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Rayane Quintão Castro

Efeitos das estratégias de retreinamento de marcha em desfechos clínicos e biomecânicos em indivíduos com osteoartrite de joelhos: uma revisão sistemática com metanálise e recomendações GRADE

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Dissertação apresentada ao Programa de Pós-graduação em Ciências da Reabilitação e Desempenho Físico Funcional da Universidade Federal de Juiz de Fora como requisito parcial à obtenção do título de Mestre em Ciências da Reabilitação e Desempenho Físico-Funcional. Área de concentração: Desempenho e Reabilitação em diferentes condições de saúde

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Àqueles que sofrem diariamente com as dores geradas pela osteoartrite! Que este trabalho leve, direta e indiretamente, alívio e conforto para a vida de vocês.

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RESUMO

A osteoartrite de joelhos gera dor e incapacidade mundialmente. A alta prevalência da doença associada às suas repercussões instiga o estudo de estratégias que gerem alívio dos sintomas e redução da velocidade de progressão da doença. Considerando tais aspectos, o presente trabalho possui dois objetivos: 1) revisar sistematicamente a literatura no que diz respeito às estratégias neuromusculares de retreinamento de marcha aplicadas a indivíduos com osteoartrite de joelhos e seus efeitos sobre desfechos biomecânicos e clínicos; 2) apresentar o protocolo de um ensaio clínico que objetivará comparar o efeito do retreinamento de marcha associado ao fortalecimento da musculatura de joelho e quadril, sobre dor, função auto relatada, torque muscular e parâmetros espaço-temporais e cinemáticos da marcha de indivíduos com osteoartrite de joelhos. No que se refere à revisão sistemática com metanálise, foram identificadas diferentes estratégias de retreinamento, como marcha retrógrada, marcha em *toe-out* e uso de abordagens livres. A metanálise revelou uma diferença estatisticamente significante com evidências de alta qualidade favorecendo o retreinamento da marcha para dor (MD = -1,22; IC 95%: [-1,48; - 0,96]; I2 = 14%; *P* = 0,32) e função (DMP = -0,82; IC 95%: [-1,24; -0,41]; I^2 = 22%; *P* = 0,28). Foi observada diferença estatisticamente significante também favorável ao retreinamento da marcha para o primeiro momento adutor do joelho (MD = -0,20; IC 95%: [-0,38; -0,02]; I^2 = 84%; P < 0,01). As comparações indicaram semelhança entre os grupos para o segundo momento adutor do joelho (MD = −0,16; IC 95%: [−0,47; 0,16]; I^2 = 79%; P = 0,03) e para o momento flexor do joelho (MD = 0,07; 95). IC %: [-0,07; 0,20]; I^2 = 76%; P = 0,02). O segundo trabalho, por se tratar de um protocolo de ensaio clínico ainda não possui resultados que demonstrem benefícios de uma estratégia em detrimento de outra. Contudo, até o momento, sabe-se que o protocolo fornece uma descrição detalhada de todos os procedimentos que serão realizados, permitindo a replicação dos métodos em diferentes populações. Por fim, é relevante salientar que ambos os trabalhos preenchem lacunas no que diz respeito ao processo de cuidado de indivíduos com osteoartrite de joelhos. Ainda cabe enfatizar que se complementam, uma vez que a definição dos parâmetros utilizados no retreinamento de marcha e descritos no protocolo advém, em parte, dos achados da revisão sistemática.

Palavras-chave: Osteoartrite de Joelho. Marcha. Treinamento de Força.

ABSTRACT

The knee osteoarthritis induces pain and disability globally. The high prevalence of the disease coupled with its repercussions prompts the investigation of strategies that offer relief of symptoms and slow down the disease progression. Considering these aspects, the present study has two objectives: 1) to systematically review the literature regarding neuromuscular gait retraining strategies applied to individuals with knee osteoarthritis and their effects on biomechanical and clinical outcomes; 2) to present the protocol of a clinical trial that aims to compare the effect of gait retraining associated with knee and hip muscle strengthening on pain, self-reported function, muscle torque, and spatiotemporal and kinematic parameters of gait in individuals with knee osteoarthritis. In the systematic review with meta-analysis, different retraining strategies such as retrograde gait, toe-out gait, and free approaches were identified. The meta-analysis revealed a statistically significant difference with high-quality evidence favoring gait retraining for pain (MD = -1.22; 95% CI: [-1.48; -0.96]; I^2 = 14%; *P* = 0.32) and function (DMP = -0.82; 95% CI: [-1.24; -0.41]; I^2 = 22%; *P* = 0.28). A statistically significant difference was also observed favoring gait retraining for the first knee adductor moment (MD = -0.20; 95% CI: [-0.38; -0.02]; I^2 = 84%; P < 0.01). Comparisons indicated similarity between groups for the second knee adductor moment (MD = −0.16; 95% CI: [−0.47; 0.16]; I^2 = 79%; P = 0.03) and the knee flexion moment (MD = 0.07; 95% CI: [-0.07; 0.20]; I^2 = 76%; P = 0.02). The second article, being a clinical trial protocol, does not yet have results demonstrating the benefits of one strategy over another or similarity between control and intervention groups. However, it is known at this point that the protocol provides a detailed description of all procedures to be performed, enabling method replication in different populations. Finally, it is relevant to emphasize that both works fill gaps concerning the care process for individuals with knee osteoarthritis. It is noteworthy that they complement each other, as the definition of parameters used in gait retraining and described in the protocol partly stems from the findings of the systematic review.

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1 INTRODUÇÃO

A osteoartrite de joelho é uma condição de prevalência mundial (ALLEN; THOMA; GOLIGHTLY, 2022) e resulta em dor persistente, rigidez, fraqueza muscular e incapacidade (BOEKESTEIJN et al., 2021; DUFFEL et al., 2017). Além disto, gera alterações na cinemática da marcha, dificultando e tornando insegura a execução de tarefas diárias, como as travessias de ruas (BOEKESTEIJN et al., 2022; ESRAFILIAN et al., 2012). A severidade e a progressão da osteoartrite de joelho estão associadas ao aumento do momento adutor do joelho e da fraqueza dos músculos extensores de joelho e extensores-abdutores de quadril (BENNELL et al., 2013; CULVENOR et al., 2016; THOMAS et al., 2022). Sendo assim, estratégias que visam reduzir a gravidade e frear a progressão da condição podem ter extensa aplicabilidade no tratamento de pessoas com osteoartrite de joelho.

O retreinamento de marcha é uma abordagem conservadora utilizada para reduzir a sobrecarga sobre os compartimentos tibiofemorais (ANDRIACCHI; MUNDERMANN, 2006). O retreinamento de marcha pode ser realizado pela adoção de 14 diferentes estratégias (BOWD et al., 2019), dentre elas a modificação da progressão dos pés, a inclinação ipsilateral de tronco ou a medialização do joelho (SIMIC et al., 2011). A mudança de progressão dos pés realizada pelo posicionamento dos pés em *toe-in* ou *toe-out* melhora os sintomas, reduz o momento adutor de joelho e não aumenta as sobrecargas sobre o quadril de sujeitos com osteoartrite de joelhos (CHEUNG et al., 2018; SEAGERS et al., 2022).

Uma revisão sistemática de 2022 incluiu 17 trabalhos sobre retreinamento de marcha em osteoartrite de joelho. Os resultados sinalizaram que o retreinamento de marcha com ferramenta de *biofeedback* em tempo real é efetivo para modificar a biomecânica da marcha e a função auto-relatada dos participantes (RYNNE et al., 2022). Contudo, a revisão incluiu não apenas estratégias neuromusculares de retreinamento de marcha como também ferramentas e dispositivos de modificação de marcha. Outra revisão sistemática publicada em 2022 evidenciou que o retreinamento em *toe-in*, *toe-out* e inclinação de tronco ipsilateral reduziu a carga articular dos joelhos de indivíduos com osteoartrite de joelhos (SILVA et al., 2022). No entanto, os autores deste estudo incluíram diferentes tipos de estudos e não investigaram os efeitos clínicos gerados pela abordagem.

Diante do exposto, um dos objetivos do presente trabalho foi revisar a literatura no que diz respeito às estratégias neuromusculares de retreinamento de marcha aplicadas a indivíduos com osteoartrite de joelhos e seus efeitos sobre desfechos biomecânicos e clínicos. Estratégias de retreinamento de marcha podem influenciar a dor, a função e o primeiro momento adutor do joelho. Contudo, é necessário considerar os seguintes aspectos: a fraqueza muscular é importante fator de risco para o desenvolvimento da osteoartrite e está associada à severidade e progressão da condição (CULVENOR et al., 2016; ØIESTAD et al., 2022); os benefícios dos exercícios sobre os indivíduos com osteoartrite estão claros desde 2010 (VERHAGEN et al., 2019); as principais organizações de estudo da osteoartrite recomendam os exercícios terapêuticos como abordagem central de tratamento (BANNURU et al., 2019; FERNANDES et al., 2013); apesar de todos estes benefícios, os exercícios não melhoram os aspectos biomecânicos e clínicos simultaneamente (COTTMEYER et al., 2023).

Fica evidente, portanto, que os exercícios terapêuticos constituem uma importante abordagem de tratamento conservador da osteoartrite de joelho e que o retreinamento de marcha pode ser uma estratégia promissora na melhora dos desfechos biomecânicos da marcha. No entanto, não foram encontradas evidências científicas de qualidade que associassem o retreinamento de marcha a um programa bem estruturado de fortalecimento muscular. Dessa forma, o segundo objetivo do presente trabalho foi apresentar o protocolo de um ensaio clínico que objetivará comparar o efeito do retreinamento de marcha em *toe-out* associado ao fortalecimento da musculatura de joelho e quadril, sobre dor, função autorrelatada, torque muscular e parâmetros espaço-temporais e cinemáticos da marcha de indivíduos com osteoartrite de joelhos.

2 FUNDAMENTAÇÃO TEÓRICA

2.1 ASPECTOS ANATÔMICOS E BIOMECÂNICOS DA ARTICULAÇÃO DO JOELHO

O complexo articular do joelho tem como principal função alterar o comprimento do membro inferior (OATIS, 2014). Além disso, o joelho atua na sustentação de peso, o que requer equilíbrio entre a estabilidade necessária para tal e a mobilidade imprescindível para a locomoção (OATIS, 2014). A estabilidade e a mobilidade do joelho se dão pela combinação da ação entre os ligamentos, as forças musculares, as aponeuroses meniscocapsulares, assim como a topografia óssea e a carga articular (FLANDRY; HOMMEL, 2011). Além disso, o deslizamento e a rotação de uma estrutura óssea sobre a outra só é indolor e possível devido à presença de cartilagem hialina (VAIENTI et al., 2017).

O joelho é formado pela porção distal do fêmur, pela patela e pela porção proximal da tíbia e compreende as articulações tibiofemoral e patelofemoral (FLANDRY; HOMMEL, 2011). A articulação tibiofemoral tem sido classificada como uma articulação gínglimo modificada, uma vez que possui características de articulações do tipo gínglimo e pivô (OATIS, 2014). Já a articulação patelofemoral é deslizante (OATIS, 2014) e referida comumente como um importante mecanismo extensor do joelho (FLANDRY; HOMMEL, 2011).

Além das estruturas ósseas, o complexo articular do joelho conta com a cápsula articular, os meniscos e os ligamentos. A cápsula articular fibrosa envolve os compartimentos medial e lateral das articulações tibiofemoral e patelofemoral e recebe reforço significativo de músculos, ligamentos e fáscias (NEUMANN, 2018). Os meniscos são discos fibrocartilaginosos (OATIS, 2014) localizados entre os côndilos femorais e os platôs tibiais (VAIENTI et al., 2017) e responsáveis por absorver cargas, atuar como área de contato, orientar a rotação e estabilizar a translação do joelho (FLANDRY; HOMMEL, 2011). Dessa forma, são estruturas fundamentais para minimizar o estresse sobre a articulação tibiofemoral (OATIS, 2014). Os ligamentos, por sua vez, limitam movimentos excessivos. Assim, os ligamentos colaterais limitam os movimentos excessivos no plano frontal, ao passo que os ligamentos cruzados resistem, principalmente, às forças de cisalhamento (translação) anteroposterior entre a tíbia e o fêmur (NEUMANN, 2018; VAIENTI et al., 2017).

