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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO

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Efeitos de um Programa de Treinamento Excêntrico Utilizando o Exercício Nórdico de Isquiotibiais Sobre Fatores de Risco de Lesão Muscular em Indivíduos Saudáveis

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Orientador: Dr. Bruno Manfredini Baroni

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RESUMO

O estiramento dos músculos isquiotibiais está entre as lesões mais comuns relacionadas aos esportes. O principal mecanismo de lesão envolve contrações excêntricas desse grupo muscular durante a corrida de alta velocidade e outros movimentos balísticos, como o chute. Assim, o exercício excêntrico tem baseado os programas de prevenção para estiramentos dos isquiotibiais, e estudos têm demonstrado que programas envolvendo o Exercício Nórdico de Isquiotibiais (ENI) são capazes de reduzir a incidência de lesões em atletas de diferentes modalidades e níveis competitivos. No entanto, as adaptações decorrentes de um programa de ENI sobre outros fatores de risco para os isquiotibiais permanecem obscuras. Portanto, o objetivo desse estudo foi verificar os efeitos do treinamento excêntrico baseado unicamente no ENI em múltiplos fatores de risco relacionados ao estiramento muscular. Vinte jovens adultos saudáveis foram divididos em dois grupos: Grupo Treinamento (GT) e Grupo Controle (GC). O GT participou de um programa de treinamento com o ENI durante quatro semanas, enquanto o CG não recebeu nenhuma intervenção no período. Avaliou-se a força, a flexibilidade, a altura de saltos verticais e a arquitetura muscular para avaliar o efeito do treinamento sobre fatores de risco para a lesão de isquiotibiais. O GC não apresentou mudanças significativas ($p>0.05$) nas avaliações realizadas. O grupo treinamento apresentou aumentos no pico de torque isométrico (9%, $p=0.04$) e excêntrico (13%, $p=0.01$), assim como no trabalho excêntrico (18%, $p<0.01$) dos flexores de joelho. Houve aumentos também na razão de torque funcional (13%, $p<0.01$) e no salto contramovimento (8%, $p=0.01$). Além disso, houve incremento no comprimento do fascículo do bíceps femoral cabeça longa (22%, $p<0.01$) decorrente do programa de ENI. Estes resultados evidenciam que um curto período de treinamento com ENI pode levar a mudanças na estrutura e na função musculares relacionadas à prevenção das lesões dos isquiotibiais, fornecendo suporte à inclusão deste exercício na pré-temporada das equipes esportivas.

Palavras-chave: estiramentos; prevenção de lesão; treino excêntrico; flexores de joelho.

ABSTRACT

Hamstring strain is among the most common sports-related injuries. The primary mechanism of injury involves eccentric contraction of this muscle group during high speed sprinting and other ballistic movements like kicking. Thus, the eccentric exercise is the basis of prevention programs for hamstring injury and studies have shown that programs including the Nordic Hamstrings Exercise (NHE) are capable to significantly reduce the injury risk in athletes from different sports and competitive levels. However, the adaptations promoted by NHE program on other injury risk factors of the hamstrings remain unclear. Therefore, the purpose of this study was to investigate the effects of a NHE training programme on multiple risk factors for hamstring injury. Twenty healthy young adults were allocated into two groups: training group (TG) and control group (CG). The TG was engaged in a 4-week NHE programme; and CG received no exercise intervention during the same time period. Isokinetic dynamometry, ultrasonography, flexibility and jump tests were performed to assess the effect of the NHE programme on risk factor for hamstring injury. The CG subjects had no significant change on any outcome ($p>0.05$). In the TG, knee flexors isometric peak torque (9%; $p=0.04$), eccentric peak torque (13%; $p=0.01$) and eccentric work (18%; $p<0.01$) were increased by the NHE programme, as well as functional hamstring-to-quadriceps torque ratio (13%; $p<0.01$) and countermovement jump height (8%; $p=0.01$). In addition, fascicle length of biceps femoris long head was enlarged due to training (22%; $p<0.001$). These results provide evidence that a short-term NHE training can lead to changes in hamstring structure and function related to the preventive effect against injuries of this muscle group, further supporting the inclusion of the NHE at sports teams' preseason.

Keywords: Hamstring strain; Injury prevention; Eccentric training; Knee flexors. .

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LISTA DE ABREVIATURAS E SIGLAS

Revisão de Literatura:

BF_{CL}	Bíceps Femoral – Cabeça Longa
CF	Comprimento do Fascículo
EMG	Eletromiografia
ENI	Exercício Nórdico para os Isquiotibiais

LISTA DE ABREVIATURAS E SIGLAS

Artigo:

BF	Biceps Femoris
BF_{LH}	Biceps Femoris Long Head
CG	Control Group
CMJ	Countermovement Jump
FL	Fascicle Length
$H_{con}:Q_{con}$	Conventional Muscle Imbalance Ratio
$H_{exc}:Q_{con}$	Functional Muscle Imbalance Ratio
MT	Muscle Thickness
NHE	Nordic Hamstring Exercise
PA	Pennation Angle
Post	Post-intervention
Pre	Pre-intervention
SJ	Squat Jump
TG	Training Group
US	Ultrasound

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1. INTRODUÇÃO

A prática regular de atividade física e exercícios está associada a benefícios para a saúde física e mental de homens e mulheres. Recomenda-se, portanto, que um estilo de vida seja ativo em níveis suficientes para promover as adaptações positivas nos diversos sistemas fisiológicos (Garber et al., 2011). Entretanto, os efeitos benéficos ocasionados por um estilo de vida fisicamente ativo e pela participação em esportes recreativos e competitivos podem vir a ser contrabalançados pelo risco de lesões ao praticá-los (Van der Horst et al., 2014).

Uma lesão pode ser definida como uma perturbação tecidual ocasionada por uma ruptura mecânica (Kumar, 1999), sendo as mais comuns àquelas que acometem o sistema musculoesquelético (Hootman et al., 2002) como, por exemplo, os estiramentos nos músculos posteriores da coxa (Brockett, Morgan e Proske, 2004). Os estiramentos são a lesão muscular de maior prevalência relacionada aos esportes (Mendiguchia e Brughelli, 2011), particularmente naqueles em que há tiros de corrida (sprint), chutes e movimentos de agilidade em grandes velocidades (Sherry et al., 2011), como o futebol (Arnason et al., 2004).

A idade e a lesão prévia se apresentam como importantes fatores de risco para o desenvolvimento de estiramentos dos isquiotibiais (Timmins et al., 2015), ambos não podendo ser modificados por meio de programas de prevenção. No entanto, a literatura também apresenta potenciais fatores de risco modificáveis para os estiramentos dos isquiotibiais: o déficit na força muscular dos isquiotibiais (Yanamoto, 1993; Lee et al., 2009), o desequilíbrio nas razões isquiotibiais/quadríceps (Croisier et al., 2008), o reduzido ângulo ótimo do pico de torque (Brockett et al., 2004), a deficiente flexibilidade relacionada aos isquiotibiais (Hartig et al., 1999; Witvrouw et al., 2003) e o comprimento reduzido dos fascículos musculares (Timmins et al., 2015).

Alguns autores recomendam a adoção de exercícios excêntricos como parte do programa de treinamento que atue sobre os fatores de risco dos estiramentos (Tyler e Slattery, 2010), diminuindo a chance de lesão futura. Nesse sentido, o Exercício Nórdico para Isquiotibiais (ENI) vem sendo usado há mais de uma década para o fortalecimento da musculatura posterior da coxa (Mjølnes et al., 2004) e sua popularidade se deve em grande parte à praticidade de ser realizado em duplas, sem a necessidade de equipamentos (Ditroilo et al., 2013). Além disso, estudos têm reportado uma redução significativa no índice de lesões de isquiotibiais por meio de programas de prevenção baseados no ENI (Arnason et al., 2008; Petersen et al., 2011). Por outro lado, as adaptações promovidas por esse exercício sobre os fatores de risco de lesão muscular precisam ser elucidadas.

Portanto, justifica-se a realização do presente projeto de pesquisa em virtude das potencialidades desse exercício e a incerteza acerca dos seus efeitos sobre alguns dos principais fatores de risco modificáveis para as lesões por estiramento dos músculos isquiotibiais.

Assim, o objetivo geral deste estudo foi verificar o efeito do treinamento excêntrico utilizando unicamente o ENI sobre múltiplos parâmetros relacionados aos fatores de risco para lesão muscular.

Este trabalho utilizou dois grupos, um submetido a um período de 4 semanas de treinamento e outro como controle para fins dos seguintes objetivos específicos:

1) Verificar e comparar o efeito do treinamento ENI sobre as adaptações morfológicas [espessura muscular (EP), ângulo de penação (AP) e comprimento de fascículo (CF)] do músculo bíceps femoral;
2) Verificar e comparar os efeitos do treinamento ENI sobre a capacidade de produção de torque concêntrico, excêntrico e isométrico dos músculos flexores do joelho;
3) Verificar e comparar os efeitos do treinamento ENI sobre as razões de desequilíbrio muscular Isquiotibiais:Quadríceps;
4) Verificar e comparar os efeitos do treinamento ENI sobre a flexibilidade da cadeia posterior dos membros inferiores.

2. REVISÃO DE LITERATURA

2.1 Lesões de isquiotibiais

Isquiotibiais é o nome atribuído ao grupo muscular localizado na região posterior da coxa formado pelos músculos bíceps femoral, semitendinoso e semimembranoso (Woodley e Mercer, 2005), conforme ilustrado na Figura 1. As funções destes músculos incluem estender o quadril e flexionar o joelho (Petersen et al., 2011).

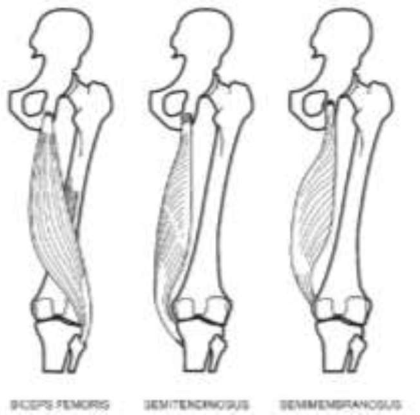

Figura 1 Ilustração do plano coronal, vista posterior da coxa direita e a localização dos três músculos que, juntos, constituem os isquiotibiais. A cabeça curta do músculo bíceps femoral é profunda em relação à cabeça longa. Fonte: Koulouris e Connel, 2005.

Os estiramentos dos isquiotibiais são lesões caracterizadas pela ruptura de um conjunto de fibras, sendo comumente classificados de acordo com a sua gravidade: lesão grau I (leve, ruptura de poucas fibras, pequeno inchaço e desconforto e mínima ou nenhuma perda de força ou de função), lesão grau II (ruptura de diversas fibras, com moderados inchaço, desconforto, perda da força e da função musculares) e lesão grau III (perda severa da força e da função musculares devido à ruptura de fibras que se estende por todo o ventre muscular) (Donatelli, 2007). Os estiramentos constituem a principal razão de dor na região posterior da coxa (Asklin et al., 2007) e a lesão muscular de maior prevalência relacionada aos esportes (Mendiguchia e Brughelli, 2011), particularmente naqueles em que há tiros de corrida (*sprint*), chutes e movimentos de agilidade em grandes velocidades (Sherry et al., 2011), como o futebol (Arnason et al., 2004). Essas lesões representam de 6% a 29% de todas as lesões observadas no futebol, futebol australiano, rúgbi, basquete, e velocistas de atletismo (Ekstrand et al., 2011; Goode et al., 2014). Ainda, são lesões que podem ser frustrantes, sobretudo porque os sintomas são persistentes, a cura pode ser lenta e a taxa de recorrência (34%) é a mais alta entre todas as lesões (Orchard et al., 2002; Petersen e Hölmich, 2005). Assim, dependendo da gravidade, podem resultar na formação de cicatrizes fibrosas no tecido muscular (Sherry et al., 2011). Consequentemente, os estiramentos costumam ser responsáveis pelo maior tempo de afastamento da prática esportiva (Bennell et al., 1998; Walden et al., 2005), prejudicando o desempenho e o orçamento das equipes (Woods et al., 2002).

2.2 Etiologia da lesão

Embora existam diversos trabalhos que estudam os estiramentos de isquiotibiais, suas causas precisas não se encontram completamente elucidadas (Iga et al., 2012). As investigações sobre a origem e os fatores de risco associados assinalam a natureza multifatorial destas lesões (Ditroilo et al., 2013). Explorar a etiologia da lesão demanda que se busque uma melhor identificação dos mecanismos que envolvem a sua ocorrência. Sabe-se que as ações musculares podem ser divididas entre aquelas que mantêm o comprimento muscular constante (isométricas), e em outras em que ocorre o encurtamento (concêntricas) ou alongamento ativo (excêntricas) das fibras musculares (Herzog, 2014). As ações excêntricas parecem ser as mais relacionadas com os estiramentos de isquiotibiais e são observadas durante as atividades esportivas e da vida diária quando há a desaceleração de um movimento ou absorção de energia, como ocorre na aterrissagem de um salto, na fase final do balanço na corrida e no chute (Vogt e Hoppeler, 2014).

