlated with the reduced mobility of ankle dorsiflexion, although dorsiflexion was also higher in the PFPS group.

Limited ankle dorsiflexion has been previously described among individuals with PFPS[43] and may lead to compensatory eversion of the calcaneus or increases in the progression angle of the foot in order to decrease the center of mass on the feet.[44] Conversely, the increase in pronation in the subtalar joint may be caused by a limitation in the mobility of ankle dorsiflexion, resulting in an increase in knee valgus during functional activities that demand knee flexion simultaneous to ankle dorsiflexion.[22]

It is also possible that situations such as those found in the present study, in which dorsiflexion, pronation, eversion, rotation and abduction were excessive, are all compensatory mechanisms to decrease knee flexion and prevent pain.

During weight-bearing activities, the mechanics of the foot are often interpreted in the context of a theoretical correlation between foot pronation and movements on the transverse plane of the knee and hip, which can contribute to PFPS, since they do not preserve the arthrokinematics of the knee during flexion and extension.

Thus, it is probable that the mechanism observed herein (excessive mobility of the ankle/foot complex) compensates for the limited knee flexion that may occur as a result of the expectation of pain.

However, it is important to stress that the association between foot pronation and the kinematics of the knee has not been consistently reported.[45] A number of studies have not reported increases in foot pronation or hindfoot eversion in individuals with PFPS during gait.[46] Similarly, the conclusion that excessive mobility of the ankle/foot complex is a compensatory mechanism must be tested in future studies involving the simultaneous analysis of the kinematics of the trunk and lower limbs of individuals with PFPS using multi-segmental models.

CONCLUSION

Women with PFPS exhibit greater mobility in the ankle/foot complex during the anterior and lateral step down tests than asymptomatic women.

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ARTIGO 3:

Influence of kinematic and verbal biofeedback on pain in women with patellofemoral pain syndrome during unipodal squats

ABSTRACT

Patellofemoral pain is one of the primary musculoskeletal injuries affecting women and young adults. Its presence is related to biomechanical disorders of the lower limb that make the hip and/or the trunk move in an altered manner during some functional activities. Among the biomechanical misalignment, dynamic knee valgus and decreased trunk range of motion in the sagittal plane during closed kinetic chain activities are the main characteristics presented. To correct the misalignment, biofeedback has been highlighted in the literature as a good method of treatment for women with patellofemoral pain. The aim of this study was to compare the effects of improvement in lower limb and trunk movement pattern through kinematic and verbal biofeedback in the immediate symptoms of women with patellofemoral pain during squatting. In total, 44 women were selected, physically active, who performed five different types of squat with valgus control and increased amplitude of trunk flexion movement. After performing each squat, pain intensity was measured through a visual pain scale. This study concluded that the forms used for biofeedback are not sufficient to improve the pain of patients during squatting immediately.

Key-words: Knee. Analysis of movement. Feedback.

INTRODUCTION

Biomechanical alterations of the lower limbs have been consistently related to predisposing factors of injuries to the foot, ankle, knee, hip, and lumbar-pelvic region.[5, 22, 25, 31, 33, 36, 39, 44, 49, 53] Among the injuries associated with these biomechanical alterations is patellofemoral pain (PFP), or anterior knee pain, which is characterized by an algic process in the anterior knee due to biomechanical derangement in the lower limb to perform functional activities such as jumping, running, squats, etc.[47, 48, 55, 56, 58]

The biomechanical derangement known as dynamic knee valgus is often associated with the presence of PFP. Studies suggest[8,40] that when individuals with PFP carry out closed kinetic chain activities (CKC), especially squats, due to a motor control deficit in the lower limb, the hip presents excessive movement of adduction and internal rotation, which overloads the patellofemoral joint, increasing stress in the region and generating pain in the patient.

Consisting of the integration process between the sensory and motor systems, movement control is needed to perform functional activities of everyday life correctly, involving the integration of various regions of the cerebral cortex, among them the frontal, central, and parietal, which are stimulated differently depending on the stimulus received.[9]

Studies have linked the trunk position as one of the predisposing factors of knee pain in women with PFP.[4,41] When individuals affected by patellofemoral pain perform squats with increased range of motion of trunk flexion, the center of mass moves anteriorly, projecting the ground reaction force closer to the knee joint, reducing the internal extensor moment, which decreases stress in the patellofemoral joint, improving the symptoms of women affected by PFP.[4]

Thus, lower limb and trunk alignment and their relationship with PFP have been described in different functional activities, from those more frequent in day to day lives such as gait,[1, 2, 43] and squatting[34, 46], to more vigorous activities, such as jumping[7, 18, 55] or running.[37]

In relation to the various forms of treatment for PFP, kinematic biofeedback has been characterized as an important tool, having as its main objective the facilitation of normal movement of the segment after an injury,[50] giving the opportunity for the patient to achieve better movements during functional activities, through measurement of movements, motor control, and the forces produced by the body. This technique provides information to the patient in real time, which may often be unknown, thus facilitating the ideal movement.[21]

Providing biofeedback treatment to patients during rehabilitation can enhance the desired therapeutic effect, as it allows them to have control of physical processes considered automatic by the nervous system, [61] as well as offering the opportunity to improve motor control during functional tasks.[21]

Among the different resources used for biomechanical biofeedback, we highlight force platforms, electrogoniometers, motion sensors, and cameras based on the measurement of three-dimensional (3D) motion, the latter being used, primarily, to provide visual biofeedback of the movement executed [21] to evaluate improvements in movement and muscle activation.[29]

Having established the relation between knee dynamic valgus and patellofemoral pain, Salsich et al [42] evaluated the immediate influence of the best hip movement through verbal feedback on the symptoms of women with PFP and concluded that, in an immediate manner, improved hip position during squatting is not able to change algesic symptoms. However, according to the authors, if some kind of kinematic biofeedback was implemented for better control of movement, in addition to verbal biofeedback, the results could be improved.

On the other hand, Noehren et al.[37]selected 10 runners with patellofemoral pain and subjected them to kinematic visual biofeedback training, aiming at reducing hip adduction during running practice, for a period of 8 sessions, and noticed that this training with biofeedback, besides improving kinematics, was able to promote an improvement in symptoms during the evaluation after the intervention, which was maintained for up to one month of follow-up.