Os músculos que agem sobre os joelhos são descritos como dois grandes grupos: os extensores de joelho e os flexores-rotadores do joelho (NEUMANN, 2018). Os extensores de joelho compreendem o músculo quadríceps que, ao se contrair isométrica, excêntrica ou concentricamente, permite diversas funções dos membros inferiores, como sentar-se e levantar-se, subir e descer degraus ou ainda saltar (NEUMANN, 2018). A força dos músculos extensores de joelho tem correlação positiva com a função dos indivíduos, assim como a debilidade muscular está associada a um desempenho deficiente em atividades diárias (OATIS, 2014). Os músculos flexores-rotadores incluem os isquiossurais, o sartório, o grácil e o poplíteo, e são indispensáveis em atividades que exigem o acelerar ou desacelerar a perna durante a fase de balanço na marcha ou na corrida. As especificidades desses músculos variam a depender do segmento que se movimenta sobre o outro (tíbia sobre fêmur ou fêmur sobre tíbia) (NEUMANN, 2018).

O complexo articular do joelho é submetido a forças tanto durante a marcha quanto em ortostatismo (VAIENTI et al., 2017). Durante a marcha, o joelho suporta as cargas desenvolvidas no choque de calcanhar e fornece as forças necessárias para vencer a inércia da perna durante a fase de balanço. Estima-se que as forças máximas sobre o joelho na marcha correspondam a 3 a 7 vezes o peso corporal. Essas forças são maiores no início da deambulação e estão associadas à atividade máxima do quadríceps (VAIENTI et al., 2017). Em uma condição ótima durante o ortostatismo, a distribuição de força se dá de forma uniforme quando os eixos mecânico (linha traçada entre cabeça femoral e tornozelo que passa pelo centro do joelho) e anatômico (projeta-se ao longo do corpo do fêmur) se encontram nos limites de normalidade. As angulações entre 170 e 175º (NEUMANN, 2018) ou de 172 a 177º (VAIENTI et al., 2017) correspondem ao valgo fisiológico. O aumento desse ângulo leva à conformação de joelho em varo, o que culmina na medialização do eixo mecânico e aumento do estresse por unidade de área (VAIENTI et al., 2017).

Cargas excessivas no complexo articular do joelho podem contribuir para o aumento dos sintomas e para a progressão da osteoartrite de joelho, visto que geram um desequilíbrio entre os danos e os reparos articulares (FARROKHI et al., 2013). Diante da impossibilidade de mensurar tais cargas, utiliza-se o momento adutor externo do joelho para estimá-las. O momento adutor externo do joelho é calculado pelo produto da força de reação ao solo e da distância entre o centro de rotação do joelho e a projeção da força de reação do solo (FARROKHI et al., 2013). A severidade e a progressão da condição estão associadas a um maior momento adutor externo do joelho. Este, por sua vez, é maior quando os indivíduos apresentam joelho em varo e/ou queda pélvica contralateral ao lado em fase de apoio e tem sido utilizado como medida de desfecho de estratégias de tratamento conservadoras para osteoartrite de joelho (FARROKHI et al., 2013).

Contudo, embora muitos trabalhos mencionem o momento adutor externo do joelho, o momento flexor externo do joelho também tem sido correlacionado com as forças de contato do joelho (ZEIGHAMI; DUMAS; AISSAOUI, 2021). Diferentemente do momento adutor externo do joelho, o momento flexor tem maior correlação com as forças de contato da região lateral do joelho. Tal diferença reflete a influência dos planos de movimento (frontal – momento adutor e sagital – momento flexor) na geração de forças de contato no joelho (ZEIGHAMI; DUMAS; AISSAOUI, 2021). No entanto, o momento flexor externo de joelho não tem mostrado relação com as medidas de desfecho de progressão da osteoartrite de joelho (CHANG et al., 2015). Assim, a magnitude de interferência do momento flexor externo de joelho sobre a condição ainda é incerta (BENNELL et al., 2013).

2.2 OSTEOARTRITE

A osteoartrite é uma doença de articulações móveis (KLOPPENBURG; BERENBAUM, 2020). Há alguns anos, a condição era conhecida como uma doença resultante de um desgaste articular puramente mecânico (GLYN-JONES et al., 2015). No entanto, atualmente, a osteoartrite é compreendida como uma condição multifatorial, decorrente da interação entre componentes genéticos, biológicos (fatores inflamatórios e metabólicos) e biomecânicos (carga excessiva ou menos frequente, regiões de contato mal posicionadas e/ou carga muscular alterada) (ABRAMOFF; CALDERA, 2020; GLYN-JONES et al., 2015; ZEIGHAMI; DUMAS; AISSAOUI, 2021). Por se tratar de uma condição complexa, as cartilagens articulares não são as únicas estruturas afetadas. Os músculos, os ligamentos, os tendões e as cápsulas articulares são estruturas também comprometidas (RAPOSO; RAMOS; LÚCIA CRUZ, 2021).

Aproximadamente 528 milhões de pessoas no mundo são afetadas por osteoartrite o que corresponde a 19 milhões de anos vividos com incapacidade (WORLD HEALTH ORGANIZATION, 2022). As articulações mais frequentemente acometidas são joelhos e quadris (KLOPPENBURG; BERENBAUM, 2020). A osteoartrite de joelho afeta de 10 a 30% dos idosos (PALAZZO et al., 2014), coexiste nas articulações patelofemoral e tibiofemoral em 40% destes idosos (WING et al., 2018), gerando dor, rigidez, disfunção na marcha e limitação funcional (BOEKESTEIJN et al., 2022; DUFFEL et al., 2017; HART et al., 2021; RYNNE et al., 2022). O tratamento medicamentoso, cirúrgico e/ou conservador dessa condição tem custos anuais aproximados de $16,5 bilhões nos Estados Unidos e $3,5 bilhões na Austrália (HAWKER, 2019; TORIO; MOORE, 2022).

O diagnóstico da osteoartrite pode ser clínico e radiográfico (ALTMAN et al., 1986). O diagnóstico clínico considera informações da história e do exame físico do indivíduo (ALTMAN et al., 1986). Atualmente, o critério diagnóstico mais utilizado é o recomendado pelo Colégio Americano de Reumatologia, em que o indivíduo deve apresentar dor no joelho associada a pelo menos três dos seguintes fatores: 50 anos ou mais, rigidez matinal por tempo inferior a 30 minutos, crepitação à movimentação do joelho, sensibilidade à compressão, alargamento ósseo e/ou ausência de aumento de temperatura local (ALTMAN et al., 1986). A escala de pontuação de Kellgren e Lawrence é o método mais comumente utilizado para classificar a osteoartrite de acordo com os exames radiográficos. Por esta escala, o indivíduo recebe uma classificação de 0 (sem osteoartrite) a 4 (osteoartrite bem estabelecida e avançada) (KOHN; SASSOON; FERNANDO, 2016).

2.3 ALTERAÇÕES DE MARCHA NA OSTEOARTRITE DE JOELHO

As propriedades biomecânicas da marcha podem ser significativamente alteradas por condições musculoesqueléticas (ZHANG et al., 2020). Indivíduos com osteoartrite de joelho apresentam alterações dos parâmetros espaço-temporais e da cinemática da marcha comparados a indivíduos sem esta condição. Dentre tais alterações, destacam-se menor velocidade de marcha, maior duração da passada, menor comprimento da passada e menor cadência (BOEKESTEIJN et al., 2022; ISMAILIDIS et al., 2021). No que se refere aos parâmetros cinemáticos, Ismailidis et al. (2021) identificaram menor pico de flexão de joelho durante as fases de apoio e de balanço do membro acometido comparado ao membro sem osteoartrite de joelho em indivíduos com osteoartrite de joelho unilateral, além de menor amplitude de movimento de joelho durante as fases de resposta à carga e balanço de indivíduos com osteoartrite de joelho comparados a indivíduos saudáveis (ISMAILIDIS et al., 2021).

Outras alterações cinemáticas na marcha de indivíduos com osteoartrite também têm sido identificadas. Boekesteijn et al. (2022) observaram menor amplitude de movimento de flexão de joelho na fase de balanço, menor amplitude de dorsiflexão no contato inicial, menor plantiflexão no pré-balanço e menor amplitude pélvica no plano coronal. Tais alterações precisam ser consideradas à luz das possíveis repercussões que podem gerar. A principal função do joelho na fase de balanço, por exemplo, é auxiliar na flexo-extensão para liberar os dedos do pé, posicioná-lo e assumir a carga do próximo passo (ZHANG et al., 2020). A dorsiflexão e plantiflexão de tornozelo, por sua vez, são importantes mecanismos de preparo da articulação para aceitar as forças de compressão (NEUMANN, 2018).

No entanto, a análise dos parâmetros cinemáticos da marcha não deve ser considerada de forma isolada. Os parâmetros espaço-temporais, como a velocidade, influenciam a biomecânica do joelho. Alterações cinemáticas em indivíduos com osteoartrite de joelho comparados a indivíduos sem esta condição podem ser resultantes de uma menor velocidade de marcha (ISMAILIDIS et al., 2020) ou ainda da combinação dos danos gerados pela osteoartrite e da redução de velocidade de marcha (BOEKESTEIJN et al., 2022). Isso porque a velocidade de marcha está relacionada positivamente à força de contato medial do joelho em indivíduos com osteoartrite de joelho (ZEIGHAMI; DUMAS; AISSAOUI, 2021).

2.4 TRATAMENTO CONSERVADOR

A educação em dor para o paciente, a prática regular de exercícios físicos e a perda de peso corporal são os pilares do tratamento não farmacológico da osteoartrite de joelho (GAY et al., 2016). As recomendações ainda incluem joelheiras, muletas ou andadores, ou outras tecnologias assistivas para aqueles pacientes com níveis elevados de dor e/ou grandes repercussões na marcha (DANTAS; SALVINI; MCALINDON, 2021). Outras estratégias, como os recursos eletrotermofototerapêuticos (termoterapia, laserterapia, estimulação elétrica), terapia manual, bandagem e acupuntura são complementares às estratégias de primeira linha, diante da ausência de evidência ou do baixo nível de evidências para suportar o uso em todos os indivíduos com osteoartrite de joelho (DANTAS; SALVINI; MCALINDON, 2021).

2.4.1 Educação em dor

A educação em saúde é um processo contínuo de treinamento do paciente para que o mesmo desenvolva habilidades de gerenciamento da sua condição de saúde (WORLD HEALTH ORGANIZATION, 1998). Consiste em diferentes formas de comunicação que objetivam aumentar o conhecimento do paciente sobre a condição de saúde, mecanismo de ação e efeitos colaterais dos medicamentos, estratégias de proteção articular, estabelecimento de metas e desenvolvimento de auto eficácia (SINATTI et al., 2022; WORLD HEALTH ORGANIZATION, 1998). Trata-se de um recurso especialmente importante no manejo de condições crônicas, como a osteoartrite de joelho, uma vez que a cronicidade exige disciplina, constância e adesão aos programas de tratamento com exercício físico a longo prazo. A educação tem, portanto, um papel indispensável na melhora da adesão dos pacientes ao tratamento conservador (GAY et al., 2016). Isso porque os protocolos de exercícios, por exemplo, são subutilizados por indivíduos com osteoartrite de joelhos (DANTAS; SALVINI; MCALINDON, 2021). Dentre os fatores envolvidos nesta subutilização, destacam-se as crenças dos indivíduos, as barreiras socioeconômicas, o medo do movimento, a falta de confiança e a ausência de tempo para inserção da rotina de exercícios no dia-a-dia (DANTAS; SALVINI; MCALINDON, 2021).