O mecanismo do estiramento dos isquiotibiais observado na corrida envolve o repetido trabalho excêntrico dos isquiotibiais em altas velocidades (Chumanov et al., 2007). Durante a parte final da fase de balanço na corrida até o contato do pé com o solo há um período de desaceleração da perna promovido pelos músculos posteriores da coxa, representando um aumento da sua carga excêntrica. Dos isquiotibiais, a atividade muscular do bíceps femoral, medida durante esta etapa da corrida, chega ao dobro da atividade dos músculos semimembranoso e semitendinoso (Slider et al., 2010). Nessa fase esses músculos são solicitados para

(1) contrair excentricamente para desacelerar a extensão do joelho, (2) contrair quase isometricamente enquanto controla a estabilidade da articulação do joelho, (3) realizar um rápido contramovimento da extensão para a flexão de joelho e (4) participar da extensão do quadril (Clark, 2008). Admite-se ser nessa fase rápida e de múltiplas exigências neuromotoras que há maior probalidade de que estas lesões aconteçam (Schache et al., 2009). É interessante notar que, mesmo em modalidades como o futebol, no qual são realizados gestos com maiores amplitudes de movimentos em relação aos utilizados nas corridas, e em que vigorosas contrações excêntricas ocorrem na fase de desaceleração do chute, o mecanismo de lesão que prevalece é justamente o associado à corrida (mais de 60% do total de lesões) (Woods et al., 2004; Opar et al., 2014; Timmins et al., 2015).

Especula-se que, como consequência de um arranjo heterogêneo dos sarcômeros individuais, quando os isquiotibiais são ativados excentricamente, unidades musculares específicas dentro de um fascículo podem ser submetidas a um alongamento não uniforme, resultando em danos microscópicos (Proske e Morgan, 2001). Sob esse raciocínio, um esporte que requer repetidas ações excêntricas pode fazer com que este dano microscópico gere um ponto fraco a partir do qual pode surgir uma lesão mais significativa. Diante disso, suspeita-se que o estiramento de isquiotibiais ocorra na fase final de balanço na corrida como decorrência de uma força excêntrica insuficiente - um ponto fraco (Croisier et al., 2008) - acarretando uma ruptura nas estruturas contráteis e elásticas que pode variar em gravidade.

2.3 Fatores de risco

A etiologia da lesão está evidentemente conexa aos seus fatores de risco. Conhecer um fator de risco, entendido como uma situação que contribui para aumentar a probabilidade de uma lesão (Whiting e Zernicke, 2001), é importante para a construção e desenvolvimento de estratégias preventivas efetivas (Petersen e Hölmich, 2005). Fatores de risco podem ser diferenciados em fatores extrínsecos, principalmente inerentes à atividade esportiva e relacionados com o meio ambiente, e fatores intrínsecos, relacionados às características individuais do atleta (Croisier et al., 2004). Orchard et al. (2001) sugerem que fatores intrínsecos são mais preditivos da lesão muscular do que os fatores extrínsecos.

Entre os potenciais fatores intrínsecos de risco para os estiramentos dos isquiotibiais, figuram a disposição anatômica biarticular deste grupo muscular (Brockett et al., 2001), a idade dos sujeitos (Gabbe et al., 2005), a existência de estiramento prévio (Orchard et al., 2001), a arquitetura muscular (Kumazaki et al., 2012), a atividade do músculo em condições de fadiga (Worrel et al., 1994), o ângulo ótimo do pico de torque (Brockett et al., 2004); o desequilíbrio nas razões isquiotibiais/quadríceps (Croisier et al., 2008), a flexibilidade reduzida associada aos isquiotibiais (Hartig et al., 1999; Witvrouw et al., 2003) e o déficit na força muscular (Yanamoto, 1993; Lee et al., 2009). Destes, os três últimos são tradicionalmente considerados importantes fatores de risco que podem ser modificados (Van der Host et al., 2014). Recentemente, incluiu-se o comprimento reduzido do fascículo da cabeça longa do músculo bíceps femoral (BF_{CL}) como um fator de risco para essas lesões (Timmins et al., 2015).

A idade e a existência de estiramento prévio são condições manifestamente não modificáveis associadas ao risco de lesão. Em diversos esportes o histórico de estiramento dos isquiotibiais é considerado o fator de risco primário para futuras lesões (Verral et al., 2001; Arnason et al., 2004; Gabbe et al., 2006; Hagglund et al., 2006). Além da lesão potencialmente causar a formação de um tecido cicatricial no local do dano, resultando em uma área tecidual menos complacente, observa-se que membros previamente lesionados apresentam sinais de inibição neuromuscular durante ações excêntricas (Opar et al., 2012). Essa inibição provavelmente afeta a capacidade do músculo de se adaptar a novos estímulos, prejudicando o desenvolvimento da força excêntrica após a primeira lesão, o que, por seu turno, aumenta sobremaneira o risco de estiramento (Opar et al., 2015). Entretanto, o efeito de um estiramento prévio sobre a capacidade adaptativa de o membro lesado aumentar a força ainda precisa ser examinada (Opar et al., 2015**b**). Muitos estudos também têm apresentado o avanço da idade como um fator de risco não modificável independente para as lesões musculares (Orchard, 2001; Verrall et al., 2001; Arnason et al., 2004). Não obstante, recentemente sugeriu-se que as interações entre estes fatores de risco não modificáveis previamente identificados e os fatores modificáveis devem ser levados em consideração (Thorborg, 2014).

Um estudo de coorte conduzido por Croisier et al. (2008) acompanhou 462 jogadores após uma avaliação isocinética inicial para avaliação de desequilíbrios entre a musculatura flexora e extensora de joelho. Seus resultados indicam que a incidência de lesão para os sujeitos sem desequilíbrio (4.1%) foi quatro vezes menor do que a incidência observada durante a temporada de sujeitos identificados com desequilíbrios e que não se submeteram a um programa de reforço muscular (16.5%). Estes dados reforçam que as causas do estiramento podem estar relacionadas com a incapacidade dos isquiotibiais atuarem excentricamente para desacelerar o momento causado pelos músculos extensores de joelho.

Sugiura et al. (2008) avaliaram a força dos flexores de joelho e extensores de quadril em um estudo de coorte e observaram que todas as lesões ocorreram no lado do membro que se apresentou mais fraco nos testes isocinéticos iniciais. A relação entre força dos isquiotibiais deficitárias na pré-temporada e o aumento no risco de lesão na temporada de futebol Australiano foi aprofundada em estudo prospectivo realizado por Opar et al. (2014). Neste trabalho, os autores acompanharam 210 atletas e seus achados indicaram que uma força excêntrica de flexores de joelho inferior a 279 Newtons (realizada em um equipamento que simulava o exercício nórdico) aumentou em mais de 4 vezes o risco relativo de lesão, e que este risco não estava associado ao desequilíbrio bilateral dos isquiotibiais.

Outro estudo de coorte prospectivo (Witvrouw et al., 2003) encontrou uma associação significativa entre a diminuta flexibilidade dos flexores de joelho, avaliada durante a pré-temporada em 146 jogadores de futebol, e o subsequente incidente de estiramentos de isquiotibiais. Os autores não consideraram estes achados surpreendentes por estarem de acordo com as práticas sugeridas por muitos especialistas em medicina esportiva que acreditam no papel protetivo na flexibilidade no risco de lesão.

Timmins et al. (2015) foram pioneiros em associar menores comprimentos de fascículo (CF) do músculo bíceps femoral na sua porção longa (BF_{CL}) a um maior risco de lesões. Neste estudo prospectivo de coorte, foram coletadas imagens de ultrassom (US) do BF_{cl} de 152 futebolistas no início da pré-temporada. Os autores concluíram que para a amostra avaliada, possuir um CF menor do que 10.56

centímetros em repouso representava um risco relativo aumentado de 4.1 vezes para lesão dos isquiotibiais. Este estudo ainda demonstrou o efeito protetor que o ganho de força excêntrica de isquiotibiais e aumento no CF do BF_{CL} podem ter, se contrapondo aos riscos não modificáveis, como a idade.

2.4 Programas de prevenção da lesão

Considerando a alta recidiva da lesão, espera-se um maior resultado em termos de prevenção quando estratégias que evitem a lesão inicial forem concebidas (Heiderscheidt et al., 2010). Programas que promovam a estabilidade articular, que demandem esforços em maiores amplitudes de movimentos, que alterem a arquitetura musculotendínea, que aumentem a força e aprimorem o controle neuromuscular tem potencial para alcançar esse objetivo (Malliaropoulos et al., 2012). Na falta de um consenso sobre um protocolo ideal para a prevenção da lesão por estiramento dos isquiotibiais, muitos autores recomendam a adoção de exercícios excêntricos como parte do programa de treinamento que operem sobre os fatores de risco modificáveis (Tyler e Slattery, 2010).

Asklin et al. (2003) observaram uma redução de no número de lesões em um grupo de 15 jogadores de futebol que realizaram 16 sessões de treinamento com ênfase na fase excêntrica utilizando um equipamento isoinercial comparados com 15 jogadores que compuseram o grupo controle (3 x 15 lesões). Estes resultados encorajaram outros estudos prospectivos a avaliarem os efeitos de programas de exercício excêntrico de flexores de joelho. Arnason et al. (2008) introduziram o Exercício Nórdico de Isquiotibiais (ENI) na Liga Profissional de Futebol Norueguesa demonstrando uma redução de 57% nas lesões dos times que aderiram ao programa de exercícios em comparação com os que não o seguiram, além de uma diminuição de 58% em relação às lesões do próprio time no ano anterior. Petersen et al. (2011) conduziram um ensaio controlado randomizado multicêntrico para investigar o efeito protetor oferecido pelo fortalecimento excêntrico, adotando um programa de 10 semanas de ENI como exercício adicional do grupo intervenção (n=461). Seus resultados apontaram uma diminuição de 59% de novas lesões para o grupo que treinou e uma redução de 86% na taxa de reincidências. Esses achados reforçam que a alteração de fatores de risco modificáveis pode contrabalançar aqueles decorrentes de fatores não modificáveis.

Com isso, o exercício excêntrico tem sido classificado como o método mais importante na prevenção de lesões de isquiotibiais em diferentes modalidades desportivas. Equipamentos de dinamometria isocinética, aparelhos convencionais de treinamento resistido, faixas elásticas, pesos livres ou exercícios com a própria massa corporal dos atletas, como o ENI, estão entre os exercícios excêntricos adotados nas intervenções relacionadas à prevenção de lesões. Em programas de prevenção elaborados pelos clubes futebol da primeira divisão de diversos países, o ENI foi classificado em 5º lugar com adesão de 65% dos clubes avaliados no estudo de McCall et al. (2014).

Um programa de 10 semanas de treinamento em um aparelho que enfatizava a ação excêntrica dos isquiotibiais levou a um aumento significativo do torque excêntrico (15%) dos flexores do joelho (Askling et al., 2003). Baroni et al. (2013) relataram achados indicando que os ganhos de força se devem tanto à adaptação neuromuscular (melhora da capacidade de ativação excêntrica) como à resposta hipertrófica (ganho de massa muscular). No entanto, evidências em modelo animal apontam que o exercício excêntrico é também capaz de aumentar o comprimento da fibra muscular devido à adição de sarcômeros em série (Morgan e Allen, 1999). Em humanos, foi relatado o aumento do comprimento fascicular (CF) dos músculos isquiotibiais após programas de treinamento excêntrico de flexores de joelho utilizando equipamentos de musculação (Potier et al., 2009) e dinamômetro isocinético (Timmins et al., 2016). Ademais, programas de treinamento excêntrico têm se mostrado eficazes no aumento da flexibilidade dos isquiotibiais em níveis similares aos alcançados pelo alongamento estático (Nelson e Bandy, 2004), assim como alterar o ângulo ótimo de produção de torque em direção aos maiores comprimentos musculares (Brughelli et al., 2010).

2.5 Exercício Nórdico de Isquiotibiais (ENI)

O ENI, descrito primeiramente por Brockett et al. (2001), vem se tornando popular entre profissionais da saúde e do esporte nos últimos anos (Ditroilo et al., 2013), principalmente devido a sua praticidade e baixo custo (Gabbe et al., 2006), uma vez que não requer nenhum equipamento para ser realizado. Embora haja a possibilidade de utilizar um aparato feito especificamente para a sua execução (Opar et al., 2013), o mais frequente é que o ENI seja executado em duplas (Van der Horst et al., 2014) no próprio local de treinamento dos atletas (campos ou quadras desportivas).

Figura 2 Execução do Exercício Nórdico para Isquiotibiais (ENI). Fonte: Arnason et al., 2008.

