Luciana De Michelis Mendonça

TENDINOPATIA PATELAR: INVESTIGANDO FATORES ASSOCIADOS À SOBRECARGA NO TENDÃO PATELAR EM ATLETAS

Belo Horizonte
Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG
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Tese apresentada ao Curso de Doutorado em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais, como requisito parcial à obtenção do título de Doutor em Ciências da Reabilitação.

Orientador: Prof. Dr. Sérgio Teixeira da Fonseca
Co-Orientador: Prof[a]. Dr[a]. Juliana de Melo Ocarino

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ATA DE NÚMERO 37 (TRINTA E SETE) DA SESSÃO DE ARGUIÇÃO E DEFESA DE TESE APRESENTADA PELA CANDIDATA **LUCIANA DE MICHELIS MENDONÇA** DO PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO.

Aos 2 (dois) dias do mês de dezembro do ano de dois mil e quatorze, realizou-se na Escola de Educação Física, Fisioterapia e Terapia Ocupacional, a sessão pública para apresentação e defesa da Tese de Doutorado intitulada: **"TENDINOPATIA PATELAR: INVESTIGANDO FATORES ASSOCIADOS A SOBRECARGA NO TENDÃO PATELAR EM ATLETAS ".** A comissão examinadora foi constituída pelas seguintes Professores Doutores: Sérgio Teixeira Fonseca, Jilliane Cook, Alexandre Dias Lopes, Rosana Ferreira Sampaio e Paula Lanna Pereira da Silva sob a Presidência do primeiro. Os trabalhos iniciaram-se às 08 horas com apresentação oral da candidata, seguida de arguição dos membros da Comissão Examinadora. Após avaliação, os examinadores consideraram a candidata ***aprovada e apta a receber o título de Doutor após a entrega da versão definitiva da Tese***. Nada mais havendo a tratar, eu, Marilane Soares, secretária do Colegiado de Pós-Graduação em Ciências da Reabilitação dos Departamentos de Fisioterapia e de Terapia Ocupacional da Escola de Educação Física, Fisioterapia e Terapia Ocupacional, lavrei a presente Ata, que depois de lida e aprovada será assinada por mim e pelos membros da Comissão Examinadora.Belo Horizonte, 02 de dezembro de 2014.-.

Professor Dr. Sérgio Teixeira Fonseca ______________________

Professora Dra. Jilliane Cook ______________________

Professor Dr. Alexandre Dias Lopes ______________________

Professora Dra. Rosana Ferreira Sampaio ______________________

Professora Dra. Paula Lanna Pereira da Silva ______________________

Marilane Soares – SIAPE: 084190______________________
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PARECER

Considerando que a Tese de Doutorado de **LUCIANA DE MICHELIS MENDONÇA** intitulada: **"TENDINOPATIA PATELAR: INVESTIGANDO FATORES ASSOCIADOS À SOBRECARGA NO TENDÃO PATELAR EM ATLETAS"**, defendida junto ao Programa de Pós-Graduação em Ciências da Reabilitação, nível: Doutorado cumpriu sua função didática, atendendo a todos os critérios científicos, a Comissão Examinadora **APROVOU** a Tese de doutorado, conferindo-lhe as seguintes indicações:

Nome do Professor (a)/Banca	Aprovação	Assinatura
Prof. Dr. Sérgio Teixeira Fonseca	Aprovado	[signature]
Profa. Dra. Jilliane Cook	Approve	[signature]
Prof. Dr. Alexandre Dias Lopes	Aprovada	[signature]
Profa. Dra. Rosana Ferreira Sampaio	APROVADA	[signature]
Profa. Dra. Paula Lanna Pereira da Silva	Aprovada	[signature]

Belo Horizonte, 02 de dezembro de 2014.

Colegiado de Pós-Graduação em Ciências da Reabilitação/EEFFTO/UFMG

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RESUMO

A aplicação de forças excessivas (magnitude e duração) no tendão patelar estão relacionadas ao mecanismo de desenvolvimento da tendinopatia patelar (TP), uma vez que podem promover processos irritativos no tecido e/ou microtraumas repetitivos no tendão. Fatores locais relacionados à articulação do joelho (local) e à articulação do quadril e ao complexo do pé (não-locais) podem contribuir no mecanismo de lesão do tendão patelar. O varismo excessivo de antepé, a diminuição da força muscular do quadril e a restrição na amplitude de movimento articular dos membros inferiores podem alterar o padrão correto do gesto esportivo e impor sobrecarga no tendão patelar. Entretanto, a investigação de fatores associados a TP apresenta uma dificuldade para encontrar de forma consistente fatores que estejam fortemente associados à ocorrência de TP. Além disso, fatores não-locais são pouco explorados nas investigações acerca de variáveis relacionadas a sobrecarga do tendão patelar. O objetivo da presente tese foi investigar os fatores associados à sobrecarga no tendão patelar em atletas. Um primeiro estudo foi planejado para realizar uma exploração inicial dos fatores relacionados as articulações do quadril, do joelho e do complexo do pé com o desfecho de anormalidades morfológicas do tendão patelar identificado por meio de ultrassonografia. A área abaixo da curva ROC indicou associação da flexibilidade da banda íliotibial, alinhamento perna antepé e rotação da patela no plano frontal (ângulo de Arno) com a presença de anormalidades morfológicas no tendão patelar. Um segundo estudo foi desenvolvido pois havia a necessidade de estabelecer um critério diagnóstico com acurácia para identificar atletas com e sem anormalidades no tendão. Os resultados indicaram que a combinação entre o questionário VISA-P, o teste de agachamento unipodal descendente e a história de dor no tendão patelar, denominado *patellar tendon clinical test* (PTCT) identificou de forma acurada atletas com anormalidades identificadas por meio da ultrassonografia. Um terceiro estudo foi realizado com o objetivo de identificar a contribuição de fatores relacionados as articulações do quadril e do pé na ocorrência da tendinopatia patelar em atletas de basquetebol e voleibol. A árvore de classificação e regressão utilizada indicou que nenhuma variável isolada foi capaz de classificar indivíduos com ou sem TP e revelou que fatores relacionados aos segmentos proximais de distais a articulação do joelho podem participar do mecanismo de sobrecarga do tendão patelar. Interações entre o torque isométrico dos rotadores laterais do quadril, alinhamento perna-antepé, amplitude de movimento (ADM) de dorsiflexão e ADM passiva de rotação medial do quadril foram identificadas na ocorrência da tendinopatia patelar. Os resultados da presente tese revelaram a participação de fatores não-locais nos dois desfechos analisados relacionados a sobrecarga do tendão patelar.