Além de influenciar na adesão ao tratamento, a educação do paciente com osteoartrite de joelho tem papel fundamental na desconstrução de crenças limitantes responsáveis por gerar um estilo de vida restrito (DANTAS; SALVINI; MCALINDON, 2021). Um consenso internacional identificou 21 frases-chave sobre aspectos importantes que pacientes com osteoartrite de quadril e joelho devem conhecer. Dentre as frases estão: "Atividade física regular e programas de exercícios individualizados podem reduzir a sua dor, prevenir a progressão da osteoartrite e melhorar a sua função", "Se você tem sobrepeso e osteoartrite, será interessante perder peso e manter um peso saudável por meio de um plano individualizado de mudanças alimentares e aumento de atividade física" e "Seus sintomas de osteoartrite podem, geralmente, ser aliviados significativamente sem a necessidade de um procedimento cirúrgico" (FRENCH et al., 2015).

A educação do paciente maximiza os efeitos do treinamento com exercícios, reduz a dor e melhora a função em indivíduos com osteoartrite de joelho (BANNURU et al., 2019; GAY et al., 2016; SINATTI et al., 2022; VAN DOORMAAL et al., 2020).Uma das ferramentas utilizadas para este fim é o programa *Physiotherapy Exercise and Physical Activity for Knee Osteoarthritis* (PEAK), que consiste em estratégias de atendimento a pessoas com osteoartrite de joelho. O programa possui materiais com orientações de exercícios domiciliares de alongamento e fortalecimento muscular, assim como técnicas de empoderamento do paciente por meio da educação (JONES et al., 2021).

2.4.2 Retreinamento de marcha e estratégias de *feedback*

O retreinamento de marcha visa aperfeiçoar componentes específicos da função mediante a modificação das variáveis espaço-temporais, cinemáticas ou da carga articular (CHARLTON et al., 2021). Na osteoartrite de joelhos, o retreinamento de marcha tem sido aplicado visando à redução das cargas articulares, principalmente do compartimento medial do joelho. No entanto, como não é possível mensurar essas cargas *in vivo*, utiliza-se o momento adutor externo do joelho como medida de desfecho (FARROKHI et al., 2013). Assim, menores valores do momento adutor externo do joelho (fornecidas pela redução da força de reação ao solo ou pela redução da distância entre o centro de rotação do joelho e a projeção da força de reação ao solo) contribuem para a redução de sobrecarga articular (FARROKHI et al., 2013). O retreinamento de marcha pode ser realizado pela adoção de 14 diferentes estratégias (BOWD et al., 2019), dentre as quais destacam-se a modificação da progressão dos pés, a inclinação do tronco e a medialização do joelho (SIMIC et al., 2011). Ressalta-se ainda que o uso de estratégias de *feedback*, como o *feedback* visual podem otimizar o treino, melhorando o programa de reabilitação e superando as dificuldades de se ajustar o padrão de marcha do indivíduo com osteoartrite de joelho (VAN DEN NOORT et al., 2015).

2.4.3 Fortalecimento muscular

A capacidade do músculo em produzir trabalho é definida como o desempenho muscular, que compreende a capacidade de gerar força, de gerar potência e de resistir à fadiga (KISNER; COLBY; BORSTAD, 2021). A presença de comprometimentos no desempenho muscular requer a prescrição de um elemento essencial dos programas de reabilitação: exercícios resistidos (KISNER; COLBY; BORSTAD, 2021). Os exercícios resistidos geram adaptações fisiológicas, sejam neurais e/ou do músculo esquelético, capazes de aumentar a capacidade máxima de produção de força do músculo (KISNER; COLBY; BORSTAD, 2021). Além disso, os programas de exercícios são estratégias seguras, efetivas e fortemente recomendadas para o tratamento de osteoartrite de joelho (KISNER; COLBY; BORSTAD, 2021; KOLASINSKI et al., 2020; RAPOSO; RAMOS; LÚCIA CRUZ, 2021).

Comprometimentos da função muscular, que inclui força, ativação e propriocepção dos músculos são comuns entre os indivíduos com osteoartrite de joelho (BENNELL et al., 2013). O treino resistido prescrito com doses adequadas aumenta a massa muscular e/ou o recrutamento de fibras musculares (FRANSEN et al., 2015). O aumento da força dos extensores de joelho e dos abdutores de quadril reduz os níveis de dor e aumenta a função física dos sujeitos (DEVITA et al., 2018; NEELAPALA; BHAGAT; SHAH, 2020; THOMAS et al., 2022). Não apenas, o fortalecimento muscular altera a biomecânica e resulta em menores taxas de sobrecarga articular ou menor estresse sobre a cartilagem articular do joelho. O exercício pode prevenir a degeneração de cartilagem, inibir a inflamação, e prevenir a perda de osso subcondral e das trabéculas ósseas das metáfises (MARRIOTT; BIRMINGHAM, 2023; PUTS et al., 2023; ZENG et al., 2021). Consequentemente, o treino de força tem papel crucial no retardo do desenvolvimento da osteoartrite de joelho, assim como na redução da velocidade de progressão da condição (BANNURU et al., 2019; ØIESTAD et al., 2022).

Uma revisão sistemática publicada em 2021 evidenciou que os programas de exercícios mais comumente utilizados no tratamento conservador da osteoartrite de joelho são realizados por 8 a 12 semanas, por 3 a 5 sessões semanais, com duração de até 1 hora

(RAPOSO; RAMOS; LÚCIA CRUZ, 2021). A diretriz holandesa de prática clínica publicada em 2020 ainda reforça os parâmetros para assegurar uma prescrição de treino de força, sendo 60%–80% de 1 repetição máxima (escala Borg, 14–17), com 2 a 4 séries de 8 a 15 repetições e intervalo entre as séries de 30 a 60 segundos (VAN DOORMAAL et al., 2020). Além disso, estudos recentes têm demonstrado que tanto os exercícios resistidos específicos para o quadríceps, como exercícios para todo o membro inferior são efetivos na redução de dor e melhora da função (FERNANDES et al., 2013; NEELAPALA; BHAGAT; SHAH, 2020).

3 MÉTODOS E RESULTADOS

A seguir estão dispostos os dois artigos científicos que são os produtos deste trabalho. O primeiro corresponde à revisão sistemática e o segundo corresponde ao protocolo de ensaio clínico com suas respectivas imagens, tabelas e materiais complementares.

3.1 Revisão Sistemática

Effect of gait retraining strategies on clinical and biomechanical outcomes in subjects with knee osteoarthritis: a systematic review with meta-analysis and GRADE recommendations

ABSTRACT

Background: Gait retraining has been considered as a promising approach to knee osteoarthritis patients. While prior studies indicate that such strategies effectively alter biomechanical variables, there remains a gap in assessing their tangible clinical impact. **Research question:** To assess the effects of gait retraining strategies on clinical and/or biomechanical variables in knee osteoarthritis individuals. **Methods:** This study was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered in PROSPERO (CRD42023402778). Studies were searched from Cochrane Library, PubMed Central, Embase, Medline (OVID), Scopus, Web of Science and Scielo databases up to March 2023. PEDro scale and GRADE approach were used to assess methodological quality and certainty of evidence, respectively. A meta-analysis was conducted using R software. **Results:** The included studies employed diverse strategies, including backward walking/retrowalking (4), toe-out (1), and freely strategies (2). The meta-analysis revealed a significant statisticaly difference with high quality of the evidence favoring gait retraining for pain (MD = -1.22; 95% CI: [-1.48; - 0.96]; I^2 = 14%; P = 0.32) and function analysis (SMD = -0.82; 95% CI: [-1.24; -0.41]; I^2 = 22%; P = 0.28). A statistically significant difference also favoring the gait retraining was observed for the first knee adduction moment (MD = -0.20; 95% CI: [-0.38; -0.02]; I^2 = 84%; P < 0.01). The comparisons indicated similarity between groups for the second knee adduction moment (MD = −0.16; 95% CI: [−0.47; 0.16]; I^2 = 79%; P = 0.03) and for the knee flexion moment (MD = 0.07; 95% CI: [-0.07; 0.20]; I^2 = 76%; P = 0.02). **Significance:** Gait retraining improved pain, however it was not clinically important. It also improved function and first knee adduction moment of knee osteoarthritis individuals. Second knee adduction moment and knee flexion moment did not modify.

Keywords: Knee osteoarthritis. Gait. Pain. Function. Knee adduction moment.

Abbreviations: KAM – Knee adduction moment, KFM – Knee flexion moment, WOMAC - Western Ontario and McMaster Universities Osteoarthritis Index, KOOS - Knee and Osteoarthritis Outcome Score, TUG - Timed up and go test, GRADE - Grading of Recommendations Assessment, Development, and Evaluation, NRS - Numeric rating scale, KAM1 – First knee adduction moment, KAM2 – Second knee adduction moment.

Knee osteoarthritis is a chronic and complex disease characterized by mechanical, inflammatory and metabolic factors (1). The condition will affect one in four individuals during the lifetime (2), typically manifesting as pain, stiffness and impaired movement (3–5). Notably, a reduction in gait speed is among the impairments, and it is associated with changes in gait kinematics, increased disability and a diminished health status (4,6,7). Additionally, a reduced knee range of motion in the sagittal plane holds a clinical significance in knee osteoarthritis (4). These factors hinder the performance of daily activities, such as street crossing (4,8,9).

Moreover, other biomechanical variables undergo alterations in patients with knee osteoarthritis. These individuals exhibit an increased external knee adduction moment (KAM), which is associated with increased radiographic severity (10), accelerated disease progression (11), and worse function and pain (12). The KAM indirectly measures the medial compartment load, and is estimated by the magnitude of the ground reaction force vector and its distance to the knee articular center (13). Thus, treatment approaches targeting its reduction provide tibiofemoral offloading, offer symptomatic relief, and mitigate the disease structural progression (13).

Gait retraining is a promising approach to subjects with knee osteoarthritis (14) and there are, described in the literature, 14 different gait retraining strategies applied to them (15). Previous works suggest that it modifies the gait pattern and, consequently, reduces internal knee loads (15–19). The subjects who underwent gait retraining not only demonstrate adaptability during the training session, but also exhibit the ability to learn and incorporate these modifications over multiple sessions (20).

There are two recent systematic reviews approaching gait retraining in patients with knee osteoarthritis (14,19). Rynne et al. (19) showed that gait retraining strategies may improve biomechanics and symptoms. However, it presented high methodological heterogeneity due to including not only studies about gait retraining strategies, but also papers which assessed mechanical devices intended to modify gait mechanics. Silva et al. (14) suggested that gait strategies including toe-in, toe-out and ipsilateral trunk lean reduced knee joint load in people with medial knee osteoarthritis. However, despite assessing the mechanical effects, they did not assess the clinical effects of these strategies.

Our systematic review contributes to prior reviews by assessing the effects of gait modification strategies on both clinical and biomechanical outcomes in knee osteoarthritis patients. Therefore, this systematic review aims to assess the effects of gait retraining strategies on KAM, gait spatiotemporal parameters, global index of limb involvement with osteoarthritis and physical function tests in knee osteoarthritis individuals.

METHODS

This study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered in PROSPERO (CRD42023402778). The online search was performed between February 2023 and March 2023, in Cochrane Library, PubMed Central (PMC), Physiotherapy Evidence Database (PEDro), Web of Science, EMBASE, Scopus, LILACS, and Scielo databases. The search strategy comprised the following terms: (Osteoarthritis OR Osteoarthrosis OR "Degenerative Arthritis" OR Arthrosis OR Gonarthrosis OR soft tissue disorder OR "Degenerative cartilage disease") AND ("knee joint" OR knee) AND (gait OR "gait retraining" OR "gait modification" OR "gait analysis" OR Biofeedback OR Feedback OR Ambulat* OR walk*) AND ("randomized controlled trial" OR "controlled clinical trial" OR "clinical trial"). The database-specific MeSH terms were employed, and the detailed search strategy for each is presented in complementary file A.