Quando o ENI é realizado em duplas (Figura 2), o sujeito ativo adota a posição de joelhos e esforça-se para resistir ao movimento de queda à frente causado pela força gravitacional, acionando excentricamente seus isquiotibiais. O sujeito é orientado a manter os quadris com uma ligeira flexão durante toda a amplitude de movimento mantendo os músculos flexores do joelho tensionados mesmo após sentir que não é mais capaz de controlar o movimento. O sujeito é instruído a usar seus braços e mãos no amortecimento da queda, deixando o seu peito tocar no chão, e a voltar imediatamente à posição inicial impulsionando o solo com os membros superiores para minimizar a ação concêntrica dos isquiotibiais (Mjølsnes et al., 2004). Um colega ou investigador aplica pressão sobre os tornozelos, assegurando que os pés do executante permaneçam em contato com o solo durante todo o exercício (van der Horst et al., 2014).

Por ser um exercício excêntrico de emprego simples e acessível, o ENI tem sido objeto de investigação quanto a sua eficácia na prevenção de lesões e quanto aos seus efeitos sobre os fatores de risco de lesão modificáveis. Em dois estudos prospectivos, a inclusão de ENI no programa de treinamento da Liga Profissional de Rúgbi (Brooks et al., 2006) e de jogadores de elite de futebol (Arnason et al., 2008) resultou em uma diminuição significativa tanto da incidência como da gravidade dos estiramentos dos isquiotibiais. Em outros dois ensaios clínicos randomizados controlados, a taxa de lesão nos isquiotibiais de jogadores de futebol (Petersen et al., 2011) e futebol australiano (Gabbe et al., 2006) foi significativamente reduzida naqueles atletas que realizaram o ENI como parte de um programa preventivo de lesões na pré-temporada e temporada.

A efetividade do ENI na prevenção de lesões despertou o interesse dos pesquisadores em detalhar os aspectos de ativação neuromuscular relacionados ao exercício. Demonstrou-se que a ativação eletromiográfica (EMG) dos músculos isquiotibiais é semelhante entre os lados dominante e não dominante durante o ENI (Iga et al., 2012), e que as porções medial e lateral desse grupo muscular têm níveis de ativação mioelétrica equivalentes durante a execução do exercício (Tsaklis et al., 2015). O sinal EMG caracteriza-se por ser mais fraco na fase inicial, atingindo um nível significativamente mais alto no meio do exercício, e assim permanecendo em posições articulares de joelho mais estendidas (Iga et al., 2012. Ditroilo et al., 2013; Tsaklis et al., 2015). Curiosamente, já foi demonstrado que a maioria dos indivíduos exibe um pico de ativação EMG maior no ENI do que no exercício excêntrico realizado no dinamômetro isocinético e em média, durante o ENI, a ativação EMG foi 134% mais alta em uma amplitude de movimento pareada (Ditroilo et al., 2013).

Portanto, é compreensível que um programa de treinamento baseado no ENI aumente a força excêntrica (11-21%) e isométrica (7%) dos flexores de joelho (Mjølsnes et al., 2004; Iga et al., 2012; Tansel et al., 2008); assim como diminuir de 10 para 5% o desequilíbrio bilateral de torque concêntrico dos isquiotibiais (Anastasi et al., 2011). Em relação à força concêntrica dos isquiotibiais, mínimos (Mjølsnes et al., 2004) ou nenhum (Clark et al., 2005) efeito foi observado após um programa de ENI. Mjølsnes et al. (2004) verificaram a maior efetividade do ENI em comparação ao treinamento convencional de flexão de joelhos em equipamento de musculação sobre a melhora da razão de torque isquiotibiais-quadríceps. Ainda, o treinamento com o ENI é capaz de aumentar o torque excêntrico dos flexores de joelho nas velocidades de 60, 120 e 240°/s, indicando que, embora o ENI seja realizado em velocidade angular baixa, o treinamento resulta em adaptações transferíveis aos movimentos de alta velocidade, como os que ocorrem na prática esportiva (Iga et al., 2012). Além dos efeitos do treinamento com o ENI sobre a força muscular, encontramos três trabalhos que avaliaram os efeitos desse tipo de intervenção sobre o ângulo de pico de torque (Clark et al., 2005; Iga et al., 2013; Delahunt et al., 2016). Esses estudos não nos permitem chegar a uma conclusão, visto que tanto foi encontrado um aumento de 6,5° (Clark et al., 2005) como ausência de efeito significativo (Iga et al., 2013; Delahunt et al., 2016) do ENI sobre o ângulo ótimo de produção de torque. Efeitos do ENI sobre outros fatores de risco, como a flexibilidade e o comprimento dos fascículos musculares, parecem não ter sido investigados até o momento.

Enfim, percebe-se que alguns estudos têm se preocupado em investigar as adaptações do ENI sobre parâmetros considerados fatores de risco modificáveis na lesão por estiramento dos músculos posteriores da coxa. Contudo, o tema é recente e diversas controvérsias e lacunas merecem ser apuradas. A carência da literatura em relação aos mecanismos que expliquem o efeito protetor do ENI sobre as lesões de isquiotibiais (Arnason et al., 2008; Petersen et al., 2011; van der Horst et al., 2015) pode ser uma explicação para a baixa adoção e implementação do programa de ENI no nível mais alto do futebol europeu (Bahr et al 2015). Ao mesmo tempo, esta baixa adesão das equipes de futebol de elite aos programas com eficiência cientificamente respaldada pode ser uma razão para o aumento anual de 4% das lesões isquiotibiais entre 2001-2014 nesta população (Ekstrand et al., 2016). Assim, justifica-se a realização do presente projeto de pesquisa em virtude das potencialidades desse exercício e a incerteza acerca dos seus efeitos sobre alguns dos principais fatores de risco modificáveis para as lesões por estiramento dos músculos isquiotibiais.

2.6 REFERÊNCIAS BIBLIOGRÁFICAS

Aagaard P, Andersen JL, Dyhre-Poulsen P, Leffers AM, Wagner A, Magnusson SP, Halkjaer-Kristensen J, Simonsen EB. A mechanism for increased contractile strength of human pennate muscle in response to strength training: changes in muscle architecture. J Physiol. 534 (Pt. 2): 613-623, 2001.

Aboodarda SJ, George J, Mokhtar AH, Thompson M. Muscle strength and damage following two modes of variable resistance training. J Sports Sci Med. 2011; 10(4): 635-642. J Sports Sci Med. 10(4): 635-42, 2011

AnastasI SM, Hamzeh MA. Does the eccentric Nordic Hamstring exercise have an effect on isokinetic muscle strength imbalance and dynamic jumping performance in female rugby union players? Isokinetics and Exercise Science. 19: 251-260, 2011.

Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. Scand J Med Sci Sports. 18(1): 40-48, 2008.

Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand J Med Sci Sports. 13: 244-250, 2003.

Bahr R, Thorborg K, Ekstrand J. Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey. Br J Sports Med. 49(22):1466-1471, 2015.

Baroni BM, Geremia JM, Rodrigues R, De Azevedo Franke R, Karamanidis K, Vaz MA. Muscle architecture adaptations to knee extensor eccentric training: rectus femoris vs. vastus lateralis. Muscle Nerve. 48(4): 498-506, 2013.

Bennell K, Wajswelner H, Lew P, Schall-Riaucour A, Leslie S, Plant D, Cirone J. Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. Br J Sports Med. 32(4): 309–314, 1998.

Brockett CL, Morgan Dl, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. Med Sci Sports Exerc. 33(5): 783-790, 2001.

Brughelli M, Mendiguchia J, Nosaka K, Idoate F, Arcos AL, Cronin J. Effects of eccentric exercise on optimum length of the knee flexors and extensors during the preseason in professional soccer players. Phys Ther Sport. 11: 50-55, 2010.

Chumanov ES, Heiderscheit BC, Thelen DG. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase os sprinting. J Biomech. 40(16): 3555-3562, 2007.

Clark R, Bryant A, Culgan Jp, Hartley B. The effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameters: a pilot study on the implications for the prevention of hamstring injuries Phys Ther Sport. 6(2): 67-73, 2005.

Croisier JL. Factors associated with recurrent hamstring injuries. Sports Med. 34(10):681-695. Review. 2004.

Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players a prospective study. The Am J Sports Med. 36(8): 1469-1475, 2008.

Ditroilo M, De Vito G, Delahunt E. Kinematic and electromyographic analysis of the Nordic Hamstring Exercise. J Electromyogr Kinesiol. 23: 1111-1118, 2013.

Donatelli R. Sport-Specific Rehabilitation. Chapter 6: Overuse Injury and Muscle Damage. Churchill Livingstone, Elsevier. 2007.

Ekstrand J, Waldén M, Hägglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. Br J Sports Med. 50(12):731-737. 2016.

Ekstrand J, Hägglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. Br J Sports Med. 45(7): 553–558, 2011.

Gabbe BJ, Branson R, Bennell Kl. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. J Sci Med Sport. 9(1-2): 103-109, 2006.

Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc. 43(7): 1334-1359, 2011.

Goode AP, Reiman MP, Harris L, Delisa L, Kauffman A, Beltramo D, Poole C, Ledbetter L, Taylor AB. Eccentric training for prevention of hamstring injuries may depend on intervention compliance: a systematic review and meta-analysis. Br J Sports Med. 49(6): 349-356, 2015.

Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. Br J Sports Med. 40(9):767-772, 2006.

Hartig DE, Henderson JM. Increasing hamstring flexibility decreases lower extremity overuse injuries in military basic trainees. Am J Sports Med. 27(2):173-176, 1999.

Herzog W. Mechanisms of enhanced force production in lengthening (eccentric) muscle contractions. J Appl Physiol (1985). 116(11):1407-1417, 2014.

Hootman JM, Macera CA, Ainsworth BE, Addy CL, Martin M, Blair SN. Epidemiology of musculoskeletal injuries among sedentary and physically active adults. Med Sci Sports Exercise. 34(5): 838-844, 2002.

Iga J, Fruer CS, Deighan M, Croix MDS, James DVB. “Nordic” hamstring exercise – engagement characteristics and training responses. Int J Sports Med. 33: 1000-1004, 2012.

Koulouris G e Connel D. Hamstring muscle complex an imaging review. Radiographics. 25(3): 571-586, 2005.

Kumar S. Biomechanics in Ergonomics. Chapter 1: Selected theories of musculoskeletal injury causation. Taylor & Francis, 1999.

Kumazaki T, Ehara Y, Sakai T. Anatomy and physiology of hamstring injury. Int J Sports Med. 33(12): 950-954, 2012.

Lee MJ, Reid SL, Elliott BC, Lloyd DG. Running biomechanics and lower limb strength associated with prior hamstring injury. Med Sci Sports Exerc. 41(10): 1942-1951. 2009.

Malliaropoulos N, Mendiguchia J, Pehlivanidis H, Papadopoulou S, Valle X, Malliaras P, Maffulli N. Hamstring exercises for track and field athletes: injury and exercise biomechanics, and possible implications for exercise selection and primary prevention. Br J Sports Med. 46(12): 846-851, 2012.

Mccall A, Carling C, Nedelec M, Davison M, Le Gall F, Berthoin S, Dupont G. Risk factors, testing and preventative strategies for non-contact injuries in professional football: current perceptions and practices of 44 teams from various premier leagues. Br J Sports Med. 48(18):1352-1357. 2014.

Mendiguchia J, Arcos AL, Garrues MA, Myer GD, Yanci J, Idoate F. The use of MRI to evaluate posterior thigh muscle activity and damage during nordic hamstring exercise. J Strength Cond Res. 27(12): 3426-3435. 2013.

Mendiguchia J, Brughelli MA return-to-sport algorithm for acute hamstring injuries. Phys Ther Sport. 12(1): 2-14. 2011.

Mjølsnes R, Arnason A, Østhagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand J Med Sci Sports. 14: 311-317, 2014.

Morgan DL, Allen DG.Early events in stretch-induced muscle damage. J Appl Physiol (1985). 87(6): 2007-2015, 1999.

Nelson RT, Bandy WD. Eccentric Training and Static Stretching Improve Hamstring Flexibility of High School Males. J Athl Train. 39(3): 254-258, 2004.

Opar DA, Williams MD, Timmins RG, Dear NM, Shield AJ. Knee flexor strength and bicep femoris electromyographical activity is lower in previously strained hamstrings. J Electromyogr Kinesiol. 23(3):696-703, 2012.

Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. J Orthop Sports Phys Ther. 43(9): 636-640, 2013.

Opar DA, Williams MD, Timmins RG, Hickey J, Duhig SJ, Shield AJ. Eccentric Hamstring Strength and Hamstring Injury Risk in Australian Footballers. Med Sci Sports Exerc. 47(4):857-865. 2014.

Opar DA, Williams MD, Timmins RG, Hickey J, Duhig SJ, Shield AJ. The effect of previous hamstring strain injuries on the change in eccentric hamstring strength during preseason training in elite Australian footballers. Am J Sports Med. 43(2):377-384, 2015.