Palavras-chave: Joelho. Esporte. Salto vertical. Lesão.

ABSTRACT

Excessive forces (magnitude and duration) applied to the patellar tendon are related to the mechanisms that lead to patellar tendinopathy (PT) development, as result of tissue inflammation and/or repetitive micro traumas. Factors related to the knee joint (local) and/or to the hip and foot joints (non-local) may contribute to patellar tendon overload. Excessive varus forefoot alignment, muscle weakness and restricted joint range of motion (ROM) could alter the correct movement pattern and overload the patellar tendon. However, research on factors associated with PT is inconsistent and rarely find factors that are strongly associated with PT occurrence. Moreover, non-local factors are not frequently investigated. The purpose of this thesis was to investigate factors associated to patellar tendon overload in athletes. The first study was conducted to explore possible association of factors related to hip, knee and foot joints with the occurrence of patellar tendon morphological abnormalities. The ROC curve showed an association of iliotibial band flexibility, shank-forefoot alignment (SFA) and frontal plane patellar rotation (Arno angle) with patellar tendon morphological abnormalities identified by ultrasonography. The second study was developed to establish diagnostic criteria to identify athletes with patellar tendon morphological abnormalities. The results indicated that the combination of VISA-P questionnaire, single-leg decline squat and patellar tendon pain history, named Patellar Tendon Clinical Test (PTCT), accurately identified athletes with abnormalities identified at ultrasound. The third study was performed to identify the contribution of factors related to the hip and foot joints to the occurrence of patellar tendinopathy (jumper's knee) in volleyball and basketball athletes. Classification and regression tree analysis indicated that no isolated factor could classify PT occurrence and revealed that proximal and distal factors may be involved in mechanisms related to patellar tendon overload. Interactions among hip lateral rotators isometric torque, SFA, hip passive medial rotation ROM and ankle dorsiflexion were found to be related to the occurrence of patellar tendinopathy and should be investigated in future prospective studies. The results of this thesis founded non-local factors participating in patellar tendon overload mechanism in athletes.

Keywords: Knee. Sport. Vertical jump. Injury.

SUMÁRIO

PREFÁCIO

A presente tese foi elaborada de acordo com as normas estabelecidas pelo Colegiado do Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Federal de Minas Gerais. Ela está estruturada em quatro seções. A primeira seção contém a Introdução com a problematização e uma revisão da literatura, além da justificativa dos estudos realizados e objetivos geral e específicos da tese. Segue indicada na segunda seção, a descrição detalhada dos métodos utilizados em cada estudo. A terceira seção apresenta os artigos científicos correspondentes aos três estudos realizados na tese. O primeiro artigo está formatado de acordo com as normas do periódico *Journal of Science and Medicine in Sports*. O segundo artigo segue as normas do periódico *Journal of Ortophaedic & Sports Physical Therapy.* O terceiro artigo está formatado de acordo com o periódico *British Journal of Sports Medicine*. Na quarta seção desta tese estão expostas as considerações finais relacionadas aos resultados encontrados nos estudos realizados. Em seguida, estão indicadas as referências bibliográficas, apêndices e anexos.

1 INTRODUÇÃO

A tendinopatia patelar (TP) é a lesão crônica mais prevalente e incapacitante em esportes que envolvem salto vertical (HAMILTON & PURDAM, 2004; COOK *et al.*, 2004; DAVENPORT *et al.*, 2005; BISSELING *et al.*, 2007; REES *et al.*, 2009; ELVIN *et al.*, 2009). Atletas de elite do voleibol e basquetebol podem apresentar cerca de 50% de prevalência e a reabilitação dessa lesão pode durar até 32 meses (COOK *et al.*, 2001; LIAN *et al.,* 1996; LIAN *et al.*, 2005). As apresentações clínicas da TP incluem classicamente a paratendinite, que é a inflamação do envoltório do tendão sem acometimento da estrutura tendínea, e a tendinose, caracterizada por sinais degenerativos no tendão sem sinais inflamatórios (REES *et al.*, 2009; ELVIN *et al.*, 2009; REINKING *et al.*, 2012). Em ambas as condições clínicas, geralmente o atleta acometido refere dor no tendão relacionada a prática esportiva como saltar, agachar e correr (DAVENPORT *et al.*, 2005; REES *et al.*, 2009; ELVIN *et al.*, 2009). Por outro lado, cerca de 22% dos atletas que apresentam lesões hipoecóicas, características morfológicas que podem estar relacionadas ao desenvolvimento de degeneração na região proximal do tendão patelar, não possuem sintomatologia (COOK *et al.*, 1998). Dessa forma, a presença de anormalidades morfológicas no tendão patelar e/ou dor e/ou sinais de disfunção (lesões ou sintomas que requerem afastamento da prática esportiva e/ou redução da performance) são desfechos comumente investigados em pesquisas sobre a tendinopatia patelar.