Randomized clinical trials comparing the effect of gait retraining strategies on clinical and/or biomechanical variables in knee osteoarthritis were included. Biomechanical outcomes encompassed linear and/or angular gait kinematics, such as KAM, cadence, step and stride lengths, step width, and gait speed. The clinical outcomes included pain, assessed on a quantifiable scale, such as the Numeric Rating Scale; a global index of limb involvement with osteoarthritis, measured by questionnaires, such as Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Lequesne or Knee and Osteoarthritis Outcome Score (KOOS); and physical function tests, like Timed Up and Go test (TUG), Six Minute

Walk Test, and Sit to Stand Test. There was no restrictions regarding participants' age or gender. The eligibility criteria are summarized in Table 1.

Table 1. Eligibility criteria for the systematic review

Inclusion criteria	Exclusion criteria
(1) randomized clinical trials (2) comparing the effect of gait retraining strategies in knee osteoarthritis; (3) having as outcome: gait kinematics, pain, global index of limb involvement and/or physical function tests	(1) studies with an animal model; (2) articles not published in English, Portuguese, Spanish or French; (3) studies in which individuals have diseases or comorbidities other than osteoarthritis or gone into surgery; (4) studies that did not have their contents completely available; (5) articles that investigate specific tasks like squat and step up and down.

Following the exclusion of duplicate articles, the screening process involved the assessment of titles, and when necessary, the abstracts were independently reviewed by two evaluators (JVVO, RQC). In case of disagreement between the first two reviewers, a third (CPSC) established a consensus.

The methodological quality of the selected studies was evaluated with the PEDro Scale, which is a tool with fair to good reliability (21). Studies achieving a PEDro score of 9–10 were considered as "excellent" quality, those between 6 and 8 "good," and scores of 4 or 5 as "fair." Studies with a score lower than four were classified as "poor" (22).

Certainty of evidence assessment: GRADE approach

To evaluate the certainty of the evidence, the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was employed, using the GRADEpro software free version (GRADEpro GDT: GRADEpro Guideline Development Tool [Software].,). GRADE comprises assessments of risk of bias, inconsistency, indirectness, imprecision, and publication bias (23). Additionally, evidence regarding the magnitude of the effect, dose-response gradient, and the influence of plausible residual confounding to upgrade the certainty (24). Finally, the evidence was categorized as very-low, low, moderate or high certainty.

A one-level downgrade in the risk of bias domain was implemented in the following situations: when 50% of the studies had a PEDro score equal to or lower than "4" or when 50% of the studies did not fulfill three or more critical items on this scale (items 2 - randomization, 3 – allocation secret, 5, 6 and 7 - blinding, and 9 – intention-to-treat analysis). Quality was lowered by two levels when more than 50% of the studies had a PEDro score lower than "4" or when more than 50% did not meet critical criteria on the scale, such as randomization and secret allocation blinding, and intention-to-treat analysis. Analyzes composed of a single randomized controlled trial were downgraded by one level in this domain.

For the inconsistency domain, a one-level reduction was applied when the heterogeneity I^2 ranged from 50% to 75%, and a two-level reduction was implemented when I^2 exceeded 75%. Within the indirectness domain, analyzes in which less than 50% of the studies included individuals different from the target audience were downgraded by one level. If higher than 50%, they were downgraded by two levels.

The imprecision domain incorporated the optimal information size as a criterion, leading to a one level downgrade for analysis with a total of participants count lower than 400. Furthermore, analysis consisting of a single randomized controlled trial incurred one level reduction in this domain.

Statistical analyzes were conducted using the R software (The R Project for Statistical Computing) and the "Meta" package. Random-effects models, with a 95% confidence interval (CI), were estimated to analyze the study's outcomes. The mean difference (MD) was used to compare the results, but when distinct tools were used to assess an outcome, the results were compared using the standardized mean difference (SMD).

Heterogeneity was assessed with an I^2 index, and sensitivity analyses, whenever feasible, were conducted for studies with high heterogeneity ($I^2 > 40\%$). All statistical comparisons assumed a significance level of $\alpha = 0.05$.

RESULTS

A total of 6815 articles were identified across the Cochrane Library, PubMed Central, Embase, Medline (OVID), Scopus, Web of Science and Scielo databases, with 7 meeting eligiblility criteria (Fig. 1). The manual search did not yield any additional studies. After excluding duplicate studies, 3393 articles remained. After title and abstract screening, 3368 studies were excluded. The remaining 25 studies were evaluated for full-text reading, and 18 studies were excluded. A flowchart of the selection process is displayed in Figure 1.

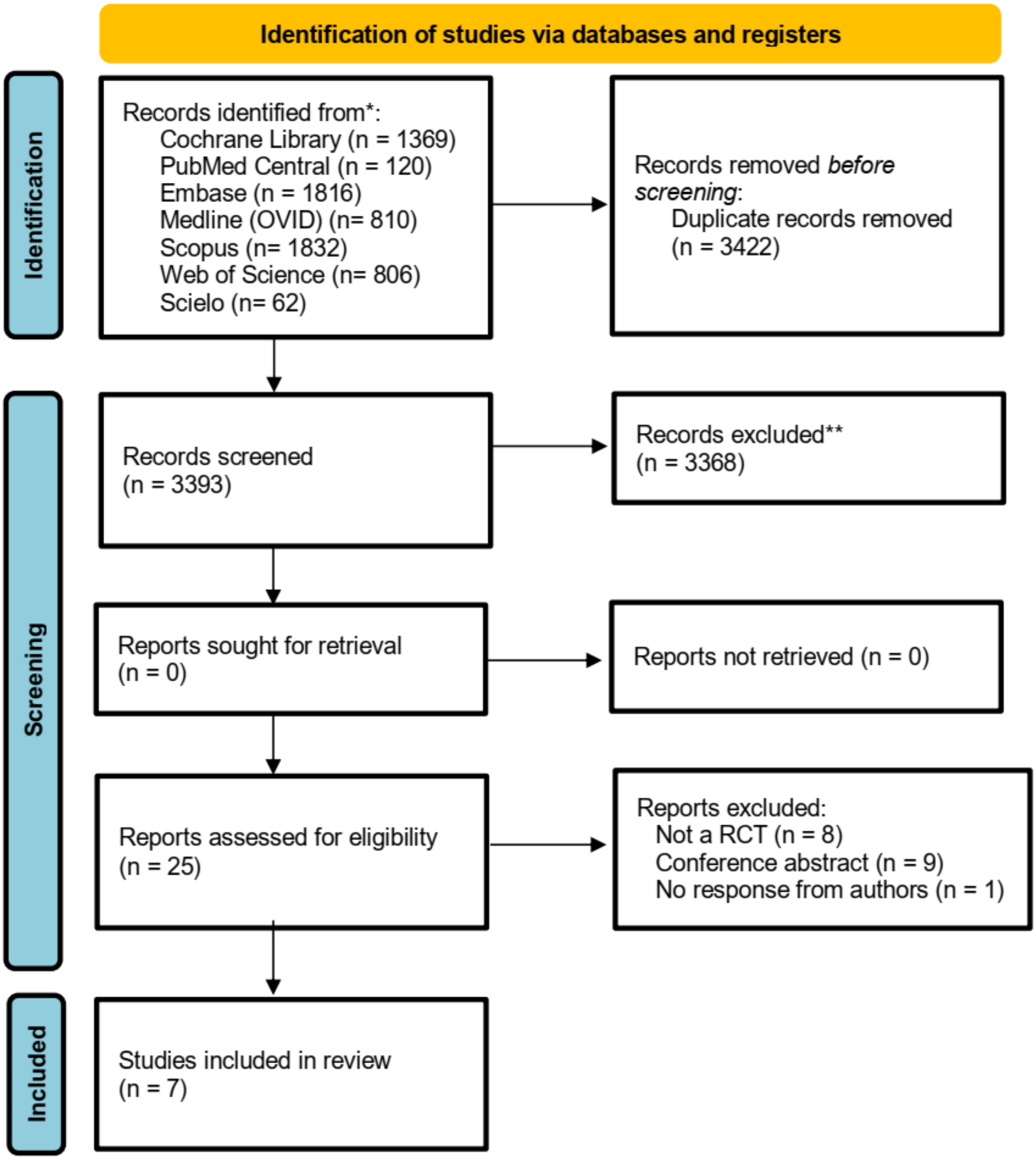

Figure 1. Flowchart of the selection process of studies for a systematic review with meta-

analysis according to the declaration of preferred items for systematic reviews and meta-analyses (PRISMA). RCT: Randomized Clinical Trial.

Study characteristics and gait retraining strategies details

The cumulative sample size across the 7 studies amounted to 335 participants. These studies employed diverse gait retraining strategies, including backward walking/retrowalking (k = 4, n = 162), toe-out (k = 1, n = 79), and freely strategies involving adjustments in foot progression angle, hip adduction/rotation, and/or trunk sway aimed at promoting KAM reduction (k = 2, n = 94) with (k = 3, n= 173) or without (k= 4, n= 162) feedback. Notably, feedback strategies also varied among the studies, incorporating visual real-time feedback based on the KAM curve (16,17) and mirror feedback (25).

Intervention duration varied from 3 to 16 weeks, and outcome assessments occurered at various time points, ranging from immediately after to 6 months following the program's conclusion. Implementation methods varied across the studies and a comprehensive overview of their characteristics is provided in Table 2.

Effects on clinical outcomes – pain and function

The comparison of pain responses, assessed by Numeric Rating Scale, revealed a significant statistical difference between gait retraining and control groups (MD = -0.96; 95% CI: [-1.45; -0.48]; I^2 = 73%; P < 0.01) favoring the gait retraining group (Figure 2). Due to the high heterogeneity introduced by Gondhalekar and Deo (26), a sensitivity analysis was conducted (Figure 3). The heterogeneity was reduced and the statistical difference, with high quality of evidence assessed by GRADE, continued to favor the gait retraining strategy (MD = -1.22; 95% CI: [-1.48; - 0.96]; I^2 = 14%; P = 0.32).

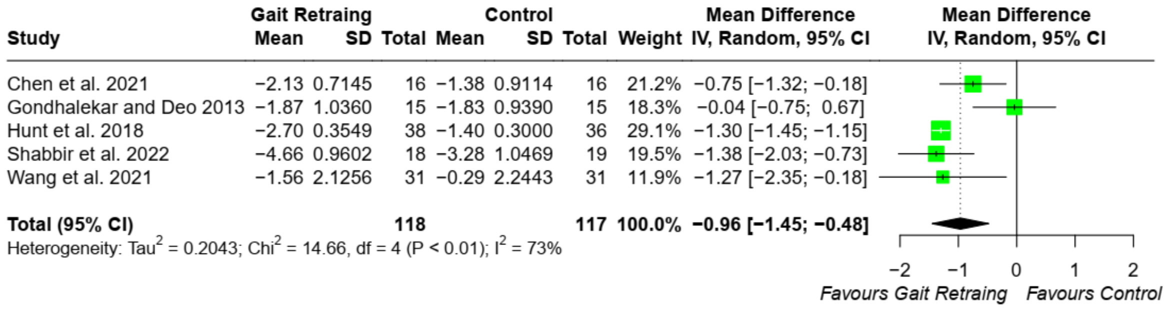

Figure 2. Pain without sensitivity analysis. Forest plot of mean difference (MD) and

confidence interval (95% CI) evaluating the effects of gait retraining × control for pain, measured with Numeric Rating Scale (NRS).