Opar D, Williams M, Timmins R, et al. Eccentric hamstring strength and hamstring injury risk in Australian Footballers. Med Sci Sports Exerc. 47:857-865, 2015**b.**

Orchard JW. Intrinsic and extrinsic risk factors for muscle strains in Australian football. Am J Sports Med. 29(3): 300-303, 2001.

Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997-2000. Br J Sports Med. 36(1):39-44, 2002.

Petersen J, Holmich P. Evidence based prevention of hamstring injuries in sport. Br J Sports Med. 39(6): 319-323, 2005.

Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. Am J Sports Med. 39(11): 2296-2303, 2011.

Potier TG, Alexander CM, Seynnes OR. Effects of eccentric strength training on bíceps femoris muscle architecture and knee joint range of movement. Eur J Appl Physiol. 105:939-944, 2009.

Proske U, Morgan DL, Brockett CL, Percival P. Identifying athletes at risk of hamstring strains and how to protect them. Clin Exp Pharmacol Physiol. 31(8): 546-550, 2004.

Proske U, Morgan DL. Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications J Physiol. 537(2): 333-345, 2001.

Schache AG, Wrigley TV, Baker R, Pandy MG. Biomechanical response to hamstring muscle strain injury. Gait Posture. 29(2): 332-338, 2009.

Sherry MA, Best TM, Silder A, Thelen DG, Heiderscheit BC. Hamstring strains: basic science and clinical research applications for preventing the recurrent injury. Strength Cond J. 33(3): 56-71, 2011.

Thorborg K. What are the most important risk factors for hamstring muscle injury? Clin J Sport Med. 24(2):160-161, 2014.

Timmins RG, Bourne MN, Shield AJ, Williams MD, Lorenzen C, Opar DA. Short biceps femoris fascicles and eccentric knee flexor weakness increase the risk of hamstring injury in elite football (soccer): a prospective cohort study. Br J Sports Med. Dec 16. pii: bjsports-2015-095362. doi: 10.1136/bjsports-2015-095362. [Epub ahead of print]. 2015.

Tyler TF, Slattery AA. Rehabilitation of the hip following sports injury. Clin Sports Med. 29(1): 107-126, 2010.

Van Der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. Am J Sports Med. 43(6):1316-1323, 2015.

Van Der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the Nordic hamstring exercise on hamstring injuries in amateur soccer players study protocol for a randomised controlled trial. Inj Prev. 20(4):e8, 2014.

Verrall GM, Slavotinek JP, Barnes PG, Fon GT, Spriggins AJ. Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. Br J Sports Med. 35(6):435-439, 2001.

Vogt M, Hoppler HH. Eccetrinc training: mechanisms and effects when used as training regime or training adjunct. J Appl Physiol. 116: 1446-1454, 2014.

Walden M, Hagglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. Br J Sports Med. 39:542–6, 2005.

Whiting WC, Zernicke RF. Biomecânica da Lesão Musculoesquelética. Guanabara Koogan, 2001.

Witvrouw E, Danneels L, Asselman P, D'have T, Cambier D. Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. Am J Sports Med. 31(1): 41-46, 2003.

Woodley SJ, Mercer SR. Hamstring muscles: architecture and innervation. Cells Tissues Organs. 179(3): 125-141, 2005.

Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. Br J Sports Med. 38(1): 36-41, 2004.

Woods C, Hawkins R, Hulse M, Hodson A. The Football Association Medical Research programme: an audit of injuries in professional football: an analysis of ankle sprains. Br J Sports Med. 37(6): 233-8. 2002.

Worrel TD, Denegar CR, Armstrong SL, PERRIN DH. Effect of Body Position on Hamstring Muscle Group Average Torque. J Orthop Sports Phys Ther. 11(10): 449-452, 1990.

3. ARTIGO

Manuscript for Journal of Orthopaedic & Sports Physical Therapy (JOSPT)

Title:

Four weeks of Nordic hamstring exercise reduce muscle injury risk factors in young adults

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ABSTRACT

Study design: Interventional controlled trial.

Objectives: The purpose of this study was to investigate the effects of a Nordic hamstring exercise (NHE) training programme on multiple hamstring injury risk factors.

Background: NHE is a field-based exercise designed for knee-flexor eccentric strengthening, aimed at muscle strains prevention. However, possible effects of NHE programmes on other hamstring injury risk factors remain unclear.

Methods: Twenty healthy young adults were allocated into two equal sized groups: control (CG) and training group (TG). The TG was engaged in a 4-week NHE programme, while CG received no exercise intervention during the same time period. Hamstring injury risk factors were evaluated before and after training: the knee flexor and extensor strength capacity was assessed through isokinetic dynamometry; the biceps femoris muscle architecture through ultrasound images; and the hamstring flexibility through sit-and-reach test.

Results: CG subjects had no change in any outcome. In TG, hamstring isometric peak torque (9%), eccentric peak torque (13%), eccentric work (18%), and functional hamstring-to-quadriceps torque ratio (13%) increased from pre-training to post-training. The NHE programme led also to increased fascicle length (22%) and reduced pennation angle (-17%) in biceps femoris long head of the TG, with fascicle length presenting the largest effect size (ES=2.77) among the outcomes.

Conclusion: These results provide evidence that a short-term NHE training programme can improve hamstring structure and function that might provide a preventive injury effect on this muscle group.

Keywords: Hamstring strain; Injury prevention; Eccentric training; Knee flexors.

INTRODUCTION

Hamstring strain is one of the most common sports injuries. In professional soccer, for example, a team with a 25 player-squad typically suffers about 5-6 hamstring injuries per season [14], and older and previously injured players are the most affected[30]. The primary injury mechanism includes high-speed running (82%), stretching for a ball or opponent (11%) and kicking (7%)[30]. During the terminal running swing phase, the hamstrings are required to contract forcefully whilst lengthening to decelerate the extending knee and flexing hip[17]. Similarly, the other two-abovementioned injury mechanisms involve hamstring eccentric actions associated with knee extension and hip flexion movements. In view of these injury mechanisms, low level of hamstring eccentric strength[24, 30], deficient hamstring-to-quadriceps strength ratio[8], poor flexibility[33], and, more recently, short muscle fascicle length[30], have been cited as important modifiable risk factors for hamstring injury.

The Nordic hamstring exercise (NHE) is a simple partner exercise where the subject starts kneeling and attempts to resist a forward-falling motion using his hamstrings to maximize loading in the eccentric phase[22]. During the NHE execution, a progressive resistant torque imposed by the trunk position leads to increased neuromuscular hamstring activation at longer muscle lengths[18, 11], precisely at the most vulnerable injury position. Mjølsnes et al[22] firstly demonstrated that a NHE programme performed on the training environment of professional soccer players is more effective in developing maximal eccentric hamstring strength than a comparable programme based on hamstring curl machine at the fitness center. Thereafter, studies involving NHE training programmes have demonstrated a significant hamstring strains incidence reduction in football athletes over the last decade[2, 25, 32]. This efficacy in injury prevention is usually credited to hamstring muscles eccentric strengthening. However, possible effects of NHE programmes on the other risk factors for hamstring injury remain unclear.

Even in the face of promising NHE preventive effect shown by previous studies[2, 25, 32], adoption and implementation of the NHE programme at the sports' elite level is still low[4]. This fact highlights the need for a deeper understanding about the NHE effects on the hamstring structure and function, especially regarding the modifiable injury risk factors. Therefore, the aim of this study was to investigate the effects of a NHE training programme on multiple risk factors for hamstring injury in physically active young adults.

METHODS

Study Design

An interventional controlled trial was designed to verify the effects of a 4-week NHE eccentric training program on the following knee flexor injury risk factors: hamstring strength; hamstring-to-quadriceps strength ratio; posterior chain flexibility; and biceps femoris long head (BF_{LH}) fascicle length. Volunteers were allocated according to their availability to participate on the training sessions into two equal sized groups: training group (TG) and control group (CG). Evaluations were performed before and after the NHE training programme or the control period. All participants gave written informed consent to participate in the study and their rights were protected. This study was previously approved by the institutional ethics in research committee for human studies (#38025814.3.0000.5345).

Participants

Sample size estimation was completed using G-Power version 3.1.9.2. The two primary outcomes were considered from studies encompassing healthy young adults: hamstring eccentric peak torque (data extracted from Delahunt et al[10]) and BF_{LH} fascicle length (data extracted from Guex et al[16]). Power was set at 80% with an alpha level of 0.05, returning a calculated sample size of 10 subjects per group.

Twenty healthy young adults aged 18-35 years of age were recruited to participate voluntarily in the study. All participants were classified as moderately physically active, according the IPAQ short form[19]. None of them were currently undertaking any kind of lower limb strength training at least 6 months prior to their participation in the study nor were engaged in any kind of systematic training programme during data collection. Exclusion criteria included: (1) history of lower limb injury within the previous 12 months and/or history of previous hamstring strain throughout life; (2) musculoskeletal, respiratory or cardiovascular conditions considered a risk or a limiting factor for maximal exercise; and (3) users of nutritional supplements or anabolic steroids. Participants were asked to maintain their normal physical activity routine during the study. All the testing and training sessions were conducted at the physiotherapy laboratory.

Ultrasonography

Participants were assessed in the prone position with the hips at neutral position, the knees fully extended and the muscles relaxed. The feet were kept hanging off the stretcher, forming a 90° angle with the leg. A Velcro strap was used to keep the medial malleolus from abutting one another during the evaluation. Subjects rested for 10 minutes before ultrasound images were taken, and they were previously instructed not to engage in any vigorous physical activity for 48 hours before the tests. The scanning site for the BF_{LH} was determined as the halfway point between the ischial tuberosity and the superior border of the fibular head. Distances between anatomical landmarks were measured with measuring tape and their values recorded, ensuring the repositioning of the probe on the same muscle sites at second evaluation. The same experienced researcher made all ultrasound scans.

A B-mode ultrasonography system (Vivid*i*; GE Medical Systems, Fairfield, USA) with a linear-array probe (GE 8L; frequency: 13 MHz; depth: 8 cm; width: 4 cm) was used to assess muscle architecture parameters of BF_{LH}. A layer of water-soluble conductive gel was applied between the ultrasound probe and the skin. The ultrasound probe was positioned perpendicular to the skin in the muscle's longitudinal axis and care was taken to ensure minimal pressure over the skin. If necessary, slight adjustment in the probe orientation was made by the examiner in order to optimise the fascicle identification. Three images from each subject were taken and stored for further analysis with the ImageJ software (National Institutes of Health, USA).

Muscle thickness, pennation angle and fascicle length from each image were assessed (Figure 1), and the average value of the three collected images was considered for statistical analysis[5]. Muscle thickness was considered the mean length of three mutually parallel lines perpendicular to the superficial and deep aponeurosis. The most visible fascicle in each image was used for pennation angle and fascicle length analysis. Pennation angle was calculated as the angle between the muscle fascicle and the deep aponeurosis. Fascicle length was measured as the length of the fascicular path between the two aponeuroses. Because fascicle length was greater than the probe surface, the nonvisible part was estimated through a trigonometric function[26, 5].

<< Figure 1 >>

Flexibility assessment

Between ultrasonography and flexibility assessments, subjects performed a standard bilateral warming-up consisting of the following ballistic movements in the standing position: 10 reps of hip abduction/adduction, 10 reps of hip flexion/extension, 10 reps of shoulder flexion/extension, 10 reps of trunk rotation, 10 reps of wrist flexion/extension and 10 body weight squats. Next, subjects seated barefoot with the soles of the feet flat against the sit-and-reach box (Sanny, SP, Brazil) keeping the knees fully extended. Participants should slowly reach forward with both hands as far as possible, holding this position for approximately 2 seconds[3]. Evaluator registered only a correct execution, and volunteers had three valid attempts. The highest score (measured in centimeters) was considered for statistical analysis.

Isokinetic dynamometry

Subjects were positioned on the isokinetic dynamometer (Biodex System 4; Biodex Medical Systems, Shirley, NY, USA) for the assessment of the dominant lower limb according to the manufacturer's recommendations. Tests were conducted by experienced researchers, and the testing protocol was adapted from a previous study of our research group[9]. After a warm-up consisting of 10 concentric knee extension/flexion repetitions at an angular velocity of 120°/s with a submaximal effort level, subjects performed isometric, concentric and eccentric maximal tests. Three maximum 5-sec knee flexor isometric contractions were executed at 60° of knee flexion (0° = full extension) with a 2-min rest between tests. Peak torque values from each contraction were checked during data collection and an additional test was performed when torque variation was higher than 10% between the first three tests. Thereafter, three consecutive maximum contractions were executed in the concentric-concentric mode at 60°/s and a controlled range of motion (20-100° of knee flexion). The test was repeated twice with a 2-min resting period between attempts. Finally, two attempts of three consecutive maximal contractions were executed in the eccentric-eccentric mode at 60°/s and a controlled range of motion (35-90° of knee flexion).