A etiologia mais aceita da tendinopatia patelar é a sobrecarga tecidual. A magnitude, direção e duração das forças aplicadas no tendão patelar estão relacionadas ao mecanismo de desenvolvimento da TP, uma vez que podem promover processos irritativos no tecido (e.g. inflamação) e/ou microtraumas repetitivos no tendão (JANSEN *et al.*, 2013; DILLON *et al.*, 2008). Esses traumas podem alterar a diferenciação celular e modificar a composição da matriz extracelular e dos componentes celulares (SHARMA & MAFFULLI, 2006; REES *et al.*, 2009; RUMIAN *et al.*, 2009; SAMIRIC *et al.*, 2009; ZHANG & WANG, 2010). Um tendão que recebe uma imposição excessiva de forças (magnitude e/ou duração) pode adaptar a essa condição e recuperar sua morfologia ou apresentar um aumento da taxa de degradação comparada à de remodelação tecidual e lesionar (COOK & PURDAM, 2014). Dessa forma, alterações morfológicas no tendão patelar identificadas por meio de exames de imagem (ultrassonografia ou ressonância magnética) indicam algum nível de dano tecidual (VISNES *et al.*, 2014). Entretanto, existem inconsistências na literatura relacionadas à associação entre alterações morfológicas e dor ou lesão no tendão patelar (FREDBERG & BOLVIG, 2002;

Khan *et al.*, 1997; Cook *et al.*, 2001; Cook *et al.*, 2000; Gisslén *et al.*, 2007). Alguns estudos reportaram achados similares em que 28 a 41% de tendões patelares com anormalidades na fase de baseline da investigação estavam normais no follow-up e cerca de 12-30% desenvolveram sintoma (Fredberg & Bolvig, 2002; Khan *et al.*, 1997; Cook *et al.*, 2001; Cook *et al.*, 2000). Esse fato pode ser explicado pela severidade da região hipoecóica analisada (Comin *et al.*, 2013). Alterações leves (estágio inicial) têm maior chance de reversibilidade por meio da adaptação tecidual (Comin *et al.*, 2013). Por outro lado, alterações moderadas a severas podem ser indicativas de uma inabilidade do tendão em adaptar a carga e recuperar (Cook & Purdam, 2014). Provavelmente, os tendões que possuem áreas hipoecóicas mais extensas são aqueles que desenvolvem lesão ao longo da temporada esportiva (Comin *et al.*, 2013). Nesse sentido, as investigações acerca dos mecanismos de sobrecarga do tendão patelar devem explorar desfechos relacionados à alterações morfológicas encontradas no tendão patelar.

É comumente investigado na literatura a associação de fatores antropométricos e relacionados a articulação do joelho com a TP. Uma revisão sistemática publicada por Van der Worp e colaboradores (2011) a respeito dos fatores de risco para a TP indicou nove variáveis: peso corporal, índice de massa corpórea, razão cintura-quadril, diferença de comprimento de membros inferiores, altura do arco plantar, flexibilidade de quadríceps e isquiossurais, força de quadríceps e performance no salto vertical. Interessantemente, Van der Worp e colaboradores (2011) indicaram que nenhum dos fatores investigados possuem evidência moderada ou forte de sua associação com a TP. Embora o foco da maior parte dos estudos seja em fatores locais, já existem evidências da contribuição de fatores não locais relacionados as articulações do quadril e do pé para o surgimento de outras lesões do joelho, como dor patelofemoral e ruptura do ligamento cruzado anterior. (Gross & Foxworth, 2003; Barton, 2010; Cichanowski, 2007; Dierks, 2008; Levinger, 2004; Myer *et al.*, 2011). Entretanto, essa mesma contribuição não tem sido explorada na tendinopatia patelar. Por exemplo, Souza e colaboradores (2010) mostraram que a cinemática alterada da articulação patelofemoral em mulheres com dor patelofemoral foi resultante da rotação medial excessiva do fêmur durante o agachamento unipodal. O mesmo mecanismo de rotação medial excessiva do fêmur poderia contribuir para a sobrecarga do tendão patelar na aterrissagem do salto vertical em atletas de voleibol e basquetebol. Nesse sentido, percebe-se uma necessidade de ampliar a investigação dos fatores possivelmente associados a tendinopatia patelar.

Fatores como varismo excessivo de antepé, diminuição da força muscular do quadril e restrição na amplitude de movimento articular e/ou flexibilidade dos membros inferiores tem sido apontadas como fatores que podem alterar o padrão correto do gesto esportivo e aumentar o risco de lesão da articulação do joelho (GROOT *et al.*, 2012; CROSSLEY *et al.*, 2007; LAVAGNINO *et al.*, 2008; LIN *et al.*, 2008). Nesse sentido, esses fatores poderiam contribuir na sobrecarga no tendão patelar em atletas de voleibol e basquetebol. Por exemplo, a fraqueza dos músculos abdutores do quadril pode levar a adução do fêmur e alteração do padrão de movimento da articulação do joelho na aterrissagem do salto vertical (DIERKS, 2008). Consequentemente, poderia ocorrer uma imposição de forças distintas nas porções medial e lateral do tendão patelar e acarretar em maior susceptibilidade a lesão (POWERS, 2010; AGEBERG *et al.*, 2010). Além disso, como a tendinopatia patelar envolve a participação de múltiplos fatores, existe a necessidade de se compreender como possíveis relações entre essas variáveis poderiam contribuir no processo patológico do tendão patelar (FONSECA *et al.*, 2007). De acordo com essa perspectiva, a presença de varismo excessivo de antepé, por exemplo, pode impor forças de tração sobre a porção distal do tendão patelar devido a rotação medial da tíbia consequente à pronação excessiva da subtalar (NIGG, 1993; GROSS & FOXWORTH, 2003). Além disso, uma rotação medial excessiva da tíbia leva a rotação medial do fêmur devido ao acoplamento articular entre esses segmentos (FUSS, 1992). Entretanto, a presença de rigidez passiva e/ou de força adequada dos músculos rotadores laterais do quadril poderia minimizar as forças de tração sobre o tendão patelar (promovidas pelo varismo excessivo do antepé) por meio do controle da rotação medial do membro inferior (SOUZA, 2012). Dessa forma, é possível que mesmo na presença de varismo excessivo do antepé, o atleta não desenvolva tendinopatia patelar por causa da contribuição dos fatores relacionado a articulação do quadril. Esse exemplo identifica uma possibilidade de interação entre fatores que podem determinar a ocorrência ou não da TP (FONSECA *et al.*, 2007). Nesse sentido, a etiologia de lesões do sistema musculoesquelético pode ser melhor revelada por meio de interações entre os fatores e desfecho e não apenas na identificação desse fatores de forma isolada (QUATMAN *et al.*, 2009; FONSECA *et al.*, 2007; BAHR & HOLME, 2003).