Teng and Powers,[51] in a single intervention in asymptomatic individuals during running practice, concluded that when increased trunk flexion is demanded, the stress in the patellofemoral joint decreases, which may improve symptoms in women with patellofemoral pain, however, this study was performed only with asymptomatic individuals. The impact of anterior trunk flexion or the real effect of kinematic biofeedback on pain in women living with patellofemoral pain syndrome during functional activities is still not known.

Thus, it seems that movement correction strategies, for the lower limb or trunk, are not yet fully understood in the literature regarding their ability to improve knee pain in women with PFP. In this context, the aim of this study was to compare the effects of improvement in lower limb and trunk movement pattern through kinematic and verbal biofeedback in the immediate symptoms of women with anterior knee pain during squatting. We hypothesized that, regardless of the type of biofeedback, women would present improvement in knee pain while squatting.

MATERIALS AND METHODS

Participants

This cross-sectional study included 44 women with PFP. All participants were informed about the procedures that would be performed and signed the free and informed consent form.

The sample was calculated according to the study by Salsich et al [42] to find a 3.5 degree difference in hip adduction, with a standard deviation estimated to be 5.9, an alpha of 0.05, and a power of 80%. Thus, the required sample was 44 individuals.

Physically active[6] women were recruited, aged 18 to 35 years[3, 23,30], who presented dynamic valgus knee, evaluated visually,[42] pain in the anterior knee region greater than 3 on the *Numerical Pain Rating Scale* (NPRS)[14], for a minimum of 6 months with at least two of the following activities provoking pain in the knee:[52] remaining seated for prolonged periods, going up or down stairs, squatting, running, or jumping. Volunteers with a history of surgery in the lower limb, recurrent patellar dislocation or chronic instability, dysfunction associated with the knee joint such as meniscal and/or ligament injuries, or any disorders of the heart or musculoskeletal system that could influence evaluation and treatment, were excluded from the study. In addition, volunteers who presented length discrepancies between the lower limbs greater than 1 cm were excluded, measured using a tape measure.

Instrumentation

A Vicon system (Vicon, UK) consisting of 8 cameras with a frequency of 120 Hz was used to capture the trajectory of markers during squats. The cameras were connected to a capture computer, where the data were further processed.

Procedures

After screening according to the inclusion and exclusion criteria, the volunteers were asked to perform 4 unipodal squats while being filmed by one of the researchers, in order to assess whether they presented dynamic knee valgus or not.[42] This analysis was performed independently by two professionals, who were required to reach agreement. If there were divergent responses between the two investigators, a third was called on to arbitrate.

Once dynamic valgus was confirmed and the volunteer was definitely included in the study, they were sent for kinematic evaluation. Initially a form was completed with personal data such as name, age, date of birth, telephone number, duration of symptoms, dominant leg (defined by questioning the preference of kicking a ball as far as possible), and side of pain predominance. Next, appropriately dressed in shorts and a top, the participants underwent the anthropometric measurements protocol, necessary for realization of the three-dimensional examination of movement, consisting of: height, weight, distance between the anterior superior iliac spines, lower limb length, knee and ankle diameter, and tibial torsion.[17] Finally, the participants completed a questionnaire translated and validated in Brazil to evaluate functionality of the lower limbs: *Anterior Knee Pain Scale –AKPS,*[14] in addition to indicating the intensity of their knee pain in the previous two weeks on a scale, also intended to quantify pain in patients with PFP, the NRPS,[14] prior to kinematic analysis (figure 1).