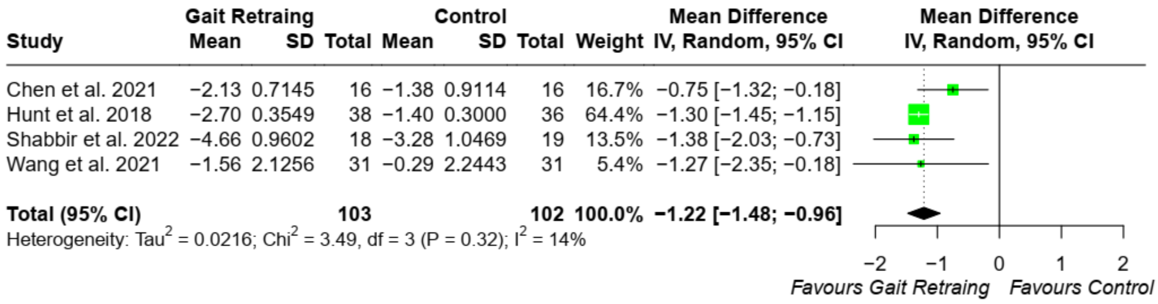

Figure 3. Sensitivity analysis removing Gondhalekar and Deo. Pain with sensitivity analysis. Forest plot of mean difference (MD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for pain, measured with Numeric Rating Scale (NRS).

For the function analysis, measured by global lower limb osteoarthritis index (WOMAC and KOOS), the comparison between the gait retraining and the control groups did not show a significant difference (SMD = -0.58; 95% CI: [-1.18; 0.02]; I^2 = 76%; P < 0.01) (Figure 4). The study conducted by Wang et al (17) was identified as the source of the high heterogeneity (76%). Considering this, a sensitivity analysis was performed, and the results favored the gait retraining strategies over control group interventions, with high quality of the evidence assessed by GRADE (SMD = -0.82; 95% CI: [-1.24; -0.41]; I^2 = 22%; P = 0.28) (Figure 5).

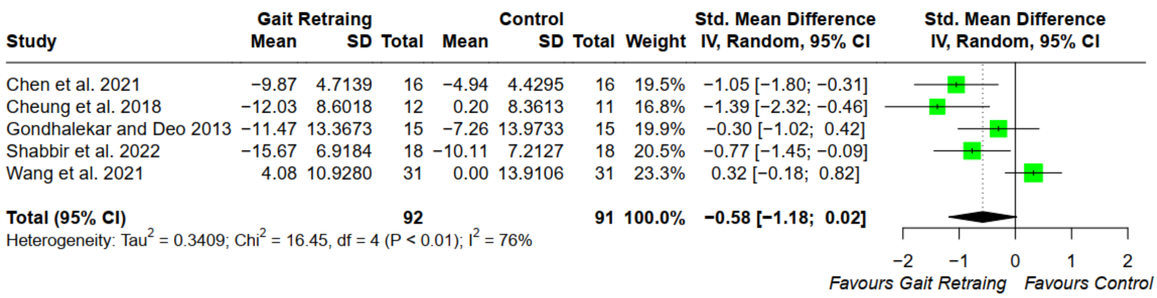

Figure 4. Function without sensitivity analysis. Forest plot of standard mean difference (SMD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for function, measured with global lower limb osteoarthritis index (WOMAC and KOOS).

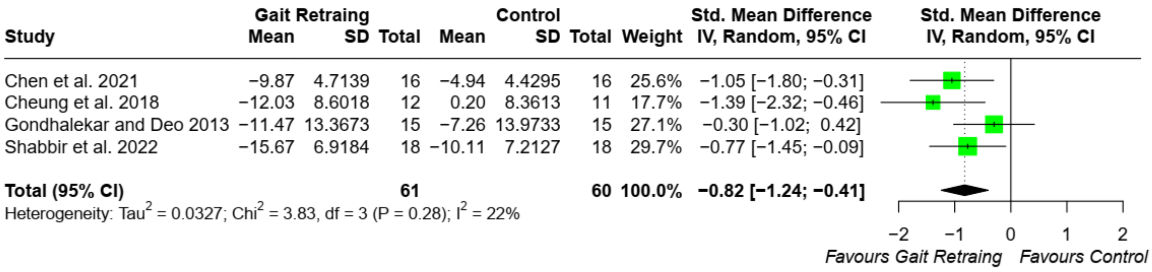

Figure 5. Sensitivity analysis removing Wang et al. Function with sensitivity analysis. Forest plot of standard mean difference (SMD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for function, measured with global lower limb osteoarthritis index (WOMAC and KOOS).

Effects on gait biomechanical outcomes

The KAM and knee flexion moment (KFM) were considered to the gait biomechanical outcomes. Given that the KAM typically exhibits two peaks during the stance phase of gait (27), we distinguished between the first peak KAM (KAM1) and the second peak KAM (KAM2), when the data was available. In cases where this distinction was not feasible, we used the peak KAM as the KAM1.

When comparing the gait retraining strategies to control interventions, a statistically significant difference favoring the gait retraining group was observed for the first knee adduction moment (KAM1) (MD = -0.20; 95% CI: [-0.38; -0.02]; I^2 = 84%; P < 0.01). The source of high heterogeneity was traced back to Wang et al (17). However, no clinical or methodological sources of heterogeneity were identified, justifying its removal from the analysis (Figure 6).

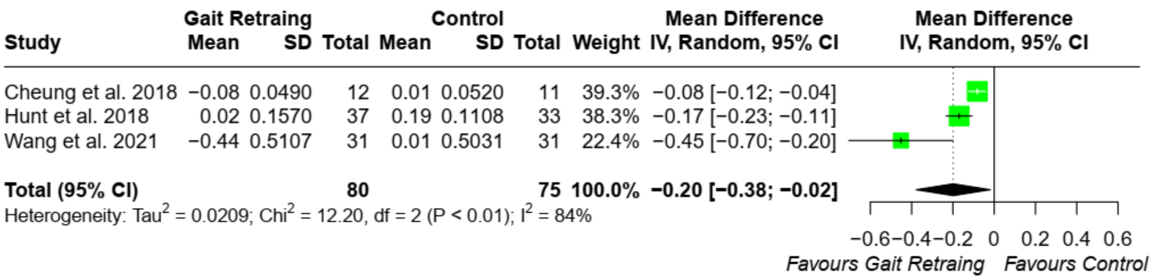

Figure 6. First knee adduction moment (KAM1). Forest plot of standard mean difference

(SMD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for KAM1.

For the second knee adduction moment (KAM2), the comparisons between gait retraining strategies and control strategies indicated similarity between the groups (MD = −0.16; 95% CI: [−0.47; 0.16]; $I^2 = 79\%$; P = 0.03) (Figure 7).

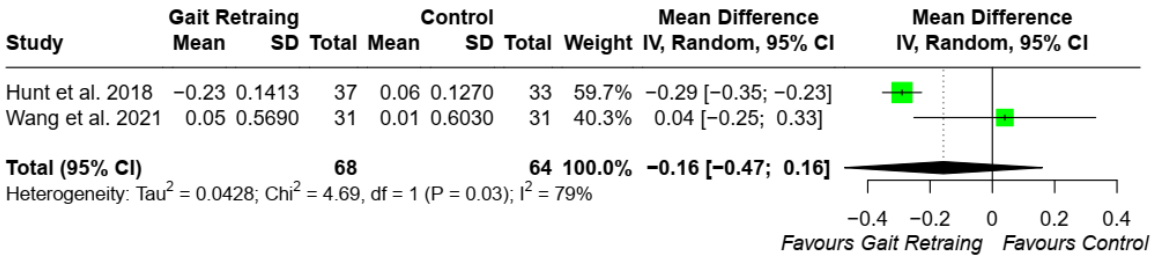

Figure 7. Second knee adduction moment (KAM2). Forest plot of standard mean difference (SMD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for KAM2.

Comparisons between gait retraining and control groups, with very-low quality of evidence assessed by GRADE, indicated no significant difference in knee flexion moments between the two groups (MD = 0.07; 95% CI: [-0.07; 0.20]; $I^2 = 76\%$; P = 0.02) (Figure 8).

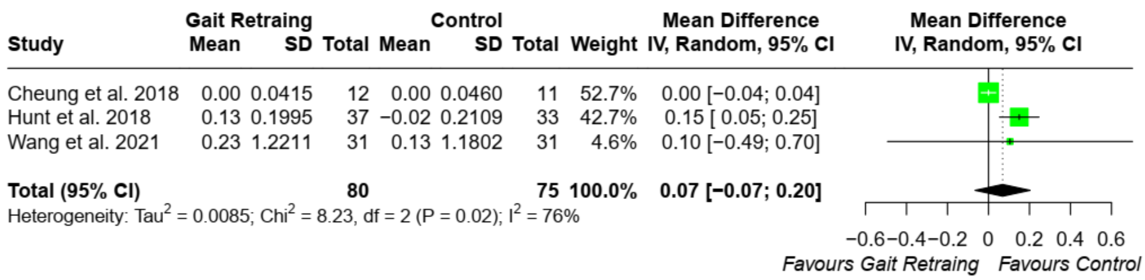

Figure 8. Knee flexion moment (KFM). Forest plot of standard mean difference (SMD) and confidence interval (95% CI) evaluating the effects of gait retraining × control for KFM.

Table 2. Risk of Bias assessed with Physiotherapy Evidence Database (PEDro) for the included studies (n = 7)

Study (Author, year)	**Item 1** Elegibility criteria	**Item 2** Random allocation	**Item 3** Concealed Allocation	**Item 4** Groups similar at baseline	**Item 5** Participant blinding	**Item 6** Therapist blinding	**Item 7** Assessorblinding	**Item 8** < 15% drop outs	**Item 9** Intention-to treat analysis	**Item 10** Between-group difference reported	**Item 11** Point estimate-variability reported	**Total** (0 to 10)
Alghadir et al., 2019	N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8/10
Chen et al., 2021	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8/10
Cheung et al., 2018	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Gondhalekar; Deo., 2013*	Y	Y	Y	N	N	N	N	Y	N	Y	Y	5/10
Hunt et al., 2018*	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	7/10
Shabbir et al., 2022	N	Y	Y	Y	N	N	N	Y	N	Y	Y	6/10
Wang et al., 2021	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6/10

N = No, Y = Yes. *denotes studies not reviewed by PEDro.