O objetivo do presente projeto foi investigar os fatores associados a sobrecarga no tendão patelar em atletas. Foram considerados na presente tese a utilização de desfechos que são comumente investigados na tendinopatia patelar: 1) anormalidades morfológicas identificadas pela ultrassonografia, considerada uma condição pré-lesão e 2) diagnóstico clínico da tendinopatia patelar, geralmente realizada por meio da aplicação de questionários e testes funcionais. Um primeiro estudo foi planejado para realizar uma exploração inicial dos fatores relacionados as articulações do quadril, do joelho e do complexo do pé com o desfecho de anormalidades morfológicas do tendão patelar identificado por meio de ultrassonografia. Um segundo estudo foi desenvolvido pois havia a necessidade de estabelecer um critério diagnóstico com acurácia para identificar atletas com e sem anormalidades no tendão. Um terceiro estudo foi realizado com o objetivo de identificar a contribuição de fatores relacionados as articulações do quadril e do pé na ocorrência da tendinopatia patelar em atletas de basquetebol e voleibol.

1.1 Objetivo geral

Investigar os fatores associados a sobrecarga no tendão patelar em atletas.

1.2 Objetivos específicos

Estudo 1: investigar a associação entre alinhamento anatômico, amplitude de movimento articular/flexibilidade e força muscular dos membros inferiores com a presença de alterações morfológicas no tendão patelar em atletas de basquetebol e de voleibol.

Estudo 2: determinar a acurácia diagnóstica de um teste clínico desenvolvido para identificar atletas com alterações morfológicas no tendão patelar.

Estudo 3: identificar a contribuição de fatores relacionados às articulações do quadril e do pé para a ocorrência de tendinopatia patelar (*jumper's knee*) em atletas de voleibol e basquetebol.

2. MATERIAL E MÉTODOS

2.1 ESTUDO 1

2.1.1 Contextualização breve

Este estudo teve como objetivo investigar a associação do alinhamento anatômico, da amplitude de movimento articular/flexibilidade e da força muscular dos membros inferiores com a presença de alterações morfológicas no tendão patelar identificadas por meio de ultrassonografia. A presença de áreas hipoecóicas no tendão patelar identificadas em exames de imagem pode ser considerada um estágio de pré-disfunção, ou seja, uma característica que prediz o desenvolvimento de sintomatologia e limitação funcional. Dessa forma, a determinação de fatores associados a esse estágio auxiliam na tomada de decisão para o desenvolvimento de programa preventivos.

2.1.2 Amostra

Este estudo transversal incluiu atletas de elite de voleibol (n=18) e de basquetebol (n=13) do sexo masculino recrutados em dois clubes esportivos participantes regulares de avaliações pré-temporada. Todos os atletas deveriam estar participando integralmente das atividades da equipe esportiva na época da avaliação. Os participantes foram submetidos a uma avaliação pré-temporada e ao exame de ultrassonografia do tendão patelar em ambos membros inferiores. Durante a ultrassonografia, se o atleta apresentasse sinais de outras patologias na articulação do joelho, além daquelas relacionadas ao tendão patelar, ele seria excluído. Além disso, o participante era excluído se não se apresentasse em todos os testes da avaliação pré-temporada. Os participantes assinaram um termo de consentimento livre e esclarecido aprovado pelo Comitê de Ética da Universidade (0493.0.203.000-09).

Inicialmente, um total de 48 atletas que realizaram a avaliação pré-temporada foram convidados para o exame de ultrassonografia. Quarenta e três atletas compareceram ao exame e 4 deles foram identificados com Osgood-Schlatter e foram excluídos do estudo (BACKMAN & DANIELSON, 2011). Outros 8 atletas foram excluídos por não terem realizado todos os testes da avaliação pré-temporada. Nesse sentido, trinta e um atletas do sexo masculino com média de idade de 25.26±6.6 anos, de peso de 90.74±11.2 quilogramas e de altura de 1.95±0.09 metros participaram do presente estudo. O questionário VISA-P (*Victoria Institute of Sport Assessment*) foi aplicado em todos os atletas para fins de caracterização de dor e disfunção no tendão patelar (VISENTINI et al, 1998).

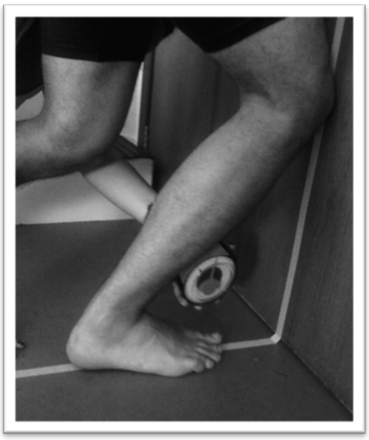
2.1.3 Procedimentos

A avaliação pré-temporada foi composta pelos seguintes testes: amplitude de movimento (ADM) de dorsiflexão, alinhamento perna-antepé (APA), flexibilidade da banda íliotibial, ADM passiva de rotação medial (RM) da articulação do quadril, alinhamento da patela no plano frontal, ângulo de projeção frontal dos joelhos e força isométrica dos músculos abdutores rotadores e laterais (RL) da articulação do quadril. Todos os testes foram realizados bilateralmente.

Avaliação da ADM de dorsiflexão:

O atleta foi posicionado de frente para uma parede. O ponto médio da borda inferior e posterior do calcâneo e o segundo dedo do pé do membro inferior a ser testado foi colocado em cima de uma linha no chão, perpendicular a parede, e que segue ascendente pela parede. O outro membro foi posicionado posteriormente em local definido pelo atleta, sem permitir a rotação do tronco e pelve. O atleta era orientado a encostar a patela na linha localizada na parede, sem retirar o calcanhar do chão. Se necessário, a distância entre o pé e a parede poderia ser modificada para que o atleta conseguisse realizar essa orientação. Um inclinômetro (Starrett®) foi posicionado 15 centímetros abaixo da tuberosidade da tíbia e o valor angular em relação ao eixo vertical foi registrado (Figura 1). Esta medida foi realizada 3 vezes em cada membro inferior e a média foi considerada para análise (BENNELL *et al.*, 1998). Um estudo piloto com o objetivo de determinar a confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essa medida foi realizado com 12 sujeitos (média de idade de 20,7 anos; peso de 64,1 kg; altura de 1,71m) e os resultados revelaram valores de 0.98 e 0.92, respectivamente, e um erro padrão da medida de 0,04^{o}.