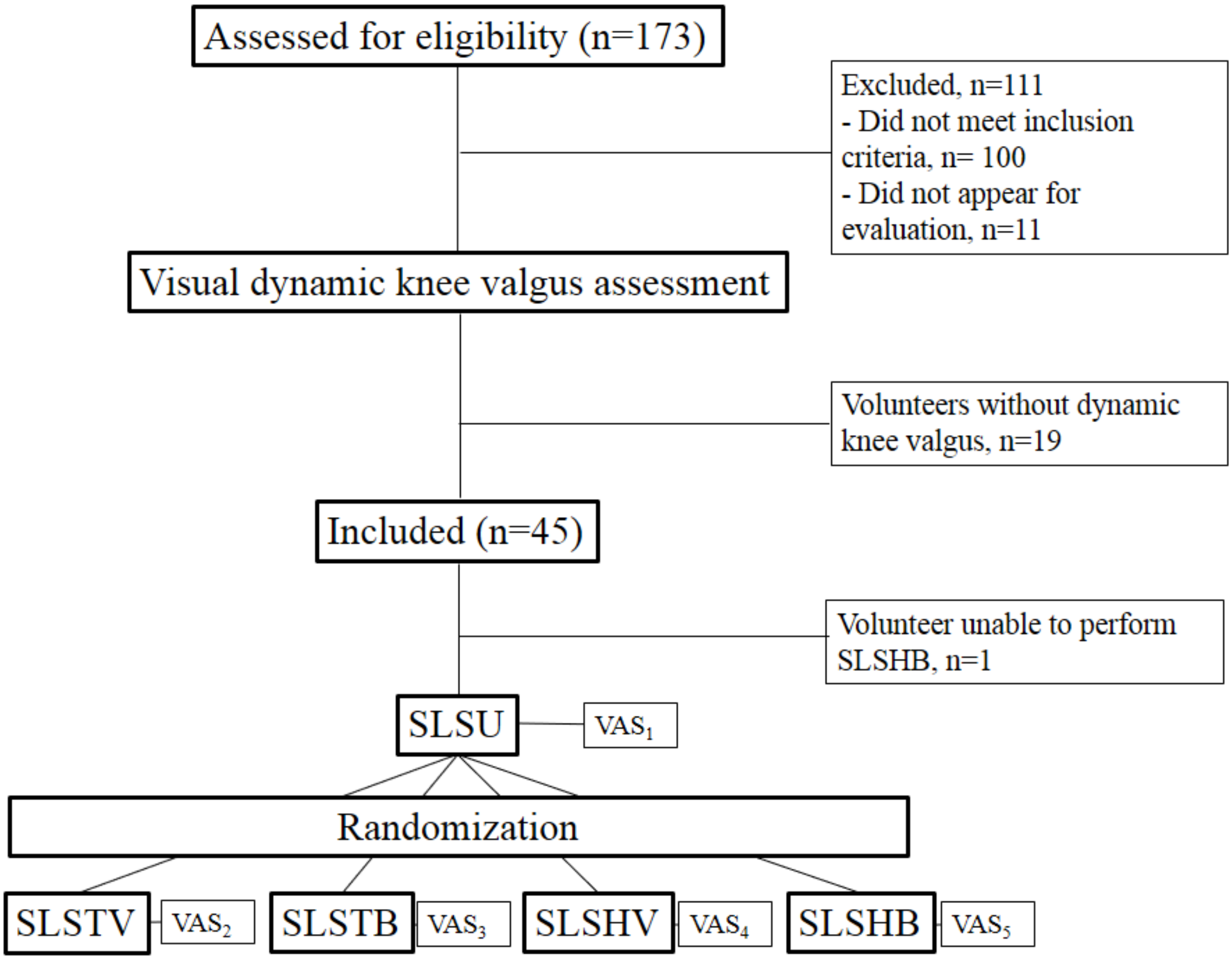

Figure 1: Flow chart study

Twenty-four spherical retro-reflective markers (12 mm diameter) were then fixed with double-sided tape on the following anatomical points: acromioclavicular joint, seventh cervical vertebra, inferior angle of the right scapula, tenth thoracic vertebra, posterior superior iliac spines (with a third marker on a rigid base), anterior superior iliac spines, lateral thigh region, lateral base of the patella, lateral femoral epicondyle, lateral tibia, lateral malleolus, calcaneus, and the region between the second and third toes. This set of markers is based on the Helen Hayes model, used to estimate the position of the joint centers and calculate the three-dimensional kinematics of the joints of the pelvis, hip, knee, and ankle,[15, 26] (Figure 1) which served as a reference for the movement analysis capture system. These markers were used for both static and dynamic collection. After placement of the markers, the volunteers performed as many unipodal squats as they thought necessary to become familiar with the activity.

Figure 2: positioning of the markers for kinematic collection

Intervention

SLSU

Once familiar with the activity, a static trial collection was performed and, consecutively, 3 standard unipodal squats (SLSU).[10, 24, 34] To standardize the position of all volunteers, they were instructed to perform the squats with upper limbs crossed on the anterior chest (below the xiphoid process, not to obstruct the trunk markers) for a total period of 4 seconds,[56] always starting and ending the activity with full knee extension. In the case of imbalance or poor execution, a new opportunity was given to the volunteer, up to a maximum of 10 attempts. If any volunteer was still unable to perform the test they were deemed unfit to participate in the study.

For execution of the SLSU no additional information was given to the patient in relation to the movement of the trunk or hip. The peak of trunk flexion and hip adduction were collected for this activity, which were later used for the other squats: unipodal trunk squat kinematic biofeedback (SLSTB), unipodal hip squat kinematic biofeedback (SLSHB), trunk squat verbal biofeedback (SLSTV), and hip squat verbal biofeedback (SLSHV).The volunteers performed these tasks three times with an interval between each attempt judged sufficient to avoid the effects of fatigue.

After completion of the SLSU, the order that each volunteer would perform the other squats was randomized, through an opaque envelope containing the four types of squat (SLSTB, SLSTV, SLSHB, and SLSHV). This randomization was performed 45 times, shortly after the inclusion of the volunteer in the study, and always after the execution of SLSU.

During all types of squat, auditory biofeedback was given to the patient through Vicon Nexus software, which was activated when the knee reached 60° of flexion, [42] indicating that the participant could return to the initial position of full knee extension.

SLSTB e SLSHB

During the squats with kinematic biofeedback, the Vicon system was placed in the "Kinematic Fit" mode and the angle of trunk flexion or hip adduction was projected in real time in front of the volunteers, on a 42-inch TV, 5 meters from where the activities were being performed (figure 3).

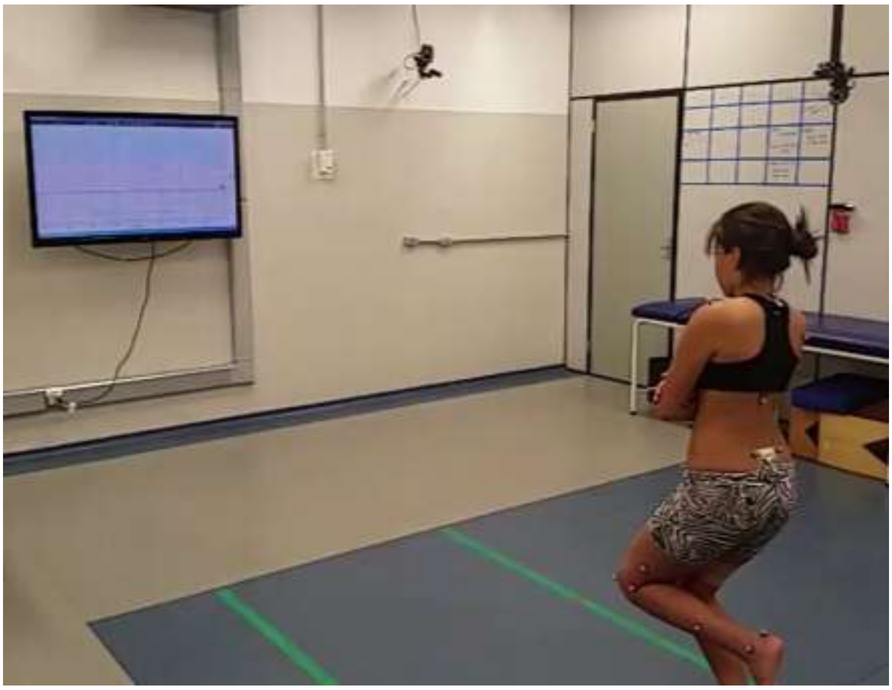

Figure 3: Volunteer position to perform SLSTB and SLSHB

For projection of the trunk angulation to the volunteers, the trunk segment was selected in the biomechanical model of the Vicon system and, on the "communications" tab the Y axis of trunk movement was selected with respect to the laboratory. After selecting the Y axis, the parameters of the call target line were placed in the "Threshold" mode, which utilized the mean peak flexion of the trunk acquired during the SLSU, plus 20% (Figure 3). These data were input in the "Upper Threshold" field. Thus, if the volunteer presented 20 degrees of flexion of the trunk during the SLSU, in the SLSTB the value with respect to the target line was 24 degrees of trunk flexion and during the squat the participant was required to perform the activity increasing trunk flexion so as to cause the trunk flexion line to exceed the target line. (figure 4).