The highest knee-flexor peak torque values in each contraction type were used for statistical analysis. Knee extensor peak torques were used to calculate the H:Q conventional ratio (concentric hamstring peak torque/concentric quadriceps peak torque) and the H:Q functional ratio (eccentric hamstring peak torque/concentric quadriceps peak torque). Knee flexor work (area under the torque-angle curve) in concentric and eccentric tests was also analysed.

NHE training programme

Volunteers allocated in the TG were engaged in a 4-week NHE training programme. This reduced period of training was chosen due to the limited duration of preseason experienced by professional teams in soccer (4-6 weeks)[34] and other sports. Thus, our intention was to verify the short-term responses to a NHE programme. Evaluations were performed five days before the first training session and five days after the last training session for TG, while 4-5 weeks were respected between evaluations for CG.

The same warm-up protocol described for the evaluation sessions was performed at the beginning of each training session. The NHE training periodization is detailed in Table 1. During exercise sessions, subjects kneeled on the padded mat and had their lower legs stabilized by a researcher. Participants were encouraged to slowly lowering their body in a constant-cadence (4 sec per repetition), sustaining a rigid torso position and only moving the knee joint. During the return to the NHE starting position, subjects used their upper limbs in order to avoid concentric actions of their hamstrings.

<< Table 1 >>

Statistical analysis

Data distribution from each outcome was checked with the Shapiro-Wilk test. Possible baseline differences between groups were assessed through independent t-tests. Percent changes (Δ% = post-training/pre-training-1) were used to verify the training effects, comparing groups through independent t-tests. The significance level was set at 5 % ($\alpha<0.05$). The effect size (ES) between pre- and post-training for each group was calculated using the Cohen's *d* formula: $ES = (M_{post} - M_{pre})/SD_{pooled}$, where M_{post} is the mean post-training measure, M_{pre} is the mean pre-training measure, and SD_{pooled} is the pooled standard deviation of the pre- and post-measurements. Training effect sizes were considered as "trivial" (ES<0.2), "small" (ES>0.2), "moderate" (ES>0.5), "large" (ES>0.8) or "very large" (ES>1.5).

RESULTS

At baseline evaluation, groups were similar in gender distribution, age, body mass and height (Table 2; p>0.05 for all variables), and presented similar values in all outcomes assessed in this study (Table 3; p>0.05 for all).

<< Table 2 >>

<< Table 3 >>

TG presented significant higher increases than CG on the hamstring isometric peak torque, eccentric peak torque, eccentric work, and H:Q functional ratio (Figure 1). No between-group differences were found on the hamstring concentric peak torque, concentric work, and H:Q conventional ratio (Figure 1). CG presented only trivial effect in all dynamometric outcomes (Table 3). TG had a small effect for isometric peak torque, concentric peak torque, and concentric work; a moderate effect for eccentric peak torque; and a large effect for eccentric work (Table 3).

<< Figure 2 >>

BF_{LH} muscle thickness did not change between evaluations for both groups (Table 3). A greater percent decrease on pennation angle was accompanied by a higher percent increase on fascicle length of TG compared to CG (Figure 2). The non-trained subjects presented only trivial effects on BF_{LH} muscle architecture parameters (Table 3). TG subjects had a trivial effect on BF_{LH} muscle thickness, a large effect on pennation angle, and a very large effect on fascicle length (Table 3).

<< Figure 3 >>

No significant differences were found for the flexibility changes between CG (-4.60 ± 6.81%; ES = 0.12) and TG (4.04 ± 15.33%; ES = 0.01) for the two evaluations (Table 3).

Figure 4 shows the individual responses of the TG on the primary outcomes of this study (ie, hamstring eccentric peak torque and fascicle length), considered very important risk factors for hamstring injury[30].

<< Figure 4 >>

DISCUSSION

The major findings of this study were that a 4-week NHE programme led to (1) significant improvements in the hamstring eccentric strength capacity (peak torque and total work) and (2) improvements in the H:Q functional ratio compared to a CG, as well as (3) decreased the BF_{LH} pennation angle and (4) increased the BF_{LH} fascicle length, (5) with no effect on lower-limb posterior chain flexibility. These findings provide support to some of the mechanisms that might provide a preventive effect of the NHE against hamstring injury.

To the best of our knowledge, this seems to be the first study to assess the effect of a NHE programme on the three different types of muscle contraction. In view of the specificity effect of eccentric training, expressive increases were already expected in eccentric compared to isometric or concentric strength[6]. Although hamstring injuries occur predominantly during eccentric actions, isometric tests may also provide relevant information on the injury risk[29]. In this sense, the isometric peak torque results from our study are consistent with the 7% increment reported by Mjølsnes et al[22], and demonstrated the transfer effect of this training programme to a type of muscle action different from that emphasized by the NHE. In contrast, the insignificant changes verified on concentric strength (peak torque and work) suggest that complementary exercises should be used concurrently to the NHE programme in order to promote hamstring concentric strength gain.

The NHE programme used in this study led to similar changes in eccentric peak torque (13%) than reported after 6-10 weeks of NHE in physically active adults (15%)[10] and professional athletes (11%)[22]. Interestingly, a previous study involving the same 4-week intervention period used in our training programme documented the greatest increase ever (21%) on eccentric peak torque[18]. Therefore, our findings further support the short-term gain in eccentric peak torque promoted by the NHE, providing a plausible explanation to the protective effect against hamstring injury evidenced by previous studies with professional athletes[2, 25, 32].

The H:Q conventional ratio used to be the most common muscular imbalance measurement, but it has been criticized by some experts due to the fact that it considers only the concentric strength capacity of thigh muscles. Therefore, the H:Q functional ratio emerged as a more useful outcome by considering the hamstring eccentric strength, which is the muscle action usually involved in hamstring strains. The NHE programme implemented in our study promoted a significant increase (13%) with a large effect size at the H:Q functional ratio, and the percent increase was close to the 10% observed by Mjølsnes et al[22]. As professional soccerplayers have H:Q functional ratio mean values of 0.75-0.79[27] (similar to subjects from our study; 0.75-0.77), the enhancement observed in this outcome through the NHE programme was probably not sufficient to reach the reference value of 1.0, described as the optimal muscle balance[1]. However, athletes with an H:Q functional ratio of 0.83 would certainly be farther away from the zone of greatest injury risk.

As far as we know, no other study evaluated the effect of the NHE on isokinetic work. This isokinetic parameter is calculated as the area under the torque-angle curve, and therefore characterizes muscle performance over the entire range of motion[21]. The increased eccentric work suggests that the NHE training not only improved the maximum torque, but it also shifted the torque-angle curve upwards. To date, there is no cohort study assessing the influence of hamstring eccentric work on injury risks for this muscle group. However, the persistent deficit on hamstring work at the injured compared to the uninjured limb when athletes return to sport has been related with a high level of reinjury[28]. In fact, it seems reasonable that a muscle with higher strength production capacity throughout the entire range of motion would be more protected from a muscle strain, so further attention should be given to this isokinetic parameter.

Similar to our study, Mjølsnes et al[22] also found no effect of the NHE programme on the hamstring flexibility. In contrast, an average gain of 7° and 13° on passive knee range of motion was observed following eccentric training programmes using exercises at the leg curl machine[26] and with elastic bands[23], respectively. These findings may suggest a real disadvantage of NHE in relation to other hamstring eccentric exercises. However, the sit-and-reach test score is an indirect measure of hamstring extensibility because this test involves the whole body motion. Thus, the validity of sit-and-reach test may also be influenced by anthropometric and joint flexibility factors in the shoulders, spine, and lower and upper extremities[3]. Moreover, no association has been found between sit-and-reach test performance and the risk of hamstring strain in prospective studies (eg, Orchard et al[24], thus caution is needed when claiming that a reduced posterior chain flexibility is a strong risk factor for hamstring muscle strains. In view of the abovementioned factors, our choice by the sit-and-reach test may be considered a limitation of this study, even with the widespread use of this test in the sport and clinical environments.

Ultrasound is a valid and reliable tool currently used to examine in vivo hamstring architecture[26, 12, 13, 30]. The unchanged BF_{LH} muscle thickness after the NHE programme in this and previous studies[16, 31] suggests that strength enhancement at the TG cannot be attributed to hypertrophic response to the NHE program. Our study did not assess neural adaptations to the NHE program, but expressive neuromuscular enhancements were already reported with eccentric training (eg, Baroni et al[6]). In fact, the NHE presents a growing resistant torque, leading to the highest neuromuscular activation from the middle to the terminal phases of the movement[18, 11]. Therefore, a great engagement occurs in the most extended hamstring position, possibly increasing the activation capacity precisely at the most common injury situation (ie, eccentric contractions at long muscle length).

The increased fascicle length as a response to eccentric training has been reported by a series of studies in knee extensors (eg, Baroni et al[5]) and plantar flexors (eg, Duclay et al[12]). However, although short BF_{LH} fascicles increase the risk of hamstring injury[30], few studies have evaluated the effects of eccentric training on the hamstrings architecture, and none evaluated these parameters in response to the NHE. Potier et al[26] reported impressive 33% increased fascicle length after an 8-week eccentric training in leg curl machine. Recently, Timmins et al[31] added that the majority of the fascicle length response to an isokinetic eccentric training for the hamstrings (16% increased) occurs at the initial 14 days of training. These findings are in agreement with the results found by Guex et al[16], who observed 10% increase in the BF_{LH} fascicle length after a 3-week isokinetic eccentric intervention. Since elite soccer teams usually have 4-6 weeks of preseason preparation[34], this short-term response towards longer fascicle lengths can counteract the injury risk for hamstring injury in athletes before the first match of the competitive season. Interestingly, the concentric training seems to promote an opposite response on BF_{LH}, leading to shorter fascicles[31], while the hamstring stretching training has presented conflicting findings on fascicular adaptation (eg, e Lima et al[13]; Freitas and Mil-Homens[15]). Therefore, the eccentric overload seems to be the most efficient way to increase fascicle length in humans.

Previous findings[26, 31] have demonstrated that eccentric training is able to increase the BF_{LH} fascicle length in about 2 cm, which is further supported by our results. Considering the multivariate logistic regression models established by Timmins et al[30], an 18-year old football athlete with a 10 cm BF_{LH} fascicle has the same probability to suffer a hamstring injury than a 32-year old athlete with 12 cm BF_{LH} (see figure 2 in Timmins et al[30]). Additionally, in a scenario where a previously injured player enhanced his BF_{LH} fascicle from 10 cm to 12 cm, his probability of a re-injury almost equals to when he had a 10 cm fascicle length and no history of hamstring injury (see figure 1 in Timmins et al[30]). In other words, the increased fascicle length helps to counteract the influence of non-modifiable hamstring injury risk factors, such age and previous injury. These rationales provide strong arguments in favour of introducing the BF_{LH} ultrasonography to the screening tests for muscle injuries in sports, and thus providing additional attention through eccentric exercise in those players with short fascicles. Evidence in animal model has confirmed that increased fascicle length in response to eccentric training is attributed to the addition of serially arranged sarcomeres (sarcomerogenesis)[7]. Thus, additionally to the preventive effect against muscle injury[30], longer fascicles allow faster fiber shortening and have a positive effect on athletics performance[20].

Surprisingly, adoption and implementation of the NHE programme at the top level of European soccer is low[4] even in face of the efficiency of this training program on injury prevention[2, 25, 32]. This poor compliance of elite soccer teams may be one of the reasons for the hamstring injuries increase by 4% annually between 2001 and 2014 in this population[14].

We hope that the findings of the present study contribute for a deeper understanding about the mechanisms responsible for the preventive effect of the NHE against hamstring strains, and encourage members of the medical staff to use this kind of exercise on the prevention programmes of their teams/athletes. However, future investigations should verify if professional athletes have similar responses to the NHE programme compared to the healthy youg adults assessed in this study. Moreover, the optimal NHE training periodization for athletes needs to be further investigated.

CONCLUSION

In conclusion, this is the first study to demonstrate positive effects of the NHE training programme on multiple risk factors for hamstring injury. Our findings suggest that changes in hamstring structure and function are related to the preventive effect of the NHE against injuries of this muscle group. Although this study has been conducted with a non-athletic population, the significant improvements on hamstring eccentric strength and fascicle length through a short intervention period (4 weeks) support the inclusion of the NHE at preseason stage for sports teams.

KEY POINTS

Findings

NHE practiced by physically active young adults for 4 weeks enhanced the knee flexors isometric and eccentric strength capacity and increased the BF_{LH} fascicle length.

Implications

This information can guide the staff engaged in training programs and injury prevention in choosing proper exercises selection in order to improve performance and reduce the risk of athlete suffering from hamstring strains.

Caution

This study was conducted in healthy participants without known impairments related to disability or injury. Therefore, care should be taken when extrapolating these data to a population of athletes or individuals in rehabilitation.

AKNOWLEDGEMENTS

The authors thank CAPES-Brazil for the scholarship (JBA), CNPq-Brazil for funding (MAV) and all the volunteers for their participation in this study.

