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CINTIA LOPES FERREIRA

ANÁLISE DA CINEMÁTICA TRIDIMENSIONAL E SINERGIA MUSCULAR DE MULHERES COM DOR FEMOROPATELAR

SÃO PAULO

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Tese apresentada à Universidade Nove de Julho para obtenção do título de Doutora em Ciências da Reabilitação.

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RESUMO

Introdução: A Dor Femoropatelar (DFP) tem etiologia multifatorial e dentre os fatores associados à DFP, os biomecânicos são os mais discutidos na literatura. Alterações cinemáticas de tronco, pelve e membros inferiores são as mais frequentes, porém nem todas as alterações são apresentadas por todos os pacientes e em todas as tarefas realizadas. Identificar uma tarefa que mais diferencia o indivíduo com e sem DFP pode ajudar na tomada de decisão clínica quanto à avaliação dos pacientes e então nortear a identificação das possíveis causas das alterações cinemáticas, uma vez que somente a força muscular parece não ter relação. Sabendo que a ativação muscular depende de controles neurais que ativam a musculatura por meio de sinergias musculares e que a dor pode influenciar o controle motor, investigar se a DFP apresenta alterações na organização neuromuscular pode contribuir ainda mais para o entendimento da DFP e ajudar na busca de melhores estratégias de avaliação e tratamento para os pacientes com DFP. **Objetivos:** 1. Identificar qual tarefa funcional diferencia mais a cinemática de mulheres com e sem DFP. 2. Analisar a sinergia muscular de mulheres com DFP e correlacionar com a cinemática de tronco, pelve e membros inferiores durante o *step down* lateral (SDL). **Métodos:** 1. Estudo transversal que avaliou a cinemática de 35 mulheres com DFP e 35 mulheres assintomáticas durante a execução de sete tarefas funcionais. Os dados da cinemática tridimensional foram analisados através do *Movement Deviation Profile* (MDP) e para identificar qual tarefa apresentou maior diferença entre os grupos o Z-*score* da média do MDP foi calculado. 2. Estudo transversal com 15 mulheres com DFP e 14 mulheres assintomáticas submetidas à avaliação da cinemática tridimensional e eletromiográfica (EMG) durante a execução do SDL. As sinergias musculares foram extraídas do sinal EMG usando o algoritmo de fatorização de matriz não negativa e a cinemática analisada por meio do MDP. Os dados foram comparados pelo teste *t* independente e correlacionados pelo teste de correlação de *Pearson*. **Resultados:** 1. Todas as tarefas apresentaram diferenças entre os grupos com e sem DFP, porém de acordo com o Z-*score* o SDL (7,97) e o *step down* anterior (7,62) foram as tarefas que mais

diferenciaram os grupos. 2. Mulheres com DFP não apresentaram diferenças no número mínimo de sinergias musculares necessárias para explicar a variabilidade da reconstrução do EMG (VAF) para realizar o SDL, porém foi observado maior VAF_{total} e $VAF_{músculo}$ para o reto femoral e vasto medial comparadas às mulheres assintomáticas. Na DFP, quanto menor a semelhança na participação dos músculos em cada sinergia muscular (W2, W3 e $W_{média}$) comparado ao controle, maior a diferença na cinemática de tronco, pelve e membros inferiores durante o SDL. **Conclusão:** As tarefas de *step down* são as que mais diferenciam a cinemática de mulheres com e sem DFP sendo o SDL aquela com maior poder de diferenciação. Durante o SDL, mulheres com DFP apresentam pior controle e coordenação muscular, principalmente para os músculos vasto medial e reto femoral e este achado tem correlação com as maiores alterações cinemáticas na execução da tarefa.

Palavras-Chave: Dor Femoropatelar; Cinemática; Tarefas Funcionais; Eletromiografia; Sinergias Musculares.

ABSTRACT

Introduction: Patellofemoral pain (PFP) has a multifactorial etiology and among the factors associated with PFP, the biomechanical are the most discussed in the literature. Kinematics changes in trunk, pelvis and lower limbs are normally associated with PFP patients, but not all changes appear in all patients and in all assessed tasks. Identify which task that most differentiates the subjects with and without PFP could help to make clinical decision regarding assessment of these patients and then guide the identification of possible causes of kinematic changes, since muscle strength appears to be unrelated with kinematic. We know that muscle activities depend on the neural control that activates the musculature by muscle synergies and the motor control could be influenced by pain, to investigate if there are changes in neuromuscular organization could contribute to a better understanding of PFP and help to improve the treatment and assessment strategies to PFP patients. **Objective:** 1. Identify which functional tasks differentiates the three-dimensional kinematic of women with and without PFP. 2. Analyze the muscle synergies of women with PFP and correlate with the kinematic of the trunk, pelvis and lower limbs during the lateral step down (LSD). **Methods:** 1. Cross-sectional study that evaluated 35 women with PFP and 35 asymptomatic women during the execution of seven functional tasks. Three-dimensional kinematic data were analyzed through the Movement Deviation Profile (MDP). To identify which task presented the most differences between the groups, the Z-score of the mean MDP was calculated. 2. Cross-sectional study with 15 women with PFP and 14 asymptomatic submitted to three-dimensional kinematic and electromyography (EMG) assessment during the LSD. Muscle synergies were extracted from EMG signals using a non-negative matrix factorization algorithm. Kinematics data were analyzed through MDP. The data were compared by independence t test and correlated by Pearson correlation test. **Results:** 1. For all tasks, the groups presented differences, but according with Z-score the LSD (7.97) and forward step down (7.62) were the tasks that most differentiate the kinematic of the groups. 2. Women with PFP showed no differences in the minimum number of muscle synergies necessary to explain most variability of EMG (VAF) to

perform the LSD, but showed higher VAF_{total} and VAF_{muscle} for rectus femoris and vastus medialis compared to asymptomatic women. For PFP, the lower the similarity in the muscle participation in each muscle synergies (W2, W3 e W_{mean}) compared to control, the higher the differences in trunk, pelvis and lower limbs during the LSD. **Conclusion:** Step down tests are the tasks that most differentiate the kinematic of women with and without PFP, the LSD was the tasks with the highest sensitivity to detect differences. During the LSD, PFP women showed poor muscle control and coordination, mainly for the rectus femoris and vastus medialis muscles and these findings have correlation with the higher changes kinematics during the task execution.

Keywords: Patellofemoral Pain; Kinematic; Functional Tasks; Electromyography; Muscle Synergies.

SUMÁRIO

PREFÁCIO

Esta tese de Doutorado aborda o tema referente à dor femoropatelar em mulheres. A Universidade Nove de Julho possui regras para obtenção do título de doutor e uma delas é a submissão de pelo menos dois artigos científicos em periódicos indexados no sistema *Journal Citation Reports* (JCR). Para isso as teses de doutorado seguem regras que, para melhor entendimento da banca, serão explicadas durante este prefácio. A tese é divida em 7 capítulos: 1: Contextualização; 2: Objetivos; 3: Resultados; 4: Considerações finais; 5: Referências; 6: Apêndices e 7: Anexos.

No primeiro capítulo é apresentado um panorama geral da literatura a respeito do assunto abordado. As características e incidência da dor femoropatelar, possíveis fatores etiológicos, fatores biomecânicos associados à dor femoropatelar, alguns tópicos ainda não esclarecidos na literatura e uma abordagem sobre controle motor e sinergia muscular. No segundo capítulo são apresentados os objetivos desta tese que, segundo as regras da universidade, devem ser respondidos em forma de artigos.

O terceiro capítulo contém os resultados e neste encontram-se os artigos elaborados pelo aluno, o primeiro já aceito para publicação e na língua inglesa com introdução, métodos, resultados e discussão, e o segundo, este ainda na língua portuguesa, com introdução, métodos, resultados e discussão. Portanto, esta tese é composta por dois artigos sendo os dois de natureza transversal. As referências de cada artigo encontram-se logo abaixo do texto referente ao mesmo. O capítulo cinco é a referência correspondente à contextualização da tese.

O primeiro artigo foi aceito e publicado no período Gait & Posture e sua versão em PDF foi incluída no capítulo 6 da tese, como apêndice. O segundo artigo será submetido à um periódico à definir.

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LISTA DE ABREVIATURAS

º: Graus

%: Porcentagem

2MSE: 2 *mean square errors*

ABDQ: Abdutores do quadril

AdLo: Adutor longo

Ag/AgCl: Prata/Cloreto de prata

AKPS: Escala para avaliação de dor no joelho – *Anterior Knee Pain Scale*

BECK: Escala de depressão de BECK

BiFe: Bíceps femoral

BMI: *Body Mass Index*

CI: *Confidence Interval*

cm e m: centímetros e metros

dB: Decibéis

DFP: Dor femoropatelar

DP: Desvio Padrão

e: erro residual

EMG: Eletromiografia

EMG_0: Matriz dos dados eletromiográficos originais/normalizados

EMG_r: Matriz dos dados eletromiográficos reconstruídos

EXTQ: Extensores do quadril

EXTJ: Extensores do joelho

FPI: *Foot Posture Index*

FSD: *Forward Step Down*

GaMe: Gastrocnêmio medial

GMe: Glúteo médio

H: Matriz coeficiente de ativação

H1: Coeficiente de ativação da sinergia 1

H2: Coeficiente de ativação da sinergia 2

H3: Coeficiente de ativação da sinergia 3

$H_{média}$: Média do coeficiente de ativação das sinergias 1, 2 e 3

$H_{ref:}$ Matriz coeficiente de ativação correspondente à referência do controle

Hz: Hertz

IASP: *International Association for the Study of Pain*

IC: Intervalo de Confiança

IMC: Índice de massa corporal

IPAQ: Questionário internacional de atividade física

Kg/m²: Quilogramas por metro quadrado

Kg: Quilogramas

L: Left

LSD: *Lateral Step Down*

m: Número de músculos

MDP: Perfil de desvio do movimento

MDP_{mean}: Média da curva do MDP

n: Número de sinergias

N: Número da amostra

NAPAM: Núcleo de Apoio à Pesquisa em Análise do Movimento

NNMF: matriz de fatorização não negativa

NPRS: *Numerical Pain Rating Scale*

PCS: Escala de pensamentos catastróficos sobre a dor

PFP: *Patellofemoral Pain*

R: *Right*

ReFe: Reto Femoral

RLQ: Rotadores laterais do quadril

SD: *Standard Deviation*

SDL: *Step down* lateral

SF-36: Questionário de Qualidade de Vida

SLHT: *Single Leg Hop Test*

SNC: Sistema Nervoso Central

SENIAM: *Surface Electromyography for the Non-Invasive Assessment of Muscle*

SOM: *Self-organizing map*

t: Tempo base do ciclo

TAMPA: Escala de Cinesiofobia

TiAn: Tibial anterior

VAF: Coeficiente de variação

VAF_{total}: Coeficiente de variação da reconstrução de todos os músculos

$VAF_{músculo}$/VAF_{muscle}: Coeficiente de variação da reconstrução de um músculo

VaLa: Vasto lateral

VaMe: Vasto medial

W: Matriz vetor sinérgico

W1: vetor sinérgico da sinergia 1

W2: vetor sinérgico da sinergia 2

W3: vetor sinérgico da sinergia 3

$W_{média}$/W_{mean}: média dos vetores sinérgicos das sinergias 1, 2 e 3

W_{ref}: Matriz sinérgica correspondente à referência do controle

1. CONTEXTUALIZAÇÃO

Segundo a *International Association for the Study of Pain* (*IASP*), a dor é uma experiência sensorial e emocional desagradável associada ao dano real ou potencial do tecido (1). Quando a dor acomete o sistema musculoesquelético e de forma crônica, caracteriza-se por dor persistente ou recorrente com duração superior a três meses e surge como parte de um processo de doença que afeta diretamente ossos, articulações, músculos ou tecidos moles associados (2). A dor musculoesquelética é uma das principais causas de incapacidade e atinge cerca de 20-33% da população mundial (3), 21,6% da população brasileira (4) e aproximadamente 27% da população da cidade de São Paulo com prevalência de 35% para as mulheres e de 16% para os homens (5).

A articulação do joelho é uma região recorrente de queixas de dor musculoesquelética, sendo a dor femoropatelar (DFP) a manifestação de dor no joelho mais comum (6). A prevalência anual de pacientes com DFP na população adulta em geral é de 22,7% sendo de 15,5% entre os homens e de 29,2% entre as mulheres, destas 12-13% com idade entre 18 e 35 anos (7,8).

Por ser a maior articulação do sistema musculoesquelético, o joelho suporta o peso corporal em todas as atividades bípedes, sendo constituído por duas articulações distintas a tibiofemoral formada pela tíbia e o fêmur e a femoropatelar formada pelo fêmur e a patela (9). A patela realiza um importante papel na articulação do joelho por aumentar a vantagem mecânica do quadríceps, além de proteger a cartilagem articular da tróclea e dos côndilos femorais e transmitir as forças de tração do músculo quadríceps para o tendão patelar (10). A cartilagem da articulação femoropatelar é um tecido altamente organizado, espesso, com propriedades biomecânicas complexas e expressiva durabilidade que ajuda a distribuir as forças sobre a articulação (11). No entanto, possui baixa capacidade intrínseca de cicatrização (12), e os defeitos podem levar à considerável comprometimento funcional e subsequente degeneração articular e dor quando alterações estruturais ou biomecânicas aumentam as forças compressivas sobre a articulação (10,13).

1.1. Dor Femoropatelar

A DFP é uma condição clínica caracterizada por uma dor difusa na região anterior do joelho associada às atividades que envolvem carga nos membros inferiores e/ou aumentam as forças compressivas na articulação femoropatelar como a corrida, o salto, a subida e a descida de escadas e a permanência por horas prolongadas na posição sentada com os joelhos flexionados ou ajoelhado (6,14–16). A DFP promove um efeito debilitante por reduzir a capacidade dos pacientes em realizar atividades esportivas, relacionadas ao trabalho e de vida diária livres de dor (6,16).

A DFP é uma condição comum em indivíduos ativos ao longo da vida sendo frequentemente encontrada em jovens e mulheres (17). A DFP está associada à carga anormal e elevado estresse na articulação femoropatelar que afeta várias estruturas locais que podem contribuir para a nocicepção como o osso subcondral, gordura infrapatelar, retináculos e estruturas ligamentares, entretanto, o tecido fonte de dor ainda não é conhecido (18). A etiologia da DFP é multifatorial e suas causas ainda não são bem compreendidas (19), o consenso de DFP publicado em 2017 (20) sugere ser uma interação complexa entre fatores anatômicos, biomecânicos, psicológicos, sociais e comportamentais.

Os fatores biomecânicos abordados na literatura como possíveis contribuintes para o aumento do estresse na articulação femoropatelar podem ser de origem local, proximal e distal. O mau alinhamento e/ou *maltracking* da patela (21,22) assim como a fraqueza do músculo quadríceps (23,24) são indicados como fatores locais. Dentre os fatores proximais estão a alteração da força muscular dos músculos abdutores, extensores e rotadores externos do quadril (25,26) e alterações na cinemática como maior adução e rotação interna do quadril, queda da pelve contralateral e inclinação do tronco ipsilateral (27–30). Como fatores distais a rotação interna do retropé em relação à tíbia, a pronação excessiva da articulação subtalar acompanhada da rotação interna da tíbia também tem sido associados à DFP (21,31,32).

Os fatores listados acima quando associados ou não podem diminuir a área de contato da articulação femoropatelar, aumentando o estresse e pressão na articulação gerando dor. Entretanto, todos os fatores associados à DFP não são encontrados em todos os grupos de pacientes. A literatura ainda é inconsistente para a maioria dos achados, além disso, nenhum deles, com exceção da fraqueza do quadríceps em militares e o aumento da força dos músculos abdutores de quadril em adolescentes (23,24,33), podem ser considerados fatores de risco para desenvolver a DFP, uma vez que faltam estudos prospectivos para confirmar essas hipóteses (33).

Para o tratamento da DFP exercícios direcionados para o quadril e joelho são recomendados obtendo como resultados diminuição da dor e melhora da capacidade a curto, médio e longo prazo (34,35). Entretanto, a literatura não é clara na abordagem de quais exercícios são os mais indicados para estes pacientes, se são indicados para todos os pacientes com DFP e quais contribuem para maior melhora clínica (35,36). Apesar dos pacientes com DFP apresentarem melhora na dor e função, cerca de 40% dos indivíduos tem recorrência da dor em um ano após o tratamento (37) e mais de 50% dos pacientes não se recuperam completamente entre cinco e oito anos (38).

O mau prognóstico da DFP em longo prazo parece estar associado ao maior tempo de duração da dor e pior relato de dor e funcionalidade no momento do início do tratamento (38). Ensaios clínicos embasam o tratamento em exercícios de força muscular para pacientes com DFP com a hipótese de que o fortalecimento contribuirá para o alinhamento dos segmentos corporais e consequentemente corrigirá as alterações biomecânicas e melhorará a dor, porém a melhora da dor após o tratamento, até o momento, não foi associada às correções das alterações cinemáticas e esta não é apontada na literatura como efeito das intervenções (35,36,39–41). Alguns estudos mostram que os movimentos do tronco, pelve e membros inferiores não são alterados após o tratamento da DFP mesmo havendo melhora na dor, função e força muscular (42–44). Não se sabe se o fato de não se observar modificações na cinemática se deve a falta de treinamento específico da tarefa usada como parâmetro de

melhora e avaliação dos pacientes durante o tratamento e se isto pode ser indicativo de recidiva dos sintomas (45).

Os estudos que envolvem a cinemática como ferramenta de avaliação dos pacientes com DFP abrangem uma grande diversidade de tarefas funcionais. A inconsistência entre os estudos poderia ser reduzida se uma mesma bateria de tarefas fosse utilizada facilitando a comparação entre os estudos (16). Caso seja identificada uma tarefa que demonstre mais alterações do movimento do que outras, poderíamos responder, mesmo que para um determinado grupo de tarefas, que os pacientes podem apresentar padrões de movimentos dependentes das tarefas que estão realizando.

O melhor entendimento das possíveis diferenças entre os movimentos de pacientes e pessoas assintomáticas em cada tarefa pode assistir profissionais e pacientes com DFP no processo de avaliação e melhorar a tomada de decisão terapêutica. Caso seja possível identificar uma tarefa que mais diferencie os pacientes do ponto de vista do movimento, pode-se ainda estudar outros fatores que não os relacionados à cinemática do movimento, como por exemplo, possíveis alterações neuromusculares, e assim traçar um perfil mais completo dos pacientes.

1.2. Alterações Neuromusculares na Dor Femoropatelar

Alterações neuromusculares relacionadas à cinemática também vem sendo identificadas em pacientes com DFP (34). A fraqueza muscular e a alteração na ativação dos músculos do quadril e joelho são apontadas por alguns autores como responsáveis pela falta de controle de movimento dos membros inferiores em indivíduos com DFP (16,21,27,46,47).

Durante a subida e descida de escada, por exemplo, o músculo glúteo médio de mulheres com DFP apresenta atraso na ativação comparado às mulheres saudáveis, o que possivelmente contribuiria para a rotação interna do fêmur (48,49). A literatura tem abordado também o desequilíbrio na ativação

dos músculos quadríceps, alguns estudos mostram que o músculo vasto medial apresenta atraso na ativação comparado ao vasto lateral o que provocaria o deslocamento lateral da patela (49,50).

Na fase de propulsão de um salto triplo unipodal, os músculos bíceps femoral, vasto lateral, glúteo médio e glúteo máximo apresentam maior atividade eletromiográfica (EMG) em mulheres com DFP (27). Instantes antes da aterrissagem do salto triplo unipodal, os músculos bíceps femoral e vasto lateral apresentam maior ativação. O vasto lateral ativa mais durante a fase excêntrica da aterrissagem comparada à fase concêntrica, e atinge antecipadamente o pico de ativação em mulheres com DFP (46,47). Este comportamento observado na musculatura do quadril e joelho durante a propulsão e aterrissagem do salto triplo unipodal pode indicar uma tentativa das pacientes com DFP em controlar os déficits no alinhamento de tronco e membros inferiores (27,46,47).

As alterações musculares parecem depender da tarefa a ser analisada e os resultados são inconsistentes entre os estudos. Além disso, os resultados encontrados na literatura apresentam informações da atividade muscular analisada de forma isolada, ou seja, apesar de se medir a atividade muscular de vários músculos os estudos não interpretam os resultados como um grupo de músculos que trabalham em sincronia para realizar uma determinada tarefa. Até o momento, que seja de nosso conhecimento, isto não foi estudado em pacientes com DFP.

1.3. Dor e Controle Motor

A dor musculoesquelética promove uma adaptação no comportamento e controle motor (51,52). A teoria da adaptação motora à dor proposta por Hodges (52) sugere que em situações de dor o sistema nervoso central (SNC) redistribui a atividade muscular intra e entre os músculos, alterando o comportamento mecânico e do movimento no intuito de proteger o sistema

musculoesquelético de movimentos ou situações que possam provocar dor ou estejam associados à lesão.