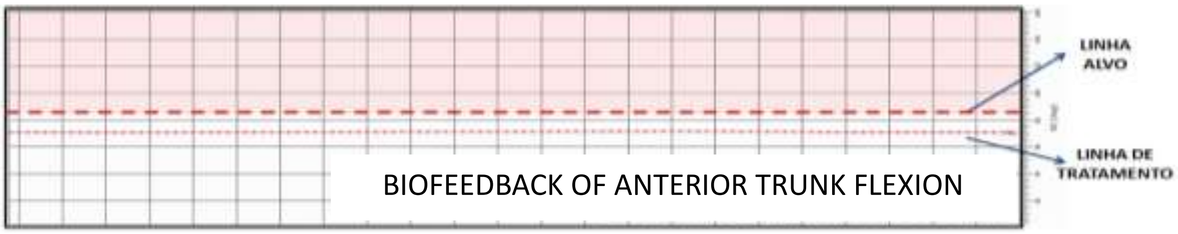

Figure 4: Vicon Nexus system graph presented to the volunteers as a form of biofeedback during SLSTB

The same was performed for the kinematic biofeedback of hip adduction, however, the target line parameters input in the "Threshold" field were 20% less than the peak hip adduction reached during the SLSU (i.e., if the volunteer presented ten degrees of hip adduction, the value of 8 degrees was input in the "Lower Threshold") and during the squat the volunteer was required to perform the activity decreasing their hip adduction so as not to allow the adduction line to exceed the target line (figura 5).

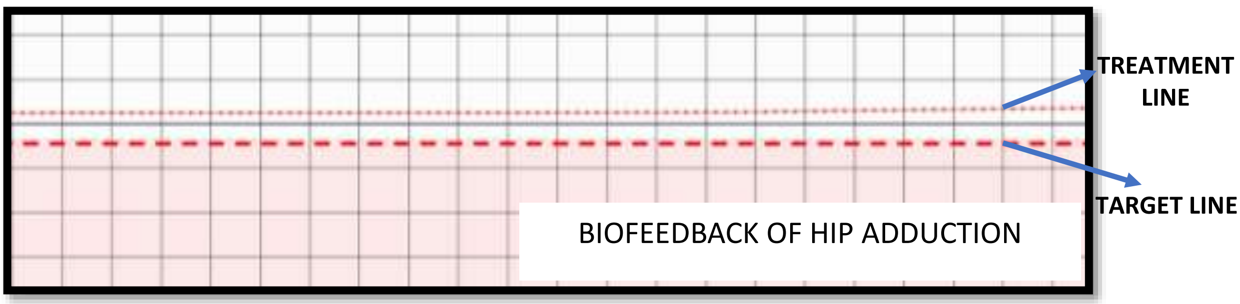

Figura 5: Vicon Nexus system graph presented to the volunteers as a form of biofeedback during SLSHB

SLSTV and SLSHV

During squats with verbal biofeedback there was no projection for the volunteers. For the execution of the SLSTV, the following verbal command was given: "during the squat, bend your trunk forward in a comfortable way as you flex your knee”. During the SLSHV the command given was: "do not let your pelvis drop or your knees rest against each other during the squat”

For the verbal biofeedback, in order to maintain the standardization of each squat, auditory biofeedback related to the angle of 60º of knee flexion continued to be given to patients, also through the Vicon Nexus software.

Between each of the different tasks, the participant was asked to demarcate the intensity of their pain during that particular squat on the NPRS, for statistical analysis to establish which of the forms of squat most reduced the pain of the volunteers.

The data used for this analysis were collected throughout the training process of the volunteers. If a volunteer unbalanced during the trial or could not perform the task for some other reason, the trial was canceled and a new attempt started.

Data Processing

After collecting the data, reconstruction, appointment, and processing of data was carried out in Vicon Nexus software (VICON, Oxford, UK).[54] As in previous studies evaluating dynamic tasks, data were filtered with a fourth order Butterworth filter and zero phase delay of 12 Hz low pass. The joint kinematics were calculated from a coordinate system [15, 26] and reported in relation to the static trial to measure the movements of one segment relative to another and in relation to the laboratory.

For data analysis, the activity cycle was considered as the moment when the knee flexion started (0% of cycle) to the moment it returned to the starting position in extension (100% of cycle). The mean range of motion of the three trials was used for statistical analysis.

STATISTICAL ANALYSIS

Descriptive statistics are presented as mean and standard deviation (SD). All data were normally distributed or approximately normal, confirmed by visual inspection of the histograms. Analysis of variance (ANOVA) for repeated measures was performed to verify the interactions between the dependent variables in each analyzed task (SLSU, SLSTV, SLSTB, SLSHV and SLSHB). The sphericity of the data was evaluated using Mauchly's test, and, if violated, the degrees of freedom were corrected via the Greenhouse-Geisser test. When significant results were found in the ANOVA, post hoc Bonferroni analysis was used to verify the significant interactions between the analyzed tasks. Statistical significance for all tests was set at $P < 0.05$. The following were considered: 0-0.49 small; 0.50-0.79 medium; and greater than 0.80 high (Cohen, 1988). All statistical analyzes were performed using SPSS version 20.0 (IBM Corporation, Armonk, NY).

RESULTADOS

The demographic data is presented in Table 1.

Table 1: Demographic datas

	PFP (n = 44)*
Age (y)	24.0 ± 4.6
Body mass (kg)	55.9 ± 7.1
Height (m)	1.65 ± 0.12
BMI (kg/m^2)	21.3 ± 2.7
AKPS (0-100)	69.0 ± 11.0
NPRS (Last 15 days)[ł]	5.8 ± 1.5

Abbreviations: BMI, body mass index; PFP, patellofemoral pain; NPRS, numerical pain ratio scale
* Data are mean ± SD
[ł] Scored from 0 to 10, where 0 is no pain and 10 is the worst imaginable pain. Score is for the average amount of pain the respective test.

PAIN

There were no statistically significant differences between any of the forms of squats (tabela 2).