Table 3. Assessment of the certainty of evidence by GRADE gait retraining strategies x control strategies

Quality assessment outcomes	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Effect	Certainty	Importance
Osteoarthrtits index	not serious	not serious	not serious	serious	Publication bias strongly suspected	SD = -0.82; 95%CI -1.24 to - 0.41	⊕ ⊕ ⊕ ⊕ High	Critical
Pain	not serious	not serious	not serious	serious	Publication bias strongly suspected	MD = -1.22; 95%CI –1.48 to -0.96	⊕ ⊕ ⊕ ⊕ High	Critical
First knee adduction moment	not serious	very serious	not serious	serious	Publication bias strongly suspected	MD = -0.20; 95%CI -0.38 to -0.02	⊕◯ ◯ ◯ Very low	Important
Second knee adduction moment	not serious	very serious	not serious	serious	Publication bias strongly suspected	MD = -0.16; 95%CI -0.47 to 0.16	⊕ ◯◯ ◯ Very low	Important
Knee flexion moment	not serious	very serious	not serious	serious	Publication bias strongly suspected	MD = 0.07; 95%CI -0.07 to 0.20	⊕◯ ◯ ◯ Very low	Important

CI: confidence interval; **MD**: mean difference; **SMD**: standardized mean difference

Table 4. Details of gait retraining programs of included studies

Studies	Population			Intervention		Comparison	Duration and assessment time points		Outcomes	
Author, year	**Number of participants**	**Age (years)**	**KL grade**	**Gait retraining strategy**	**Gait implementation and Feedback**	**Control Strategy**	**Duration (weeks)**	**Assessment time point**	**Gait biomechanical**	**Clinical**
Alghadir et al., 2019	68	RWG: 54.6 FWG: 55.3 CG: 56.8	-	Retrowalking training Forward walking training	10 min of training 3 days a week, with gradually increase of the time up to 30 min. Without feedback	Exercise training	6	At baseline and at 6 weeks	-	Pain (NRS) and function (WOMAC)
Chen et al., 2021	32	BWG: 60.3 ± 7.9 CG: 60.9 ± 6.9	BWG: 3.4 ±0.6 CG: 3.2 ± 0.7	Backward walking training	10 min of training 3 days a week, with gradually increase of the time up to 30 min. Without feedback	Acupotomy, medications and exercise training	4	At baseline and at 4 weeks	-	Pain (NRS) and function (WOMAC)
Cheung et al., 2018	23	GRC: 60.8 ± 6.4	GRC: 2 grade I; 8	Freely different	15 min of 1 session per	Treadmill traditional	6	At baseline, At 6 weeks	Knee adduction	Knee pain, physical

		CG: 63.1 ± 5.9	grade II CG: 3 grade I; 7 grade II	strategies (adjustments in foot progression angle, hip adduction/ rotation, and/or trunk sway) to lower the knee adduction moment	week with training time incrementally increase to 30 min. Visual real-time feedback based on the KAM curve	walking without feedback		and at 6 months	moment (KAM), knee flexion moment (KFM)	function, and joint stiffness (WOMAC)
Gondhalekar ; Deo., 2013	30	-	-	Retrowalking training	Three sessions of per day (10 min per session). Without feedback	Deep heating treatment for 20 min and free exercises	3	At baseline, at 1 week and at 3 weeks	-	Pain (VAS), function (WOMAC)
Hunt et al., 2018	79	Toe-out group: 64.6 ± 7.6 CG: 65.4 ± 9.6	Toe-out group: 19 grade II, 17 grade III and 4 grade IV CG: 18 grade II, 14 grade III and 7 grade IV	Toe-out gait retraining	8 sessions (at weeks 1, 2, 4, 6, 8, 10, 12 and 15) of 15º toe-out. The initial sessions lasted 20 min and was increased up to 40 min.	Progressive walking without change in foot progression angle	16	At baseline, at 16 weeks and ate 20 weeks.	Gait speed, foot progression angle, knee adduction moments 1 and 2, knee flexion moment.	Pain (NRS), function (WOMAC)

					Home training to spend more time walking and in toe-out angle during walking. Mirror feedback.					
Shabbir et al., 2022	32	IG: 52.2 ± 7.4 CG: 53.8 ± 7.4	-	Retrowalking training	30 min, for three days per week. Without feedback.	Conventional therapy	6	At baseline and at 6 weeks	-	Pain (NRS) and function (WOMAC)
Wang et al., 2021	71	IG: 59.1 ± 7.2 CG: 61.7 ± 6.8	IG: 15 grade I and 16 grade II CG: 16 grade I and 15 grade II	Free strategy to reduce knee adduction moment	15 min per week. The time was incrementally increased up to 30 min. Visual real-time feedback based on the KAM curve	Conventional treadmill walking	6	At baseline and at 6 weeks	Foot progression angle, knee adduction moments 1 and 2, knee flexion moment	Pain (VAS) and function (KOOS)

DISCUSSION

This systematic review aimed to evaluate the effects of gait retraining strategies on clinical and biomechanical parameters in individuals with knee osteoarthritis. The findings indicate that these strategies effectively improve pain, function, and the KAM1. However, gait retraining strategies did not demonstrate superiority over control strategies in reducing KAM2 and KFM.

Pain, a characteristic manifestation of knee osteoarthritis (28), improved with retrowalking (29,30), toe-out (31) and freely chosen strategies (17). Pain relief may be attributed to alterations in the magnitude and distribution of tibiofemoral compartment loads. Nonetheless, the mean difference observed in the meta-analysis lacked clinically importance (32), showing that gait retraining alone or combined with acupotomy and/or “conventional therapy” might not be sufficient for clinically important pain reduction in knee osteoarthritis patients.

Recognizing that knee osteoarthritis involves not only inflammatory, metabolic, and mechanical factors (33), improvements in joint biomechanics are considered supplemental to core treatments (34). It is important to consider that core treatments encompass exercises performed with appropriate frequency and intensity, coupled with body weight management and educational strategies (35–37). However, the exercise therapies described in the included articles did not consistently meet these recommendations or adequately define what they termed as “conventional therapy,” complicating result interpretation.

The benefits of exercise therapy in knee osteoarthritis management have been evident since 2010 (38). However, the mechanisms through which exercises contribute to pain and function improvements remain a topic of discussion. Puts et al. (2023) (39) conducted a systematic review, revealing that regular exercise therapy induces circulatory and intra-articular anti-inflammatory effects. Although, KAM, unlike pain and function, remains unaffected by such exercises (40). Therefore, the alteration in KAM observed in the articles included in this systematic review cannot solely be attributed to the anti-inflammatory effects of exercises or an increase in physical activity levels.

The KAM is the product of ground reaction force and the frontal plane lever arm (27). Alterations in the angle of foot progression (toe-out) or body direction (retrowalking) during walking were found to modify the KAM1, as showed in this meta-analysis. These strategies induce a shortening of the lever arm, resulting in a reduction of the KAM (27). According to our results, biomechanical changes with gait retraining were restricted to the KAM1, which is related to knee osteoarthritis progression (41). KFM remained unaltered with gait retraining strategies. It is hypothesized that the lack of change in the KFM may be due to the conversion of part of the KAM into the KFM, as proposed by Jenkyn et al. (2008) (42).

Study limitations

To our knowledge, this is the first systematic review to investigate the effect of gait retraining strategies on both clinical and biomechanical parameters. However, the results should be analyzed in the context of the study's limitation. Only a limited number of articles met the eligibility criteria for inclusion in this systematic review. This limitation could affect the quality of the information and emphasizes the necessity for further research in this area.

CONCLUSIONS

This systematic review highlights the scarcity of randomized controlled trials investigating the effects of gait retraining strategies on the clinical and biomechanical variables of knee osteoarthritis. Despite the limited number of studies, our meta-analysis indicates that gait retraining strategies improve pain, function and KAM1 of knee osteoarthritis individuals and do not modify KAM2 and knee flexion moment. However, it is imperative to interpret the findings of this review cautiously, considering both their statistical significance and clinical relevance.

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3.2 Protocolo de Ensaio Clínico

Effects of gait retraining associated to muscle strengthening in knee osteoarthritis: a study protocol

ABSTRACT

Background: Knee osteoarthritis is a prevalent condition worldwide that leads to pain and limits daily living activities. Among the treatment approach, gait retraining strategies have been studied in last years and exercise therapy is considered as knee osteoarthritis core treatment. However, studies addressed gait retraining associated with lower limb strengthening program are scarce. In this way, the objective of this protocol is to present a randomized clinical trial protocol that aims to investigate the effects of gait retraining in toe-out associated to a knee and hip muscles strengthen, and an educational program in patients with knee osteoarthritis. **Methods:** Fifty-six subjects will be recruited. Gait kinematics, muscle torque and physical function via WOMAC questionnaire, will be assessed. The participants will be randomly assigned to control or intervention groups. The control group will undergo a lower limb strengthening exercises program and an osteoarthritis educational process delivered through digital audio materials. The intervention group will receive the strategies applied to the control group associated to gait retraining in toe-out. **Discussion:** The results of this study will show whether gait retraining adds an effect to knee osteoarthritis core treatment. In this way, it will provide physical therapists with guidance in knee osteoarthritis treatment plan to promote clinical and biomechanical improvements.

Rebec platform trial: RBR-4pzsfxw. Registered 09 August 2023. https://ensaiosclinicos.gov.br/rg/RBR-4pzsfxw

Keywords: Knee Osteoarthritis. Gait. Strength Training.

BACKGROUND

Knee osteoarthritis is a prevalent condition worldwide (1) and the 10th largest contributor to global years lived with disabilities (2). It is a complex chronic progressive disease that affects the whole joint and leads to pain, disability, and societal burden (3). Moreover, the condition limits daily living activities such as going up stairs, doing household tasks, getting up from a chair and crossing streets (4–7). Knee osteoarthritis severity and progression are associated with muscles weakness and an increased knee adductor moment (8–13). Thus, these factors must be considered in the knee osteoarthritis rehabilitation process.

Since 2010, it is clear the benefit of exercise in knee osteoarthritis management (14). Exercise therapy is part of the first line for knee osteoarthritis treatment and generates symptoms relief and physical function improvement (15–19). Recent studies have shown that muscle-strengthening exercises for knee extensors (20) and hip muscles (8,12) are effective in improving pain, functional outcomes, and spatial-temporal gait parameters, such as cadence and speed (21). However, a systematic review published in 2023 showed that exercise therapy does not generate pain relief and biomechanical load reduction simultaneously (22).

Although muscle strengthening of knee extensors and/or hip extensor-abductors is not effective in reducing the knee external adductor moment (21), gait retraining has shown promising results for this purpose. Gait retraining can be performed by adopting 14 different strategies (23), among them changing the foot progression angle, ipsilateral trunk inclination, or knee medialization (24). The change in foot progression angle performed by positioning the feet in toe-in or toe-out improves symptoms, reduces the adductor moment of the knee and does not increase overloads on the hips of subjects with knee osteoarthritis (25,26). Furthermore, a systematic review from 2022 included 17 papers on gait retraining in knee osteoarthritis. The results showed that gait retraining with a real-time biofeedback tool is effective in modifying gait biomechanics and participants' self-reported function (27). However, despite the benefits of gait modification and muscle strengthening, none of the studies addressed retraining associated with lower limb strengthening in improving the clinical, functional, and biomechanical parameters of individuals with knee osteoarthritis.

Considering that both strategies can be effective and directly impact several relevant outcomes, the objective of the present study is to introduce a randomized clinical trial protocol that combines gait retraining in toe-out with visual and sound feedback to strengthen knee and hip muscles. The aim is to investigate the effects on physical function, gait kinematics and muscle torque in subjects with knee osteoarthritis.

METHODS

Study setting

The sample was estimated using the G-Power 3.1 software considering the effect size of 0.86 for the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) function domain (27), alpha level of 5 %, confidence interval of 95% and 80% of power. The program indicated a minimum of 23 individuals for each group. However, considering the possibility of a minimum sample loss of 20%, at least 28 subjects will be recruited for each group.

Participants will be recruited in health care spaces and by social media promotion in Juiz de Fora, Minas Gerais, Brazil. The eligibility criteria are described in table 1. After recruitment, screening and evaluation, participants will be randomly assigned to one of two possible groups by block randomization. Subject randomization will be conducted after an initial assessment, through a routine built into the R software (version 3.6.1, R Core Team 2019, Vienna, Austria) by a research team member not related to the data collection. This researcher will also be responsible for recording the assessment data in separate digital files. Thus, the investigators can later analyze the data without having access to information regarding participant allocation. It is noteworthy that the intervention scheduling will prevent individuals assigned to different groups from having contact with each other to prevent allocation recognition. Due to the nature of the study, only participants and evaluators will remain blind to the group to which the subject belongs. Group assignments will only be revealed at the conclusion of protocol application, after all participants have accept the intervention proven to be most effective. Participants who withdraw from the research after enrollment will be contacted via phone, email, or mail to schedule a reassessment at the institution. Data from those who do not undergo reassessment will be treated as missing values and replaced by the mean or median, depending on the data’s characteristic.

Data collection procedures will be performed at the Movement Analysis Laboratory at the physical therapy school at the Universidade Federal de Juiz de Fora by a previously trained team. Participants will be informed about the research and the procedures they will undergo and will sign the informed consent form. The research will be in accordance with Resolution 466/12 of the National Health Council and the project was conducted in accordance with the recommendations of the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT). This research is registered on the Brazilian Registry of Clinical Trials (ReBEC) platform (RBR-4pzsfxw).