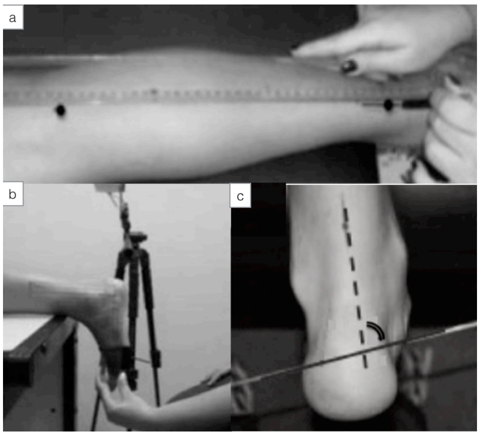
FIGURA 1: Teste de ADM de dorsiflexão



Alinhamento perna-antepé:

O atleta foi posicionado em decúbito ventral em uma maca e foi determinada a bissecção da perna a partir do ponto médio entre os platôs tibiais e entre os maléolos (Figura 2-A). Uma haste metálica foi colocada na região metatarsofalangeana com auxilio de velcro para indicar o alinhamento do antepé. O calcâneo foi voltado para uma câmera digital (Nikon®) posicionada perpendicular e paralelamente a maca e o atleta sustentou a articulação do tornozelo em 90º com a utilização de um goniômetro para registro fotográfico (Figura 2-B). Foram tomadas três medidas e cada foto foi posteriormente analisada no software de análise bidimensional para se determinar a média do ângulo referente ao alinhamento tíbia-antepé (ângulo entre a linha de bissecção da tíbia e haste metálica) (MENDONÇA *et al.* 2013). Um estudo piloto com o objetivo de determinar a confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essa medida foi realizado com 10 sujeitos (média de idade de 22,1 anos; peso de 64,3 kg; altura de 1,65 m) e os resultados revelaram valores de 0.93 e 0.90, respectivamente, com erro padrão da medida de 2,47^{o}.

FIGURA 2. A: Marcações correspondentes ao ponto médio dos platôs tibiais e maléolos; B: Posicionamento do tornozelo do atleta e da câmera para avaliação do APA e C: Registro fotográfico para análise no software bidimensional.



Flexibilidade da BIT:

O participante deitou em uma maca em decúbito lateral e o examinador movimentou passivamente o membro inferior a ser testado sequencialmente em flexão, abdução e extensão do quadril. Além disso, o examinador evitou a rotação medial do quadril. Foi solicitado que o participante mantivesse o membro relaxado enquanto o suporte ao membro inferior fosse gradativamente retirado, de forma que o movimento de adução do quadril, produzido pelo peso do membro inferior do atleta, ocorresse até que a tensão passiva das estruturas interrompesse este movimento. Nesse momento, o examinador apenas não permitiu o movimento de rotação medial do membro. Em seguida, um segundo examinador posicionou um inclinômetro (Starrett®*)* superiormente ao epicôndilo femoral lateral (Figura 3) (WANG *et al.*, 2006). Valores positivos foram atribuídos ao membro que se mantivesse em abdução e negativos para segmentos aduzidos na posição final de teste. Foram realizadas três medidas em cada membro inferior e a média normalizada pelo peso corporal do atleta foi considerada para análise (graus/Kg). A confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essa medida foi determinada em um estudo piloto com seis indivíduos (média de idade de 20,2 anos; peso de 60,6 kg; altura de 1,68 m) e foram encontrados valores de 0.99 e 0.94, respectivamente, com o erro padrão da medida de $0{,}01^{o}$.

FIGURA 3. Teste de flexibilidade da BIT

ADM passiva de rotação medial do quadril:

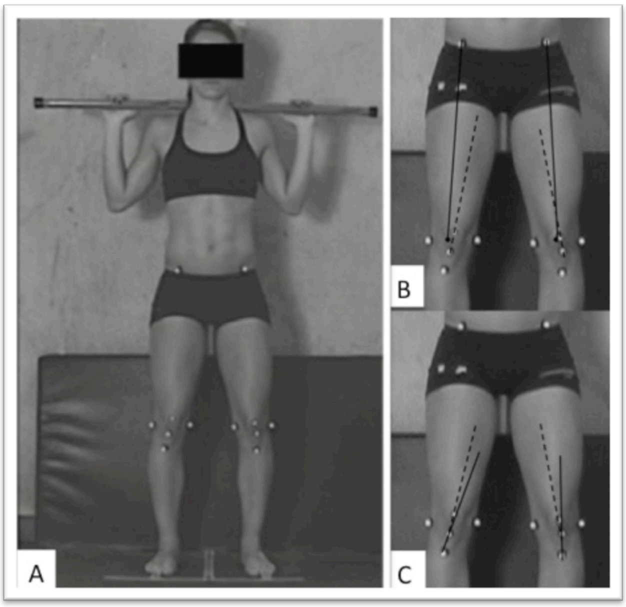
O participante foi posicionado em decúbito ventral na maca, com a pelve estabilizada por uma faixa e foi solicitado que posicionasse a articulação do joelho a 90º de flexão. O movimento passivo de rotação medial de quadril, produzido pelo peso da perna e pé do atleta, foi permitido pelo examinador até que a tensão das estruturas passivas e musculares do quadril interrompesse este movimento. A ADM passiva de rotação medial do quadril foi mensurada, com um inclinômetro (Starrett®) posicionado em uma marcação realizada a 5 cm distalmente a tuberosidade anterior da tíbia (Figura 4). A medida foi descartada e repetida se o avaliador percebesse qualquer contração muscular visualmente ou por meio de palpação (CARVALHAIS *et al.*, 2011). Foram realizadas 3 medidas para cálculo da média e esse valor foi normalizado pelo peso corporal do atleta para permitir a comparação entre os indivíduos (graus/kg). A confiabilidade intra e inter-examinador ($ICC_{3,3}$) foi determinada em um estudo piloto com seis indivíduos (média de idade de 22,4 anos; peso de 64,7 kg; altura de 1,67 m) e foram obtidos valores de 0.99 para ambas análises e um erro padrão da medida de 0,55^{o}.