Table 2: *Numerical pain ration scale* durante o SLSU, SLSHV, SLSHB, SLSTV e SLSTB

	PFP (n = 44)*
NPRS (SLSU Test)ƚ	4.6 ± 2.0
NPRS (SLSHV Test)ƚ	4.5 ± 2.4
NPRS (SLSHB Test)ƚ	4.7 ± 2.6
NPRS (SLSTV Test)ƚ	4.2 ± 2.3
NPRS (SLSTB Test)ƚ	4.3 ± 2.5

Abbreviations: SLSU: single leg squat usual; SLSHV: single leg squat hip verbal; SLSHB: single leg squat hip biofeedback; SLSTV: single leg squat trunk verbal; SLSTB: single leg squat trunk biofeedback; PFP, patellofemoral pain ; NPRS:Numerical Pain Ratins Scale
* Data are mean ± SD
ƚ Scored from 0 to 10, where 0 is no pain and 10 is the worst imaginable pain. Score is for the average amount of pain the respective test.

SLSU X SLSTB

The volunteers presented greater range of anterior trunk inclination (33.2 ± 1.7 vs 13.1 ± 1.2), anterior pelvic tilt (16.8 ± 1.0 vs 9.2 ± 0.8), and hip flexion (60.1 ± 2.0 vs 48.1 ± 2.0) during SLSTB, while dorsiflexion was higher during the SLSU (32.6 ± 0.8 vs 36.6 ± 0.8) (Table 3).

SLSU X SLSHB

The volunteers presented lower amplitude of hip adduction movement during SLSHB (9.0 ± 0.9 vs 13.4 ± 0.9) (Table 3).

Tabela 3: Range of motion of the trunk, pelvis, hip, knee, and ankle in women with PFP during SLSU, SLSTB, and SLSHB

	SLSU (n=44)*	SLSTB (n=44)*	SLSHB (n=44)*	SLSU X SLSTB		SLSU X SLSHB	
	Mean (95% CI)	**Mean (95% CI)**	**Mean (95% CI)**	**Mean Difference**	**Effect size****	**Mean Difference**	**Effect size****
Trunk flexion§	13.1 (10.6; 15.6)	33.2 (29.5; 36.8)	9.6 (7.1; 12.2)	20.0	13.0	3.4	2.9
Ipsilateral trunk lean	5.3 (4.3; 6.4)	5.0 (3.9; 6.0)	4.4 (3.5; 5.3)	0.3	0.5	0.8	1.9
Trunk Rotation	4.8 (4.0; 5.6)	4.4 (3.7; 5.7)	3.6 (3.1; 4.1)	0.4	1.3	1.2	4.7
Anterior pelvic lean§	9.2 (7.5; 10.8)	16.8 (14.6; 19.0)	7.6 (5.5; 9.6)	7.6	8.3	1.5	1.7
Contralateral pelvic drop	6.3 (5.2; 7.3)	6.1 (4.9; 7.2)	4.8 (4.0; 5.7)	0.2	0.4	1.1	3.3
Ipsilateral pelvic rotation	7.2 (6.0; 8.4)	6.6 (5.3; 7.8)	5.1 (4.2; 5.9)	0.6	1.0	2.1	4.1
Hip flexion§	48.1 (44.0; 52.1)	60.1 (56.0; 64.1)	40.6 (36.5; 44.8)	12.0	6.0	7.4	3.7
Hip adduction¥	13.4 (11.5; 15.4)	10.6 (8.8; 12.3)	9.0 (7.2; 10.9)	2.8	3.2	4.4	5.0
Hip internal rotation	9.5 (8.3; 10.7)	10.3 (9.0; 11.6)	8.9 (7.7; 10.1)	0.7	1.3	0.6	1.0
Knee flexion	75.2 (72.2; 78.1)	75.2 (71.9; 78.5)	69.7 (67.0; 72.3)	0	0.0	5.5	4.0
Knee adduction	4.1 (3.3; 4.9)	4.5 (3.8; 5.3)	3.9 (3.3; 4.5)	0.3	1.1	0.2	0.5
Dorsiflexion§	36.6 (34.8; 38.2)	32.6 (30.8; 34.2)	33.9 (32.2; 35.7)	4.0	1.2	2.5	3.3

Abbreviations: PFP: patellofemoral pain; SLSU: single leg squat usual; SLSTB: single leg squat trunk biofeedback; SLSHB: single leg squat hip biofeedback.
* Data presented as mean (95% confidence interval)
** Size of the effect, calculated by the Cohen's D formula (considered trivial when less than 0.2; small when between 0.2 and 0.5; medium when between 0.5 and 0.8; and large when higher than 0.8).
§ Statistically significant difference when comparing the means of the groups SLSU X SLSTB
¥ Statistically significant difference when comparing the means of the groups SLSU X SLSHB

SLSU X SLSTV

The volunteers presented greater amplitude of anterior trunk inclination (35.4 ± 1.7 vs 13.1 ± 1.2), anterior pelvic tilt (17.7 ± 1.1 vs 9.2 ± 0.8), and hip flexion (63.0 ± 1.9 vs 48.1 ± 2.0) during the SLSTV, while dorsiflexion was higher during the SLSU (32.9 ± 0.7 vs 36.6 ± 0.8) (Table 4).

SLSU X SLSHV

There were no statistically significant differences in the comparison between these two conditions (Table 4).

SLSTV X SLSTB and SLSHV X SLSHB

There were no statistically significant differences in the comparison between these conditions (Table 5).

Tabela 4: Range of motion of the trunk, pelvis, hip, knee, and ankle in women with PFP during SLSU, SLSTV e SLSHV