Este mecanismo de proteção pode gerar benefícios à curto prazo sendo eficiente na estratégia para evitar o mecanismo de dor, porém com potencial consequências à longo prazo podendo gerar aumento ou modificação da carga na região acometida ou em outras regiões associadas às compensações, além de poder provocar redução do movimento e da variabilidade motora (53).

O controle motor pode ser simplificado por uma organização modular, ou seja, um adequado número de módulos motores é recrutado para produzir um movimento desejado (54). A hipótese é que o SNC controla a ativação muscular utilizando um grupo de elementos de controle básico chamados de módulos motores ou sinergias musculares (54). Portanto, o SNC não ativaria os músculos de forma independente, ele enviaria um único comando neural que pode ser capaz de ativar grupos musculares simultaneamente e de forma coordenada para execução das tarefas (55–57). Cada sinergia muscular define um grupo de músculos que são coativados e estes, portanto, trabalham como uma única unidade funcional (54).

A sinergia muscular representa uma enorme quantidade de subtarefas motoras, que o SNC pode combinar de maneira flexível para produzir movimentos complexos e naturais (58–60). Um único comando neural pode recrutar uma sinergia muscular para produzir confiavelmente uma subtarefa motora (61). A sinergia muscular pode compreender um número qualquer de músculos e os músculos individualmente podem pertencer à múltiplas sinergias, elas podem ser recrutadas simultaneamente em diferentes proporções, dando origem a uma ampla possibilidade de movimentos (61).

A sinergia muscular não somente descreve quais músculos trabalham em coordenação, mas também como eles trabalham juntos (54). A sinergia muscular é representada por número de módulos consistentes e estimada através dos dados EMG por diferentes algoritmos de fatorização de matriz sendo o mais utilizado em estudos que analisam os sinais de ativação muscular e em indivíduos com dor musculoesquelética a fatorização de matriz

não negativa. A fatorização consiste na decomposição da matriz correspondente ao sinal EMG de todos os músculos analisados em duas matrizes distintas: a matriz de coeficiente de ativação (H) que especifica o tempo de ativação de cada sinergia durante todo o período da tarefa executada e a matriz de vetor sinérgico (W) que especifica a contribuição de cada músculo em cada sinergia (62). A fatorização da matriz não negativa restringe os dados analisados à valores positivos o que pode não ser interessante para dados como o de cinemática em que os dados positivos e negativos indicam movimentos diferentes e com isto algumas informações podem ser perdidas na análise (63). Contudo, para análise de dados EMG a fatorização de matriz não negativa é uma ferramenta robusta com uma boa acurácia para identificar as sinergias e reflete o fato dos dados EMG serem inerentemente não-negativos levando a uma interpretação mais fisiológica dos dados (64–66).

A análise da sinergia muscular, portanto, reflete o *output* do SNC e pode ajudar a interpretar a atividade muscular durante uma tarefa motora, além de se mostrar uma ferramenta com potencial diagnóstico que pode ser usado para quantificar a avaliação das habilidades motoras de pacientes com déficits motores e neurais (54). Uma vez que os déficits neurais podem ser mascarados na análise cinemática pelas estratégias de compensação e movimentos similares podem ser produzidos através de diferentes mecanismos neuromusculares (61). Compreender a sinergia muscular de pacientes com DFP pode esclarecer melhor como as alterações na ativação muscular acontecem simultaneamente e a possível relação com o controle e alinhamento das articulações do membro inferior e tronco e o papel do SNC ao executar um comando neural para a realização das tarefas nesses pacientes. A memória da dor pode estar diretamente relacionada aos fatores neurais e os mesmos podem alterar processos somatossensoriais e provocar prejuízos na função sensório motora (67–70). Os fatores neurais podem, portanto, de uma forma ainda desconhecida interferir em como o SNC comanda a atividade realizada, seja por estratégias compensatórias que fujam dos mecanismos que podem gerar dor ou alterando o movimento e ativação muscular quando há dor.

A literatura tem apresentado dados sobre a sinergia muscular de indivíduos com lesões neurais. Sabe-se que pacientes com lesão medular (71), paralisia cerebral (72) e acidente vascular cerebral (73) apresentam uma estratégia motora simplificada para a execução da marcha, comparado a indivíduos saudáveis, ou seja, realizam a tarefa com o menor número de sinergias musculares possíveis. Com relação às lesões musculoesqueléticas que produzem dor durante tarefas motoras, as evidências são inconsistentes (74). Indivíduos com lesão de ligamento cruzado anterior (57), impacto femoroacetabular (75) e dor induzida na região posterior da perna e coluna lombar (51) não apresentam diferenças no número mínimo de sinergias para realizar a marcha, porém é observada maior variabilidade da reconstrução do sinal EMG para pacientes com impacto femoroacetabular e dor experimental sendo associada à pior coordenação e controle muscular nestas duas condições de dor. Em contrapartida, pacientes com epicondilite lateral (76) e dor lombar (77) apresentam menor número de sinergias para realizar tarefas motoras específicas. É possível observar ainda redução na similaridade entre os vetores da sinergia e maior variabilidade da reconstrução do sinal EMG para a dor em condições como epicondilite lateral (76,78), dor induzida experimentalmente na cervical (79) e ombros (80) e dor lombar (77,81).

Parece não existir um comportamento semelhante para a maioria das variáveis das sinergias musculares e os diferentes quadros de dor. A análise da sinergia muscular na dor musculoesquelética não apresenta dados suficientemente consistentes, além de ter sido estudada em poucas condições de dor. Sendo assim, é possível afirmar, até o momento, apenas que a similaridade entre as sinergias é menor e a qualidade da reconstrução das sinergias musculares extraídas em condições dolorosas é maior, indicando que a dor pode levar à maior variabilidade nas sinergias musculares (74) em pessoas com dor musculoesquelética enquanto que para o número de sinergias musculares, os pesos dos vetores sinérgicos e os coeficientes de ativação ainda são inconclusivos. Desta forma, a análise da sinergia muscular pode ser um método promissor para revelar novos entendimentos sobre as alterações no controle motor e pode ser usada clinicamente para diagnosticar e avaliar as estratégias de controles neuromusculares e planejar melhor o

tratamento de pacientes com DFP (64,74) uma vez que o estudo da sinergia pode elucidar questões clínicas importantes sobre as habilidades de um sujeito em produzir um resultado funcional desejado.

1.4. Justificativa

Os fatores associados à DFP ainda não são claros, consistentes e não há consenso na literatura. Dentre todos os fatores envolvidos na questão multifatorial da DFP, os fatores biomecânicos são os mais discutidos e mesmo assim ainda não sabemos qual é a melhor forma de avaliar a biomecânica destes pacientes. As alterações cinemáticas geralmente associadas aos pacientes com DFP como maior inclinação do tronco, queda da pelve, adução e rotação interna do quadril, rotação interna da tíbia e pronação do pé nem sempre são observadas em todos os grupos de pacientes com DFP em todas as tarefas analisadas (20-22,27,28). Não sabemos se as alterações cinemáticas podem ser consideradas tarefas dependentes, se o tratamento deveria ser direcionado para a tarefa a ser avaliada e se existe uma tarefa que mais diferencia indivíduos com DFP e assintomáticos (16,45). Identificar a tarefa que mais diferencia indivíduos com e sem DFP poderia ajudar os clínicos e pesquisadores na tomada de decisão clínica quanto à avaliação, acompanhamento da evolução do tratamento e da melhora do controle do movimento dos pacientes e assim direcionar a avaliação biomecânica na DFP.

Ao identificar a tarefa que mais diferencia a cinemática de indivíduos com e sem DFP poderíamos melhorar a precisão das avaliações com base nas alterações cinemáticas, neuromusculares e de controle motor. Uma vez que a fraqueza muscular parece não ter relação linear com as alterações cinemáticas, visto que estudos tem demonstrado que a redução da dor e aumento da força muscular após programas de fortalecimento da musculatura de quadril e joelho não produzem mudanças na cinemática dos membros inferiores (42-44). Em mulheres assintomáticas sabemos que a relação entre a força dos músculos do quadril e alinhamento dos membros inferiores só existe

em tarefas de alta demanda como o salto unipodal (82), porém para mulheres com DFP parece que esta relação não é observada em pelo menos sete tarefas funcionais sendo elas a marcha, *step down* anterior e lateral, subida e descida de escada e as fases de propulsão e aterrissagem do *single leg hop test* (83). Desta forma, podemos sugerir que as alterações cinemáticas podem não ter relação com a fraqueza muscular, mas talvez com o padrão de ativação muscular.

Estudos que avaliaram a atividade muscular de indivíduos com DFP analisaram os músculos individualmente (27,46–50). Sabendo que o comportamento muscular depende de controles neurais e estes ativam as musculaturas por meio de módulos motores e que a dor pode influenciar o comportamento motor (52,54). O propósito desta tese é identificar a tarefa que mais diferencia a cinemática de mulheres com e sem DFP, e assim, por meio desta tarefa avaliar as diferenças nas sinergias musculares de pacientes com DFP comparado às mulheres assintomáticas com a intenção de compreender melhor o padrão de ativação muscular e se há um possível componente neural envolvido na DFP. O entendimento das possíveis diferenças na sinergia muscular poderá ajudar a traçar melhor o perfil desses pacientes.

2. OBJETIVOS

2.1 Objetivo do Estudo 1

Identificar qual tarefa funcional, entre marcha, *step down* anterior, *step down* lateral (SDL), subida e descida de escada e as fases de propulsão e aterrissagem do *single leg hop test*, mais diferencia a cinemática tridimensional de mulheres com dor femoropatelar e mulheres assintomáticas.

2.2 Objetivo do Estudo 2

Analisar as sinergias musculares de mulheres com dor femoropatelar e mulheres assintomáticas durante a execução do *step down* lateral e verificar se existe correlação entre as sinergias musculares e a cinemática tridimensional dos membros inferiores, pelve e tronco de mulheres com dor femoropatelar.

3. RESULTADOS

Os resultados da presente tese serão apresentados no formato de artigo. O estudo 1, intitulado "*Step down tests are the tasks that most differentiate the kinematics of women with patellofemoral pain compared to asymptomatic controls*", já publicado no periódico *Gait & Posture*. O estudo 2, intitulado "*Women with patellofemoral pain show poor motor control and altered muscle coordination during lateral step down*" será posteriormente submetido à um periódico a definir.

3.1 ESTUDO 1

Lateral step down is the task that most differentiates women with patellofemoral pain compared to asymptomatic controls

ABSTRACT

Research Question

Identify which functional task, between gait, forward step down (FSD), lateral step down (LSD), stair ascent and descent and propulsion and landing phase of the single leg hop test (SLHT), differentiates the three-dimensional kinematics of women with patellofemoral pain from asymptomatic women.

Methods

This cross-sectional study evaluated thirty-five PFP and thirty-five asymptomatic women during the execution of the following tasks: gait, FSD, LSD, stair ascent and descent and the propulsion and landing phase of single leg hop test. Frontal, sagittal and transverse plane angles of the trunk, pelvis and hip, frontal and sagittal plane angles of the knee, ankle dorsiflexion, foot progression angle and hindfoot eversion were analyzed through the Movement Deviation Profile (MDP). To compare the groups, the multivariate analysis with Bonferroni post hoc test were used, with a significance level of $p<0.01$. To identify which task presented the most difference between the groups, the Z-score of the mean MDP was calculated.

Results

For all tasks, the groups presented significant differences. According to the Z-score, the groups got farther apart considering the MDP for each task in the following order: LSD (7.97), FSD (7.62), landing phase of SLHT (3.43), gait (2.85), propulsion phase of SLHT (1.64), descending stairs (1.63) and ascending stairs (1.00).

Significance

We suggest that step down tests should be included in the assessment of PFP patients, since these tests most differentiate the kinematics of women with and without PFP. Identifying the tasks with the highest sensitivity to detect the kinematic differences is expected to improve clinical decision-making.

Keywords: Kinematics, Lateral step down, Step down tests, Patellofemoral pain, Movement Deviation Profile

HIGHLIGHTS

All analyzed tasks differentiate the kinematics between PFP and asymptomatic women.

MDP can be used to differentiate the kinematics of PFP from asymptomatic women.

Step down tests are the tasks that most differentiate the kinematics of PFP women.

The LSD has the highest sensitivity to detect the kinematic differences.

PFP kinematic differences are less evident in stair ascent and descent.

3.1.1. INTRODUCTION

Patellofemoral pain (PFP) is a multifactorial clinical condition characterized by retro- and/or peripatellar pain with an annual prevalence of approximately 23% in the general population and a point prevalence of 12-13% in 18-35 year old females [1–4]. Kinematic changes such as greater trunk inclination, pelvic drop, adduction and internal rotation of the hip, poor alignment and/or maltracking of the patella, internal rotation of the tibia and excessive pronation of the subtalar joint are associated with patients with PFP [5–8]. However, kinematic changes are not always observed in all groups of patients with PFP and in all analyzed tasks [9].

The lack of standardization of the functional tasks used to assess patients with PFP makes it difficult to compare studies and interpretation of results for clinical practice [10]. It is not known if the kinematic changes found can be considered tasks-dependent, if the treatment should be directed to the task to be assessed and if there is a task that most differentiates the individual with PFP from the healthy individual [10,11].

The Movement Deviation Profile (MDP) is an artificial neural network based method that calculates the deviation of a patient's movement from normality [12,13]. The MDP unifies and simplifies the understanding of kinematic data, since the analysis of several angle curves in three anatomical planes describing the movement of several joints poses a difficult challenge [12]. The MDP has never been explored with PFP patients. This analysis can help to differentiate a set of kinematic variables between groups of individuals considering the temporal waveforms of several variables in a given cycle of movement, as opposed to comparing discrete variables like peak values of joint movements and their timing. Providing a simplified summary measure of multivariate temporal data is an attempt to help clinicians to interpret the results of a kinematic analysis more easily and to guide their decision making towards functional tasks which show more kinematic changes in women with PFP.

The identification of a task that makes the biomechanical changes of the patient with PFP more evident could help researchers and clinicians to make a

decision regarding the assessment, treatment evolution and improving movement control of these patients, by making the interpretation of the results and the comparison between the studies easier. Therefore, the objective of this study was to identify which functional task, between gait, forward step down (FSD), lateral step down (LSD), stair ascent and descent and propulsion and landing phase of the single leg hop test (SLHT), differentiates the three-dimensional kinematics of women with patellofemoral pain from asymptomatic women. Gait and stairs represent daily tasks and the tests are usually used in clinical trials to quantify the improvement in the function of the patient with PFP after treatment and assess lower limbs abilities as functional muscle strength, power and neuromuscular control.

3.1.2. METHODS

Study Design

This is a cross-sectional study carried out at a Laboratory of Analysis of the Human Movement of the Nove de Julho University between 2013 and 2016.

Subjects

Invited by means of oral invitation, 35 women with patellofemoral pain and 35 asymptomatic women aged between 18 and 35 took part in the study. In the group of women with patellofemoral pain those who were included showed anterior knee pain for at least three months during performance of at least two of the following tasks: ascending and descending stairs, squatting, running, jumping or remaining seated for a long time, besides showing a minimal score of 3 points in the Numerical Pain Rating Scale (NPRS) [14]. The NPRS consists of a scale from 0 to 10 points, where higher scores characterize higher intensity of pain [14]. The first clinical examination of the volunteers was conducted by two experienced physiotherapists to verify the eligibility criteria [15].

The symptomatic or more symptomatic limb of the PFP group was assessed and the side of the control group was matched to the painful side of the patients. The demographic data of each group are shown in Table 1.

Table 1. Demographic data of the control group and the PFP group.

	Control Group **Mean (SD)**	**PFP Group** **Mean (SD)**
N	35 (22R/13L)	35 (22R/13L)
Age (years)	24.68 (3.53)	25.60 (6.74)
Body mass (kg)	57.77 (9.20)	57.31 (7.32)
Height (m)	1.63 (0.06)	1.60 (0.06)
BMI (kg/m²)	21.45 (2.28)	22.29 (2.44)
NPRS (0-10)	0	6.42 (1.33)

N: number of volunteers assessed; R: right lower limb assessed; L: left lower limb assessed; BMI: Body mass index; NPRS: Numerical Pain Rating Scale; SD: Standard Deviation

The exclusion criteria for both groups were: history of surgical procedures of the lower limbs, recurrent patellar instability, associated ligament and/or meniscal injuries, cardiac or locomotion disorders that could interfere with the assessment, as well as leg length difference higher than 1 cm. In the control group of asymptomatic women, the volunteers did not report any musculoskeletal pain in the lower limbs.

Procedures and Instruments

All assessments were carried out in a single day. The volunteers eligible for the study were informed about the details of the study and those who agreed to participate signed the informed consent form. The institutional ethics committee approved the study (protocol number 124.075).

The kinematic analysis of the following functional tasks was performed: gait, forward step down, lateral step down, stair ascent and descent and the

propulsion and landing phase of the single leg hop test. For the group of women with patellofemoral pain the intensity of the pain was assessed using the NPRS [14].

The anthropometric data of each subject required for the reconstruction of the biomechanical model including mass, height, length of lower limbs, distance between the anterior superior iliac spines and the diameter of the knees and ankles were measured before the placement of the kinematic markers. A total of 43 retro reflective markers were fixed to the skin at specific anatomical locations of the lower limbs and trunk of each volunteer included in the study, using hypoallergenic double-sided tape, according to the Plug-in Gait and Oxford Foot Model [16,17]. The Vicon system consisting of eight infrared cameras operating at a frequency of 120 Hz was used to acquire kinematic data. The Vicon Nexus software (version 1.8.5) was used for data acquisition and processing.

After the placement of the markers, the participants received verbal explanation, followed by a demonstration of how to perform each task. The kinematic data were only collected after the volunteers were familiarized with each task.

Functional Tasks

Between all tasks and series of movements that were performed, two minute long breaks were held. All collections and verbal commands were performed by a single physiotherapist. The order for the execution of the tasks was always the same for all volunteers: gait, FSD, LSD, stair ascent, stair descent, SLHT.

Gait

The volunteers were instructed to walk as naturally as possible at self-selected speed on a 6-meter-long by 1-meter wide track.

Forward Step Down and Lateral Step Down

The FSD and LSD tasks consisted of three sets of three consecutive squats standardized at 60° knee flexion [11]. A step measuring 18 cm high, 30 cm wide and 30 cm deep was used to perform both tasks. For the FSD it was requested that the foot of the assessed limb be centrally positioned on the step, near the end of its anterior edge and the contralateral foot was held at the same height in front and in the air. For the LSD the medial border of the foot was be aligned with the lateral edge of the step and the contralateral limb was held in the air immediately to the side. The initial position of the limb tested in both tasks was maximal extension of the knee on the support side, while the contralateral limb had to remain with the knee completely extended and the ankle in maximum dorsiflexion, arms crossed and close to the trunk throughout the execution of the tasks.

The volunteer was asked to perform the squats slowly, over two seconds, and immediately return to the initial position, also over two seconds, in each repetition requested.

Ascending and Descending Stairs

The task of ascending and descending stairs was performed on three steps, 20 cm high and 30 cm deep each without handrails [18]. During ascent the volunteer took two steps before making the initial contact with the first step. For the descent the volunteers were instructed to take at least two steps after the end of the stairs. Both ascent and descent had to be performed with limbs alternating between the steps at a self-selected speed, so for each repetition of the task a cycle of one stair ascending and one stair descending were collected.

Single Leg Hop Test

The test consisted of a single one-legged horizontal jump with the assessed limb in support. The volunteer was asked to keep her arms crossed and close to her trunk and to remain in one-legged support with the knee of the assessed limb in extension. Under the evaluator’s command the volunteer should jump horizontally as far as she could without putting the contralateral

limb on the ground at the time of landing. The test was divided into two phases: the propulsion phase and the landing phase.

Data Processing

After the reconstruction of the markers, the movement cycle for each task was identified as described above. For gait, ascent and descent of stairs, kinematic variables of the support and swing phases of the cycle were analyzed; for the FSD, LSD, propulsion and landing the eccentric (squatting) phase and the concentric phase were analyzed. The descriptions of each task cycle and the number of cycles considered for analysis are in the Supplementary Data.

The kinematic data were filtered using the Woltring filter applied with 2 mean squared errors (2MSE) to the marker trajectories to reduce noise due to soft tissue artefacts causing marker movement during the movement cycle.

For all tasks, the following kinematic variables were considered: the frontal, sagittal and transverse planes of the trunk and pelvis segments in relation to the laboratory, hip in relation to the pelvis, frontal and sagittal planes of the knee in relation to the thigh, sagittal plane from the foot in relation to the shank, the transverse plane of the foot in relation to the laboratory, and the frontal plane movement of the hindfoot in relation to the tibia.

Movement Deviation Profile (MDP)

The MDP uses a self-organizing map (SOM), a type of artificial neural network which employs unsupervised learning. The neural network was first trained with control data, and the data from each healthy subject and patient were presented to the trained SOM which compared their movement data to the learned distribution of normality. The SOM calculates the multidimensional Euclidean distance between each patient and normality, providing a single curve for each patient which reflect the distance from normality during the whole duration of the movement [12].

For each patient and each task, an MDP curve was calculated in relation to the control group consisting of a series of 51 data points of 14 kinematics

curves in 9 trials. The mean of the 51 points of the MDP curves (MDP_{mean}) of each group was considered for the statistical analysis.