REFERENCES

TABLES

TABLE 1. Nordic hamstring exercise training programme

Week	Weekly frequency	Number of sets	Repetitions per set	Volume per session
1	2	3	6	18
2	2	3	7	21
3	2	3	8	24
4	2	3	10	30

TABLE 2. Characteristics of subjects from control and training groups

	Control Group	Training Group
Female/male	7 / 3	7 / 3
Age (years)	26.0 ± 2.7	23.7 ± 3.3
Body mass (kg)	63.7 ± 11.1	59.1 ± 12.8
Height (cm)	166.4 ± 7.2	165.1 ± 9.0

TABLE 3. Risk factors for hamstring injury at pre- and post-training evaluations in control group and training group (Mean and SD).

		Control Group			Training Group		
		Pre	**Post**	**Effect size**	**Pre**	**Post**	**Effect size**
Muscle Strength	Isometric peak torque (Nm)	88.6 ± 36.6	86.8 ± 36.5	0.05	79.1 ± 26.1	86.7 ± 33.4	0.27 *
	Concentric peak torque (Nm)	78.5 ± 28.3	80.9 ± 28.1	0.09	70.8 ± 24.5	79.5 ± 34.7	0.31 *
	Eccentric peak torque (Nm)	123.3 ± 30.3	124.8 ± 30.3	0.05	110.9 ± 21.2	126.9 ± 33.4	0.60 #
	Concentric work (J)	230.6 ± 80.2	244.4 ± 77.0	0.19	219.4 ± 88.3	246.3 ± 110.1	0.28 *
	Eccentric work (J)	259.5 ± 82.9	262.1 ± 70.1	0.04	218.3 ± 34.2	259.1 ± 62.1	0.86 &
	H:Q conventional ratio	0.48 ± 0.06	0.49 ± 0.07	0.06	0.46 ± 0.06	0.50 ± 0.09	0.55 #
	H:Q functional ratio	0.77 ± 0.08	0.78 ± 0.06	0.15	0.75 ± 0.12	0.83 ± 0.09	0.80 &
Muscle Architecture	Muscle thickness (cm)	2.05 ± 0.39	2.07 ± 0.42	0.05	2.02 ± 0.36	2.04 ± 0.30	0.06
	Pennation angle (^{o})	12.77 ± 2.05	12.64 ± 2.08	0.07	14.00 ± 2.06	11.64 ± 1.85	1.27 &
	Fascicle length (cm)	9.40 ± 1.78	9.59 ± 2.03	0.10	8.36 ± 0.63	10.18 ± 0.75	2.77 §
Flexibility	Sit-and-reach test (cm)	26.7 ± 9.4	25.6 ± 10.0	0.12	25.0 ± 8.5	25.1 ± 7.1	0.01

* small effect size; # moderate effect size; & large effect size; § very large effect size.

FIGURES CAPTIONS

FIGURE 1. Muscle architecture assessment from a volunteer and her biceps femoris long head ultrasound image. MT = muscle thickness; PA = pennation angle; FL = fascicle length.

FIGURE 2. Percentage changes (mean ± standard error) in dynamometry measures. TG = Training Group; CG = Control Group; ISO = Isometric; CON = Concentric; ECC = Eccentric; H:Q = Hamstring to Quadriceps Muscle Imbalance; p-values are presented when significant difference was observed between groups.

FIGURE 3. Percentage differences (mean ± standard error) in biceps femoris long head (BF_{LH}) muscle architecture. MT = muscle thickness; PA = pennation angle; FL = fascicle length; p-values are presented when significant difference was observed between groups.

FIGURE 4. Individual responses of the training group for the two primary outcomes of the study: hamstring eccentric peak torque and biceps femoris long head (BF_{LH}) fascicle length. Before the NHE programme (white circles), all volunteers were at a foursquare with higher risk of muscle injury (ie, weak muscle with short fascicles). After 4-weeks (black circles), only one remained at the higher risk foursquare.

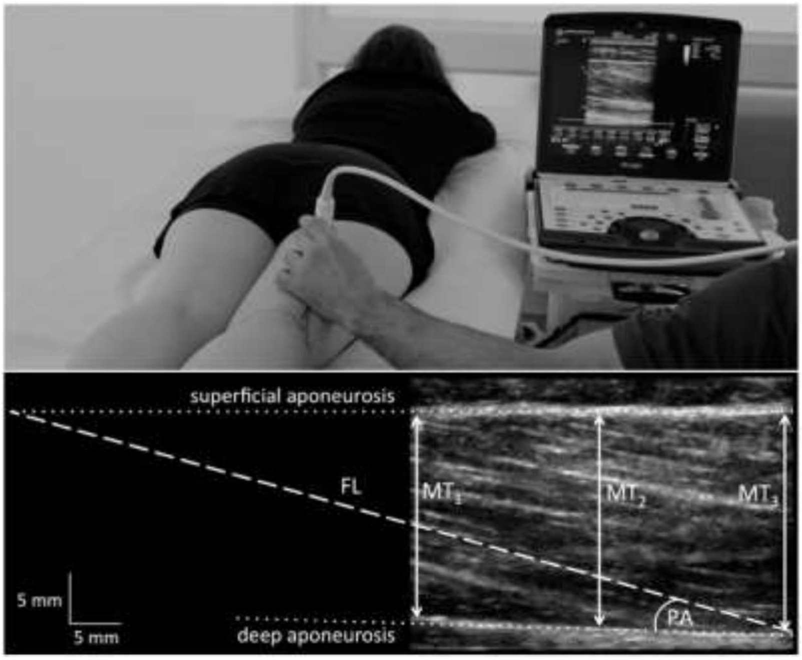

superficial aponeurosis
FL
MT1
MT2
MT3
5 mm
5 mm
PA
deep aponeurosis

Figure 1

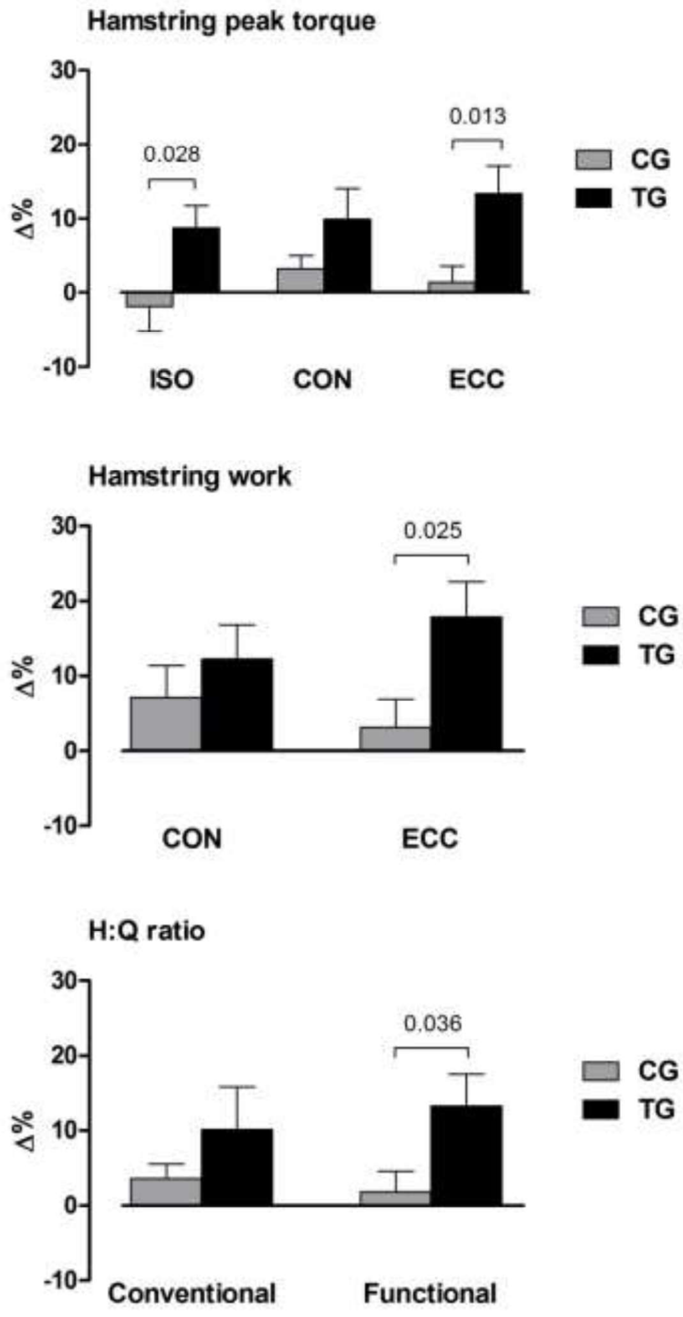

Hamstring peak torque
30
20
10
0
-10
Δ%
0.028
0.013
ISO
CON
ECC
CG
TG
Hamstring work
30
20
10
0
-10
Δ%
0.025
CON
ECC
CG
TG
H:Q ratio
30
20
10
0
-10
Δ%
0.036
Conventional
Functional
CG
TG

Figure 2

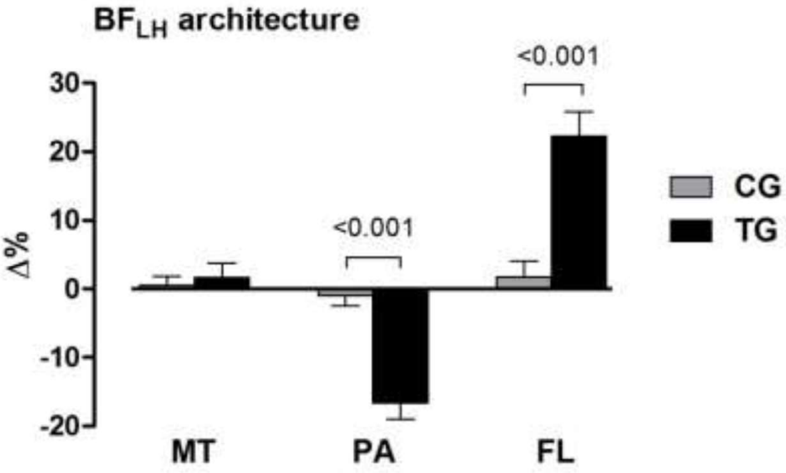
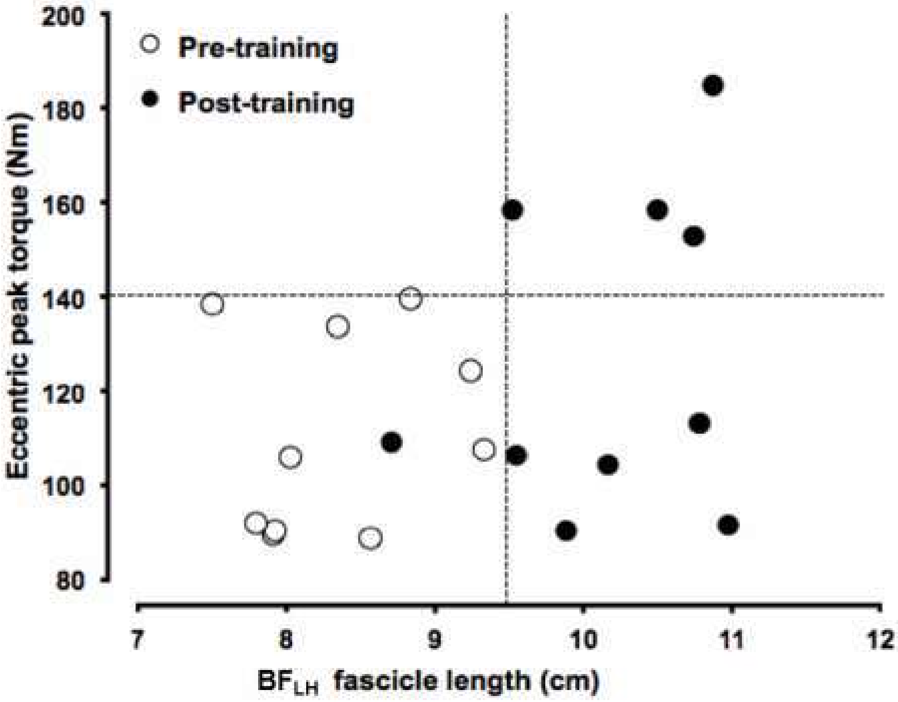


Figure 3



Pre-training
Post-training
Eccentric peak torque (Nm)
200
180
160
140
120
100
80
7
8
9
10
11
12
BF_LH fascicle length (cm)

Figure 4

4. CONSIDERAÇÕES FINAIS

Este parece ser o primeiro estudo a avaliar os efeitos de um programa de treinamento utilizando unicamente o ENI sobre os múltiplos fatores que são mais frequentemente relacionados aos riscos de lesão dos isquiotibiais. Além disso, é a primeira investigação a verificar as adaptações originadas por este tipo de exercício excêntrico sobre a arquitetura da cabeça longa do bíceps femoral, justamente o músculo mais afetado por essas lesões.