	SLSU (n=44)*	SLSTV (n=44)*	SLSHV (n=44)*	SLSU X SLSTV		SLSU X SLSHV	
	Mean (CI 95%)	Mean (CI 95%)	Mean (CI 95%)	Mean difference	Effect size**	Mean difference	Effect size**
Trunk flexion§	13.1 (10.6; 15.6)	35.4 (32.0; 38.7)	9.6 (7.4; 11.7)	22.3	15.1	3.5	3.0
Ipsilateral trunk lean	5.3 (4.3; 6.4)	4.7 (4.0; 5.4)	4.3 (3.3; 5.3)	0.6	1.4	1.0	2.0
Trunk rotation	4.8 (4.0; 5.6)	4.1 (3.4; 4.9)	4.3 (3.6; 4.9)	0.7	1.9	0.5	1.6
Anterior pelvic lean§	9.2 (7.5; 10.8)	17.7 (15.4; 19.9)	7.3 (5.8; 8.7)	8.5	8.8	1.9	2.5
Contralateral pelvic drop	6.3 (5.2; 7.3)	6.5 (5.5; 7.5)	5.3 (4.3; 6.2)	0.2	0.4	1.0	2.0
Ipsilateral pelvic rotation	7.2 (6.0; 8.4)	6.1 (4.9; 7.2)	5.6 (4.7; 6.4)	1.1	1.9	1.6	3.1
Hip flexion§	48.1 (44.0; 52.1)	63.0 (59.1; 66.9)	39.0 (32.7; 45.2)	14.9	7.6	9.1	3.5
Hip adduction	13.4 (11.5; 15.4)	9.7 (8.0; 11.3)	10.3 (8.4; 12.1)	3.7	4.3	3.1	3.4
Hip internal rotation	9.5 (8.3; 10.7)	10.4 (9.1; 11.6)	8.4 (7.2; 9.7)	0.9	1.5	0.9	1.8
Knee flexion	75.2 (72.2; 78.1)	76.8 (73.9; 79.6)	68.5 (61.7; 75.4)	1.6	1.1	6.7	2.5
Knee adduction	4.1 (3.3; 4.9)	4.6 (3.8; 5.4)	4.1 (3.3; 4.9)	0.5	0.0	0.0	0.0
Dorsiflexion§	36.6 (34.8; 38.2)	32.9 (31.3; 34.4)	33.6 (30.1; 37.0)	3.7	4.9	3.0	10.5

Abbreviations: PFP: Patellofemoral pain; SLSU: single leg squat usual; SLSTV: single leg squat trunk verbal; SLSHV: single leg squat hip verbal
* Data presented as mean (95% confidence interval)
** Size of the effect, calculated by the Cohen's D formula (considered trivial when less than 0.2; small when between 0.2 and 0.5; medium when between 0.5 and 0.8; and large when higher than 0.8).
§ Statistically significant difference when comparing the means of the groups SLSU X SLSTV

§ Statistically significant difference when comparing the means of the groups SLSU X SLSTV

Tabela 5: Range of motion of the trunk, pelvis, hip, knee, and ankle in women with PFP during the SLSTV, SLSTB, SLSHV e SLSHB

	SLSTV (n=44)*	SLSTB (n=44)*	SLSHV (n=44)*	SLSHB (n=44)*	SLSTV X SLSTB	SLSHV X SLSHB
	Mean (CI 95%)	Mean (CI 95%)	Mean (CI 95%)	Mean (CI 95%)	Mean difference	Mean difference
Trunk flexion	35.4 (32.0; 38.7)	33.2 (29.5; 36.8)	9.6 (7.4; 11.7)	9.6 (7.1; 12.2)	2.2	0
Ipsilateral trunk lean	4.7 (4.0; 5.4)	5.0 (3.9; 6.0)	4.3 (3.3; 5.3)	4.4 (3.5; 5.3)	1.7	0.1
Trunk rotation	4.1 (3.4; 4.9)	4.4 (3.7; 5.7)	4.3 (3.6; 4.9)	3.6 (3.1; 4.1)	0.3	0.7
Anterior pelvic lean	17.7 (15.4; 19.9)	16.8 (14.6; 19.0)	7.3 (5.8; 8.7)	7.6 (5.5; 9.6)	0.9	0.3
Contralateral pelvic drop	6.5 (5.5; 7.5)	6.1 (4.9; 7.2)	5.3 (4.3; 6.2)	4.8 (4.0; 5.7)	0.4	0.5
Ipsilateral pelvic rotation	6.1 (4.9; 7.2)	6.6 (5.3; 7.8)	5.6 (4.7; 6.4)	5.1 (4.2; 5.9)	0.5	0.5
Hip flexion	63.0 (59.1; 66.9)	60.1 (56.0; 64.1)	39.0 (32.7; 45.2)	40.6 (36.5; 44.8)	2.9	1.6
Hip adduction	9.7 (8.0; 11.3)	10.6 (8.8; 12.3)	10.3 (8.4; 12.1)	9.0 (7.2; 10.9)	0.9	1.3
Hip internal rotation	10.4 (9.1; 11.6)	10.3 (9.0; 11.6)	8.4 (7.2; 9.7)	8.9 (7.7; 10.1)	0.1	0.5
Knee flexion	76.8 (73.9; 79.6)	75.2 (71.9; 78.5)	68.5 (61.7; 75.4)	69.7 (67.0; 72.3)	1.6	1.2
Knee adduction	4.6 (3.8; 5.4)	4.5 (3.8; 5.3)	4.1 (3.3; 4.9)	3.9 (3.3; 4.5)	0.1	0.2
Dorsiflexion	32.9 (31.3; 34.4)	32.6 (30.8; 34.2)	33.6 (30.1; 37.0)	33.9 (32.2; 35.7)	0.3	0.3

Abbreviations: PFP Patellofemoral pain; SLSTV: single leg squat trunk verbal; SLSTB: single leg squat trunk biofeedback; SLSHV: single leg squat hip verbal; SLSHB single leg squat hip biofeedback

* Data presented as mean ± Standard Deviation

DISCUSSÃO

This study evaluated the influence of different types of biofeedback for better hip and trunk control on the immediate improvement in pain during squatting in 44 women who presented PFP and dynamic knee valgus. We hypothesized that regardless of the form in which biofeedback was given women would present improvement in pain symptoms during squatting, which was not confirmed after analysis of the results. In view of this, we believe, in an immediate manner, reduction in hip adduction or increased trunk flexion through biofeedback, be it verbal or kinematic, are not enough to promote an improvement in pain in patients affected by patellofemoral pain.

When comparing the SLSU with SLSTB, the volunteers presented higher anterior trunk flexion, pelvic tilt, and hip flexion; and less dorsiflexion during SLSTB. Comparing the SLSU with SLSHB the only difference was in relation to the greater hip adduction obtained during SLSHB. When comparing the SLSU with SLSTV, the volunteers presented higher anterior trunk inclination, anterior pelvic tilt, and hip flexion, as well as lower dorsiflexion, during SLSTV. In the comparative analysis between the SLSU and SLSHV no differences were found in any kinematic variable, which leads us to think that the verbal command of hip stability does not seem to be sufficient to promote the desired kinematic improvement, unlike other strategies utilized in the study.