Statistical Analysis

The z-score was calculated by subtracting the average MDP_{mean} of the control group from the average MDP_{mean} of the PFP group divided by the standard deviation of the control group's MDP_{mean} in each task to compare the standardized results between the groups. Multivariate analysis to verify the interaction between groups with Bonferroni *post hoc* test was used, considering a $p<0.01$.

3.1.3. RESULTS

The multivariate analysis showed interaction between groups ($F=358.11$, $p<0.0001$). The MDP curves representing each task compared between groups are shown in Figure 1. The means and confidence intervals (95%) of the MDP are available on supplementary data. All tasks presented significant differences between groups with $p<0.01$ (Bonferroni *post hoc* test). According to the z-score of the mean MDP, the groups got farther apart for each task in the following order: LSD (7.97), FSD (7.62), landing phase of SLHT (3.43), gait (2.85), propulsion phase of SLHT (1.64), descending stairs (1.63) and ascending stairs (1.00) (Figure 2).

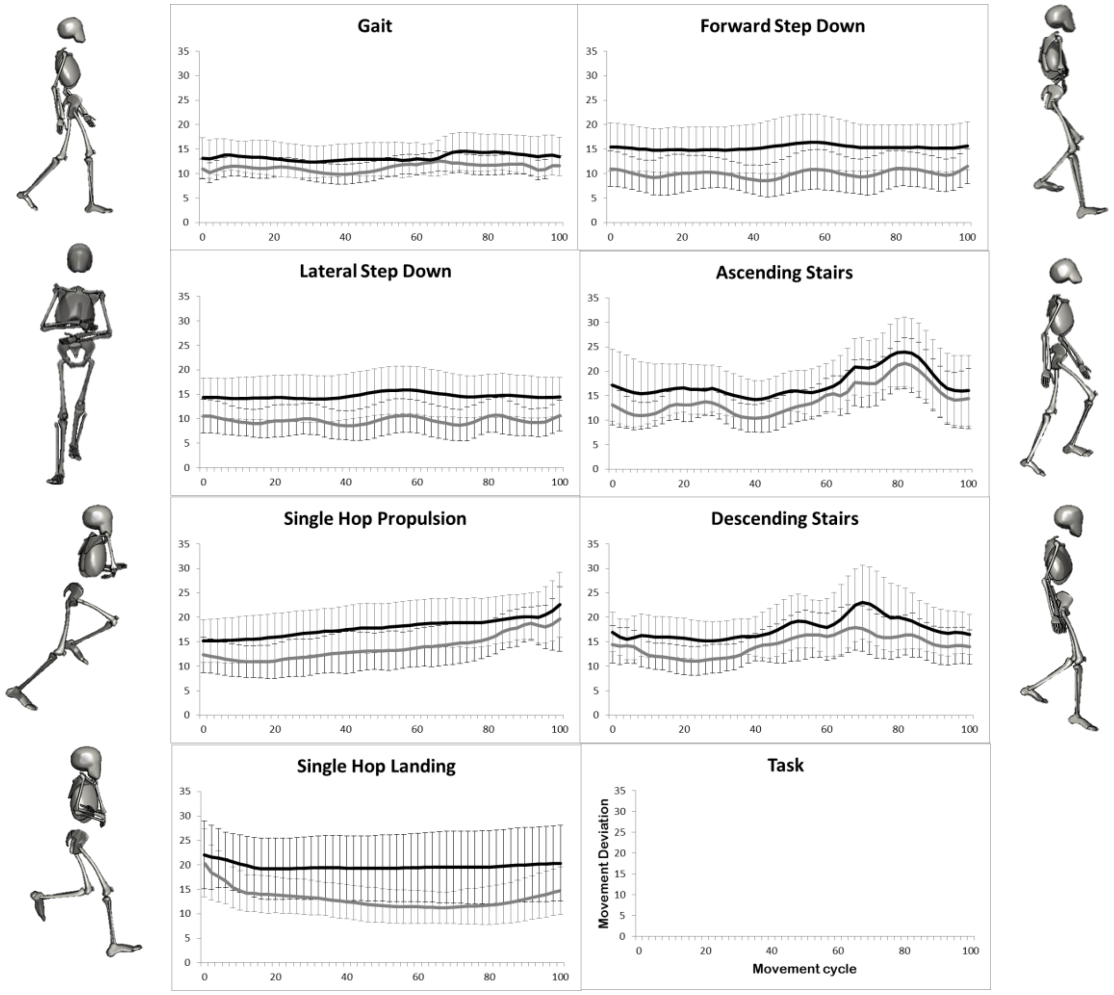

Figure 1. The Movement Deviation Profile chart (mean and standard deviation bands) summarizes the 14 angle curves of each task for participants with patellofemoral pain (black) and the control group (grey) during the movement cycle.

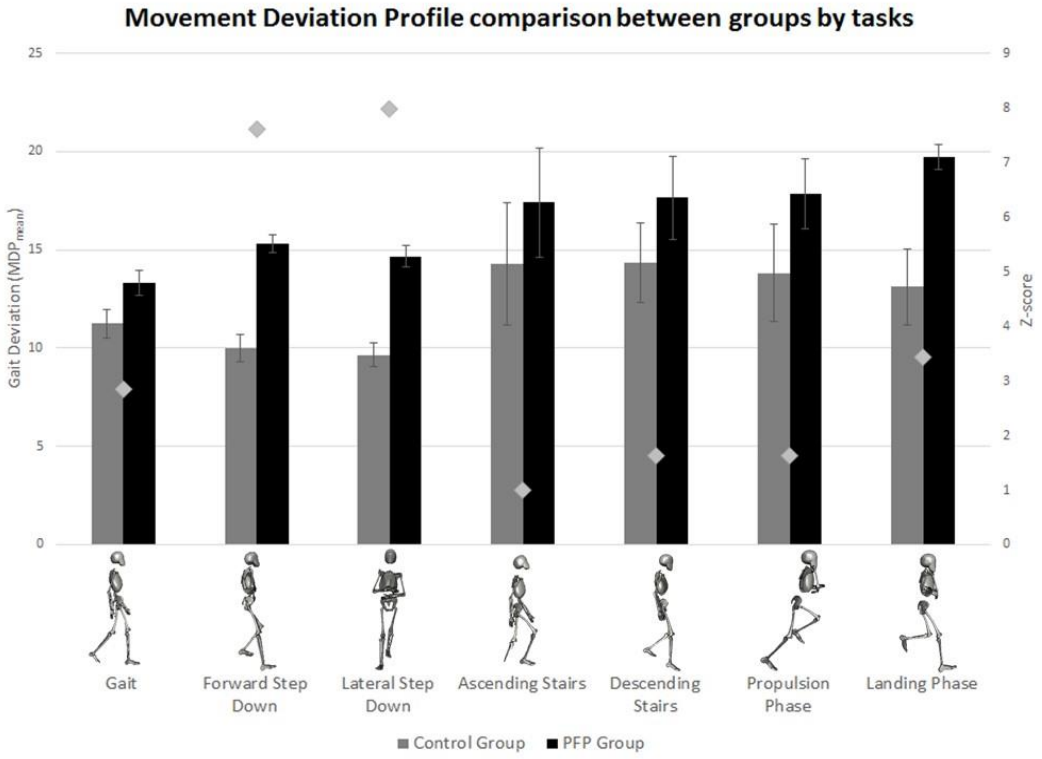

Figure 2. Means and standard deviations of MDP graphics and Z-score (diamonds) of task deviations between the PFP group and controls for each task.

3.1.4. DISCUSSION

LSD and FSD are clinical tests that assess the quality of movement based on the observation of the trunk, pelvis and lower limb alignment [19–22]. During LSD, patients with PFP present greater adduction and internal rotation of the hip [23], movements that can expose the patellofemoral joint to excessive loads and increased stress causing pain symptoms [1,10,23–25]. In addition to the hip, changes such as poor movement quality and increase of the movement of the ankle-foot complex and hindfoot eversion are also found in patients with PFP and may contribute to increased differences in kinematics when compared to asymptomatic individuals during LSD [21,23,26].

Although both tests are a one-legged squat, where one of the lower limbs is fixed on a step, the positioning of the contralateral limb makes the biomechanics of the tests different. During the FSD the contralateral lower limb is positioned forward maintaining the pelvis in anterior/ external rotation, the hip

flexed, the knee extended and the ankle dorsiflexed. The assessed lower limb (support side) performs the task by initiating movement from the external rotation of the pelvis, internal rotation and extension of the hip, extension of the knee and neutral position of the ankle. From the initial positioning, squats occur predominantly with movements of flexion and extension of the hip and knee and dorsiflexion of the ankle. Supposedly, LSD demands more of the action of the muscles that control the movements in the frontal plane of the pelvis and hip than the FSD, since the position of the contralateral limb is parallel to the assessed limb, and this way may have contributed to the LSD differentiated women with and without PFP a little more than FSD.

Despite the fact women with PFP show kinematic changes in the trunk, pelvis, hip and ankle during the propulsion phase of the one-legged jump [7], these changes were not enough to differentiate the groups as well as with LSD, FSD, landing and gait. Women with PFP who were assessed may have adopted other motor strategies to perform propulsion satisfactorily, avoiding movements that could cause pain, since kinetic and electromyographic changes are also observed in the hip and knee in this group of patients [7].

During the one-legged landing, the kinematic changes found between women with and without PFP occur at different time in the task cycle [8]. It is known that moments before the landing of a one-legged jump and in its eccentric phase, women with PFP present an increase in the electromyographic activity of muscles that involve the knee joint, and this a possible mechanism of joint protection and stabilization to avoid the pain that the impact of the task can cause in the patellofemoral joint [27,28]. It is worth noting that kinematic changes do not seem to be influenced by the impact and demand of the task on people with PFP [29].

In spite of the lower reaction force and mechanical challenges to the joint at the patellofemoral joint during gait compared to stair ascent and descent [30], gait was able to better differentiate the kinematics of women with PFP than stair ascent and descent or the propulsion phase of the jump. The peak and the time of hindfoot eversion, internal rotation and adduction of the hip are the main differences between individuals with and without PFP during gait [31,32].

Besides, the trunk segment and the swing phase offers scarcely explored variables during the gait analysis of patients with PFP but these were included in our study and may have contributed to increase the differences between the groups.

The findings in the literature regarding the kinematic alterations of patients with PFP during ascending and descending stairs are inconsistent [33,34]. Novello et al. [18] pointed out that stairs, more specifically the descent, may not be the best task to highlight the kinematic differences that women with PFP possibly present and should be used with caution in the assessment and clinical decision making for the treatment of patients with PFP.

This study presents some limitations in that pain during the execution of the tasks was not assessed. Besides, it is a study carried out only with women, and by being aware of the differences between the genders, it is suggested that future studies should assess men with PFP to identify the task that best distinguishes them from asymptomatic men. Another limitation is that we did not randomize the order of tasks, but the kinematic differences between individuals with and without PFP appear to be uninfluenced even after an effort protocol [29].

Identifying the tasks that maximize the kinematic differences between women with and without PFP can help clinicians in the decision making about which tasks to assess, compare and track improvements during treatment of these patients. The tasks that show the kinematic changes of PFP patients best probably require better motor and neuromuscular control and can be used to draw the most detailed profile about these patients and develop a treatment plan with a focus on improving these biomechanical factors.

MDP can help to identify at which percentage of the tasks the deviation patient’s movement is more different from normality and assist clinicians in being more directive and assertive in a conventional kinematic analysis that are needed to identify the cause of these differences. Future studies identify the role of each joint and each movement plane in the tasks for differentiation between groups and understand what possible strategies or neuromuscular

changes may be behind these differences in the biomechanics of women with and without PFP. As well as consider also the whole cycle of tasks, the swing in the gait and the stairs and the concentric and eccentric phases of the squats and the propulsion and landing of jumps. We believe that important changes can be present in those phases that the literature, to date, has not studied sufficiently.

We conclude that step down tests are the tasks that most differentiate the kinematics of women with and without PFP. We suggest that LSD and FSD be included in the assessment of patients with PFP, but we emphasize that this result does not exclude the option of assessing the other tasks, because all of them showed differences between the groups and also because of being a multifactorial dysfunction. It is important to consider the symptomatology, occupation, physical activity and biopsychosocial factors of each patient assessed at the time of prescribing the treatment and the inclusion of the other tasks in the assessment when clinician deems necessary.

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SUPLEMENTARY DATA

Task cycles

The descriptions of each task cycle and the number of cycles considered for analysis are following:

Gait

A total of six gait cycles including the support and swing phase were collected and used for the kinematic analysis.

Forward Step Down and Lateral Step Down

Six cycles of each task were used for the kinematic analysis. The FSD and LSD movement cycles started with the maximal knee extension position of the lower limb tested, followed by its maximum flexion (60°) and return to the initial position with maximum knee extension.

Ascending and Descending Stairs

Three cycles were used, taking into account the support and balance phase for each task, ascent and descent, for kinematic analysis.

Single Leg Hop Test

The test was divided into two phases: the propulsion phase, determined by the maximum initial extension of the knee up to the acceleration of the forefoot marker to be above zero in Z direction, perpendicular to the ground, and the landing phase that corresponded to the moment the volunteer touched the ground with her foot until her knee got back to its extension. Three replicates of each phase were used for analysis.

Table 2. Supplementary Data

Means and confidence of interval (95%) of the MDP_{mean} between the PFP group and controls for each task.

Tasks	Control Group Mean (CI 95%)	PFP Group Mean (CI 95%)
Gait	11.24 (11.04-11.45)	13.32 (13.14-13.50)
Forward Step Down	10.01 (9.81-10.20)	15.33 (15.20-15.45)
Lateral Step Down	9.65 (9.47-9.83)	14.65 (14.50-14.81)
Ascending Stairs	14.28 (13.40-15.16)	17.42 (16.64-18.20)
Descending Stairs	14.35 (13.78-14.91)	17.63 (17.04-18.23)
Propulsion Phase	13.82 (13.13-14.51)	17.86 (17.36-18.36)
Landing Phase	13.10 (12.56-13.65)	19.72 (19.55-19.90)

3.2. ESTUDO 2

WOMEN WITH PATELLOFEMORAL PAIN SHOW ALTERED MUSCLE COORDINATION DURING LATERAL STEP DOWN

ABSTRACT

Study Design: Cross-sectional.

Background: Patients with patellofemoral pain (PFP) present altered activation of the hip and knee muscles. Electromyographic (EMG) analyses in PFP patients are performed individually for each muscle. However, several studies suggest that the central nervous system may modulate neural commands directed to groups of co-activated muscles, called muscle synergies. Investigating the synergistic organization in PFP will advance our knowledge on the influence of pain on muscle coordination.

Objective: To analyze muscle synergies of women with PFP and correlate them with Movement Deviation Profile (MDP) during lateral step down (LSD).

Methods: 15 women with PFP and 14 asymptomatic women underwent three-dimensional kinematics and EMG assessment during LSD. MDP, which assesses movement deviation from normality, was calculated with kinematic data. Muscle synergies were extracted from the EMG signals of eight lower limb muscles using a non-negative factorization algorithm.

Results: Women with PFP presented higher variability accounted for (VAF_{total}) computed with 3 synergies and VAF_{muscle} for rectus femoris and vastus medialis

when compared to asymptomatic ones. The degree of similarity of PFP synergies with a healthy reference correlated with MDP, i.e., the lower the similarity of PFP synergies compared to the reference, the higher was MDP (deviation from normality).

Conclusion: Women with PFP present poorer muscle control and coordination, especially of vastus medialis and rectus femoris. The analysis of muscle synergies seems to be able to identify impaired muscle coordination in some women with PFP and may be explored as complementary biomarkers to improve the assessment of PFP patients.

KEYWORDS: Anterior Knee Pain; Muscle Synergies; Kinematic; Motor Control; Electromyography.

3.2.1. INTRODUCTION

Musculoskeletal pain is one of the major causes of functional disability and affects between 20-33% of the world's population.[9] Patellofemoral pain (PFP) is the most common manifestation of musculoskeletal pain in the knee,[15] with an annual prevalence of 22.7% in adult population, affecting 29.2% of women and 15.5% of men.[46] PFP is characterized by diffuse pain in the anterior knee area, and its etiology comes from a complex interaction between anatomical, biomechanical, psychological, social, and behavioral factors.[38]

The pain may be associated with an adaptation of muscle activity across muscles to protect the muscle tissue from further pain or injury threatening.[24] In patients with PFP, the changes in activation of hip and knee muscles are pointed out by some authors as responsible for the lack of control of movement and are hypothesized to be the result of protective and stabilizing mechanisms to avoid movements that may lead to overload and pain in the patellofemoral joint.[7,26,27,55] These studies on hip and knee muscles in PFP usually analyze individual electromyographic (EMG) signals for each muscle,[8,14,32] compare differences between activation onset time of a muscle in relation to another muscle, or compare individual muscle activation for subjects with and without PFP.[7,26,27]

The muscle synergy hypothesis suggests that the central nervous system (CNS) manages the orchestration of complex coordinated motor tasks by sending common neural commands to different muscle groups, called muscle synergies or motor modules.[3,6,44,51] Through the analysis and decomposition of the EMG signals of the most important muscles involved in a given task, it is

possible to identify the minimum number of synergies necessary to execute that same task, in which period of the movement each synergy is activated, and which muscles are contributing to each synergy.[49,50,51] The analysis of muscle synergies has been previously proposed as biomarkers of neural impairment by us [1,2,37] and others [10,12] in stroke and spinal cord injury patients. In patients with musculoskeletal pain, the literature is inconsistent as to the number of synergies, the contribution of each muscle to each synergy and the activation period of each synergy during the execution of the studied tasks.[29] However, recent evidence highlighted differences in the similarity and quality of the muscle synergy reconstruction between asymptomatic and musculoskeletal pain individuals.[29]

We previously showed that lateral step down (LSD) is one of the tasks (out of seven studied) that most differentiate kinematics between PFP and asymptomatic controls.[30] On the other hand, neural deficits can be masked by compensation strategies, which produce similar movements with different neuromuscular mechanisms.[41] Therefore, quantifying the muscle coordination mechanisms in PFP patients may help to unveil the possible changes in the neural substrates associated with the biomechanical factors already described in the literature,[15,38,54,55] and be used as new biomarkers of the pathology.

The main objective of this study was to analyze muscle synergies of women with and without PFP during the execution of LSD. The secondary objective was to verify if there is a correlation between the muscle synergies and the Movement Deviation Profile (MDP) kinematics of women with PFP.

3.2.2. METHODS

Study Design

A cross-sectional study was designed, approved by the ethics committee and conducted at the Núcleo de Apoio à Pesquisa em Análise do Movimento (NAPAM) of the Nove de Julho University (protocol number 2.732.037).

Participants

A convenience sample of 29 women was selected for the study. 15 subjects presented PFP while 14 subjects were asymptomatic. Subjects were informed about all the details of the study, agreed to participate and signed the corresponding informed consent.

General inclusion criteria were: age between 18-35 years and body mass index below 30kg/m². For the PFP group, subjects should had anterior knee pain for at least three months with a minimum Numerical Pain Rating Scale (NPRS)[16] score of three points at least during two of the following activities: squat, run, ascent and descent stairs, kneeling or sitting for prolonged hours with flexed knees and present pain while performing LSD.

Exclusion criteria for both groups were presence of lateral and/or posterior knee pain, history of ligament and/or meniscal injuries, surgical procedures in the lower limbs or spine, ankle sprain, low back pain, having had more than one episode of patellar dislocation, cardiorespiratory, neurological or musculoskeletal problems that could interfere or prevent the subject from performing the entire assessment, taking controlled medication such as antidepressants and having a difference of more than 1 cm between the length

of the lower limbs. For the asymptomatic group, the subjects could not present any type of lower limb musculoskeletal pain.

Procedures and instrumentation

The assessments were performed on two non-consecutive days with a maximum interval of 15 days between them.