FIGURA 4: Teste de ADM passiva de rotação medial do quadril

Alinhamento da patela no plano frontal:

Com o sujeito em apoio bipodal sem calçados e flexão dos joelhos a 30º foram fixados marcadores reflexivos na espinhas ilíacas anterossuperiores, côndilos femorais, polo inferior da patela, no ponto médio da base da patela e na tuberosidade da tíbia bilateralmente. Em seguida foi registrado por uma filmadora (Samsung SC-D385®) a manutenção desta mesma posição com os membros superiores posicionados em um bastão localizado atrás da nuca para controle da rotação de tronco (Figura 7). Nesse momento, o atleta manteve os 30º de flexão dos joelhos. Posteriormente, foram determinados através de um software de análise de movimento bidimensional (*Simi Motion Twinner*®) os ângulos McConnell (ângulo entre as linhas de bissecção do fêmur e bissecção da patela) e Arno (ângulo entre as linhas de bissecção da patela e bissecção do tendão patelar) na analise frontal conforme indicado nas figuras 5-B e 5-C, respectivamente (MENDONÇA *et al.*, 2014). Um estudo piloto com o objetivo de determinar a confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essas medidas foi realizado com nove sujeitos (média de idade de 23,2 anos; peso de 67,1 kg; altura de 1,66 m) e os resultados revelaram valores de 0.97 e 0.85, respectivamente, para o ângulo de McConnell, e 0.98 e 0.90, respectivamente, para o ângulo de Arno. O erro padrão da medida de 0,93º para o primeiro e 1,38º para o segundo ângulo citado anteriormente.

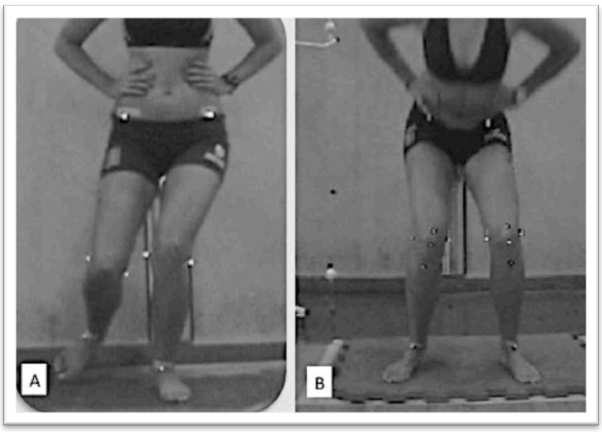
FIGURA 5: A-Posicionamento do participante para análise angular da rotação da patela no plano frontal. As figuras B e C representam respectivamente as análises para obtenção dos ângulos de McConnell e Arno. As linhas pontilhas indicam a bissecção patelar e as linhas contínuas a bissecção do fêmur (B) e do tendão patelar (C)



Ângulo de projeção frontal dos joelhos no agachamento unipodal (A) e na aterrissagem do salto vertical (B):

Foram mantidos os marcadores reflexivos utilizados no teste anterior e incluídos marcadores no ponto médio dos maléolos bilateralmente. O participante, com os pés descalços, realizou 3 agachamentos unipodais intercalando os membros inferiores, até a angulação de 60º de flexão de joelhos, com os membros superiores posicionados em um bastão localizado atrás da nuca para controle da rotação de tronco (Figura 6-A). Em seguida, o participante realizou 3 saltos não consecutivos com as mãos posicionadas na cintura (Figura 6-B). Uma câmera filmadora (Samsung SC-D385®) foi posicionada a 2 metros de distância do atleta para filmagem dos movimentos e posterior análise do pico do ângulo de projeção frontal do joelho (ângulo entre os marcadores da espinhas ilíacas anterossuperiores, ponto médio dos côndilos e ponto médio dos maléolos) no agachamento e aterrissagem do salto tomando-se a média das três repetições através do software *Simi Motion Twinner®* (BITTENCOURT *et al.*, 2012). A confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essa medida foi determinada em um estudo piloto com seis indivíduos (média de idade de 20,2 anos; peso de 60,6 kg; altura de 1,68 m) e foram encontrados valores de 0.83 e 0.80, respectivamente, na condição de agachamento unipodal e 0.88 e 0.83, respectivamente, na aterrissagem do salto. O erro padrão da medida foi 1,65^{o} no agachamento e 1,93^{o} na aterrissagem do salto.

FIGURA 6: Posicionamento do participante para análise do ângulo de projeção frontal do joelho no agachamento unipodal (a) e aterrissagem do salto vertical (b).



Força isométrica dos músculos abdutores do quadril:

O atleta se posicionou em decúbito lateral com um suporte para o conforto da cabeça e foi estabilizado na região da pelve por uma faixa estabilizadora. O examinador colocou em seguida o dinamômetro manual (*Hand Held – Microfet2*®) a cinco centímetros da linha interarticular do joelho com auxílio de uma faixa (velcro) com o objetivo de posicionar o equipamento e limitar a amplitude de movimento de abdução de quadril. Após o procedimento de familiarização, o participante realizou três contrações isométricas máximas dos abdutores de quadril com duração de 5 segundos e com intervalo de 15 segundos entre cada repetição (Figura 7). Foi dado incentivo verbal durante o teste para garantir que o indivíduo realizasse a contração máxima (BITTENCOURT *et al.*, 2012). O torque foi obtido pelo produto da média das três medidas de força isométrica pela distância do trocânter maior até a localização do dinamômetro manual no momento do teste. Para permitir a comparação dos valores obtidos entre sujeitos, o valor de torque foi normalizado pelo respectivo peso corporal do indivíduo, obtendo-se a variável preditora torque dos abdutores de quadril normalizado pelo peso corporal (Nm/kg). A confiabilidade intra e inter-examinador ($ICC_{3,3}$)

para essa medida foi determinada em um estudo piloto com seis indivíduos (média de idade de 21,6 anos; peso de 62,2 kg; altura de 1,64 m) e foram encontrados valores de 0.94 e 0.90, respectivamente, com um erro padrão da medida de 0,08 Nm/kg.