In the comparison between the amplitude of motion obtained between SLSU and SLSHV, there was 20.9% improvement in hip adduction during SLSVH; however this value was not able to improve the movement amplitude of this joint during squatting. Noehren et al.[37] performed a running workout also with verbal biofeedback and noticed that 23% less hip adduction was able to change the angular kinematics. Thus, although they are different tasks, we believe that while we achieved the desired improvement in our volunteers (20%), if they had controlled the movement a little more, the difference could be achieved.

Treatment based on biofeedback has been used in rehabilitation for over 50 years in order to facilitate movement patterns considered normal after the onset of an injury[50]. The effects of various types have also been increasingly studied in the literature, in a wide variety of patients, whether neurological,[12, 38] orthopedic[16, 19, 35, 37, 42, 57, 60] or even in asymptomatic individuals.[11, 13, 27, 59] Sometimes with a favorable outcome[13, 27, 37] and sometimes not.[42]

Interventions aimed at better positioning of the trunk and hip have been performed principally for running. Teng and Powers [51] evaluated the influence of trunk positioning in the sagittal plane in a single intervention with 24 runners during 3 different running situations: Comfortable extension, normal, and comfortable flexion. After analyzing the data it was concluded that comfortable trunk flexion during running is able to decrease pressure in the patellofemoral joint. The authors concluded that this strategy may be beneficial to promote improvement in symptoms in women with patellofemoral pain, which was not confirmed in the present study, since SLSTV and SLSTB squats, despite having changed the angulation of the trunk relative to SLSU, were not able to decrease the intensity of pain in the volunteers during squatting.

On the other hand, Noehren and colleagues, [37] after biofeedback training of 8 sessions in runners, aiming at lower hip adduction during running, concluded that training with kinematic biofeedback is sufficient to, as well as maintaining, improve the kinematics of women living with pain, and improve algesic symptoms. However, the main difference to our study is that besides the activity being different, we conducted a single intervention. If we had performed a protocol focused on multiple sessions the volunteers could have presented algesic improvements.

A fact that should also be brought to attention is that in the present study, during SLSHV no difference to SLSU was found with regard to the angle of hip adduction. This makes us think that a verbal stimulus is not able to promote the desired improvements in hip kinematics, unlike biomechanical biofeedback, which was able to change the kinematics of the hip compared to SLSU. However, neither of these techniques was able to improve the pain of these volunteers.

Karni et al.[28] claim that motor learning through biofeedback follows two distinct lines, processed in the motor cortex. The first of these constitutes a routine day to day task, which can be learned in a single session. The second constitutes a slower learning phase, which to be attained requires long-term practice over several weeks. Despite our task constituting a relatively common day to day activity, perhaps because it constitutes an algesic situation for the patients falls within the second form of motor learning.

In the work of Chang et al.,[9] the authors state that the area stimulated in the cerebral cortex depends directly on how the stimulus is given. When visual feedback is given to the patient (in the case of SLSTB and SLSHB), neurological activity is stimulated in the regions of the prefrontal lobe (called the visual association cortex) and parietal lobe, to enable processing of information and control of postural stability. When the visual stimulus is removed (in the case of SLSTV and SLSHV) the individual presents increased stimulation in the parietal lobe added to which the occipital lobe is activated.

However, in some situations there is no difference in the control of movement whether a visual stimulant is given or not[9]. Thus, we believe that technological apparatus of high commercial value such as that used in the present study is not always crucial, since the clinical outcomes between the two conditions seem to be the same, as found in the present study.

The results obtained in the present study confirm those found by Salsich et al., [42] who evaluated the influence of improved dynamic knee valgus on the immediate algesic response of women with patellofemoral pain during unipodal squatting and also found no reduction in symptoms. According to the authors, one of the main biases of the work was the manner in which the stimulus was given to patients (only verbal stimulus). We tried to improve this aspect during our study; however, the results were not satisfactory with regard to pain relief, since SLSTB and SLSHB squats were not able to improve the symptoms of the volunteers during squatting.

When performing activities in CKC with greater anterior trunk flexion, the internal knee extensor moment decreases, [20, 32] decreasing the patellofemoral stress, which could improve the symptoms of women with patellofemoral pain, [41, 51] however, when this stimulus is given in a single session the results do not seem to be as expected. We believe that if this intervention is performed more intensely, based on a program of treatment, the results could be enhanced, as in the results obtained by Noehren et al.[37].

The literature associates dynamic knee valgus with PFP, however, this study and that of Salsich et al. [42] tried to correct the biomechanical misalignment in an attempt to reduce the pain of women with patellofemoral pain in an immediate manner, and neither found satisfactory results.

A fact that may have contributed to the unfavorable results may also have been the number of repetitions performed by each of the volunteers in the present study. Selfe et al.[45] evaluated the minimum number of repetitions required to achieve the specific proprioceptive objectives in women with patellofemoral pain and came to the conclusion that, when performed actively, it takes at least 5 trials, which was not carried out in the present study. In future studies, increasing the number of times that patients perform attempts could change the results. However, we carried out training with the use of biofeedback, which ensures that all objectives outlined in relation to the movements were achieved.

Comparisons with other studies in the literature that address the same results as the present study are limited as, to our knowledge, there is only one other study that evaluated the immediate results on pain in women with patellofemoral pain,[42] which also did not obtain satisfactory results, however, the main difference between that study and the present work was, in addition to the way the biofeedback was given (kinematic biofeedback and verbal biofeedback *versus* verbal biofeedback only), the number of volunteers in the study (44 participants in the present study versus 10 volunteers in the other study), which makes us think that in reality the kinematic change is not able to improve the symptoms of women with patellofemoral pain in an immediate manner during unipodal squatting.

Different from the squat, the studies that evaluated the algesic impact of better hip and trunk positioning during running [37, 51] presented satisfactory results, which implies that, depending on the activity that the patient performs, the results could be different.

This may be the main limitation of the present study. If different activities had been evaluated, the results could have been different between each of them. Another limitation is the fact that we evaluated the two conditions together (better hip positioning associated with better trunk movement), however, during our pilot tests there was some difficulty on the part of the volunteers in correct execution when asked to perform the two forms of squat in a combined manner. This constituted a confounding factor for them, since the trunk flexion had to increase and the hip adduction decrease during the activity.

Conclusion

Kinematic biofeedback and verbal biofeedback are not able to improve the pain of women with PFP during squatting when performed in a single session.