On the first day, the candidates for the PFP group were evaluated by two experienced physiotherapists specialized in the assessment of orthopedic patients, in order to clinically confirm PFP, ruling out any other type of injury that could cause knee pain.[54] All selected subjects underwent 3D kinematics and EMG assessment during LSD. Kinematic analysis was performed using an eight-camera Vicon system operating at 240 Hz. A total of 25 retroreflective markers were attached to the skin of each subject using a hypoallergenic double-sided tape, according to the Plug-in Gait model.[25] EMG signals were captured using an eight-channel wireless acquisition system (EMG System do Brasil Ltda®) composed of bipolar active electrodes with a 1k amplification gain and 20-500 Hz band pass analog filter. The EMG signals were captured at 2,400 Hz sampling frequency. Following SENIAM recommendations,[23] Ag/AglCl (Miotec®) disposable, double self-adhesive and 2 cm center-to-center distance surface electrodes were positioned on the skin parallel to the fibers of the muscle belly taking into account the following locations: Adductor Longus (AdLo),[17] Gluteus Medius, (GlMe); Vastus Lateralis, (VaLa); Rectus Femoris, (ReFe); Vastus Medialis, (VaMe); Biceps Femoris, (BiFe); Tibialis Anterior, (TiAn) and Gastrocnemius Medialis (GaMe). The limb considered for analysis was the limb with pain or the most painful one for the PFP volunteers and the

dominant one for the asymptomatic volunteers. Prior to electrode placement, the skin was shaved and cleaned with 70% alcohol. LSD was performed according to the study description by Lopes Ferreira et al., 2019.[30] Three consecutive squats corresponded to one repetition of the LSD. Each subject performed about 20 repetitions to obtain at least between 25-30 squats where corresponding EMG signals presented no artifacts or noise that would prevent a trustful analysis. A 30-second resting interval was taken after each LSD repetition. After five consecutive repetitions, each participant rested for at least two minutes. During this resting period, PFP participants were asked to assign a score from 0 to 10, on the perceived mean knee pain while performing the test, according to the NPRS.[16]

On the second day, the maximal voluntary isometric strength test was performed on hip abductors and lateral rotators and hip and knee extensors using the Lafayette Instrument Company® manual dynamometer (Lafayette, IN, USA),[7,53] the foot posture index (FPI)[39] and the lunge test.[5] On the same day, all subjects answered the questionnaires on the quality of life (SF-36- Medical Outcomes Study 36 – Item Short-Form Health Survey)[11], level of physical activity (International Physical Activity Questionnaire – IPAQ – Short version)[31], depression (BECK Depression Inventory)[22] and function (Anterior Knee Pain Scale – AKPS).[16] Subjects in the PFP group also answered questionnaires related to the intensity of pain in the last 15 days (NPRS),[16] symptom duration, catastrophizing (Pain Catastrophizing Scale – PCS)[43] and kinesiophobia (Tampa Scale of Kinesiophobia – TAMPA).[45]

Data Analysis

Two researchers with long experience on EMG analysis and that did not take part in the assessment and acquisition of the data assessed, guaranteed the quality of EMG data required for all eight muscles assessed, for 25-30 squat cycles. Selection of cycles was made by a rigorous visual inspection of the data.

The 3D marker trajectories were processed using the Vicon Nexus 2.8 software to estimate the joint centers.[25] The movement cycles was identified according to Lopes Ferreira et al., 2019.[30] The Woltring filter was applied with 2 mean square errors to reduce the vibratory noise that could arise during the marker trajectories due to soft tissue artefact.

MDP is a self-organizing neural network based method that calculates the deviation of a patient's movement from normality[4]. For MDP calculation, the following kinematic angles were considered: absolute frontal, sagittal and transverse planes of the trunk and pelvis segments and hip in relation to the pelvis, frontal and sagittal planes of the knee to the thigh, sagittal plane from the foot to the shank and absolute transverse plane of the foot. For each LSD cycle, an MDP curve consisting of normalized data points every 2% of the movement cycle was calculated in relation to the control group. The average of the 51 points of the MDP curve of all movements of all subjects was considered for statistical analysis to compare the groups. Finally, the MDP value for each subject was calculated based on the control group.

EMG data were exported from the Vicon Nexus software and processed using custom software in MATLAB (MathWorks, Natick, MA, USA). Detailed explanation of processing applied to extract muscles synergies has been

previously published by us.[3,37] In this study, concatenated raw EMG signals from each participant were high-pass filtered at 20 Hz, rectified and low-pass filtered at 5 Hz to obtain the EMG envelopes.[12] EMG envelopes of each muscle were amplitude-normalized by the average of the maximum values of each LSD cycle and time-normalized every 1% of the task cycle. For each subject, normalized EMG envelopes were combined into m x t (EMG_o) matrix, where *m* is the number of muscles (eight in this study) and *t* is the time base (number of LSD cycles (25-30) x 100).[37] Muscle synergies were extracted through a non-negative matrix factorization algorithm (NNMF).[28] Mathematically, the algorithm is described by the following equation:

$$EMG_0 = WH + e = EMG_r + e$$

Where *W* is the matrix *m* x *n*, being *n* the number of synergies, that specifies the weight of each muscle in each synergy, *H* is the matrix *n* x *t* specifying the time-varying activation coefficients which represents the recruitment of each synergy throughout the cycle. EMG_r is the matrix *m* x *t* resulting from the multiplication of *W* and *H*, representing the envelope reconstruction of the EMG and *e* is the residual error.[3,37] For each EMG_o, ,NNMF algorithm was run three times, considering different number of synergies in the range from 2 to 4. For each of the three times, the NNMF was repeated 40 times and the repetition with the smallest reconstruction error was selected.[37]

The minimum number of synergies required to guarantee adequate reconstruction of the EMG signal was determined as the minimum number

necessary to obtain variability account for (VAF_{total}) $\geq$ 90%, as well as VAF_{muscle} $\geq$ 75% for all muscles assessed. [3,12,37]

Data from the asymptomatic control group were used to obtain two reference matrices: W_{ref}, which represents the weight or contribution of each muscle to each synergy; and H_{ref}, which contains the activation coefficients and represents how each synergy is modulated over time. For this purpose, EMG_o matrices of all asymptomatic subjects were concatenated and the NNMF algorithm was applied to obtain W_{ref} and H_{ref} for 2, 3 and 4 synergies. For each patient and number of synergies, we ordered muscle synergy vectors (columns of matrix W) based of the similarity values with synergy vectors from W_{ref} using the normalized scalar product. After ordering the synergy vectors and the corresponding activation coefficients (H), matrices W and H of each patient were compared with the asymptomatic group reference using the normalized scalar product. For synergy vectors, this comparison was represented as $Wi \cdot Wi_{ref}$, being i the column number compared. For activation coefficients, this comparison was represented as $Hi \cdot Hi_{ref}$, being i the row number compared. The similarity of columns and rows from W and H matrices, respectively, between PFP patients and the control reference is hereafter referred to as $W \cdot W_{ref}$ and $H \cdot H_{ref}$, with W_{mean} and H_{mean} representing the mean $W \cdot W_{ref}$ and $H \cdot H_{ref}$ values of all synergies, respectively, for each PFP subject.

Statistical Analysis

The Shapiro-Wilk test was used to verify the distribution of the analyzed data. For the data identified as parametric, the t-test for independent samples was used. For the non-parametric variables, the Mann-Whitney test was applied

to compare the following variables between groups: demographic data, FPI, lunge test, muscle strength, questionnaire score and MDP. Descriptive analysis of the sample characterization data, clinical tests and questionnaires was performed by calculating the mean and confidence interval (CI 95%).

For the synergy data analysis, t-test was applied to compare the following variables between groups: number of synergies, VAF_{total} and VAF_{muscle}, expressed as mean, standard deviation and confidence interval. For the similarity analysis $W \cdot W_{ref}$ and $H \cdot H_{ref}$, values close to 1 mean high similarity with the control group and values below 0.75 mean low similarity.[37]

The Z-score was calculated to quantify the difference in MDP between the groups.[30] Pearson correlation test was used to evaluate the relationship between MDP and the following synergy metrics in PFP subjects: $W1 \cdot W1_{ref}$, $W2 \cdot W2_{ref}$, $W3 \cdot W3_{ref}$, W_{mean}, $H1 \cdot H1_{ref}$, $H2 \cdot H2_{ref}$, $H3 \cdot H3_{ref}$ and H_{mean}, considering that a correlation coefficient of 0.00-0.10 = no correlation; 0.10-0.39 = weak correlation; 0.40-0.69 = moderate correlation; 0.70-0.89 = strong correlation and 0.90-1.00 = very strong correlation.[42]

A statistically significant p value was considered when $p \leq 0.05$. The effect size (ES) was calculated for the muscle synergy variables with statistical differences using the Cohen's d index considering 0-0.2 = no effect, 0.2-0.5 = small effect, 0.5-0.8 = intermediate effect and effect greater than 0.08 = large effect.

3.2.3. RESULTS

Table 1 shows the mean and confidence interval (CI 95%) of the anthropometric characteristics and the values of the muscle strength tests, FPI and lunge test while Table 2 shows the scores of the questionnaires.

TABLE 1. Means and confidence interval (95%) of demographic, muscle strength, foot posture and dorsiflexion range of motion and comparison between the groups.

Groups	Control		PFP		
	Mean (CI 95%)		Mean (CI 95%)		p
Age (years)⁺	25.21	(22.15-28.28)	22.93	(19.88-25.98)	0.13
Height (m)	1.63	(1.60-1.66)	1.63	(1.58-1.68)	0.94
Body mass (kg)	58.21	(53.72-62.71)	58.80	(52.10-65.50)	0.87
BMI (kg/m²)	21.77	(19.93-23.61)	21.91	(19.89-23.92)	0.91
HABD (%BW)	20.26	(16.30-24.22)	17.84	(14.49-21.18)	0.32
HEXT (%BW)	18.41	(14.22-22.60)	19.81	(15.49-24.13)	0.62
HLR (%BW)	9.43	(7.58-11.28)	10.38	(8.97-11.80)	0.38
KEXT (%BW)	32.98	(27.87-38.08)	35.19	(29.98-40.39)	0.52
FPI	4.00	(2.53-5.47)	4.47	(2.69-6.24)	0,66
Lunge test (º)⁺	38.77	(36.55-41.00)	41.00	(37.50-45.74)	0.60

CI: confidence interval; ⁺: Nonparametric data, Mann-Whitney test to compare the groups; m: meters; Kg: kilogram; BMI: body mass index; Kg/m²: kilogram per square meter; %BW: body weight percentage; Maximal voluntary isometric strength: the mean of two measurements with a difference between them below 10% normalized by the percentage of body weight X100 of each subject was considered for analysis of the following muscles: HABD: hip abduction maximal voluntary isometric strength; HEXTQ: hip extension maximal voluntary isometric strength; HLR: lateral rotator maximal voluntary isometric strength; KEXT: knee extension maximal voluntary isometric strength; FPI: Foot Posture Index – score of the 6 items; Lunge test: dorsiflexion range of motion – for each subjects the mean of three measurements was used; º: degrees.

TABLE 2. Means and confidence interval (95%) of questionnaires scores and comparison between the groups

Groups	Control Mean (CI 95%)	PFP Mean (CI 95%)	p
SF-36			
Physical functioning (0-100)+*	93.93 (88.03-99.83)	70.33 (60.95-79.72)	0.00
Role physical (0-100)+*	87.50 (71.74-103.26)	70.00 (55.96-84.04)	0.04
Bodily Pain (0-100)+*	85.71 (76.31-95.12)	57.47 (47.20-67.74)	0.01
General health (0-100)+	74.36 (61.51-87.20)	68.78 (55.61-81.59)	0.44
Vitality (0-100)	59.64 (49.11-70.17)	58.67 (47.13-70.20)	0.89
Social functioning (0-100)+	78.64 (63.74-93.55)	74.23 (63.91-84.55)	0.27
Role emotional (0-100)+	59.50 (35.38-83.62)	66.64 (45.68-87.61)	0.69
Mental health (0-100)+	73.43 (63.77-83.08)	69.00 (60.24-77.76)	0.40
BECK (0-63)+	6.71 (2.77-10.66)	6.07 (3.52-8.61)	0.75
AKPS (0-100)*	100	70.40 (64.45-76.35)	0.00
TAMPA (17-68)	-	34.60 (31.14-38.06)	-
PCS (0-52)	-	16.93 (11.63-22.24)	-
NPRS last 15 days (0-10)	-	5.67 (4.69-6.64)	-
NPRS during LSD (0-10)	-	5.63 (4.62-6.64)	-
Symptom duration (months)	-	46.73 (19.44-74.03)	-

CI: confidence interval; +: Nonparametric data, Mann-Whitney test to compare the groups; *: Statistically relevant difference $p \leq 0.05$; SF-36: 36-item short form health survey questionnaire; BECK: Beck depression inventory; AKPS: anterior knee pain scale; TAMPA: Tampa scale of kinesiophobia; PCS: Pain catastrophizing scale; NPRS: numerical pain rating scale.

The representation of the MDP curve for each group is shown in Figure 1. The mean value from the MDP curve of the control group was 8.14 (0.33) and for the PFP group was 12.20 (0.86). The two groups showed significant differences, with $p<0.01$ and the Z-score = 12.03.

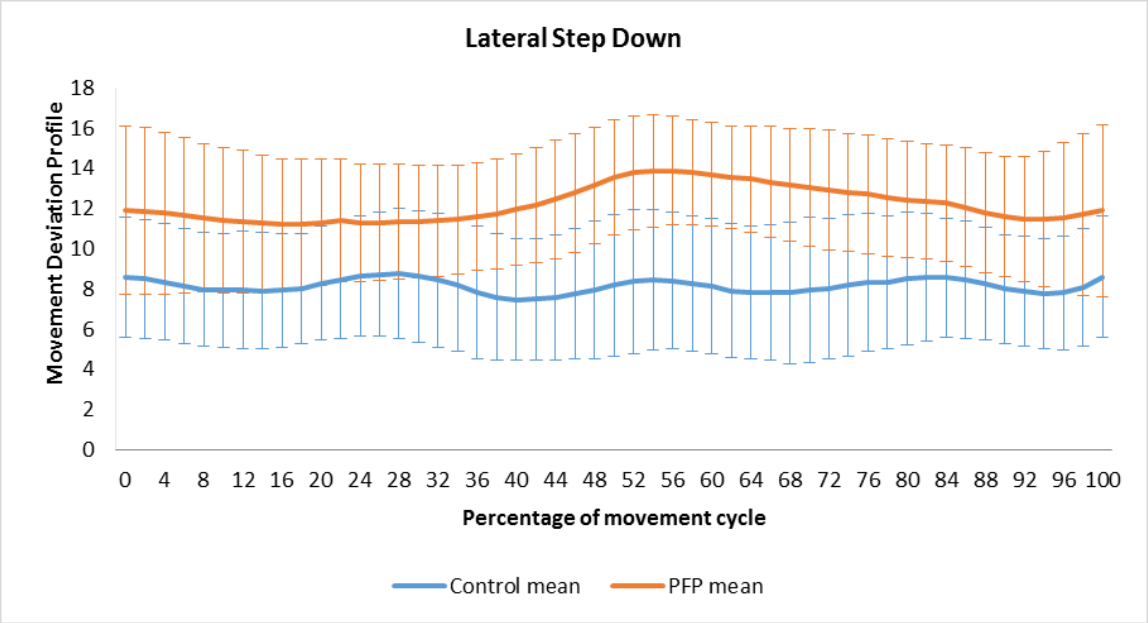

Figure 1. The Movement Deviation Profile chart (mean and standard deviation bands) summarizes the 13 angle curves for control group (blue) and patellofemoral group (orange) during the lateral step down.

In the control group, two synergies were sufficient to reconstruct the EMG signals (EMG_r matrices) of six subjects (42.85%), three synergies were needed to properly reconstruct the EMG signals in seven subjects (50%), and four synergies were required to properly reconstruct the EMG signals in one participant (7.14%). In the case of the PFP group, two synergies were needed in eleven patients (73.33%) and three synergies were needed in four patients (26.66%) to properly reconstruct the EMG signals. However, differences in the

number of muscle synergies were not statistically significant between the two groups (p=0.08) (Table 3).

VAF_{total} values were significantly different between groups when EMG signals were reconstructed (EMG_r matrices) with three synergies (p=0.04 and ES=1.99 – see Table 3), with the PFP group presenting higher VAF_{total} values (0.94 ± 0.01) than the control group (0.92 ± 0.01) (see Figure 2A). Regarding the reconstruction of EMG signals with two synergies, VAF_{total} values were 0.91 ± 0.02 and 0.89 ± 0.02 for the PFP and the control, respectively, and these differences were not significant between groups. There were no significant differences between EMGs reconstruction with four signals: VAF_{total} values were 0.96 ± 0.01 and 0.95 ± 0.01 for the PFP and the control, respectively. In view of this, three synergies were set for the comparisons between groups in further analyses.

VAF_{muscle} values of each assessed muscle for the control and the PFP group are shown in Figure 2B. Significant differences were observed for ReFe (p=0.01 and ES=1.26), with VAF_{muscle} of 0.91 (±0.04) for the control group and 0.95 (±0.02) for the PFP group, as well as for VaMe (p=0.03 and ES = 1.00), with VAF_{muscle} of 0.94 (±0.01) for the control group and 0.96 (±0.01) for the PFP group (Table 3). No significant differences were found between the two groups for the other VAF_{muscle} values.

TABLE 3. Means and confidence interval (95%) of number of synergies, VAF_{total} and VAF_{muscle} and comparison between the groups

Groups	Control	PFP	
	Mean (CI 95%)	Mean (CI 95%)	p
Number of Synergies	2.64 (2.27-3.00)	2.26 (2.01-2.52)	0.08
VAFtotal using 3 synergies * VAFmuscle using 3 synergies	0.92 (0.91-0.93)	0.94 (0.93-0.95)	0.04
AdLo	0.89 (0.86-0.92)	0.91 (0.89-0.94)	0.26
GlMe	0.91 (0.88-0.94)	0.91 (0.88-0.94)	0.95
VaLa	0.94 (0.93-0.95)	0.95 (0.94-0.96)	0.16
ReFe*	0.91 (0.88-0.94)	0.95 (0.94-0.96)	0.01
VaMe*	0.94 (0.93-0.95)	0.96 (0.95-0.96)	0.03
BiFe	0.91 (0.90-0.92)	0.91 (0.89-0.94)	0.81
TiAn	0.93 (0.89-0.97)	0.95 (0.91-0.99)	0.47
GaMe	0.94 (0.91-0.96)	0.93 (0.90-0.96)	0.77

CI: confidence interval; *: Statistically relevant difference; AdLo: adductor longus; GlMe: gluteus medius; VaLa: vastus lateralis; ReFe: rectus femoris; VaMe: vastus medialis; BiFe: biceps femoris; TiAn: tibialis anterior; GaMe: gastrocnemius medialis.

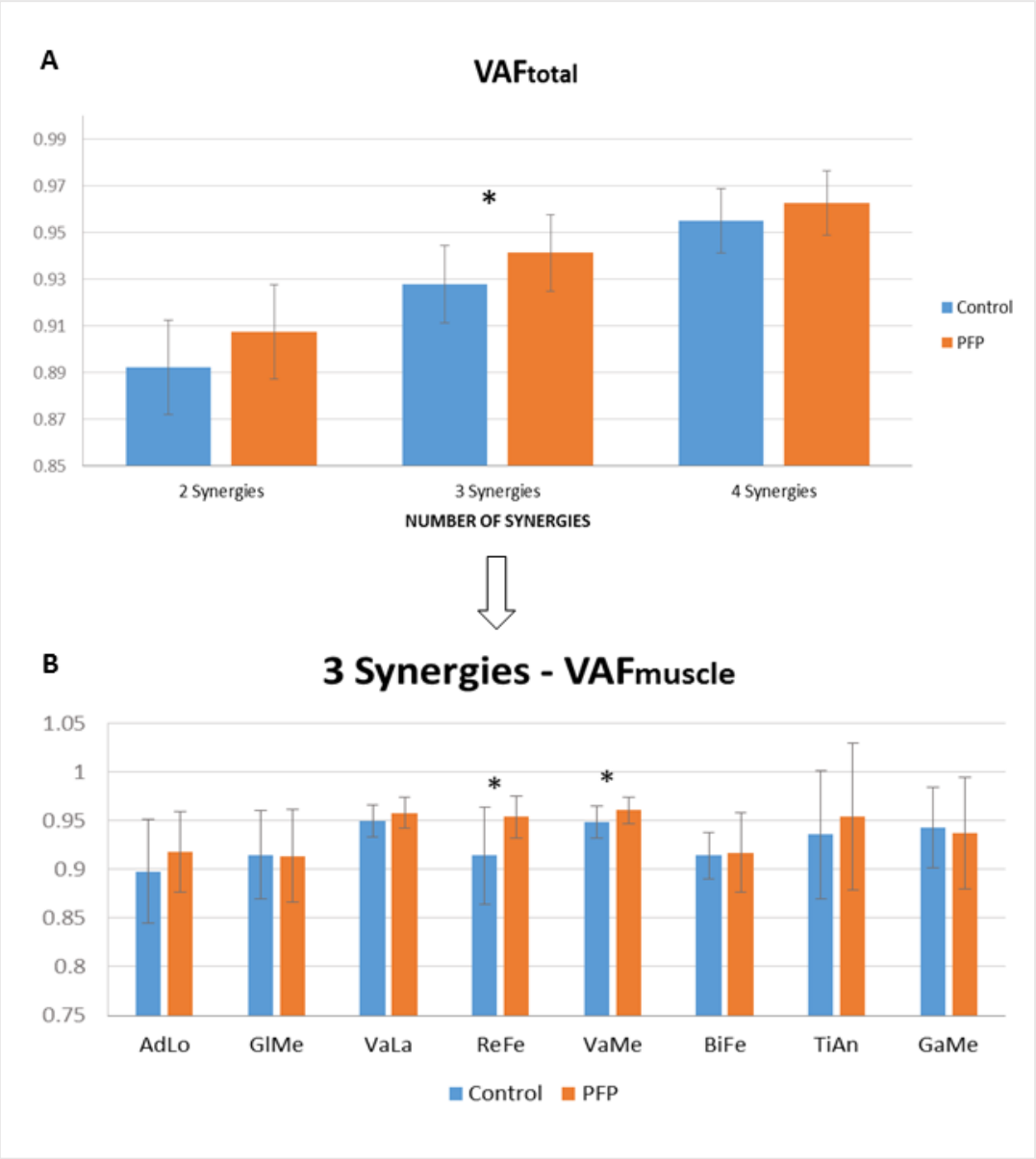

Figure 2. Mean, standard deviation and VAF_{total} comparison between control group (blue) and PFP group (orange) for 2, 3 and 4 synergies **(A)**. Mean, standard deviation and VAF_{muscle} for the eight assessed muscles between the control and PFP group with 3 synergies (AdLo: adductor longus; GlMe: gluteus medius; VaLa: vastus lateralis; ReFe: rectus femoris; VaMe: vastus medialis; BiFe: biceps femoris; TiAn: tibialis anterior; GaMe: gastrocnemius medialis) **(B).**

Figure 3 shows the synergistic behavior of the control group to perform the LSD with three synergies. The activation peaks and duration of each activation coefficient (H) were different across the cycle. The onset of movement seems to be dominated by synergy 1, which showed its first activation peak at around 2% of the cycle (see Figure 3a). Synergy 1 was represented mainly by the activity of GaMe and GlMe. Subsequently, synergies 2 and 3 overlapped by co-activating to drive and control the squat movement. Synergy 2, mainly represented by the activity of TiAn, reached its activation peak at the moment of the cycle corresponding to the final squat phase (around 40% of the cycle) and decreased its activation shortly after that (Figure 3b). In the transition of movement between the squat and the rising phase to return to starting position, the synergy 3 peak was observed at around 55% of the LSD cycle, and was activated for almost all LSD rise phase (Figure 3c). Synergy 3 was composed by the activity of VaMe, VaLa, ReFe, BiFe, GlMe, and AdLo. During the final part of LSD cycle, synergy 1 activated again to return to the starting position (Figure 3d).