FIGURA 7: Teste de força isométrica dos abdutores do quadril

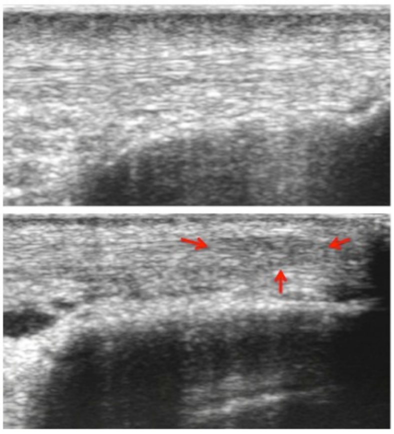
Força isométrica dos músculos rotadores laterais do quadril:

Após 5 minutos de descanso do teste anterior, o mesmo procedimento foi adotado para a avaliação da força isométrica dos músculos rotadores laterais do quadril com o participante deitado em decúbito ventral com o joelho do membro a ser testado fletido a 90^{o}. O dinamômetro manual foi posicionado na face medial da articulação do tornozelo, a 5 centímetros do maléolo medial e o examinador teve o auxílio da mesma faixa utilizada anteriormente (Figura 8) (WILLIY & DAVIES, 2011). Incentivo verbal foi direcionado para a execução da força de forma progressiva e, assim que o examinador percebesse qualquer movimento compensatório (e.a. adução do quadril, rotação da pelve e tronco), o teste era interrompido. O torque foi obtido pelo produto da média das três medidas de força isométrica pela distância do côndilo femoral medial até a localização do dinamômetro manual no momento do teste. De forma similar, o valor de torque foi normalizado pelo respectivo peso corporal do indivíduo, obtendo-se a variável preditora torque dos rotadores laterais normalizado pelo peso corporal (Nm/kg). A confiabilidade intra e inter-examinador ($ICC_{3,3}$) para essa medida foi determinada em um estudo piloto com seis indivíduos (média de idade de 21,6 anos; peso de 62,2 kg; altura de 1,64 m) e foram encontrados valores de 0.98 e 0.90, respectivamente, com um erro padrão da medida de 0,04 Nm/kg.

FIGURA 8: Testes de força isométrica dos rotadores laterais do quadril

Finalmente, os atletas realizaram o exame de ultrassonografia feito por um médico especialista com experiência na área e que não teve acesso aos resultados dos testes anteriores. O participante foi orientando a não fornecer informações sobre sua sintomatologia para o médico e um dos pesquisadores, responsável pela análise estatística, acompanhou o procedimento para garantir o cegamento do médico (o pesquisador não participou da mensuração). O atleta foi posicionado em decúbito dorsal na maca, com os joelhos fletidos e pés apoiados de forma que ficasse confortável. O aparelho de alta resolução Volusom® 730 GE® com transdutor linear de 12 a 19 Hz de frequência (modo B) foi utilizado. O examinador analisou com o ultrassom os dois tendões patelares dos participantes em toda extensão nos planos longitudinal (sagital) e transversal (axial). O transdutor foi mantido na posição perpendicular para evitar resultados falso-positivos devido a anisotropia (WARDEN *et al.*, 2007). Foram avaliadas a espessura e a ecogenicidade e a textura do tendão (WARDEN *et al.*, 2007; STEELE *et al.*, 2008). Foi considerado um diagnóstico positivo aquele tendão que apresentasse região hipoecóica com presença ou não de edema intratendíneo e redução de sua espessura (Figura 9). Neste momento, foram excluídos do estudo aqueles atletas que apresentaram sinais associados a Osgood-Schlater (e.g. irregularidades na tuberosidade tibial) quando não identificada na seleção inicial da amostra. Para verificar a confiabilidade teste-reteste na ultrassonografia foi realizado um estudo piloto com 6 indivíduos, 4 mulheres e 2 homens (média de idade de 23 anos, de peso de 55,6 kg e de altura de 1,65 m). O mesmo examinador realizou as análises com 4 dias de intervalo e os mesmos procedimentos descritos em seguida foram adotados no estudo piloto. Um índice Kappa de 0,75 (0.08-1.4) revelou confiabilidade teste-reteste adequada para o exame de ultrassonografia, no qual houve apenas uma discordância em 12 análises (por membro inferior).

FIGURA 9: Imagens de ultrassonografia de tendão patelar sem anormalidades (acima) e com anormalidades (abaixo). As setas indicam uma área hipoecóica.



2.1.4 Análise Estatística

A curva *receiver operating characteristic* (ROC) foi inicialmente utilizada para determinar um ponto de corte relevante para cada variável independente. Nos casos em que a área abaixo da curva foi estatisticamente significativa ($\alpha = 0.05$) o *Odds Ratio* (OR), a razão de prevalência (RP) e o intervalo de confiança (IC) de 95% foram calculados para indicar a força de associação do alinhamento anatômico, ADM/flexibilidade e força muscular com alterações morfológicas do tendão patelar na ultrassonografia. A seleção do ponte de corte foi baseada na maior distância em relação a linha de referência e nos valores de sensibilidade e especificidade (BACKMAN & DANIELSON, 2011).

2.2 ESTUDO 2

2.2.1 Contextualização breve

Este estudo buscou determinar a acurácia diagnóstica de um teste clínico desenvolvido para identificar atletas com alterações morfológicas no tendão patelar. O teste clínico auxilia na definição da melhor abordagem terapêutica, uma vez que aqueles positivos no teste clínico, ou seja, com alterações morfológicas no tendão patelar devem ser direcionados a intervenções baseadas na remodelação tecidual, como o protocolo excêntrico.