Table 1. Eligibility criteria

Inclusion criteria	Exclusion criteria
• Subjects within 50 to 65 years old; • Clinical diagnosis of unilateral or bilateral knee osteoarthritis according to American College of Rheumatology criteria; • Radiographic severity grade II and III according to Kellgren and Lawrence criteria; • Who are able to walk freely for at least 10 minutes without an assistive device; • Not having infectious, inflammatory, autoimmune, or traumatic arthropathies, history of arthroplasty or any other lower limb surgery; • Individuals who have not used intra-articular injections in the last 6 months; • Individuals with an index body mass less than 30 kg/m^2; • Individuals who do not have neurological and/or vascular diseases; • Individuals who have controlled blood pressure levels (given by resting blood pressure below 160/110 mmHg).	• Subjects who do not have the minimum score* on the cognitive screening test (Mini Mental State Examination - MMSE). • Subjects who perform intra-articular or surgical infiltration procedures during the application of the research protocol; • Subjects who present cardiovascular decompensations, given by blood pressure levels higher than 220/105 mmHg during the exercises (28).

* The score will be evaluated according to the participant's education level. Therefore, for illiterate subjects, the cutoff point will be 20 points; for individuals with 1 to 4 years of schooling, 25 points; for those with 5 to 8 years of schooling, 26.5 points; 9 to 11 years of study, 28 points; and for individuals with more than 11 years of schooling, the minimum score to be achieved should be 29 (29).

Outcomes - data collection procedures and instruments

A questionnaire will be used to collect participants' sociodemographic and clinical information, including age, sex, profession, marital status, mass, height, time since diagnosis of osteoarthritis, and medications used. Additionally, aspects of pain, function, gait kinematics, muscle torque, and the lower limbs' length will be assessed.

All outcomes will be evaluated in baseline and after eight weeks of treatment (a day or two after the treatment end). Before the evaluations, a warm-up will be conducted for five minutes on a horizontal stationary bicycle with no load and at a speed considered comfortable by the participants.

Pain and physical function assessment

Pain and function will be assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire, designed to be used in patients with osteoarthritis and translated and adapted to the Brazilian population by Fernandes (2002) (30). The WOMAC comprises 24 items that evaluate three domains: pain (5 items), joint stiffness (2 items) and functionality/physical capacity (17 items) (31). The total score of the questionnaire ranges from 0 to 96 points, in which higher values are associated with worse outcomes (30). The mean score for each domain will be calculated since the instrument is multidimensional. It should be noted that, although the WOMAC was designed for self-administration, the research team will administer the questionnaire using an assisted method.

Gait biomechanical parameters assessment

Gait kinematic parameters, such as ankle, knee and hip joint angles in the sagittal plane during the stance and swing phases, along with spatiotemporal parameters including cadence, step length, stride length, step width and gait speed, will be assessed using MyoMotion™, an inertial measurement unit system developed by Noraxon (Noraxon U.S.A. Inc., Scottsdale, USA).

The sensors (dimensions: 37.6 mm x 52.0 mm x 18.1 mm) will be fixed with specific fixation bands and tapes for each body region: sacrum (1), thoracic region (1), in the distal half of the thigh (2), in the medial portion of the tibia (2) and in the dorsal portion of the feet (2). After positioning the sensors, equipment calibration will be performed with the participant seated in a chair, on a wooden platform in order to avoid electromagnetic interference on the sensors, with all hip, knee and ankle joints at 90º for 20 seconds. Then, participants will be instructed to move, and the research team will assess the joint angles, and accelerations to check the signal quality. If inconsistencies are detected, the sensors will be repositioned and recalibrated until the data are adequate. The signal will be sampled at a frequency of 100 Hz.

Gait-related data will be collected for both overground and treadmill gait. For overground assessment, participants will walk on a flat, linear 10-meter surface at a self-determined maximum speed and at a self-determined comfortable speed. For treadmill data collection, participants will initially walk on the treadmill for 5 minutes to adapt and determine their maximum speed, followed by recording kinematic data for 20 consecutive steps. The treadmill assessment will also be conducted at a predetermined speed of 1.2 m/s, which is an average speed suitable for street crossing (32). Participants will wear usual shoes with hindfoot closure and previously familiarized with the task. The order of data collection will be randomized using opaque envelopes to minimize potential interference between the two assessments. Additionally, participants will rest for 5 minutes, in a chair with backrest and feet flat on the floor. This same rest time will be adopted in case the assessment suffers interference from an external factor and a test restart is necessary.

Ground gait data will involve calculating the total distance walked (10 meters) minus the initial and the final 1 meter. For treadmill walking data analysis, the first two and the last two steps of the 20 steps cycle will be excluded, leaving 16 steps for analysis (33). The following space-time parameters will be extracted: gait speed, step and stride lengths, step length ratio, and stance-swing phase ratio.

Three-dimentional kinematic data for each step of each participant will be obtained from the hip, knee and ankle joints, with the exception of the first two and two last steps. Gait cycle phases will be identified using data acquisition and analysis software algorithms. Angular and linear kinematics parameters will be extracted using the software (MR v.3.14). The identified cycles will be normalized based on their duration (0 to 100%) and averaged.

Lower limb muscle torque assessment

The hip extensor and abductor muscles, as well as the knee extensor muscle torque, will be estimated by the maximum voluntary isometric contraction of the lower limb diagnosed with osteoarthritis. In cases of bilateral osteoarthritis, muscle strength will be assessed in the limb experiencing the most severe pain. A portable dynamometer (Lafayette Instrument) will be used to measure the maximum isometric voluntary contraction. The procedure will consist of three repetitions, each lasting 5 seconds for each muscle group, with a 1-minute rest period between data collections. All values will be recorded and the highest value among the three measurements will be considered the maximum isometric voluntary contraction of each muscle group (34).

To obtain the torque value, the force arm (distance from the center of rotation of the knee joint to the place where the dynamometer is positioned) will be measured and normalized to the subject's mass. The measurements will be conducted in a randomized sequence, and for the reassessment, the sequence will replicate the initial assessment. To minimize evaluator interference, a polyvinyl chloride (PVC) tube will be placed between the dynamometer and a wall during all measurements. Before each assessment, the evaluator will instruct the participant to apply the maximum resistance possible against the dynamometer and maintain this resistance until instructed to relax. The evaluator will provide verbal encouragement in each repetition.

The positioning of the evaluated subject, equipment, and evaluator for effective and standardized data collection for each muscle group are described as follows:

- *Hip extensors*: The participant will stand, with the stretcher adjusted to the height of the lower border of the anterosuperior iliac spine. The subject will perform hip flexion to rest the trunk on the stretcher, and knee flexion on the side to be evaluated (35). The dynamometer will be positioned in the posterior region of the thigh, 5 cm above the lateral femoral condyle. From this position, the hip extension will be requested.
- *Hip abductors*: The participant will lie in a dorsal decubitus position, with a stabilizing belt around the pelvis. The dynamometer will be positioned 5 centimeters above the lateral malleolus, and stabilized with a PVC tube positioned against the wall (36). The participant will be instructed to perform the hip abduction movement.
- *Hip adductors*: Similar to hip abductors, the participant will lie in a dorsal decubitus position with pelvic stabilizing belt. The dynamometer will be positioned 5 centimeters above the medial malleolus and stabilized with a PVC tube positioned against the wall (36). Then, the participant will be instructed to perform the hip adduction movement.
- *Hip external rotators*: The participant will be seated on a stretcher with the knee flexed at 90º and a stabilizing belt on the pelvis. The dynamometer will be positioned 5 centimeters above the lateral malleolus and stabilized with a PVC tube positioned against the wall. Then, the participant will be instructed to perform the hip external rotation movement.
- *Hip internal rotators*: Similar to hip external rotators, the participant will be seated on a stretcher with the knee flexed at 90º and a stabilizing belt on the pelvis. The dynamometer will be positioned 5 centimeters above the medial malleolus and stabilized with a PVC tube

positioned against the wall. Then, the participant will be instructed to perform the hip internal rotation movement.

- *Knee extensors*: the participant will seat on chair with hips and knees flexed at 90º, end a stabilizing belt will be positioned in the thigh's distal portion (36). The dynamometer will be positioned 5 cm above the distal portion of the medial malleolus (37), and stabilized with a PVC positioned tube against the wall. The participant will be guided to perform the extension of the assessed leg.

Pre-protocol

Here are some basic precautions aimed at maximizing exercise comfort and quality, ensuring minimally stable cardiovascular conditions for training execution, and facilitating conduction:

- *Systemic blood pressure measurement:* Blood pressure will be measured before and after the interventions using an analog sphygmomanometer positioned on the participant's left arm, which will be positioned at heart level. Participants will sit quietly for at least 3 minutes before measurement. Those with pressure values below 160/100 mmHg before the interventions will proceed with the next steps. However, participants with resting blood pressure values exceeding 160/110 mmHg will be formally advised to schedule a medical appointment before continuing their participation in the research.
- *Patellofemoral mobilization*: Given the coexistence of patellofemoral and tibiofemoral osteoarthritis in 40% of individuals with knee osteoarthritis, and the greater impact of patellofemoral osteoarthritis knee osteoarthritis symptomatology (38), all subjects will receive 5 minutes of side-to-side mobilization of the patellofemoral joint grades 1 and 2 before the evaluation and application of the exercise protocol. Participants will be positioned in lateral decubitus, with the knee to be mobilized supported by a towel roll and slightly flexed (to a degree that allows vertical gravitational sliding of the patella from lateral to medial direction) (38).
- Warm-up: Prior to initiating the protocol, participants will undergo a 5-minute warm-up on a horizontal stationary bicycle, without load, at an intensity between 2-3 on the Modified Borg Scale. This warm-up aims to increase blood supply and nutrient exchange in the joint cavity (39).
- *Familiarization with the Borg scale*: The research team will introduce the Borg scale to the participants before starting the protocol. This introduction will familiarize the participants

with the tool, allowing them to define their perception of effort during the protocol's execution.

Interventions

Following randomization, all participants included in this research will be instructed not to engage in new physical activities, such as physiotherapy or physical exercises classes, either individually or in groups, on land or in water, unless prescribed by the research team.

All participants will undergo an osteoarthritis education process, delivered through digital audio materials made available via instant messaging applications and voice calls to smartphones. Participants who do not have a smartphone will be contacted by a research team member via phone call. The objective of the audio is to enhance the effect of the education strategies delivered in printed material (40). The audio files will be adapted from the material titled "PEAK - Physical Therapy Exercise and Physical Activity for Osteoarthritis of the Knee – Osteoarthritis Information", developed by the Center for Health, Exercise and Sports Medicine of the University of Melbourne and translated into Portuguese - Brazil by Ana Elisa Serafim Jorge and Yuri Lopes Lima (41). The audio topics include: "Understanding knee osteoarthritis". "Treatment options for osteoarthritis", "Physical activity", "Barriers to exercise and physical activity", "Pace of activity", "Weight loss for osteoarthritis", "Overcoming barriers to weight loss", "Understanding and managing your pain: progressive muscle relaxation, mini relaxation, pleasant images, mindfulness (full attention)", "Sleep", "Success stories" and "Other information". These files will be brief and provided to participants on a day of the week when they are not attending the outpatient clinic for the protocol, along with a reminder to perform the PEAK program activities at home. For example, participants who attend the outpatient clinic for the protocol on Mondays and Fridays will receive the audio files and the home activity reminder on Wednesdays. After completing each home activity, participants should record their progress in the exercise diary.

In addition to the osteoarthritis education process and the home exercise program, participants will also undergo group-specific interventions as described below.