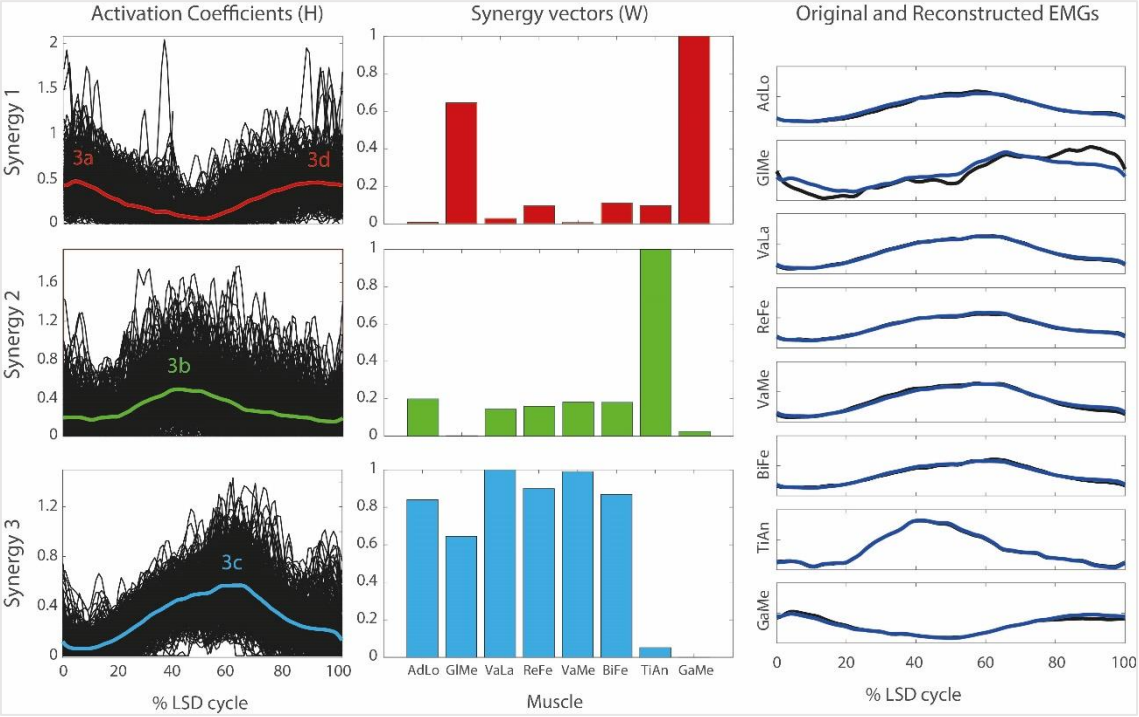

Figure 3. Three muscle synergies extracted from data of 14 asymptomatic women during LSD. Synergies were calculate using NNMF algorithm. First column - Activation coefficients show four different activation peaks: first peak of synergy 1 **(3a)**, peak of synergy 2 **(3b)**, peak of synergy 3 **(3c)**, and second peak of synergy 1 **(3d)**. Thin black lines represent activation coefficients of each individual LSD cycles, while colored thin lines represent the average of those cycles. Second column - Synergy vectors of the reference indicate the weight of each muscle to each synergy. AdLo: adductor longus; GlMe: gluteus medius; VaLa: vastus lateralis; ReFe: rectus femoris; VaMe: vastus medialis; BiFe: biceps femoris; TiAn: tibialis anterior; GaMe: gastrocnemius medialis. Third column - Average of original EMG envelopes (EMG_0 – black lines) and reconstructed EMG envelopes (EMG_r – blue lines).

The similarity analysis of the matrices $W{\cdot}W_{ref}$ and $H{\cdot}H_{ref}$ was high (> 0.75) for the PFP group (Table 4). However, it can be observed that two patients presented low similarity for $W1{\cdot}W1_{ref}$, three patients presented low similarity for $W2{\cdot}W2_{ref}$ and one patient presented low similarity for $H2{\cdot}H2_{ref}$. Pearson correlation test was used to evaluate the relationship between MDP and the similarity metrics $W{\cdot}W_{ref}$ (Figure 4A) and $H{\cdot}H_{ref}$ (Figure 4B). There was a moderate and negative association between $W2{\cdot}W2_{ref}$, $W3{\cdot}W3_{ref}$ *and* W_{mean}

with the MDP (Figure 4A). The other correlations of MDP with similarity metrics ($W1 \cdot W1_{ref}$, $H1 \cdot H1_{ref}$, $H2 \cdot H2_{ref}$, $H3 \cdot H3_{ref}$ *and* H_{mean}) were not statistically significant.

TABLE 4. Normalized scalar product between muscle synergy vectors corresponding to *W* and *H* matrices of each patient and W_{ref} and H_{ref} matrices of all asymptomatic volunteers, considering the eight muscles assessed.

	$W1 \cdot W1_{ref}$	$W2 \cdot W2_{ref}$	$W3 \cdot W3_{ref}$	$H1 \cdot H1_{ref}$	$H2 \cdot H2_{ref}$	$H3 \cdot H3_{ref}$
PFP_01	0.91	0.93	0.98	0.98	0.77	0.99
PFP_02	0.98	0.96	0.95	0.99	0.99	0.97
PFP_03	0.99	0.99	0.98	0.95	0.96	0.99
PFP_04	0.96	0.95	0.97	0.98	0.93	0.98
PFP_05	**0.74**	**0.09**	0.87	0.96	0.88	0.97
PFP_06	0.99	0.97	0.99	0.96	0.99	0.99
PFP_07	0.99	0.98	1.00	0.96	0.98	0.97
PFP_08	0.97	0.95	0.97	0.92	0.96	0.91
PFP_09	0.90	**0.16**	0.91	0.95	0.78	0.92
PFP_10	0.88	0.98	0.99	0.92	0.98	0.98
PFP_11	**0.74**	**0.71**	0.97	0.93	**0.75**	0.97
PFP_12	0.97	0.99	1.00	0.94	0.95	0.97
PFP_13	0.98	0.97	0.99	0.98	0.98	0.99
PFP_14	0.92	0.82	0.98	0.98	0.94	0.99
PFP_15	0.94	0.99	1.00	0.99	0.98	0.99
Mean (SD)	0.92 (0.08)	0.82 (0.29)	0.96 (0.03)	0.96 (0.02)	0.92 (0.08)	0.97 (0.02)

The normalized scalar product has been abbreviated with notation "*W·Wref*" and "*H·Href*". Values ≤ 0.75 appear in bold.

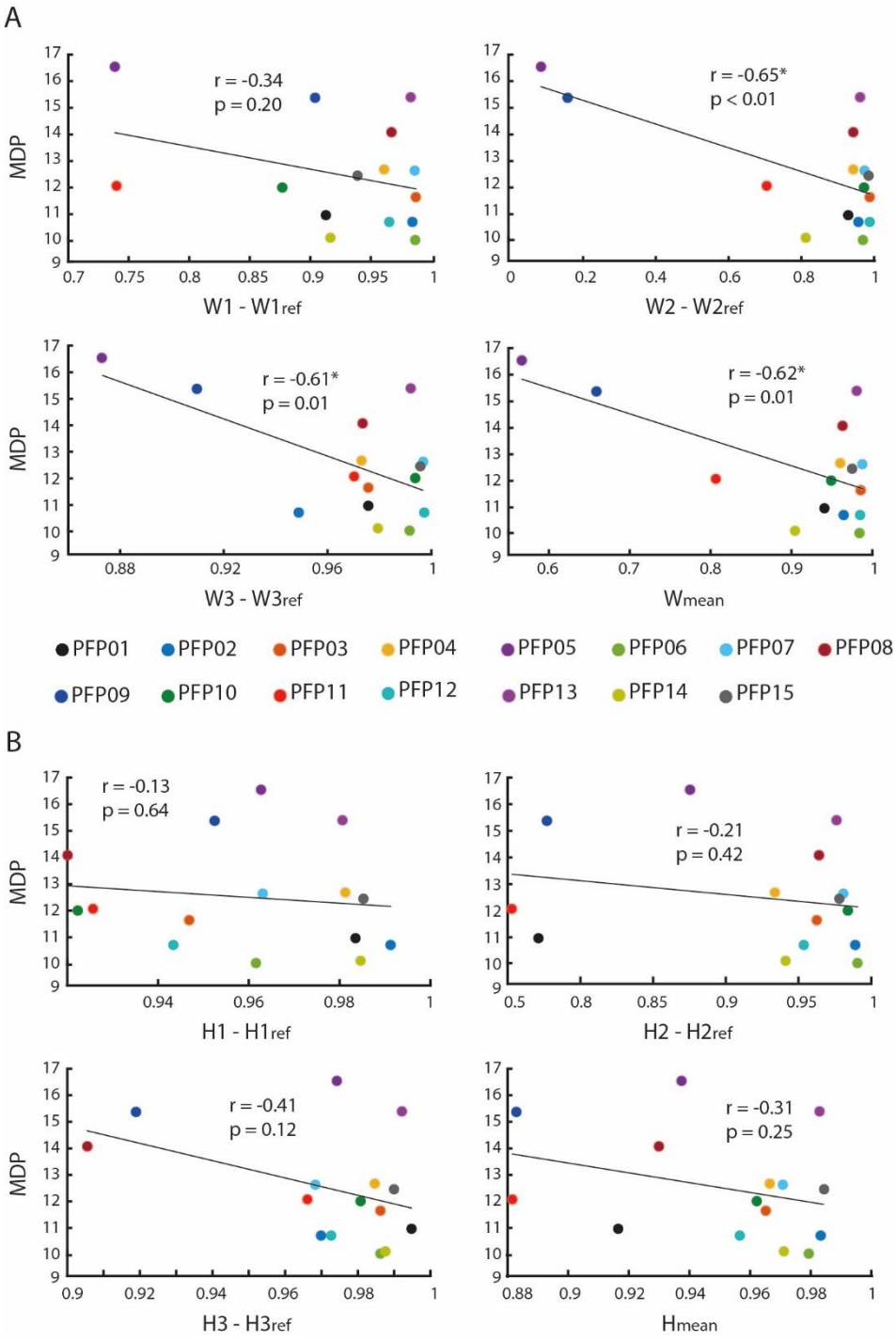

Figure 4. Pearson correlation test between the Movement Deviation Profile (MDP) and *W·Wref* **(A)** and *H · Href* **(B)** with 3 synergies to the patellofemoral pain group. Each color represents a different PFP patient. The correlation is significant when $p \leq 0.05$.

Figure 5A shows the synergistic behavior of the PFP group in comparison to the control group, to perform the LSD with three synergies. Qualitatively, both activation coefficients and synergy vectors were similar between the two groups. Results from the PFP patient presenting the lowest MDP (more similar to normality) are represented in Figure 5B. Qualitatively, both W and H were similar to the reference of the control group. Results from the PFP patient presenting the highest MDP (more different than the normality) is represented in Figure 5C. In this case, differences were observed for each of the synergy vectors compared to the control reference. Synergy 1 was represented by the activity of GaMe, BiFe, and to a lesser extent by the activity of TiAn. Synergy 2 was mainly represented by the activity of GlMe, whereas in the synergy 3 GlMe and BiFe were less active in comparison to controls (Figure 5C).

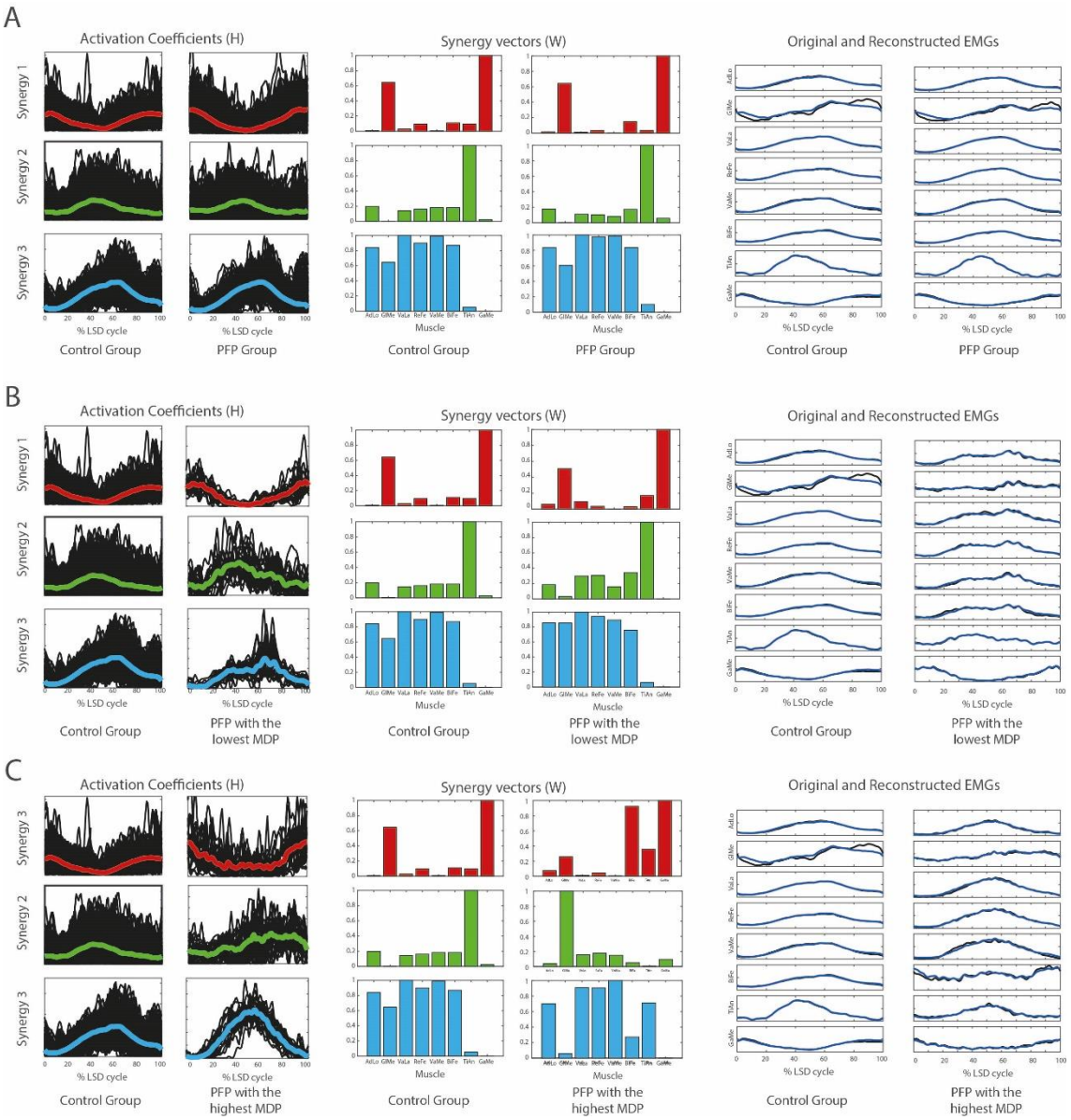

Figure 5. Activation coefficients (H), synergy vectors (W) and original and reconstructed EMG of each muscles of the control group and PFP group **(A)**, PFP with the lowest MDP **(B)** and PFP with the highest MDP **(C)**. AdLo: adductor longus; GlMe: gluteus medius; VaLa: vastus lateralis; ReFe: rectus femoris; VaMe: vastus medialis; BiFe: biceps femoris; TiAn: tibialis anterior; GaMe: gastrocnemius medialis

3.2.4. DISCUSSION

The aim of the present study was to analyze muscle synergies in women with PFP during the execution of LSD and to correlate them with MDP, which was calculated as function of trunk, pelvis and lower limb kinematics. Women with PFP showed no significant differences in the minimum number of muscle synergies required to explain the variability of EMG. However, they showed significantly higher VAF_{total} and VAF_{muscle} with 3 synergies for rectus femoris and vastus medialis when compared to asymptomatic women, which suggests reduced complexity of motor control of these muscles. In addition, we observed that the lower the similarity in muscle synergies (*W2*, *W3* and W_{mean}) with the control group, the greater the difference in trunk, pelvis and lower limb kinematic between PFP and control group.

To our knowledge, this is the first study that performed the analysis of muscle synergies in patients with PFP. In this preliminary study, we decided to assess LSD instead of common tasks such as walking, because LSD is one of the tasks that most differentiates trunk, pelvis and lower limbs kinematics in women with PFP, as we previously showed.[30] In fact, the differences here reported on MDP scores between groups add more evidence to the usefulness of LSD to assess PFP patients. However, since neural deficits can be masked by compensation strategies, combining biomechanical and neural information can give value information on impaired motor control.[41] The analysis of muscle synergies is a recent method that has been recently introduced to evaluate motor control in musculoskeletal pain[29] and was used in this study to get new

insights on consistent patterns of motor control adaptation in PFP, which is not possible with individual muscle analyses.

Although the similarity in motor complexity (number of muscle synergies) found between PFP and control groups, there are differences in the muscle coordination and control (higher VAF) to perform LSD in patients with PFP. Similar results were previously observed in patients with femoroacetabular impingement[18] and low back pain.[47,52] However, patients without pain and anterior cruciate ligament deficiency showed no differences regarding the number and the VAF of the muscle synergies during gait.[44] Also, pain memory may be directly related to neural factors and they may alter somatosensory processes and cause impairments in the sensorimotor function.[19,34]

Changes in quadriceps activation in patients with PFP, mainly between the vastus lateralis and medialis muscles, are frequently addressed in the literature.[13,35,36,38,54] Alteration or delay in the activation of the vastus medialis compared to the vastus lateralis seems to be related to PFP in patients with patellar maltracking.[35,36] However, the reduction in the activation of the vastus medialis and rectus femoris muscles during isometric contraction in the half squat position,[21] alteration in the quadriceps representation and organization in the primary motor cortex[48] and increased quadriceps corticospinal excitability[40] are observed in individuals with anterior knee pain. The present study reinforces the possibility of alterations in the quadriceps neuromuscular control by observing that the variation in the reconstruction of the EMG signals (VAF_{muscle}) of rectus femoris and vastus medialis was higher for women with PFP, which suggests lower muscle coordination capacity of these muscles during LSD.

Similar results have been reported in the deep external rotator muscles of the hip in patients with femoroacetabular impingement[18] and in the strategy of activation of the vastus lateralis and vastus medialis muscles in patients with PFP.[20]

Despite the changes found in the VAF_{muscle} of the vastus medialis and rectus femoris, the analysis of similarity between the W and the H matrices was not different between the groups, suggesting an overall reorganization of the modular control of these muscles[33] without altering the synergies configuration to complete the task. However, in the similarity analysis for each patient, it was possible to identify some PFP patients presenting low similarity for the matrices. Specifically, synergy 1 for patient PFP_05 showed greater contribution of biceps femoris, tibialis anterior and gastrocnemius medialis, while in patient PFP_11, gluteus medius was the biggest contributor. For synergy 2, patient PFP_11 showed greater contribution of the tibialis anterior and the gastrocnemius medialis muscles and low similarity to the *H* matrix, which indicates temporal differences in synergy 2 activation in comparison to the control. In contrast, in patients PFP_05 and PFP_09 the gluteus medius was the main contributor to synergy 2. These findings suggest that although the mean group of women with PFP has had the activation time and the contribution of each muscle in each synergy similar to those of the asymptomatic women, there are some patients who show a different behavior in the muscle coordination and activation. These findings presuppose the importance of the assessments and making personalized decisions toward patients.