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4. Considerações finais

Essa Tese de Doutorado abordou o tema relacionado à síndrome da dor femoropatelar em mulheres. O intuito do desenvolvimento da mesma foi entender melhor as características presentes nas mulheres que apresentam esse quadro clínico, assim como propor uma nova forma de tratamento visando uma unica sessão através de dois tipos diferentes de biofeedback. Os objetivos traçados no inicio do projeto foram perfeitamente alcançados, entretanto, as hipóteses do nosso estudo 1 e do estudo 3 não foram confirmadas. Essa Tese de Doutorado colabora fortemente com a literatura, sobretudo pelo fato de alguns dados não serem aqueles esperados, o que confirma a idéia de que maiores estudos envolvendo a dor femoropatelar, que aborde desde suas características biomecênicas, até métodos de tratamento, precisam ser mais estudados no futuro.

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6. ANEXOS

Aprovação do Comitê de Ética em Pesquisa

UNINOVE Universidade Nove de Julho — UNIVERSIDADE NOVE DE JULHO - UNINOVE — Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Influencia do treinamento de biofeedback cinemático e verbal de membros inferiores e tronco em mulheres com síndrome da dor femoropatelar

Pesquisador: Amir Curcio dos Reis

Área Temática:

Versão: 2

CAAE: 55669616.1.0000.5511

Instituição Proponente: ASSOCIACAO EDUCACIONAL NOVE DE JULHO

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.587.346

Apresentação do Projeto:

Alterações biomecânicas do membro inferior têm sido constantemente relacionadas com fatores predisponentes de lesão no pé, tornozelo, joelho, quadril e região lombo-pélvica. Dentre as lesões associadas a essas alterações biomecânicas, destacamos a síndrome da dor femoropatelar (SDFP). Atualmente existem evidencias na literatura que pacientes com essa síndrome apresentam alterações biomecânicas ao realizar atividades

funcionais como o salto, corrida, agachamento, etc. A articulação do quadril e do tronco vem recebendo especial atenção por parte dos

pesquisadores, pois acredita-se que os movimentos excessivos de adução e rotação medial do quadril, assim como pouca flexão do tronco sobrecarregarão a articulação femoropatelar, Sendo assim, o presente projeto. tem o objetivo de comparar os efeitos da melhora do padrão de movimento do membro inferior e tronco nos sintomas imediatos de mulheres com dor anterior no joelho durante o agachamento unipodal. A partir da

sua elaboração poderemos desenvolver um programa de tratamento mais especifico para a SDFP, seja ela focando primariamente na melhora do posicionamento do tronco ou na melhora do padrão de movimento do quadril.

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UNIVERSIDADE NOVE DE JULHO - UNINOVE

Continuação do Parecer: 1.587.346

Objetivo da Pesquisa:

Objetivo Primário:

Comparar os efeitos da melhora do padrão de movimento do membro inferior e tronco nos sintomas imediatos de mulheres com dor anterior no
joelho durante o agachamento unipodal.

Objetivo Secundário:

- Avaliar se a melhora do padrão de movimento do quadril é capaz de promover diminuição imediata da dor anterior no joelho durante o agachamento unipodal
- Avaliar se a melhora do padrão de movimento do tronco é capaz de promover diminuição imediata da dor anterior no joelho durante o agachamento unipodal- Comparar qual das duas estratégias é mais eficaz na promoção da melhora imediata dos sintomas álgicos
- Avaliar e comparar a influência das duas estratégias sobre a cinemática linear e angular durante o agachamento unipodal

Avaliação dos Riscos e Benefícios:

Desconforto ou Riscos Esperados: As voluntárias do estudo serão submetidas a riscos mínimos durante o período experimental, podendo ocorrer desconforto no momento dos agachamentos. A pesquisa será interrompida e a voluntária será excluída do estudo caso ocorra qualquer sensação de dor ou desconforto anormal durante os agachamentos, com aumento dos sintomas maior que 2 pontos quando avaliados na escala visual analógica de dor, e, neste caso, a voluntária será encaminhada para tratamento na clínica de fisioterapia desta mesma instituição. Os dados serão coletados através de esferas fixadas à pele por fita adesiva, sendo esta antialérgica. Caso ocorra qualquer tipo de reação alérgica, a coleta será interrompida e a voluntária será encaminhada a um serviço médico mais próximo.

Benefícios: Após a realização da pesquisa nos teremos condições de saber se as estrategias de agachamento propostas serão suficientes para promover melhora imediata da dor de mulheres com dor no joelho durante o agachamento.

Comentários e Considerações sobre a Pesquisa:

Pesquisa adequada para o objetivo proposto

Considerações sobre os Termos de apresentação obrigatória:

Os termos obrigatórios foram apresentados de forma correta.

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Recomendações:

Não existe recomendações

Conclusões ou Pendências e Lista de Inadequações:

Não existe pendências

Considerações Finais a critério do CEP:

Projeto aprovado.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_691083.pdf	01/06/2016 15:51:40		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_alteracoes_CEP.docx	01/06/2016 15:51:06	Amir Curcio dos Reis	Aceito
Folha de Rosto	Folha.pdf	28/04/2016 18:42:17	Amir Curcio dos Reis	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_detalhado.docx	03/04/2016 15:47:07	Amir Curcio dos Reis	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

SAO PAULO, 13 de Junho de 2016

Assinado por:
Raquel Agnelli Mesquita Ferrari
(Coordenador)

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Assunto: A manuscript number has been assigned to your submission

Ms. Ref. No.: GAIPOS-D-16-00722
Title: Kinematic analysis of the ankle-foot complex mobility of women with patellofemoral pain during weight bearing functional tests.
Gait and Posture

Dear Prof. Lucareli,

Your submission entitled "Kinematic analysis of the ankle-foot complex mobility of women with patellofemoral pain during weight bearing functional tests." has been assigned the following manuscript number: GAIPOS-D-16-00722.

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Para: plucareli@hotmail.com
Assunto: Journal of Sports Sciences - Manuscript ID RJSP-2016-1279

28-Oct-2016

Dear Prof. Lucareli:

Your manuscript entitled "DOES HIGH-IMPACT FUNCTIONAL ACTIVITY INCREASE LOWER LIMB MISALIGNMENT IN WOMEN WITH PATELLOFEMORAL PAIN DURING THE DIFFERENT PHASES OF THE SINGLE-LEG TRIPLE HOP TEST?" has been successfully submitted online and is presently being given full consideration for publication in the Journal of Sports Sciences.

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