Destacamos que o ENI, considerado por muitos profissionais da área da fisioterapia e da educação física como um exercício avançado, pode ser realizado com mínimo risco por jovens saudáveis com nível intermediário de atividade física após um rápido aquecimento corporal. Nenhum incidente foi registrado durante o período de desenvolvimento das fases piloto ou de treinamento. Além disso, as dores musculares de início tardio foram relatadas no máximo até a segunda sessão de treinamento, replicando a situação habitual observada após a realização de exercícios excêntricos.

O treinamento com o ENI se mostrou, além de seguro, um programa eficaz, eficiente e custo-efetivo. Eficaz por ter melhorado os desfechos primários e alguns desfechos secundários do presente estudo. Eficiente pelo fato de que os resultados foram obtidos com uma intervenção enxuta em termos de duração (4 semanas), frequência (2 sessões semanais) e tempo dispendido em cada sessão (cerca de 10 minutos). Por fim, salientamos que o programa é custo-efetivo, uma vez que não há necessidade de investimento financeiro elevado em equipamentos, pois o ENI depende apenas de colchonetes para a sua realização.

Naturalmente estes achados não podem ser automaticamente extrapolados para uma população largamente exposta a situações de risco de lesão e em que pesam outros fatores que talvez sejam concorrentes com as adaptações aqui encontradas, como o nível de condicionamento e a rotina de treinamentos/jogos, entre outros. Portanto, é oportuno que sigam as investigações para que os efeitos do ENI sejam cada vez mais conhecidos e, se sua efetividade for comprovada, doravante sua adoção permita que menos atletas sujeitem-se às lesões musculares e suas adversas consequências.

5. ANEXOS

ANEXO 1 - Author Guidelines - Scandinavian Journal of Medicine and Science in Sports

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- Undergoing exclusive review by *JOSPT*
- Address scientific, clinical, or professional issues relevant to musculoskeletal or sports-related physical therapy practice
- Written in accordance with the "Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals" by the International Committee of Medical Journal Editors, December 2013 (http://www.icmje.org/ and http://www.icmje.org/urm_main.html)
- Formatted according to AMA style guidelines (*American Medical Association Manual of Style, 9th Edition*), except for the references, which should be numbered consecutively in alphabetical order.

Author/Reviewer Tools and Resources

Authors are required and reviewers invited to take advantage of the author and reviewer tools and resources section of the *JOSPT* website (www.jospt.org), which provides useful links related to writing and reviewing manuscripts. These materials were created to assist authors in ensuring that key methodological information relevant to the conduct of their study is included in the manuscript. This section specifically provides a link to the EQUATOR Network website (http://www.equator-network.org), an excellent resource designed to help authors report on health research that includes links to resources such as the CONSORT, PRISMA, STROBE, and STARD statements, among others.

Revised Manuscripts

When the editors suggest that a manuscript be revised and resubmitted, the same guidelines outlined for the preparation of the original manuscript apply. All resubmitted manuscripts must be accompanied by a cover letter. The cover letter must include a list of all revisions with regard to suggestions in the review materials provided by the editorial office. Changes made to the text and tables must be highlighted in the manuscript.

Protection of Human Subjects

The name of the Institutional Review Board that approved the research protocol involving human subjects must be included on the title page and in the Methods section. The Methods section must also contain a statement that informed consent was obtained and that the rights of the subjects were protected.

It is mandatory that clinical trials initiated on or after January 1, 2013 be prospectively registered in a public trials registry. In these cases, authors should provide the name of the registry and the registration number on the title page. For clinical trials initiated prior to January 1, 2013, prospective clinical trial registration is desirable but not mandatory.

Case reports should include, when required by the appropriate Institutional Review Board, a statement that each subject was informed that data concerning the case would be submitted for publication or a statement indicating approval by the Board. In all cases, patient confidentiality must be protected.

Use of Animals

Manuscripts with experimental results in animals must include a statement on the title page and in the Methods section that an animal utilization study committee approved the study.

Use of Cadavers

When applicable, manuscripts with experimental results on cadavers must include a statement on the title page and in the Methods section that a relevant utilization study committee approved the study.

MANUSCRIPT CATEGORIES

Research Report

A full-length report of an original clinical, basic, or translational research investigation that advances the clinical science of musculoskeletal and sports-related physical therapy. This category also includes systematic literature reviews with or without meta-analysis.

Authors submitting a randomized controlled trial must consult the CONSORT statement (revised in 2010) and its related extension for trials of nonpharmacological treatments, checklist, and flow diagram (http://www.consort-statement.org/ and http://www.consort-statement.org/consort-statement). *JOSPT* further requires that a flow diagram illustrating the progress of patients throughout the trial be included as a figure in the manuscript. In addition, authors must include a copy of the completed CONSORT checklist appended to the manuscript, with the understanding that the checklist will not appear with any published paper.

Authors submitting manuscripts for observational studies (cohort, case-control, cross-sectional studies) should comply with the STROBE statement (http://www.strobe-statement.org/index.php?id=strobe-home) and should submit a completed STROBE checklist together with the manuscript. The checklist is used to facilitate the peer-review process but is not published with studies accepted for publication.

Large therapy or prevention studies that use a case series design should also be submitted as research reports and be submitted with an accompanying STROBE checklist.

Similarly, preparation of studies investigating the diagnostic accuracy of clinical tests will benefit from consulting the STARD statement, checklist, and flow diagram (http://www.stard-statement.org). *JOSPT* requires that a flow diagram illustrating the progress of patients throughout the study be included as a figure in the manuscript. Authors must include a copy of the completed STARD checklist appended to the manuscript, with the understanding that the checklist will not appear with any published paper.

Systematic reviews of the literature, with or without a meta-analysis, addressing a topic of interest and relevance to musculoskeletal, sports, and manual physical therapists are also considered research reports. Accordingly, systematic literature reviews must have a structured abstract and include a Methods section detailing the search strategy, inclusion/exclusion criteria, evaluation of the quality of the articles, etc. The editor-in-chief must invite manuscripts submitted in this category; however, self-nominations for an invitation to submit a systematic literature review are welcome. Self-nominations, which must include a cover letter addressed to the editor-in-chief and a current curriculum vitae, should be sent electronically to jospt@jospt.org.

Authors submitting a systematic literature review of randomized controlled trials should consult the PRISMA statement and related checklist and flow diagram for quality reporting of systematic reviews and meta-analyses (http://www.prisma-statement.org). *JOSPT* requires that a flow diagram illustrating the progress of study selection and exclusion (as well as reasons for exclusion) be included as a figure in the manuscript. Authors must include a copy of the completed PRISMA checklist appended to the manuscript, with the understanding that the checklist will not appear with any published paper. Prospective registration of systematic reviews protocol information in a database such as PROSPERO (www.crd.york.ac.uk/PROSPERO/) is recommended but not required.

The above is not a full list of study designs and the authors are required to use the appropriate checklist for their study design as available on the EQUATOR Network website (http://www.equator-network.org).

Case Report

A detailed description of the management of a unique clinical case. Case reports must include the following 4 sections: Background, Case Description, Outcomes, and Discussion. The description of the case includes the relevant patient characteristics, examination/evaluation, diagnosis, and a description of the interventions that were provided. Manuscripts describing the management of a small group of similar patients are also considered in this category and should be formatted accordingly.

Resident's Case Problem

A report on the process and logic associated with differential diagnosis (ie, clinical decision making). The Background section includes general clinical or research information pertinent to the case. The Diagnosis section provides patient characteristics and history. It then details the examination and evaluation process leading to the working diagnosis and the rationale for that diagnosis, including a presentation of medical imaging studies and the results of other clinical tests. Interventions used to treat the patient's condition and the outcome of treatment may also be briefly described at the end of the Diagnosis section; however, the focus of the resident's case problem should be on the diagnostic process. The Discussion section offers a scholarly, critical, and referenced analysis of how the diagnosis guided the care of the patient.

Clinical Commentary

A scholarly paper containing opinion or perspectives having relevance to musculoskeletal and sports physical therapy. Clinical commentaries submitted for review require an abstract that is not structured. The editor-in-chief must invite clinical commentaries. Self-nominations for an invitation to submit a clinical commentary are welcome. Self-nominations, along with a cover letter addressed to the editor-in-chief and current curriculum vitae, should be sent electronically to jospt@jospt.org.

Narrative Literature Review

Literature reviews on topics that are not conducive to a formal systematic review but are relevant to musculoskeletal and sports physical therapy may be considered for publication. The editor-in-chief must invite narrative literature reviews. Self-nominations, which must include a cover letter addressed to the editor-in-chief and current curriculum vitae, are welcome and should be sent electronically to jospt@jospt.org.

Brief Report

Suitable for high-quality, high-impact research reports that are less than 2000 words (excluding references) and have no more than a total of 4 tables or figures. The number of references should be 20 or less. Potential exists for additional supporting material (ie, tables, figures) to be included as appendices online if needed. This category of papers can be used for all types of research reports, including the description of a new instrument, technology, or methods relevant to musculoskeletal physical therapy practice or clinical research. Follow the instructions for research reports, using the additional information provided above to prepare the manuscript.

MANUSCRIPT PREPARATION

All manuscripts submitted to *JOSPT* should be double-spaced and have 2.54-cm (1-in) margins on all sides of the page. Pages should be consecutively numbered, starting with the title page. Pages should be continuously line numbered, with line numbers starting at 1 on the abstract. The font should be 12-point Arial, Times New Roman, or Courier. All measurements in the manuscript should be presented in SI units, except for those of angular measures, which should be presented in degrees rather than radians. The manuscript should be arranged as follows:

Title Page (separate page)

- Title of the manuscript
- Names of each author with their highest academic credential (ie, PhD), or most relevant professional designation (eg, PT), or both (eg, PT, PhD). Limit credentials to these 2 items only
- Institution, city, state/country for each author
- Statement of the sources of grant support (if any)
- Statement of Institutional Review Board approval of the study protocol
- Name of the public trials registry and the registration number
- Corresponding author's name, address, and e-mail address
- Word count of the text portion of the manuscript

Anonymous Title Page (separate page)

- Title of the manuscript
- Statement of financial disclosure and conflict of interest (see item 6 of the Author Agreement and Publication Rights Form)
- Acknowledgements (on a separate page)

Abstract

- Structured Abstract: Research reports (including systematic literature reviews) and brief reports require an abstract containing a maximum of 250 words, divided into 6 sections with the following headings (in this order): Study Design, Objectives, Background, Methods, Results, Conclusion. The abstract for case reports should have 5 sections with the following headings: Study Design, Background, Case Description, Outcomes, and Discussion. The abstract for resident's case problems should have 4 sections with the following headings: Study Design, Background, Diagnosis, and Discussion.
- Unstructured Abstract: Clinical commentaries and narrative literature reviews require an abstract (called synopsis) that is not structured and that contains a maximum of 250 words.
- All abstracts should include, when appropriate, a line item called "Level of Evidence," which indicates the study type and level of evidence, according to the classification system listed at the Oxford Centre for Evidence-Based Medicine website (http://www.cebm.net). This final line in the abstract should be in the following format example: "Level of Evidence: Therapy, level 2a." When the study does not fit any of the study type and level of evidence descriptors included in the above classification system, this line may be omitted.
- A list of suggested study design names and the Oxford Centre for Evidence-Based Medicine levels of evidence table are provided for reference in the Authors section of the *JOSPT* website.
- All abstracts should end with a Key Words section, containing 3 to 5 key words that do not appear in the manuscript title.

Text

- Research reports, systematic literature reviews, and brief reports require the body of the manuscript to be divided into 5 sections: Introduction, Methods, Results, Discussion, and Conclusion.
- Case reports require the body of the manuscript to be divided into 4 sections: Background, Case Description, Outcomes, and Discussion.
- Resident's case problems require the body of the manuscript to be divided into 3 sections: Background, Diagnosis, and Discussion.
- Clinical commentaries and narrative literature reviews do not have specific mandatory subdivisions or sections.

For all manuscripts, the text should be less than 4000 words and be supplemented by a reasonable number of figures and tables.

Key Points

The brief Key Points section of the manuscript (needed for research reports only, including systematic literature reviews) should be provided at the end of the text, prior to the references. These points should be written in a user-friendly language, consist of brief sentences, and summarize the most important information related to the findings, implications, and caution directly resulting from the work. These 3 subheadings should be used:

- Findings: One or 2 statements on what the study adds to current knowledge.
- Implications: A statement on how the results impact clinical practice or research on this topic.
- Caution: A statement on the most important limitations of the study, es-

pecially external validity (what may prevent wide utilization of the results).