We also found a moderate and negative association between $W2 \cdot W2_{ref}$, $W3 \cdot W3_{ref}$ *and* W_{mean} with the MDP (Figure 4A), which indicates that the lower the similarity of synergy vectors (W) of PFP patients (and thus the neuromuscular control) with the reference of the control group ($W \cdot W_{ref}$), the greater the change in kinematics of PFP patients compared to the control group. Given this, it can be assumed that understanding which muscles and what is the weight of the muscle participation in each synergy, gives information on neural control underlying impaired kinematics.

This study has some limitations. The small sample size, although similar to previous studies,[18,29,33,44] limits the ability to detect statistical differences in some of the analyzed variables. The set of assessed muscles may have limited the understanding of the muscle synergies, even though we strictly followed the evidence in the literature showing their altered activation or strength. Alternatively, this set of muscles have been the ones treated for PFP patients and they encompass the three joints biomechanically associated to PFP.[38,54]

It is clinically important to note that the subjects evaluated were extremely homogeneous in terms of anthropometric characteristics, strength, foot posture, dorsiflexion range of motion, physical activity level, quality of life, and depression, showing differences only for pain and function levels. In this exploratory study, we cannot state that neural components are associated with all patients with PFP or that they are associated with the cause or poor prognosis in treating patients. However, we can suggest that one subgroup of women with PFP may have a neural component associated with poor motor control and muscle coordination, and others may not. Further studies need to

investigate these factors in PFP patients and in other daily tasks such as gait. Muscle synergy analysis seems to be a promising method to help understanding motor control alterations that may assist the assessment of musculoskeletal pain.[29]

3.2.5. CONCLUSION

Women with PFP show alterations in muscle coordination and motor control, especially for the rectus femoris and vastus medialis muscles, which are correlated with kinematic alteration during LSD.

KEY POINTS

Findings: Women with patellofemoral pain present alteration in muscle coordination, especially for the rectus femoris and vastus medialis and kinematic changes are correlated with poor muscle coordination during lateral step down.

Implications: Muscle synergies analysis may be a complementary tool to improve the assessment of patellofemoral pain and to identify possible muscle coordination alteration in these patients.

Caution: These data do not establish cause and effect and are limited to young women and lateral step down.

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4. CONSIDERAÇÕES FINAIS

Sugerimos que os testes de *step down*, mais especificamente o SDL, deve ser incluído na avaliação de paciente com DFP. No entanto, a inclusão do SDL não descarta a análise de outras tarefas, uma vez que também mostraram poder de diferenciação entre mulheres com e sem DFP. Devido à característica multifatorial da DFP é importante considerar a sintomatologia, profissão, atividade física e os fatores biopsicossociais durante a tomada de decisão clínica quanto à avaliação dos pacientes. Este é o primeiro estudo, até o momento, que realizou a análise de sinergias musculares em pacientes com DFP e pode auxiliar no melhor entendimento sobre fatores pouco explorados na DFP como a análise do controle motor. Podemos concluir que mulheres com DFP apresentam alterações na coordenação e controle muscular, principalmente para os músculos reto femoral e vasto medial e que as alterações cinemáticas podem estar correlacionadas à pior coordenação do movimento.

Neste estudo exploratório não podemos afirmar que possíveis componentes neurais estão associados à todas as pacientes com DFP ou que estão associados à causa ou ao mau prognóstico no tratamento destes pacientes. Entretanto, podemos sugerir que algumas mulheres com DFP apresentam algum componente neural associado ao controle motor e muscular e que mais estudos precisam investigar estes fatores neuromusculares em pacientes com DFP e em outras tarefas.

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6. APÊNDICES

Artigo Estudo 1

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Full length article

Step down tests are the tasks that most differentiate the kinematics of women with patellofemoral pain compared to asymptomatic controls

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ABSTRACT

Background: Studies evaluating kinematics lead to different conclusions, not all changes appear in all assessed tasks and in all subgroups of patients with patellofemoral pain (PFP). The inconsistencies between studies could be reduced if we knew which task separates patients best from healthy controls.
Research question: Identify which functional task, between gait, forward step down (FSD), lateral step down (LSD), stair ascent and descent and propulsion and landing phase of the single leg hop test (SLHT), differentiates the three-dimensional kinematics of women with patellofemoral pain from asymptomatic women.
Methods: This cross-sectional study evaluated thirty-five PFP and thirty-five asymptomatic women during the execution of the following tasks: gait, FSD, LSD, stair ascent and descent and the propulsion and landing phase of single leg hop test. Frontal, sagittal and transverse plane angles of the trunk, pelvis and hip, frontal and sagittal plane angles of the knee, ankle dorsiflexion, foot progression angle and hindfoot eversion were analyzed through the Movement Deviation Profile (MDP). To compare the groups, the multivariate analysis with Bonferroni post hoc test were used, with a significance level of $p < 0.01$. To identify which task presented the most difference between the groups, the Z-score of the mean MDP was calculated.
Results: For all tasks, the groups presented significant differences. According to the Z-score, the groups got farther apart considering the MDP for each task in the following order: LSD (7.97), FSD (7.62), landing phase of SLHT (3.43), gait (2.85), propulsion phase of SLHT (1.64), descending stairs (1.63) and ascending stairs (1.00).
Significance: We suggest that step down tests should be included in the assessment of PFP patients, since these tests most differentiate the kinematics of women with and without PFP. Identifying the tasks with the highest sensitivity to detect the kinematic differences is expected to improve clinical decision-making.

1. Introduction

Patellofemoral pain (PFP) is a multifactorial clinical condition characterized by retro- and/or peripatellar pain with an annual prevalence of approximately 23% in the general population and a point prevalence of 12–13% in 18–35 year old females [1–4]. Kinematic changes such as greater trunk inclination, pelvic drop, adduction and internal rotation of the hip, poor alignment and/or maltracking of the patella, internal rotation of the tibia and excessive pronation of the subtalar joint are associated with patients with PFP [5–8]. However, kinematic changes are not always observed in all groups of patients with PFP and in all analyzed tasks [9].

The lack of standardization of the functional tasks used to assess patients with PFP makes it difficult to compare studies and interpretation of results for clinical practice [10]. It is not known if the kinematic changes found can be considered tasks-dependent, if the treatment should be directed to the task to be assessed and if there is a task that most differentiates the individual with PFP from the healthy individual [10,11].

The Movement Deviation Profile (MDP) is an artificial neural network based method that calculates the deviation of a patient's movement from normality [12,13]. The MDP unifies and simplifies the understanding of kinematic data, since the analysis of several angle curves in three anatomical planes describing the movement of several joints poses a difficult challenge [12].The MDP has never been explored with PFP patients. This analysis can help to differentiate a set of kinematic variables between groups of individuals considering the temporal waveforms of several variables in a given cycle of movement, as opposed

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to comparing discrete variables like peak values of joint movements and their timing. Providing a simplified summary measure of multivariate temporal data is an attempt to help clinicians to interpret the results of a kinematic analysis more easily and to guide their decision making towards functional tasks which show more kinematic changes in women with PFP.

The identification of a task that makes the biomechanical changes of the patient with PFP more evident could help researchers and clinicians to make a decision regarding the assessment, treatment evolution and improving movement control of these patients, by making the interpretation of the results and the comparison between the studies easier. Therefore, the objective of this study was to identify which functional task, between gait, forward step down (FSD), lateral step down (LSD), stair ascent and descent and propulsion and landing phase of the single leg hop test (SLHT), differentiates the three-dimensional kinematics of women with patellofemoral pain from asymptomatic women. Gait and stairs represent daily tasks and the tests are usually used in clinical trials to quantify the improvement in the function of the patient with PFP after treatment and assess lower limbs abilities as functional muscle strength, power and neuromuscular control.

2. Methods

2.1. Study design

This is a cross-sectional study carried out at a Laboratory of Analysis of the Human Movement of the Nove de Julho University between 2013 and 2016.

2.2. Subjects

Invited by means of oral invitation, 35 women with patellofemoral pain and 35 asymptomatic women aged between 18 and 35 took part in the study. In the group of women with patellofemoral pain those who were included showed anterior knee pain for at least three months during performance of at least two of the following tasks: ascending and descending stairs, squatting, running, jumping or remaining seated for a long time, besides showing a minimal score of 3 points in the Numerical Pain Rating Scale (NPRS) [14]. The NPRS consists of a scale from 0 to 10 points, where higher scores characterize higher intensity of pain [14]. The first clinical examination of the volunteers was conducted by two experienced physiotherapists to verify the eligibility criteria [15].

The symptomatic or more symptomatic limb of the PFP group was assessed and the side of the control group was matched to the painful side of the patients. The demographic data of each group are shown in Table 1.

The exclusion criteria for both groups were: history of surgical procedures of the lower limbs, recurrent patellar instability, associated ligament and/or meniscal injuries, cardiac or locomotion disorders that could interfere with the assessment, as well as leg length difference higher than 1 cm. In the control group of asymptomatic women, the volunteers did not report any musculoskeletal pain in the lower limbs.

Table 1
Demographic data of the control group and the PFP group.

	Control Group Mean (SD)	PFP Group Mean (SD)
N	35 (22R/13 L)	35 (22R/13 L)
Age (years)	24.68 (3.53)	25.60 (6.74)
Body mass (kg)	57.77 (9.20)	57.31 (7.32)
Height (m)	1.63 (0.06)	1.60 (0.06)
BMI (kg/m^2)	21.45 (2.28)	22.29 (2.44)
NPRS (0-10)	0	6.42 (1.33)

N: number of volunteers assessed; R: right lower limb assessed; L: left lower limb assessed; BMI: Body mass index; NPRS: Numerical Pain Rating Scale; SD: Standard Deviation.

2.3. Procedures and instruments

All assessments were carried out in a single day. The volunteers eligible for the study were informed about the details of the study and those who agreed to participate signed the informed consent form. The institutional ethics committee approved the study (protocol number 124.075).

The kinematic analysis of the following functional tasks was performed: gait, forward step down, lateral step down, stair ascent and descent and the propulsion and landing phase of the single leg hop test. For the group of women with patellofemoral pain the intensity of the pain was assessed using the NPRS [14].

The anthropometric data of each subject required for the reconstruction of the biomechanical model including mass, height, length of lower limbs, distance between the anterior superior iliac spines and the diameter of the knees and ankles were measured before the placement of the kinematic markers. A total of 43 retro reflective markers were fixed to the skin at specific anatomical locations of the lower limbs and trunk of each volunteer included in the study, using hypoallergenic double-sided tape, according to the Plug-in Gait and Oxford Foot Model [16,17]. The Vicon system consisting of eight infrared cameras operating at a frequency of 120 Hz was used to acquire kinematic data. The Vicon Nexus software (version 1.8.5) was used for data acquisition and processing.

After the placement of the markers, the participants received verbal explanation, followed by a demonstration of how to perform each task. The kinematic data were only collected after the volunteers were familiarized with each task.

2.4. Functional tasks

Between all tasks and series of movements that were performed, two minute long breaks were held. All collections and verbal commands were performed by a single physiotherapist. The order for the execution of the tasks was always the same for all volunteers: gait, FSD, LSD, stair ascent, stair descent, SLHT.

2.4.1. Gait

The volunteers were instructed to walk as naturally as possible at self-selected speed on a 6-meter-long by 1-meter wide track.

2.4.2. Forward step down and lateral step down

The FSD and LSD tasks consisted of three sets of three consecutive squats standardized at 60° knee flexion [11]. A step measuring 18 cm high, 30 cm wide and 30 cm deep was used to perform both tasks. For the FSD it was requested that the foot of the assessed limb be centrally positioned on the step, near the end of its anterior edge and the contralateral foot was held at the same height in front and in the air. For the LSD the medial border of the foot was be aligned with the lateral edge of the step and the contralateral limb was held in the air immediately to the side. The initial position of the limb tested in both tasks was maximal extension of the knee on the support side, while the contralateral limb had to remain with the knee completely extended and the ankle in maximum dorsiflexion, arms crossed and close to the trunk throughout the execution of the tasks.

The volunteer was asked to perform the squats slowly, over two seconds, and immediately return to the initial position, also over two seconds, in each repetition requested.

2.4.3. Ascending and descending stairs

The task of ascending and descending stairs was performed on three steps, 20 cm high and 30 cm deep each without handrails [18]. During ascent the volunteer took two steps before making the initial contact with the first step. For the descent the volunteers were instructed to

take at least two steps after the end of the stairs. Both ascent and descent had to be performed with limbs alternating between the steps at a self-selected speed, so for each repetition of the task a cycle of one stair ascending and one stair descending were collected.

2.4.4. Single leg hop test

The test consisted of a single one-legged horizontal jump with the assessed limb in support. The volunteer was asked to keep her arms crossed and close to her trunk and to remain in one-legged support with the knee of the assessed limb in extension. Under the evaluator's command the volunteer should jump horizontally as far as she could without putting the contralateral limb on the ground at the time of landing. The test was divided into two phases: the propulsion phase and the landing phase.

2.4.5. Data processing

After the reconstruction of the markers, the movement cycle for each task was identified as described above. For gait, ascent and descent of stairs, kinematic variables of the support and swing phases of the cycle were analyzed; for the FSD, LSD, propulsion and landing the eccentric (squatting) phase and the concentric phase were analysed. The descriptions of each task cycle and the number of cycles considered for analysis are in the Supplementary Data.

The kinematic data were filtered using the Woltring filter applied with 2 mean squared errors (2MSE) to the marker trajectories to reduce noise due to soft tissue artefacts causing marker movement during the movement cycle.

For all tasks, the following kinematic variables were considered: the frontal, sagittal and transverse planes of the trunk and pelvis segments in relation to the laboratory, hip in relation to the pelvis, frontal and sagittal planes of the knee in relation to the thigh, sagittal plane from the foot in relation to the shank, the transverse plane of the foot in relation to the laboratory, and the frontal plane movement of the hindfoot in relation to the tibia.

2.4.6. Movement deviation profile (MDP)

The MDP uses a self-organizing map (SOM), a type of artificial neural network which employs unsupervised learning. The neural network was first trained with control data, and the data from each healthy subject and patient were presented to the trained SOM which compared their movement data to the learned distribution of normality. The SOM calculates the multidimensional Euclidean distance between each patient and normality, providing a single curve for each patient which reflect the distance from normality during the whole duration of the movement [12].

For each patient and each task, an MDP curve was calculated in relation to the control group consisting of a series of 51 data points of 14 kinematics curves in 9 trials. The mean of the 51 points of the MDP curves (MDP_{mean}) of each group was considered for the statistical analysis.

2.4.7. Statistical analysis

The z-score was calculated by subtracting the average MDP_{mean} of the control group from the average MDP_{mean} of the PFP group divided by the standard deviation of the control group's MDP_{mean} in each task to compare the standardized results between the groups. Multivariate analysis to verify the interaction between groups with Bonferroni *post hoc* test was used, considering a $p < 0.01$.

3. Results

The multivariate analysis showed interaction between groups ($F = 358.11$, $p < 0.0001$). The MDP curves representing each task compared between groups are shown in Fig. 1. The means and confidence intervals (95%) of the MDP are available on supplementary data. All tasks presented significant differences between groups with $p < 0.01$ (Bonferroni *post hoc* test). According to the z-score of the mean MDP, the groups got farther apart for each task in the following order: LSD (7.97), FSD (7.62), landing phase of SLHT (3.43), gait (2.85), propulsion phase of SLHT (1.64), descending stairs (1.63) and ascending stairs (1.00) (Fig. 2).

4. Discussion

LSD and FSD are clinical tests that assess the quality of movement based on the observation of the trunk, pelvis and lower limb alignment [19–22]. During LSD, patients with PFP present greater adduction and internal rotation of the hip [23], movements that can expose the patellofemoral joint to excessive loads and increased stress causing pain symptoms [1,10,23–25]. In addition to the hip, changes such as poor movement quality and increase of the movement of the ankle-foot complex and hindfoot eversion are also found in patients with PFP and may contribute to increased differences in kinematics when compared to asymptomatic individuals during LSD [21,23,26].

Although both tests are a one-legged squat, where one of the lower limbs is fixed on a step, the positioning of the contralateral limb makes the biomechanics of the tests different. During the FSD the contralateral lower limb is positioned forward maintaining the pelvis in anterior/external rotation, the hip flexed, the knee extended and the ankle dorsiflexed. The assessed lower limb (support side) performs the task by initiating movement from the external rotation of the pelvis, internal rotation and extension of the hip, extension of the knee and neutral position of the ankle. From the initial positioning, squats occur predominantly with movements of flexion and extension of the hip and knee and dorsiflexion of the ankle. Supposedly, LSD demands more of the action of the muscles that control the movements in the frontal plane of the pelvis and hip than the FSD, since the position of the contralateral limb is parallel to the assessed limb, and this way may have contributed to the LSD differentiated women with and without PFP a little more than FSD.

Despite the fact women with PFP show kinematic changes in the trunk, pelvis, hip and ankle during the propulsion phase of the one-legged jump [7], these changes were not enough to differentiate the groups as well as with LSD, FSD, landing and gait. Women with PFP who were assessed may have adopted other motor strategies to perform propulsion satisfactorily, avoiding movements that could cause pain, since kinetic and electromyographic changes are also observed in the hip and knee in this group of patients [7].

During the one-legged landing, the kinematic changes found between women with and without PFP occur at different time in the task cycle [8]. It is known that moments before the landing of a one-legged jump and in its eccentric phase, women with PFP present an increase in the electromyographic activity of muscles that involve the knee joint, and this a possible mechanism of joint protection and stabilization to avoid the pain that the impact of the task can cause in the patellofemoral joint [27,28]. It is worth noting that kinematic changes do not seem to be influenced by the impact and demand of the task on people with PFP [29].

In spite of the lower reaction force and mechanical challenges to the joint at the patellofemoral joint during gait compared to stair ascent and descent [30], gait was able to better differentiate the kinematics of women with PFP than stair ascent and descent or the propulsion phase of the jump. The peak and the time of hindfoot eversion, internal rotation and adduction of the hip are the main differences between individuals with and without PFP during gait [31,32]. Besides, the trunk segment and the swing phase offers scarcely explored variables during the gait analysis of patients with PFP but these were included in our study and may have contributed to increase the differences between the groups.

The findings in the literature regarding the kinematic alterations of patients with PFP during ascending and descending stairs are inconsistent [33,34]. Novello et al. [18] pointed out that stairs, more

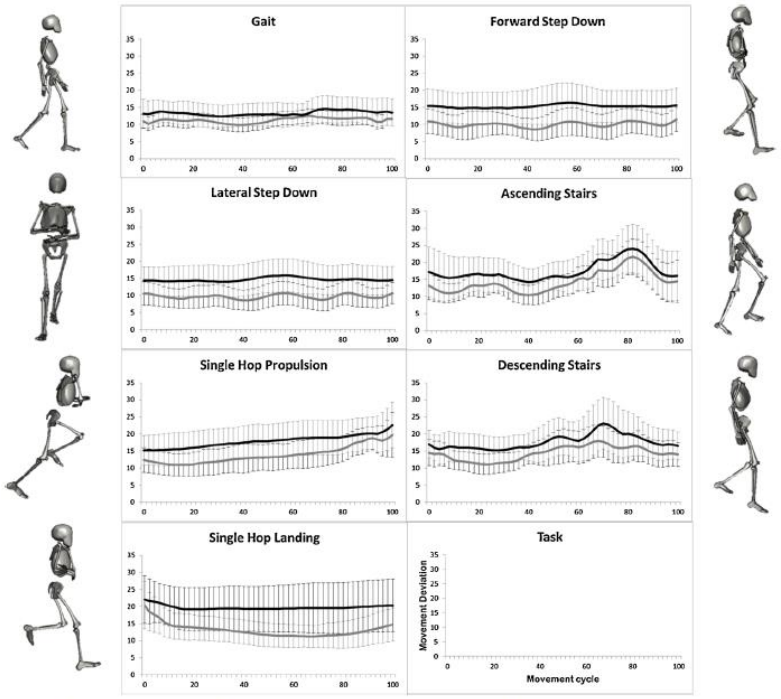

Fig. 1. The Movement Deviation Profile chart (mean and standard deviation bands) summarizes the 14 angle curves of each task for participants with patellofemoral pain (black) and the control group (grey) during the movement cycle.