Muscle strengthening group associated with gait retraining (experimental group): Participants will undergo a lower limb muscle strengthening program for 16 sessions over 8 weeks, with 2 sessions conducted each week, ensuring a minimum interval of 48 hours between sessions. The sessions will include 35 minutes of muscle strengthening training for the gluteus maximus (traditional step-up, cross-over step-up), gluteus medius (pelvic drop on step), quadriceps (extended leg raise - SLR, seated knee extension and sit and stand), hamstrings (standing knee flexion and bridge with 60º knee flexion) and sural triceps (plantar flexion in step) (8,10,42–47). Progression of each exercise will involve a 10% increment in external load when the subjective perception of exertion is less than 6 (during the first 3 weeks) or less than 7 (between weeks 4 and 8) (American College of Sports Medicine, 2009). The training volume (number of sets and repetitions) and training intensity will be progressed as described in table 2. Monitoring of training volume will consider the exercise intensity, the number of repetitions, and the series developed.

Table 2. Assistance plan and weekly progressions.

Muscle Strengthening Progressions								
Component	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Frequency	2 x/wk	2 x/wk	2 x/wk	2 x/wk	2 x/wk	2 x/wk	2 x/wk	2 x/wk
Intensity (CR-10 Borg)	5-6	5-6	5-6	7-8	7-8	7-8	7-8	7-8
Series/ rep.	3 x 8	3 x 8	3 x 8	3 x 8	3 x 8	3 x 10	3 x 12	3 x 12
Rest	40 sec	40 sec	40 sec	40 sec	40 sec	40 sec	40 sec	40 sec

Souce: Adapted from Van Doormaal (47).

In addition, participants in the experimental group will undergo gait retraining. Initially, the subjects will perform 10 minutes of treadmill training, which they will be instructed to walk with 15º toe-out angle. To achieve this, the program (MR v3.14) will be configured based on the average angle of foot progression relative to the ground observed during the participant's initial assessment, serving as a baseline. Consequently, the participant will receive visual feedback through the display of lines on the bar graph to reach the target angle (15º of toe-out). Whenever they successfully reach the target, they will also receive auditory feedback (sound tone). Starting from the fourth session, the percentage of time during which the participant receives feedback from the inertial sensors will be progressively reduced to facilitate motor learning (48). The gait retraining duration will be gradually extended, up to a maximum of 35 minutes, and participants will determine their own gait speed. Detailed information regarding the progression of gait retraining time and the percentage of service time with real-time visual feedback is presented in Table 3.

Table 3. Progression of gait retraining time and percentage of service time with real-time visual feedback.

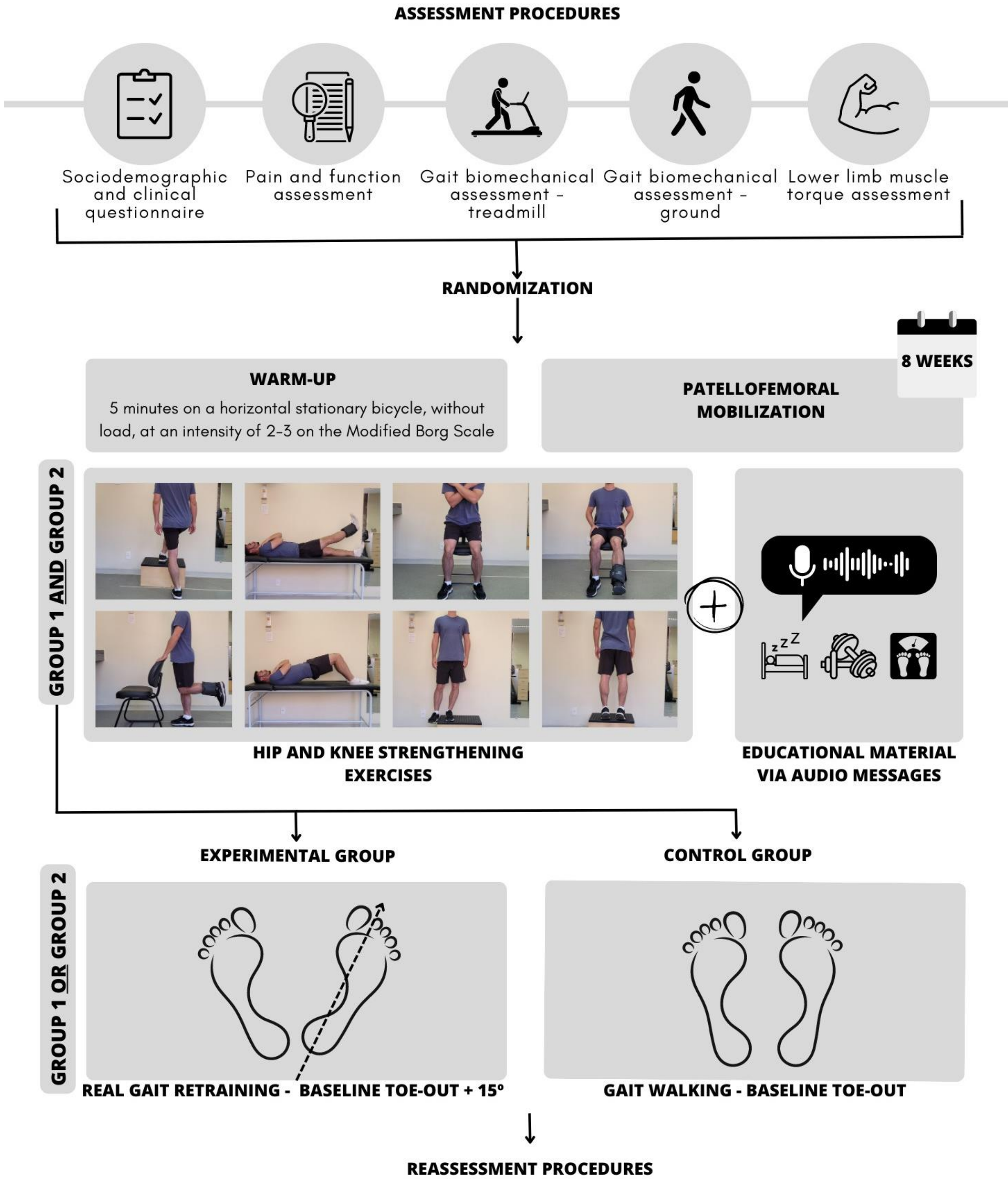
Weeks	Total time of gait retraing	Percentage of the gait retraining time with feedback
1st, 2nd and 3rd weeks	10 minutes	100% of the time with feedback
4th week	15 minutes	90% of the time with feedback
5th week	20 minutes	75% of the time with feedback
6th week	25 minutes	60% of the time with feedback
7th week	30 minutes	45% of the time with feedback
8th week	35 minutes	35% of the time with feedback

Source: Adapted from Hunt et al. (2018).

Muscle strengthening group (control group): The control group will undergo the same muscle strengthening intervention as the experimental group. Additionally, they will receive a placebo gait retraining intervention with inertial sensors. For this placebo intervention, the baseline (average angle of progression relative to the ground observed during the participant's initial evaluation) will be set to the same value as obtained during the participant's evaluation, and the target line will precisely match this average range of motion value observed during the participant's initial assessment. The percentage of feedback time, as well as the total gait retraining time, will be identical to the experimental group.

The assessment and interventions procedures are summarized in Figure 1.

Fig 1. Assessment and interventions procedures summary



Exercise program progression control variables

Considering that pain is the major osteoarthritis' symptom (49), it will be used a scale for monitoring pain during exercise training (50,51). The subjects will be asked to tell the pain level on a 0 (no pain) to 10 (the worst possible pain) scale and will be instructed that pain level up to 5 is allowed. The exercise program will be progressed as described in table 2 if any increase in pain returns to baseline or lower within 24 hours. If pain does not subside, the training will be regressed to the previous level (50).

Methodological aspects

The descriptive information about enrolment, allocation, post-allocation and close-out are described in figure 2.

Fig 2. Schedule of enrolment, interventions, and assessments

	STUDY PERIOD					
	Enrolment	Allocation	Post-allocation			Close-out
TIMEPOINT	$-t_1$	0	*2 weeks*	*4 weeks*	*6 weeks*	*8 weeks*
ENROLMENT:						
Eligibility screen	X					
Informed consent	X					
Allocation		X				
INTERVENTIONS:						
Gait retraining, education and muscle strengthening						
Education and muscle strengthening						
ASSESSMENTS:						
Pain and function	X					X
Gait kinematics	X					X
Muscle torque	X					X

DISCUSSION

Contributions to professionals and patients

The results of this study will determine whether gait retraining adds efficacy to the core treatment of knee osteoarthritis. Based on these findings, physical therapists will be able to assess whether integrating gait retraining strategies into the treatment plan is a viable alternative, or if it is preferable to continue employing only the main primary treatment approach. This approach ensures that patients receive treatment tailored to their health condition, optimizing therapeutic outcomes.

Strengths and weaknesses of the study

Guidelines for conservative treatment of knee osteoarthritis have emphasized the importance of correct doses of therapeutic exercise. However, we are not aware of any scientific studies that have utilized the recommended dosage associated with toe-out gait retraining. Therefore, to our knowledge, this is the first study that evaluates the effect of toe-out gait retraining combined with muscle strengthening and health education on clinical and biomechanical outcomes in individuals with knee osteoarthritis.

However, this work has some limitations. Among them is the impossibility of blinding the therapist. Additionally, due to lack of financial resources, we did not propose an assessment of the external knee adductor moment, which is an important parameter regarding the development and progression of the disease (13).

Prospects for future researches

Future studies investigating the effects of alternative retraining strategies or different parameters for toe-out retraining on clinical and biomechanical outcomes will address important gaps regarding the conservative knee osteoarthritis treatment.

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5 CONSIDERAÇÕES FINAIS

O presente trabalho objetivou revisar sistematicamente a literatura no que diz respeito às estratégias neuromusculares de retreinamento de marcha aplicadas a indivíduos com osteoartrite de joelhos e seus efeitos sobre desfechos biomecânicos e clínicos, e apresentar o protocolo de um ensaio clínico que objetivará comparar o efeito do retreinamento de marcha em *toe-out* associado ao fortalecimento da musculatura de joelho e quadril, sobre dor, função auto relatada, torque muscular e parâmetros espaço-temporais e cinemáticos da marcha de indivíduos com osteoartrite de joelhos.

Com relação à revisão sistemática, ressalta-se a escassez de ensaios clínicos randomizados que investiguem os efeitos das estratégias de retreinamento da marcha nas variáveis clínicas e biomecânicas da osteoartrite do joelho. Apesar do número limitado de estudos, o retreinamento da marcha se mostrou efetivo na melhora da dor dos indivíduos com osteoartrite de joelho quando comparado às intervenções dos grupos controle. Contudo, esse dado deve ser considerado com cautela, já que a melhora não foi clinicamente importante. O retreinamento também se mostrou efetivo na melhora da função e na redução do primeiro momento adutor do joelho, embora não tenha demonstrado diferença no que se refere ao segundo momento adutor e ao momento flexor.

No que se refere ao protocolo de ensaio clínico, cabe destacar que as diretrizes para o tratamento conservador da osteoartrite do joelho enfatizam a importância de doses corretas de exercícios terapêuticos. No entanto, até o momento, não estão disponíveis estudos científicos que tenham utilizado a dosagem recomendada associada ao retreinamento da marcha em *toe-out*. Apesar de ser um estudo pioneiro no que se propõe a fazer, este trabalho não inclui a avaliação do momento adutor externo do joelho diante da escassez de recursos financeiros.

Por fim, é relevante salientar que ambos os trabalhos, cada qual com seus próprios objetivos e metodologias distintas, fornecem contribuições significativas para a pesquisa e para a clínica, ao preencherem lacunas no que diz respeito ao processo de cuidado de indivíduos com osteoartrite de joelhos. Ainda cabe enfatizar que se complementam, uma vez que a definição dos parâmetros utilizados no retreinamento de marcha e descritos no protocolo advém, em parte, dos achados da revisão sistemática.

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