References

- References should be numbered consecutively in alphabetical order, according to author last name and initials, title, and year. Where the first-author names are identical, references with 1 author precede those with multiple authors. Where all the author names are identical, the title is the next ordering component, followed by the year.
- All references in the References section must be cited in the text.
- References must be cited in the text by using the reference number in superscript at the end of the sentence or the referenced portion of the sentence. The reference goes after the author's name when the author's name is listed (eg, Davies[1]). If there are only 2 authors in the reference, then the text should include both authors (eg, Davies and Ellenbecker[1]). If the reference has more than 2 authors, the text should include "et al" after the first author's name (eg, Davies et al[1]).
- In the Reference section, when a reference has 7 or more authors, list the first 3 authors, followed by "et al."
- References must include only material that is retrievable through standard literature searches. References to papers accepted but not published or published ahead of print should be designated "in press" or use the PubMed/MEDLINE [Epub ahead of print] status until an updated citation is available. Doctoral and master's theses are considered published material. Information from manuscripts not yet accepted for publication and personal communications will not be accepted. The use of abstracts and proceedings should be avoided unless they are very recent and the sole source of the information.
- Abbreviations for the journals in references must conform to those of the National Library of Medicine in Index Medicus (http://www.ncbi.nlm.nih.gov/journals).
- References that have CrossRef Digital Object Identifiers (doi) should include them at the end of the citation.
- References must be verified by the author(s) against the original documents.

Reference style and punctuation should conform to the examples that follow:

Journals

Wilson T. The measurement of patellar alignment in patellofemoral pain syndrome: are we confusing assumptions with evidence? *J Orthop Sports Phys Ther*. 2007;37:330-341. http://dx.doi.org/10.2519/jospt.2007.2281

Books

Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 3rd ed. Upper Saddle River, NJ: Prentice Hall Health; 2009.

Organization as Author and Publisher

US Food and Drug Administration. Guidance for industry: patient-reported outcome measures: use in medical product development to support labeling claims. Rockville, MD: FDA; 2006.

Chapter in a Book

Jones MA, Rivett DA. Introduction to clinical reasoning. In: Jones MA, Rivett DA, eds. *Clinical Reasoning for Manual Therapists*. Edinburgh, UK: Butterworth-Heinemann; 2004:3-24.

Master's or Doctoral Thesis

Langshaw M. *Cervical Spine Mobilisation: The Effect of Experience and Subject on Dose* [thesis]. NSW, Australia: The University of Sydney; 2001.

Published Abstract of a Paper Presented at a Conference

Chen YJ, Powers CM. The dynamic Q-angle: a comparison of persons with and without patellofemoral pain [abstract]. Proceedings of the North American Congress on Biomechanics. Ann Arbor, MI: 2008.

Universal Resource Locator (URL)

NFHS Associations. 2007-2008 National Federation of State High School Associations Participation Survey. Available at: http://www.nfhs.org. Accessed May 17, 2010.

Paper Presented at a Symposium

Nelson-Wong E, Gregory DE, Winter DA, Callaghan JP. Postural control strategies during prolonged standing: is there a relationship with low back discomfort? American Society of Biomechanics Annual Conference. Palo Alto, CA: American Society of Biomechanics; 2007.

Tables

- Each table must be self-contained and provide standalone information independent of the text.
- See *AMA Manual of Style*, section 2.13, to organize and format tables.
- Table titles should list the table number in uppercase bold (eg, "**TABLE 1**"), followed by a period, then the title of the table in sentence case.
- Abbreviations used in each table must be spelled out below the table.
- Footnotes must be listed below the table, after the abbreviations, in order of occurrence in the table (left to right, row to row). According to AMA style, footnotes are cited with the following superscript symbols (in this order): *, †, ‡, §, ||, ¶, #, **, ††, ‡‡. Where these symbols are unavailable, superscript numbers may be used.
- All tables must be referred to somewhere in the text.
- All tables go after the reference list.

Figures

- Figure captions should list the figure number in uppercase bold (eg, "**FIGURE 1**") followed by a period, and continue with the text of the caption in sentence case.
- All abbreviations appearing in the figures should be defined in the caption for each respective figure, and abbreviations appearing only in the figure caption must be defined at first use.
- Digital figures must be at least 350 dpi (dots per inch).
- Charts and graphs generated from spreadsheet programs must accompany, or allow access to, the data
- Photographs must be in JPEG file for-

mat (JPG) and graphic art in GIF file format and at a resolution of at least 350 dpi.

- All figures must be referred to in the text.
- Each view (eg, A, B, C) within the figure must be defined in the figure caption.
- Color figures and graphics are welcome.
- All figures go after the tables at the end of the manuscript.

Videos

Authors may wish to consider including supplemental videos to be published online with their manuscript. These videos can describe intervention or examination techniques as well as surgical procedures or other material pertinent to the manuscript. Intent to include videos may be mentioned in the cover letter with the initial manuscript submission or may be discussed with the editor-in-chief once the manuscript is accepted. Videos should be:

- MPEG-1, MPEG-2, or AVI files.
- No longer than 2.5 minutes.
- Introduced with a title screen and include audio narration.
- There is no limit on the number of videos that may be submitted.

ADDITIONAL REQUIRED DOCUMENTS

For submissions to qualify for review, the following documents must either be e-mailed (manuscripts@jospt.org), mailed (*JOSPT*, 1033 N Fairfax St, Ste 304, Alexandria, VA 22314-1540), or faxed (1-703-891-9065) to the *JOSPT* office.

Author Agreement and Publication Rights Form

This document must have original signatures of all authors. Author signatures may be on separate copies or 1 copy of the form. The form is at the end of these instructions. Please submit the form when you are submitting the manuscript on the manuscript submission website at http://mc.manuscriptcentral.com/jospt. Please contact the *JOSPT* office with any questions.

Photograph/Video Release Statement

Signed photograph/video release forms should accompany photographs/videos of patients and subjects. A photograph/video release statement should contain the following: (1) manuscript title; (2) names of all authors; (3) statement placed below the manuscript title and author names as follows: "I hereby grant to the *Journal of Orthopaedic & Sports Physical Therapy* the royalty-free right to publish photographs and/or videos of me for the stated journal and the above manuscript in which I appear as subject, patient, or model, and for the stated *Journal*'s website (www.jospt.org). I understand that any figure in which I appear may be modified."; and (4) the original signature and date signed from each subject who appears in the figures. This original signed statement must be submitted to the *JOSPT* office with the manuscript.

OTHER CONTRIBUTIONS

Musculoskeletal Imaging

This feature focuses on the use and interpretation of medical imaging related to a case scenario relevant to musculoskeletal or sports physical therapy practice. In most instances, these cases will emphasize how information from imaging can affect physical therapy management of the patient. In some instances, however, this feature may be used to share information on unusual medical conditions, or to simply illustrate commonly used imaging techniques and their interpretation. Contributions should include no more than 3 authors, 250 words, 3 figures, and 3 references (if any). Submissions, including text and images, must be submitted online at http://mc.manuscriptcentral.com/jospt, which can be accessed either directly or through the *JOSPT* website at www.jospt.org. Please direct questions about online submission to the *JOSPT* office at 1-877-766-3450. See the Figures section of the instructions to authors for technical specifications for the figures.

Letter to the Editor-in-Chief

A letter related to professional issues or articles published in the *Journal*. Letters will be reviewed and selected for publication by the editor-in-chief based on the relevance, importance, appropriateness, and timeliness of the topic. Letters to the editor-in-chief are copy edited and the correspondent is not typically sent a version to approve. Letters to the editor-in-chief should include a summary statement of any conflict of interest, including financial support related to the issue addressed. Letters should be sent electronically to jospt@jospt.org. Authors of the relevant manuscript are given the opportunity to respond to the content of the letter.

Invited Commentary

An expert's point of view concerning an article published in the *Journal*. Commentaries are invited by the editor-in-chief and immediately follow the article discussed. Authors of the manuscript under commentary are given the opportunity to respond to the expert's point of view.

JOSPT'S EDITORIAL POLICIES

1. The recommendations of associate editors, editorial review board members, and reviewers concerning the status of manuscripts under review are advisory to the editors.
2. The final decision concerning the publication of a manuscript is solely the responsibility of the editors.
3. Manuscripts are treated as works in progress and are viewed as new manuscripts each time a revision is submitted; each time a manuscript is reviewed, new issues may be raised for the authors to address.
4. Authors should expect to make multiple revisions of their manuscript before formal acceptance of the manuscript for publication.
5. Manuscripts submitted for review are a form of privileged communication between the authors and the *Journal* and the authors and the reviewers. Reviewers may share the paper with other professionals only with the intent to

seek information intended to enhance the review.

6. Authors are not permitted to make changes during the proof stage of publication except to correct inaccuracies.
7. The editors may refuse to publish a manuscript if the author requests substantial revisions of the manuscript content after the paper has been through the review process and accepted for publication.
8. The editors may solicit additional reviews to supplement the opinion of the assigned associate editor and reviewers.
9. *JOSPT* welcomes reports that include findings of no statistically significant differences. However, in the event of a null result, the authors need to provide additional information about the statistical properties of the analysis that led to this result (ie, evidence of reasonable protection against type II error).
10. *JOSPT* accords its authors most-favored status where reproduction policies and copyright permissions are concerned. Authors receive e-mailed PDFs of their articles; once the issue is published, authors may make personal photocopies or deposit their article in their institutional repository (intranet only). Authors also have permission, with no fee charged, to reproduce material they created in the past for *JOSPT* for use in books, chapters of books, or articles in other journals, as long as copyright credit to the *Journal* is given. Uploading articles to public-access websites (eg, ResearchGate) is not allowed.

MANUSCRIPT CHECKLIST

When submitting a new or revised manuscript, please make sure to include the following:

- Cover letter identifying the phone, fax, and e-mail address of the corresponding author and the manuscript category.
- Author Agreement and Publication Rights Form(s) with original signatures of all authors.
- Photograph/video release statement signed by the individual(s) in the photograph/video.
- Full title page.
- Name of the Institutional Review Board that approved the protocol for the study on the title page.
- Name of the public trials registry and the registration number on the title page, if applicable.
- Statement in the Methods section that informed consent was obtained and the rights of subjects were protected.
- Properly structured abstract.
- Continuous line numbering throughout the entire manuscript.
- References listed and numbered in alphabetical order and cited with superscripts in the text.
- Inclusion of the appropriate checklist (eg, CONSORT, STARD, PRISMA), if applicable.

CONTACT INFORMATION

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ANEXO 2 – PARECER CONSUBSTANCIADO DO CEP

UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE PORTO ALEGRE

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Efeitos de um programa de treinamento excêntrico utilizando o exercício nórdico de isquiotibiais sobre parâmetros neuromusculares de indivíduos saudáveis

Pesquisador: Bruno Manfredini Baroni
Área Temática:
Versão: 3
CAAE: 38025814.3.0000.5345
Instituição Proponente: Universidade Federal de Ciências da Saúde de Porto Alegre
Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 934.767
Data da Relatoria: 14/01/2015

Apresentação do Projeto:
Projeto a ser realizado na UFCSPA junto ao PPG em Ciências da Reabilitação a fim de avaliar os "EFEITOS DE UM PROGRAMA DE TREINAMENTO EXCÊNTRICO UTILIZANDO O EXERCÍCIO NÓRDICO DE ISQUIOTIBIAIS SOBRE PARÂMETROS NEUROMUSCULARES DE INDIVÍDUOS SAUDÁVEIS"

Objetivo da Pesquisa:
Verificar as adaptações neuromusculares dos músculos flexores de joelho em mulheres jovens saudáveis após um período de oito semanas de treinamento excêntrico com a utilização do Exercício Nórdico para os Isquiotibiais (ENI).

Avaliação dos Riscos e Benefícios:
Os riscos a saúde durante as avaliações são mínimos, consistindo na possibilidade de desconforto muscular decorrente da realização de esforço máximo. No caso de qualquer lesão musculoesquelética os pesquisadores se responsabilizam por fornecer reabilitação fisioterapêutica completa e gratuita nas dependências do Laboratório de Fisioterapia da UFCSPA. Possíveis benefícios aos participantes do Grupo ENI incluem aumento da força e amplitude de movimento dos músculos isquiotibiais e um efeito protetivo a futuras lesões por estiramento.

Endereço: Rua Sarmento Leite ,245
Bairro: **CEP:** 90.050-170
UF: RS **Município:** PORTO ALEGRE
Telefone: (513)303 -8804 **E-mail:** cep@ufcspa.edu.br

UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE PORTO ALEGRE

Plataforma Brasil

Continuação do Parecer: 934.767

Comentários e Considerações sobre a Pesquisa:

Projeto bem embasado pela literatura e com disponibilidade de espaço e equipamento necessários a sua execução.

Considerações sobre os Termos de apresentação obrigatória:

Todos os termos apresentados.

Recomendações:

Aprovação

Conclusões ou Pendências e Lista de Inadequações:

Sem pendências

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

PORTO ALEGRE, 19 de Janeiro de 2015

Assinado por:
Julia Fernanda Semmelmann Pereira Lima
(Coordenador)

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