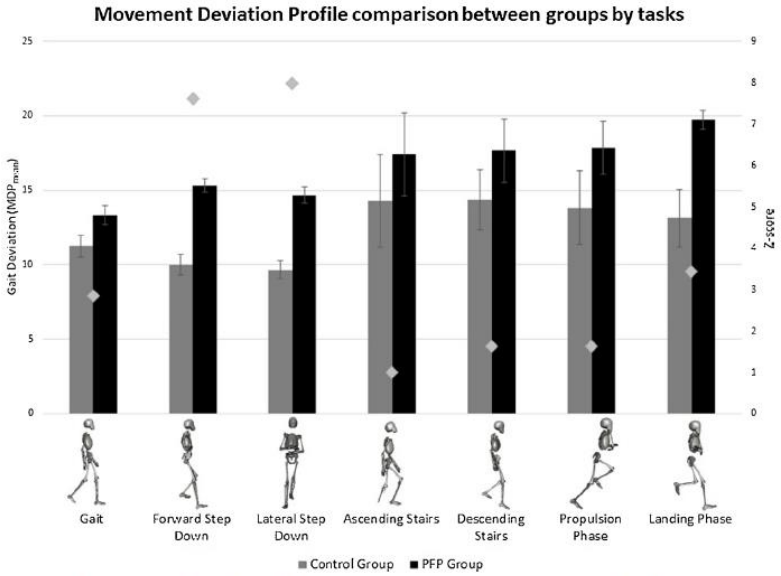

Fig. 2. Means and standard deviations of MDP graphics and Z-score (diamonds) of task deviations between the PFP group and controls for each task.

specifically the descent, may not be the best task to highlight the kinematic differences that women with PFP possibly present and should be used with caution in the assessment and clinical decision making for the treatment of patients with PFP.

This study presents some limitations in that pain during the execution of the tasks was not assessed. Besides, it is a study carried out only with women, and by being aware of the differences between the genders, it is suggested that future studies should assess men with PFP to identify the task that best distinguishes them from asymptomatic men. Another limitation is that we did not randomize the order of tasks, but the kinematic differences between individuals with and without PFP appear to be uninfluenced even after an effort protocol [29].

Identifying the tasks that maximize the kinematic differences between women with and without PFP can help clinicians in the decision making about which tasks to assess, compare and track improvements during treatment of these patients. The tasks that show the kinematic changes of PFP patients best probably require better motor and neuromuscular control and can be used to draw the most detailed profile about these patients and develop a treatment plan with a focus on improving these biomechanical factors.

MDP can help to identify at which percentage of the tasks the deviation patient's movement is more different from normality and assist clinicians in being more directive and assertive in a conventional kinematic analysis that are needed to identify the cause of these differences. Future studies identify the role of each joint and each movement plane in the tasks for differentiation between groups and understand what possible strategies or neuromuscular changes may be behind these differences in the biomechanics of women with and without PFP. As well as consider also the whole cycle of tasks, the swing in the gait and the stairs and the concentric and eccentric phases of the squats and the propulsion and landing of jumps. We believe that important changes can be present in those phases that the literature, to date, has not studied sufficiently.

We conclude that step down tests are the tasks that most differentiate the kinematics of women with and without PFP. We suggest that LSD and FSD be included in the assessment of patients with PFP, but we emphasize that this result does not exclude the option of assessing the other tasks, because all of them showed differences between the groups and also because of being a multifactorial dysfunction. It is important to consider the symptomatology, occupation, physical activity and biopsychosocial factors of each patient assessed at the time of prescribing the treatment and the inclusion of the other tasks in the assessment when clinician deems necessary.

Disclosure statement

None of the authors reports any conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2019.05.023.

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7. ANEXOS

Anexo A: Documento de Aprovação do Comitê de Ética

UNIVERSIDADE NOVE DE JULHO - UNINOVE

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: ANÁLISE DA SINERGIA MUSCULAR E CINEMÁTICA TRIDIMENSIONAL DE MULHERES COM DOR FEMOROPATELAR DURANTE O STEP DOWN LATERAL

Pesquisador: Cintia Lopes Ferreira

Área Temática:

Versão: 2

CAAE: 90136918.1.0000.5511

Instituição Proponente: ASSOCIACAO EDUCACIONAL NOVE DE JULHO

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.732.037

Apresentação do Projeto:

A Dor Femoropatelar (DFP) é caracterizada pela dor na região retro e/ou peripatelar associada a atividades que aumentam as forças compressivas na articulação femoropatelar. A DFP tem origem multifatorial e pode estar associada às alterações anatômicas, biomecânicas, sociais, psicológicas e comportamentais. A literatura apresenta divergências quanto à caracterização da biomecânica desses pacientes, a inconsistência entre os achados cinemáticos e neuromusculares dificulta a comparação entre os estudos. Além disso, os estudos que abordam a atividade muscular de pacientes com DFP avaliam os principais músculos do quadril e joelho separadamente, pouco se sabe sobre o comportamento conjunto dos músculos e se os pacientes apresentam alguma alteração quanto aos comandos de ativação muscular ao nível do sistema nervoso central. A partir da sinergia muscular é possível identificar quantos comandos neurais são necessários para se realizar uma tarefa e quanto cada músculo participa em cada uma dessas sinergias, fornecendo informações mais completas sobre as estratégias neurais adotadas por esses pacientes, auxiliando no melhor entendimento da doença.

Objetivo da Pesquisa:

Avaliar e comparar a sinergia muscular e cinemática tridimensional de mulheres com DFP e assintomáticas durante a execução do step down lateral.

Endereço: VERGUEIRO nº 235/249
Bairro: LIBERDADE **CEP:** 01.504-001
UF: SP **Município:** SAO PAULO
Telefone: (11)3385-9197 **E-mail:** comitedeetica@uninove.br

Avaliação dos Riscos e Benefícios:

Como parte da amostra será composta por pacientes que apresentam sintomas álgicos, um leve desconforto pode ser apresentado durante a execução dos testes, entretanto, eles serão supervisionados continuamente pelos pesquisadores, que tomarão as medidas cabíveis, caso necessário. Para diminuir o risco de qualquer incidente durante o teste, os pacientes receberão orientações e esclarecimentos antes da realização de cada procedimento. Se forem apresentados sintomas como desequilíbrio, tontura, intolerância a postura, algum movimento indesejado, ou qualquer outro tipo de mal estar, a intervenção será imediatamente interrompida. As voluntárias não receberão benefícios específicos imediatamente ou durante a análise, porém, o resultado desse estudo gerará benefícios para a comunidade científica e para a população portadora de DFP, uma que vez que visa esclarecer pontos que ainda não foram explorados na literatura.

Comentários e Considerações sobre a Pesquisa:

Os pesquisadores atenderam às exigencias solicitadas pelo Comite de Ética em Pesquisa

Considerações sobre os Termos de apresentação obrigatória:

Incluir a numeração de página no TCLE

Recomendações:

Não ha recomendações

Conclusões ou Pendências e Lista de Inadequações:

Aprovado, com a recomendação aos pesquisadores de incluir a numeração de página no TCLE

Considerações Finais a critério do CEP:

Para início da coleta dos dados, o pesquisador deverá se apresentar na mesma instância que autorizou a realização do estudo (Coordenadoria, Supervisão, SMS/Gab, etc).

O participante da pesquisa (ou seu representante) e o pesquisador responsável deverão rubricar todas as folhas do Termo de Consentimento Livre e Esclarecido - TCLE apondo sua assinatura na última página do referido Termo, conforme Carta Circular no 003/2011 da CONEP/CNS.

Salientamos que o pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado.

Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara e

sucinta, identificando a parte do protocolo a ser modificada e suas justificativas. Lembramos que esta modificação necessitará de aprovação ética do CEP antes de ser implementada.

Ao pesquisador cabe manter em arquivo, sob sua guarda, por 5 anos, os dados da pesquisa, contendo fichas individuais e todos os demais documentos recomendados pelo CEP (Res. CNS 466/12 item X1. 2. f).

De acordo com a Res. CNS 466/12, X.3.b), o pesquisador deve apresentar a este CEP/SMS os relatórios semestrais. O relatório final deverá ser enviado através da Plataforma Brasil, ícone Notificação. Uma cópia digital (CD/DVD) do projeto finalizado deverá ser enviada à instância que autorizou a realização do estudo, via correio ou entregue pessoalmente, logo que o mesmo estiver concluído.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1122146.pdf	13/06/2018 10:27:10		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TERMO_DE_CONSENTIMENTO_LIVRE_E_ESCLARECIDO.doc	13/06/2018 10:25:58	Cintia Lopes Ferreira	Aceito
Projeto Detalhado / Brochura Investigador	PROJETO_CINTIA.doc	11/05/2018 15:02:33	Cintia Lopes Ferreira	Aceito
Cronograma	CRONOGRAMA_DE_ATIVIDADES.doc	11/05/2018 15:01:17	Cintia Lopes Ferreira	Aceito
Folha de Rosto	Folha_de_Rosto_Cintia_Lopes.pdf	11/05/2018 14:51:08	Cintia Lopes Ferreira	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 23 de Junho de 2018

Assinado por:
Anna Carolina Ratto Tempestini Horliana
(Coordenador)

Anexo B – Ficha de Avaliação Estudo 2

FICHA DE AVALIAÇÃO

UNIVERSIDADE NOVE DE JULHO

Programa de Pós Graduação – Mestrado e Doutorado em Ciências da Reabilitação

Núcleo de Apoio à Pesquisa em Análise do Movimento – NAPAM

DATA:_____ Nº do prontuário:_____

Avaliadores:_____

Nome:_____

Data de Nascimento: ____/____/_____ Idade: ____anos

Endereço:_____

Telefones:_____Email:_____

1. Assinale em quais situações você sente dor:
   - ( ) Muito tempo em pé
   - ( ) Subir e descer escadas
   - ( ) Agachar
   - ( ) Correr
   - ( ) Muito tempo sentada
   - ( ) Ajoelhar
   - ( ) Saltar

2. Qual o lado da sua dor: ( ) D ( ) E ( ) Bilateral

Obs.: Se a sua dor for bilateral, qual lado dói mais? ( ) D ( ) E

3. Há quanto tempo sente esta dor?
( ) Até 3 meses ( ) Até 6 meses ( ) Mais de 6 meses Especifique:_____

4. Qual é o seu membro inferior dominante? ( ) D ( ) E

5. Você pratica alguma atividade física? ( ) Sim ( ) Não
Se sim, qual e com que frequência semanal?_____

6. Você já realizou cirurgias no pé, joelho, quadril ou coluna? ( ) Sim ( ) Não

7. Você apresenta alguma lesão de ligamento(s) e/ou menisco(s)? ( ) Sim ( ) Não

8. Você teve diagnóstico de pé torto congênito ou usou bota para o pé quando criança? ( ) Sim ( ) Não

9. A sua patela sai ou já saiu do lugar em algum momento? ( ) Sim ( ) Não

10. Você possui alguma alteração nervosa periférica ou cardiovascular?( ) Sim( ) Não

11. Qual foi a data de início da sua última menstruação: ____/____/_____.

1. VERSÃO BRASILEIRA DO QUESTIONÁRIO DE QUALIDADE DE VIDA – SF-36

1- Em geral você diria que sua saúde é:

Excelente	Muito Boa	Boa	Ruim	Muito Ruim
1	2	3	4	5

2- Comparada a um ano atrás, como você classificaria sua idade em geral, agora?

Muito Melhor	Um Pouco Melhor	Quase a Mesma	Um Pouco Pior	Muito Pior
1	2	3	4	5

3- Os seguintes itens são sobre atividades que você poderia fazer atualmente durante um dia comum. Devido à sua saúde, você teria dificuldade para fazer estas atividades? Neste caso, quando?

ATIVIDADES	Sim, dificulta muito	Sim, dificulta um pouco	Não, não dificulta de modo algum
a) Atividades Rigorosas, que exigem muito esforço, tais como correr, levantar objetos pesados, participar em esportes árduos.	1	2	3
b) Atividades moderadas, tais como mover uma mesa, passar aspirador de pó, jogar bola, varrer casa.	1	2	3
c) Levantar ou carregar mantimentos.	1	2	3
d) Subir vários lances de escada.	1	2	3
e) Subir um lance de escada.	1	2	3
f) Curvar-se, ajoelhar-se ou dobrar-se.	1	2	3
g) Andar mais de 1 quilômetro.	1	2	3
h) Andar vários quarteirões.	1	2	3
i) Andar um quarteirão.	1	2	3
j) Tomar banho ou vestir-se.	1	2	3

4- Durante as últimas 4 semanas, você teve algum dos seguintes problemas com seu trabalho ou com alguma atividade regular, como consequência de sua saúde física?

	SIM	NÃO
a) Você diminuiu a quantidade de tempo que se dedicava ao seu trabalho ou a outras atividades?	1	2
b) Realizou menos tarefas do que gostaria?	1	2
c) Esteve limitado no seu tipo de trabalho ou outras atividades.	1	2
d) Teve dificuldade de fazer seu trabalho ou outras atividades (p. ex. necessitou de esforço extra).	1	2

5- Durante as últimas 4 semanas, você teve algum dos seguintes problemas com seu trabalho ou outra atividade regular diária, como consequência de algum problema emocional (como se sentir deprimido ou ansioso)?

	SIM	NÃO
a) Você diminuiu a quantidade de tempo que se dedicava ao seu trabalho ou a outras atividades?	1	2
b) Realizou menos tarefas do que você gostaria?	1	2
c) Não realizou ou fez qualquer das atividades com tanto cuidado como geralmente faz.	1	2

6- Durante as últimas 4 semanas, de que maneira sua saúde física ou problemas emocionais interferiram nas suas atividades sociais normais, em relação à família, amigos ou em grupo?

De forma nenhuma	Ligeiramente	Moderadamente	Grave	Muito grave
1	2	3	4	5

7- Quanta dor no corpo você teve durante as últimas 4 semanas?

Nenhuma	Muito leve	Leve	Moderada	Grave	Muito Grave
1	2	3	4	5	6

8- Durante as últimas 4 semanas, quanto a dor interferiu com seu trabalho normal (incluindo o trabalho dentro de casa)?

De maneira alguma	Um pouco	Moderadamente	Bastante	Extremamente
1	2	3	4	5

9- Estas questões são sobre como você se sente e como tudo tem acontecido com você durante as últimas 4 semanas. Para cada questão, por favor, dê a resposta que mais se aproxime da maneira como você se sente, em relação às últimas 4 semanas.

	Todo Tempo	A maior parte do tempo	Uma boa parte do tempo	Alguma parte do tempo	Uma pequena parte do tempo	Nunca
a) Quanto tempo você tem se sentido cheio de vigor, de vontade, de força?	1	2	3	4	5	6
b) Quanto tempo você tem se sentido uma pessoa muito nervosa?	1	2	3	4	5	6
c) Quanto tempo você tem se sentido tão deprimido que nada pode animá-lo?	1	2	3	4	5	6
d) Quanto tempo você tem se sentido calmo ou tranquilo?	1	2	3	4	5	6
e) Quanto tempo você tem se sentido com muita energia?	1	2	3	4	5	6
f) Quanto tempo você tem se sentido desanimado ou abatido?	1	2	3	4	5	6
g) Quanto tempo você tem se sentido esgotado?	1	2	3	4	5	6
h) Quanto tempo você tem se sentido uma pessoa feliz?	1	2	3	4	5	6
i) Quanto tempo você tem se sentido cansado?	1	2	3	4	5	6

10- Durante as últimas 4 semanas, quanto de seu tempo a sua saúde física ou problemas emocionais interferiram com as suas atividades sociais (como visitar amigos, parentes, etc)?

Todo Tempo	A maior parte do tempo	Alguma parte do tempo	Uma pequena parte do tempo	Nenhuma parte do tempo
1	2	3	4	5

11- O quanto verdadeiro ou falso é cada uma das afirmações para você?

	Definitivamente verdadeiro	A maioria das vezes verdadeiro	Não sei	A maioria das vezes falso	Definitivamente falso
a) Eu costumo adoecer um pouco mais facilmente que as outras pessoas.	1	2	3	4	5
b) Eu sou tão saudável quanto qualquer pessoa que eu conheço	1	2	3	4	5
c) Eu acho que minha saúde vai piorar.	1	2	3	4	5
d) Minha saúde é excelente.	1	2	3	4	5

2. QUESTIONÁRIO INTERNACIONAL DE ATIVIDADE FÍSICA – IPAQ - FORMA CURTA

Você trabalha de forma remunerada: ( ) Sim ( ) Não

Quantas horas você trabalha por dia: _____

Quantos anos você estudou completo: _____

De forma geral sua saúde está:

( ) Excelente ( ) Muito boa ( ) Boa ( ) Regular ( ) Ruim

Para responder as questões lembre que:

- Atividades físicas **VIGOROSAS** são aquelas que precisam de um grande esforço físico e que fazem respirar **MUITO** mais forte que o normal.
- Atividades físicas **MODERADAS** são aquelas que precisam de algum esforço físico e que fazem respirar **UM POUCO** mais forte que o normal.

Para responder as perguntas pense somente nas atividades que você realiza **por pelo menos 10 minutos contínuos** de cada vez:

1a. Em quantos dias de uma semana normal, você realiza atividades **VIGOROSAS** por pelo menos 10 minutos contínuos, como por exemplo, correr, fazer ginástica aeróbica, jogar futebol, pedalar rápido na bicicleta, jogar basquete, fazer serviços domésticos pesados em casa, no quintal ou no jardim, carregar pesos elevados ou qualquer atividade que faça você suar **BASTANTE** ou aumentem **MUITO** sua respiração ou batimentos do coração.

_____ dias por **SEMANA** ( ) Nenhum

1b. Nos dias em que você faz essas atividades vigorosas por pelo menos 10 minutos contínuos, quanto tempo no total você gasta fazendo essas atividades **por dia**?

_____horas _____ minutos

2a. Em quantos dias de uma semana normal, você realiza atividades **MODERADAS** por pelo menos 10 minutos contínuos, como por exemplo, pedalar leve na bicicleta, nadar, dançar, fazer ginástica aer6bica leve, jogar vô1ei recreativo, carregar pesos leves, fazer serviços domésticos na casa, no quintal ou no jardim como varrer, aspirar, cuidar do jardim, ou qualquer atividade que faça você suar leve ou aumentem **moderadamente** sua respiração ou batimentos do coração **(POR FAVOR, NÃO INCLUA CAMINHADA)**

_____ dias por **SEMANA** ( ) Nenhum

2b. Nos dias em que você faz essas atividades moderadas por pelo menos 10 minutos contínuos quanto tempo no total você gasta fazendo essas atividades **por dia**?

_____horas _____ minutes

3a. Em quantos dias de uma semana normal você caminha por pelo menos 10 minutos contínuos em casa ou no trabalho, como forma de transporte para ir de um lugar para outro, por lazer, por prazer ou como forma de exercício?

_____ dias por **SEMANA** ( ) Nenhum

3b. Nos dias em que você caminha por pelo menos 10 minutos contínuos quanto tempo no total você gasta caminhando **por dia?**

_____horas _____ minutos

4a. Estas últimas perguntas são em relação ao tempo que você gasta sentado ao todo no trabalho, em casa, na escola ou faculdade e durante o tempo livre. Isto inclui o tempo que você gasta sentado no escrit6rio ou estudando, fazendo lição de casa, visitando amigos, lendo e sentado ou deitado assistindo televisão.

Quanto tempo **por dia** você fica sentado em um dia da semana?

_____horas _____ minutos

4b. Quanto tempo **por dia** você fica sentado no final de semana?

_____horas _____ minutos

3. ESCALA TAMPA DE CINESIOFOBIA

Aqui estão algumas das coisas que outros pacientes nos contaram sobre sua dor. Para cada afirmativa, por favor, indique um número de 1 a 4, caso você concorde ou discorde da afirmativa. Primeiro você vai pensar se concorda ou discorda e depois, se totalmente ou parcialmente.

	DISCORDO TOTALMENTE	DISCORDO PARCIALMENTE	CONCORDO PARCIALMENTE	CONCORDO TOTALMENTE
1. Eu tenho medo que eu possa me machucar se eu fizer exercícios.	1	2	3	4
2. Se eu tentasse superar esse medo, minha dor aumentaria.	1	2	3	4
3. Meu corpo está me dizendo que algo muito errado está acontecendo comigo.	1	2	3	4
4. Minha dor provavelmente seria aliviada se eu fizesse exercício.	1	2	3	4
5. As pessoas não estão levando minha condição médica a sério.	1	2	3	4
6. Minha lesão colocou o meu corpo em risco para o resto da minha vida.	1	2	3	4
7. A dor sempre significa que eu machuquei meu corpo.	1	2	3	4
8. Só porque alguma coisa piora minha dor, não significa que é perigoso.	1	2	3	4
9. Eu tenho medo que eu possa me machucar acidentalmente.	1	2	3	4
10. Simplesmente sendo cuidadoso para não fazer nenhum movimento desnecessário é a atitude mais segura que eu posso tomar para prevenir a piora da minha dor.	1	2	3	4

11. Eu não teria tanta dor se algo potencialmente perigoso não estivesse acontecendo com o meu corpo.	1	2	3	4
12. Embora minha condição seja dolorosa, eu estaria melhor se estivesse fisicamente ativo.	1	2	3	4
13. A dor me avisa quando parar o exercício para que eu não me machuque.	1	2	3	4
14. Não é realmente seguro uma pessoa com minha condição ser ativo fisicamente.	1	2	3	4
15. Eu não posso fazer todas as coisas que as pessoas normais fazem, porque para mim é muito fácil me machucar.	1	2	3	4
16. Embora algo esteja me causando muita dor, eu não acho que seja, de fato, perigoso.	1	2	3	4
17. Ninguém deveria fazer exercícios, quando está com dor.	1	2	3	4

4. ESCALA DE PENSAMENTO CATASTRÓFICO SOBRE A DOR (B-PCS)

Instruções: Listamos 13 declarações que descrevem diferentes pensamentos e sentimentos que podem lhe aparecer na cabeça quando sente dor. Indique o GRAU destes pensamentos e sentimentos quando está com dor.

1. A preocupação durante todo o tempo com a duração da dor é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
2. O sentimento de não poder prosseguir (continuar) é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
3. O sentimento que a dor é terrível e que não var melhorar é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
4. O sentimento que a dor é horrível e que você não vai resistir é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
5. O pensamento de não poder mais estar com alguém é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
6. O medo que a dor pode se tornar pior é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
7. O pensamento sobre outros episódios de dor é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
8. O desejo profundo que a dor desapareça é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
9. O sentimento de não conseguir tirar a dor do pensamento é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
10. O pensamento que ainda poderá doer mais é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
11. O pensamento que a dor é grave porque ela não quer parar é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
12. O pensamento de que não há nada para fazer para diminuir a intensidade da dor é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso
13. A preocupação que alguma coisa ruim pode acontecer por causa da dor é:	0 Mínimo	1 Leve	2 Moderado	3 Intenso	4 Muito Intenso

5. ESCALA DE BECK (BDI)

Este questionário consiste em 21 grupos de afirmações. Depois de ler cuidadosamente cada grupo, faça um círculo em torno do número (0, 1, 2 ou 3) diante da afirmação, em cada grupo, que descreve melhor a maneira como você tem se sentido nesta semana, incluindo hoje. Se várias afirmações num grupo parecerem se aplicar igualmente bem, faça um círculo em cada uma. Tome o cuidado de ler todas as afirmações, em cada grupo, antes de fazer a sua escolha.

1. 0 Não me sinto triste.
1 Eu me sinto triste.
2 Estou sempre triste e não consigo sair disso.
3 Estou tão triste ou infeliz que não consigo suportar.

2. 0 Não estou especialmente desanimado quanto ao futuro.
1 Eu me sinto desanimado quanto ao futuro.
2 Acho que nada tenho a esperar.
3 Acho o futuro sem esperança e tenho a impressão de que as coisas não podem melhorar.

3. 0 Não me sinto um fracassado.
1 Acho que fracassei mais do que uma pessoa comum.
2 Quando olho para trás, na minha vida, tudo o que eu posso ver é um monte de fracassos.
3 Acho que, como pessoa, sou um completo fracasso.

4. 0 Tenho tanto prazer em tudo como antes.
1 Não sinto mais prazer nas coisas como antes.
2 Não encontro um prazer real em mais nada.
3 Estou insatisfeito ou aborrecido com tudo.

5. 0 Não me sinto especialmente culpado.
1 Eu me sinto culpado às vezes.
2 Eu me sinto culpado na maior parte do tempo.
3 Eu me sinto sempre culpado.

6. 0 Não acho que esteja sendo punido.
1 Acho que posso ser punido.
2 Creio que vou ser punido.
3 Acho que estou sendo punido.

7. 0 Não me sinto decepcionado comigo mesmo.
1 Estou decepcionado comigo mesmo.
2 Estou enojado de mim.
3 Eu me odeio.

8. 0 Não me sinto de qualquer modo pior que os outros.
1 Sou crítico em relação a mim devido a minhas fraquezas ou meus erros.
2 Eu me culpo sempre por minhas falhas.
3 Eu me culpo por tudo de mal que acontece.

9. 0 Não tenho quaisquer ideias de me matar.
1 Tenho ideias de me matar, mas não as executaria.
2 Gostaria de me matar.
3 Eu me mataria se tivesse oportunidade.

10. 0 Não choro mais que o habitual.
1 Choro mais agora do que costumava.
2 Agora, choro o tempo todo.
3 Costumava ser capaz de chorar, mas agora não consigo mesmo que o queira.

11. 0 Não sou mais irritado agora do que já fui.
1 Fico molestado ou irritado mais facilmente do que costumava.

2 Atualmente me sinto irritado o tempo todo.
3 Absolutamente não me irrito com as coisas que costumava irritar-me.

12. 0 Não perdi o interesse nas outras pessoas.
1 Interesso-me menos do que costumava pelas outras pessoas.
2 Perdi a maior parte do meu interesse nas outras pessoas.
3 Perdi todo o meu interesse nas outras pessoas.

13. 0 Tomo decisões mais ou menos tão bem como em outra época.
1 Adio minhas decisões mais do que costumava.
2 Tenho maior dificuldade em tomar decisões do que antes.
3 Não consigo mais tomar decisões.

14. 0 Não sinto que minha aparência seja pior do que costumava ser.
1 Preocupo-me por estar parecendo velho ou sem atrativos.
2 Sinto que há mudanças permanentes em minha aparência que me fazem parecer sem atrativos.
3 Considero-me feio.

15. 0 Posso trabalhar mais ou menos tão bem quanto antes.
1 Preciso de um esforço extra para começar qualquer coisa.
2 Tenho de me esforçar muito até fazer qualquer coisa.
3 Não consigo fazer nenhum trabalho.

16. 0 Durmo tão bem quanto de hábito.
1 Não durmo tão bem quanto costumava.
2 Acordo uma ou duas horas mais cedo do que de hábito e tenho dificuldade para voltar a dormir
3 Acordo várias horas mais cedo do que costumava e tenho dificuldade para voltar a dormir.

17. 0 Não fico mais cansado que de hábito.
1 Fico cansado com mais facilidade do que costumava.
2 Sinto-me cansado ao fazer quase qualquer coisa.
3 Estou cansado demais para fazer qualquer coisa.

18. 0 Meu apetite não está pior do que de hábito.
1 Meu apetite não é tão bom quanto costumava ser.
2 Meu apetite está muito pior agora.
3 Não tenho mais nenhum apetite.

19. 0 Não perdi muito peso, se é que perdi algum ultimamente.
1 Perdi mais de 2,5 Kg.
2 Perdi mais de 5,0 Kg.
3 Perdi mais de 7,5 Kg.
Estou deliberadamente tentando perder peso, comendo menos: SIM ( ) NÃO ( )

20. 0 Não me preocupo mais que o de hábito com minha saúde.
1 Preocupo-me com problemas físicos como dores e aflições ou perturbações no estômago ou prisão de ventre.
2 Estou muito preocupado com problemas físicos e é difícil pensar em outra coisa que não isso.
3 Estou tão preocupado com meus problemas físicos que não consigo pensar em outra coisa.

21. 0 Não tenho observado qualquer mudança recente em meu interesse sexual.
1 Estou menos interessado por sexo que costumava.
2 Estou bem menos interessado em sexo atualmente.
3 Perdi completamente o interesse por sexo.

6. ESCALA PARA DOR ANTERIOR DO JOELHO (EDAJ – AKPS)

Em cada questão, circule a letra que melhor descreve os atuais sintomas relacionados ao seu joelho.

1. **Você caminha mancando?**
a. Não (5)
b. Levemente ou de vez em quando (3)
c. Constantemente (0)

2. **O seu joelho suporta o seu peso?**
a. Apóio totalmente, sem dor (5)
b. Apóio, mas sinto dor (3)
c. É impossível suportar o peso (0)

3. **Ao caminhar**
a. Não tenho limites para caminhar (5)
b. Caminho mais que 2 km (3)
c. Caminho entre 1 e 2 km (2)
d. Não consigo (0)

4. **Ao subir / descer escadas**
a. Não tenho dificuldade (10)
b. Sinto um pouco de dor ao desce (8)
c. Sinto dor ao descer e ao subir (5)
d. Não consigo (0)

5. **Ao agachar**
a. Não tenho dificuldade (5)
b. Sinto dor após agachamentos repetidos(4)
c. Sinto dor a cada agachamento (3)
d. Somente agacho com diminuição de meu peso (me apoiando) (2)
e. Não consigo (0)

6. **Ao correr**
a. Não tenho dificuldade (10)
b. Sinto dor após correr mais do que 2 km(8)
c. Sinto dor leve desde o começo (6)
d. Sinto dor intensa (3)
e. Não consigo (0)

7. **Ao pular/saltar**
a. Não tenho dificuldade (10)
b. Tenho um pouco de dificuldade (7)
c. Sinto dor constante (2)
d. Não consigo (0)

8. **Ao sentar com os joelhos flexionados/dobrados por período prolongado**
a. Não tenho dificuldade (10)
b. Sinto dor para me manter sentado após ter realizado exercícios (8)
c. Sinto dor constante (6)
d. A dor faz com que necessite estender (esticar) os joelhos de tempos em tempos(4)
e. Não consigo (0)

9. **Dor**
a. Nenhuma (10)
b. Leve e ocasional (8)
c. A dor atrapalha o sono (6)
d. De vez em quando é intensa (3)
e. Constante e intensa (0)

10. **Inchaço (edema)**
a. Nenhum (10)
b. Após esforço intenso (8)
c. Após atividades diárias (6)
d. Toda noite (0)
e. Constante(5)

11. **Movimentos anormais (subluxação) e doloridos da rótula (patela)**
a. Não ocorre (10)
b. Ocorre ocasionalmente durante atividades esportivas (6)
c. Ocorre ocasionalmente durante atividades diárias (4)
d. Já tive pelo menos um deslocamento (2)
e. Já tive mais que dois deslocamentos (0)

12. **Atrofia da coxa (tamanho da coxa)**
a. Nenhuma alteração do tamanho da coxa (5)
b. Leve alteração do tamanho da coxa (3)
c. Severa alteração do tamanho da coxa (0)

13. **Sente dificuldade para flexionar/dobrar o joelho?**
a. Nenhuma (5)
b. Leve (3)
c. Muita (0)

7. DADOS ANTROPOMÉTRICOS:

- ✓ Altura_____mm
- ✓ Peso_____kg
- ✓ Distância entre as EIAS_____mm

- ✓ Comprimento do membro inferior E_____mm
- ✓ Diâmetro do Joelho E_____mm
- ✓ Diâmetro do TNZ E_____mm

- ✓ Comprimento de membro inferior D_____mm
- ✓ Diâmetro do Joelho D_____mm
- ✓ Diâmetro do TNZ D_____mm

8. AVALIAÇÃO DA DOR <u>NOS ÚLTIMOS 15 DIAS</u>:

Joelho D ( ) **Joelho E ( )**

Obs.: Se a dor for bilateral, especifique e responda o nível de dor de acordo com o que dói mais entre os dois joelhos.

ESCALA DE AVALIAÇÃO NUMÉRICA DA DOR (NPRS)
Eu gostaria que você desse uma nota para sua dor numa escala de 0 a 10, onde 0 seria nenhuma dor, e 10 seria a pior dor possível. Por favor, dê um numero para descrever sua média de dor.

0	1	2	3	4	5	6	7	8	9	10
nenhuma dor										pior dor possível

9. FORÇA MUSCULAR

	DIREITO			**ESQUERDO**		
Abdução do quadril (10° ABD)						
Extensores de quadril (90° FLX joelho)						
RL em DV (90° FLX joelho)						
Extensores de joelho (60° FLX joelho)						

10. ADM DE TORNOZELO

1_____**2**_____**3**_____

11. ÍNDICE DE POSTURA DO PÉ

ÍNDICE DE POSTURA DO PÉ - Foot Posture Index®

Nome do Paciente:

	Fator	Plano	SCORE 1 Date_____ Comment_____		SCORE 2 Date_____ Comment_____		SCORE 3 Date_____ Comment_____	
			E -2 to +2	*D* -2 to +2	*E* -2 to +2	*D* -2 to +2	*E* -2 to +2	-2 to +2
Antepé	Palpação da cabeça do Tálus	*Transverso*						
	Curvas acima e abaixo do maléolo lateral	*Frontal/ transverso*						
	Inversão e Eversão do calcâneo	*Frontal*						
Retropé	Proeminência na regiao de talonavicular	*Transverso*						
	Congruência do arco longitudinal medial	*Sagital*						
	Abução e Adução de Antepé							
	TOTAL							

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Valores de Referência:
Normal= 0 a +5
Pronado= +6 a +9 Excessivamente Pronado = 10+
Supinado= -1 a -4 Excessivamente Supinado = -5 a -12

12. ANÁLISE DO MOVIMENTO

121.1. Coleta Estática

Obs:_____

12.2. Coleta dinâmica – **STEP DOWN LATERAL** (MÍNIMO DE 25 REPETIÇÕES)

ESCALA DE AVALIAÇÃO NUMÉRICA DA DOR (NPRS)
Eu gostaria que você desse uma nota para sua dor numa escala de 0 a 10, onde 0 seria nenhuma dor, e 10 seria a pior dor possível. Por favor, dê um numero para descrever sua média de dor.

0	1	2	3	4	5	6	7	8	9	10
nenhuma dor										pior dor possível

1º Intervalo _____ 2º Intervalo _____ 3º Intervalo _____ 4º Intervalo _____

Obs.:_____

12.3. Coleta dinâmica – **MARCHA** (MÍNIMO DE 25 REPETIÇÕES)

ESCALA DE AVALIAÇÃO NUMÉRICA DA DOR (NPRS)
Eu gostaria que você desse uma nota para sua dor numa escala de 0 a 10, onde 0 seria nenhuma dor, e 10 seria a pior dor possível. Por favor, dê um numero para descrever sua média de dor.

0	1	2	3	4	5	6	7	8	9	10
nenhuma dor										pior dor possível

Obs.:_____

Anexo C – Termo de Consentimento Livre e Esclarecido Estudo 2

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO
UNIVERSIDADE NOVE DE JULHO

Nome:_____ R.G._____

Endereço:_____

Telefone para contato: ( )_____Cidade:_____ CEP:_____

E-mail:_____

As informações contidas neste prontuário foram fornecidas por **Cintia Lopes Ferreira** (Aluna do Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Nove de Julho – UNINOVE) sob orientação do **Prof. Dr. Paulo Roberto Garcia Lucareli**, com objetivo de firmar acordo escrito mediante o qual, a participante da pesquisa autoriza sua participação com pleno conhecimento da natureza dos procedimentos e riscos a que se submeterá, com a capacidade de livre arbítrio e sem qualquer coação.

1. Título do Trabalho Experimental: Análise da sinergia muscular e cinemática tridimensional de mulheres com dor femoropatelar durante o *step down* lateral.

2. Objetivo: Avaliar e comparar a atividade muscular e os movimentos de mulheres com dor femoropatelar (na frente do joelho) e mulheres sem dor durante a execução de um agachamento lateral utilizando uma perna só.

3. Justificativa: Existem muitas controversas na literatura quanto à relação da fraqueza muscular e as alterações dos movimentos do tronco e das pernas de mulheres com dor na frente do joelho. Uma vez que alguns estudos tem mostrado a diminuição da dor e aumento da força muscular após programas de fortalecimento da musculatura do quadril e joelho, porém sem alteração no movimento dos membros inferiores. Podemos sugerir que essas alterações do movimento podem não ter relação com a fraqueza muscular como vem sendo questionado, mas com a forma que a musculatura ativa durante os movimentos. A nossa proposta é avaliar as diferenças na sinergia muscular, ou seja, na forma que os músculos da perna trabalham em conjunto, em mulheres com dor na frente do joelho comparada às mulheres sem dor no joelho. O entendimento das diferenças na sinergia muscular poderá ajudar a traçar melhor o perfil desses pacientes e talvez redirecionar os tratamentos de reabilitação.

4. Procedimentos da Fase Experimental: Serão selecionadas mulheres com e sem dor na frente do joelho, com idade entre 18 e 35 anos para fazer a avaliação do membro inferior durante o agachamento lateral com uma perna só. Depois de incluídas na pesquisa as voluntárias realizarão uma única avaliação distribuída em dois dias diferentes com duração média de 2 horas por dia, com intervalo de pelo menos dois dias e no máximo uma semana entre as avaliações.

No primeiro dia será feita a análise do movimento e da atividade de contração dos músculos do quadril, coxa e perna. Primeiramente será feita a colocação de marcadores em forma de esferas com fita dupla face hipoalérgicas e eletrodos autoadesivos (como os usados em exames de eletrocardiograma) em regiões anatômicas específicas. Posteriormente serão captadas as imagens e atividade muscular durante 10 séries de três agachamentos consecutivos realizados em uma perna só, que serão transferidas para um computador e depois analisadas.

No segundo dia uma avaliação física será realizada, as voluntárias terão que responder sete questionários específicos com total de 13 páginas que avaliarão: 1- a qualidade de vida; 2- o nível de atividade física; 3- o medo em realizar movimentos/exercícios; 4 – pensamentos sobre a dor; 5 – o estado emocional relacionado à depressão; 6 – questões relacionadas à dor no joelho; 7 – intensidade da dor em uma escala de pontuação de 0 a 10. Em seguida a força dos músculos do quadril e joelho, a postura do pé e a amplitude de movimento do tornozelo também serão avaliadas.

5. Desconfortos ou Riscos Esperados: O experimento não trará nenhum risco para a saúde. Entretanto, um leve desconforto poderá ocorrer durante os agachamentos. Caso ocorra qualquer sensação de dor ou desconforto anormal durante os agachamentos a pesquisa será interrompida e a voluntária será encaminhada para avaliação ou tratamento na clínica de fisioterapia da mesma instituição. Havendo qualquer outro tipo de intercorrência, como alergias, sensação de tontura, mal-estar ou até mesmo quedas durante a avaliação a voluntária será encaminhada ao serviço médico mais próximo. As voluntárias não receberão nenhum tipo de seguro de saúde ou de vida que possa beneficiá-las e também não haverá compensação financeira em função da participação no estudo.

6. Métodos Alternativos Existentes: Não serão aplicados.

7. Retirada do Consentimento: A participação nesse estudo será voluntária e é direito de cada participante interromper a participação a qualquer momento sem que isso acarrete qualquer penalidade ou prejuízo.

8. Garantia do Sigilo: A identidade das voluntárias não será revelada. As informações obtidas e as análises deste estudo serão mantidas em sigilo e não poderão ser consultadas por pessoas leigas sem autorização oficial. Estas informações só poderão ser utilizadas para fins estatísticos ou científicos, desde que fique preservada a identidade de cada voluntária. Em qualquer etapa do estudo, as participantes terão acesso aos profissionais responsáveis pela pesquisa para esclarecimento de eventuais dúvidas.

9. Formas de Ressarcimento das Despesas Decorrentes da Participação na Pesquisa: Serão ressarcidas despesas com eventuais deslocamentos, caso necessário.

10. Local da Pesquisa: Núcleo de Apoio à Pesquisa em Análise de Movimento do Programa de Pós-Graduação em Ciências da Reabilitação da Universidade

Nove de Julho – UNINOVE, campus Vila Maria – Rua Professora Maria José Barone Fernandes, 300.

11. Comitê de Ética em Pesquisa (CEP) é um colegiado interdisciplinar e independente, que deve existir nas instituições que realizam pesquisas envolvendo seres humanos no Brasil, criado para defender os interesses dos participantes de pesquisas em sua integridade e dignidade e para contribuir no desenvolvimento das pesquisas dentro dos padrões éticos (Normas e Diretrizes Regulamentadoras da Pesquisa envolvendo Seres Humanos – Res. CNS nº 466/12). O Comitê de Ética é responsável pela avaliação e acompanhamento dos protocolos de pesquisa no que corresponde aos aspectos éticos. **Endereço do Comitê de Ética da Uninove:** Rua. Vergueiro nº 235/249 – 12º andar - Liberdade – São Paulo – SP CEP. 01504-001 Fone: 3385-9010 comitedeetica@uninove.br

Horários de atendimento do Comitê de Ética: segunda-feira a sexta-feira – Das 11h30 às 13h00 e Das 15h30 às 19h00.

12. Nome Completo e telefones dos Pesquisadores para Contato: Prof. Dr. Paulo R. G. Lucareli (11) 26339300 e Cintia Lopes Ferreira (11) 37218231.

13. Eventuais intercorrências que vierem a surgir no decorrer da pesquisa poderão ser discutidas pelos meios próprios.

14. Consentimento Pós-Informação:

Eu, _____, após leitura e compreensão deste termo de informação e consentimento, entendo que minha participação é voluntária, e que posso sair a qualquer momento do estudo, sem prejuízo algum. Confirmo que recebi uma via deste termo de consentimento, e autorizo a realização do trabalho de pesquisa e a divulgação dos dados obtidos somente neste estudo no meio científico.

São Paulo, de de 201 ___.

_____

Assinatura da Voluntária

15. Eu, Cintia Lopes Ferreira, certifico que:

a) Considerando que a ética em pesquisa implica o respeito pela dignidade humana e a proteção devida aos participantes das pesquisas científicas envolvendo seres humanos;

b) Este estudo tem mérito científico e a equipe de profissionais devidamente citados neste termo é treinada, capacitada e competente para executar os procedimentos descritos neste termo;

c) A resolução CNS nº 466/12 dispõe sobre as normas aplicáveis a pesquisas em Ciências Humanas e Sociais, cujo procedimentos metodológicos envolvam a utilização de dados diretamente obtidos com os participantes.

_____

CINTIA LOPES FERREIRA

Assinatura do Pesquisador Responsável