2.2.2 Amostra

Foram recrutados através de contato telefônico 52 atletas de modalidades esportivas com prevalência significativa de anormalidades no tendão patelar (ATP) tais como voleibol, basquetebol, futebol e corrida (FREDBERG & BOLVIG, 2002; KRAEMER & KNOBLOCH, 2009; ZWERVER *et al.*, 2011). Os critérios de inclusão foram ter no mínimo 18 anos de idade, não ter realizado cirurgia nos membros inferiores nos últimos 6 meses e não estar afastado das atividades da equipe esportiva. A idade estabelecida minimiza a chance de incluir no estudo atletas com Osgood-Schlater e Sindig-Larsen-Johansson (MALLIARAS *et al.*, 2006; TUONG *et al.*, 2011). Todos os indivíduos que concordaram em participar do estudo (n=47), leram e assinaram o termo de consentimento livre e esclarecido. Quatro atletas foram identificados ao exame de imagem com Osgood-Schlater e foram excluídos do estudo. Dessa forma, participaram do estudo 43 atletas de voleibol (n=26), basquetebol (n=14) e futebol ou corrida (n=3). Essa amostra foi constituída por 38 homens e 5 mulheres com médias de idade de 24,8±6,7 anos, de peso de 87,6±13,7 kg e de altura de 1,93 ±0,1 metros.

2.2.3 Procedimentos

O exame de ultrassonografia, o questionário VISA-P (*Victoria Institute of Sport Assessment*), o teste de agachamento no plano inclinado descendente (APID) e a coleta da história pregressa de dor progressiva no tendão patelar foram realizados dentro de um período de 2 dias, para evitar que alterações da condição clínica pudessem interferir na acurácia diagnóstica dos testes. O teste de referência (ultrassonografia) foi o último exame a ser realizado para evitar qualquer interferência durante a coleta nos testes investigados (APID, VISA-P, história pregressa de dor). Os resultados obtidos em cada exame foram mantidos em sigilo pelo examinador responsável (R.A.B.) e foi repassado a um dos pesquisadores (L.D.M.)

não envolvido na coleta. Informações sobre a história de evolução de dor progressiva no tendão patelar de todos os indivíduos avaliados foram coletadas, sendo considerado como história positiva aquele atleta que apresentou dor progressiva relacionada a prática física nos últimos 6 meses que interferiu de forma progressiva no rendimento esportivo (foram excluídos os casos traumáticos e aqueles relacionados ao estirão de crescimento) (WARDEN *et al.*, 2007) .

O teste de APID consiste em um agachamento unipodal (realizado da extensão completa até cerca de 30^o de flexão da articulação do joelho) com cada perna em uma rampa de 30^o de inclinação (ZWERVER *et al.*, 2007). O objetivo deste teste é avaliar a reatividade do tendão patelar durante a execução do movimento. O examinador registrou o teste como positivo, quando o indivíduo testado relatou a presença de dor no tendão patelar. Em seguida, foi aplicado o questionário VISA-P com o objetivo de caracterizar o perfil funcional do indivíduo (VISENTINI *et al.*, 1998 ; WAGECK *et al.*, 2013). Este teste é auto-aplicado e composto por oito questões (sete com uma escala de zero a dez e uma com escala de zero a trinta), sendo seis relacionadas a presença de sintoma no tendão patelar durante tarefas funcionais/esportivas (e.g. sentar, agachar, saltar) e duas relacionadas ao nível de performance esportiva. Pontuação abaixo de 80 é usada como indicativo de presença de tendinopatia patelar (EDWARDS *et al.*, 2010; MANN *et al.*, 2012; WARDEN *et al.*, 2007). No presente estudo, não foi estabelecido um tempo limite para o preenchimento do questionário.

Os testes clínicos foram realizados por um examinador (R.A.B.) que foi submetido a um piloto de confiabilidade teste-reteste com 7 indivíduos, 6 homens e uma mulher (médias de idade de 38,57±18,8 anos; peso de 78,57±13,01 kg; altura de 1,73±0,10 m). Neste piloto, o mesmo examinador aplicou de forma individual, o VISA-P e o APID por duas vezes em um intervalo de 4 dias. Os procedimentos na segunda coleta foram idênticos àqueles adotados na primeira aplicação. Os resultados do estudo piloto revelaram uma confiabilidade excelente dos testes, com ICC de .99, para o VISA-P, e coeficiente de Kappa de 1 (0.476 – 1.524), $p<.0001$, para o APID.

Após a coleta da história de evolução de dor no tendão patelar, os atletas passaram pelo exame de ultrassonografia que foi realizado por um médico especialista que não teve acesso aos resultados dos exames anteriores (L.M.O.F.). O participante foi orientando a não fornecer informações sobre sua sintomatologia para o médico e um dos pesquisadores, responsável pela análise estatística (L.D.M.), acompanhou o procedimento apenas para garantir o cegamento do avaliador médico (o pesquisador não se envolveu na mensuração). Os mesmos procedimentos foram adotados conforme descrição da sessão de metodologia do

Estudo 1 (página 23 e 24 da presente tese). Foi considerado um diagnóstico positivo aquele tendão que apresentou região hipoecóica com presença ou não de edema intratendíneo e redução de sua espessura. Neste momento, quatro atletas foram excluídos do estudo, pois apresentaram sinais associados a Osgood-Schlatter. Para verificar a confiabilidade teste-reteste no US foi realizado um estudo piloto com 6 indivíduos, 4 mulheres e 2 homens (média de idade de 23 anos, de peso de 55,6 kg e de altura de 1,65 m). O mesmo examinador realizou as análises com 4 dias de intervalo e os mesmos procedimentos descritos foram adotados no estudo piloto. Um índice Kappa de 0,72, p= .047, revelou boa confiabilidade teste-reteste para o exame de ultrassonografia.

2.2.4 Análise Estatística

Um avaliador independente, cegado quanto aos resultados dos exames realizados, foi responsável pela análise estatística. A sensibilidade, especificidade, valores preditivos positivos e negativos, acurácia diagnóstica, razão de probabilidade positiva e negativa e o *Odds* de diagnóstico (considerando um intervalo de confiança de 95%) do VISA-P, da história, do APID e de combinações entre esses critérios foram calculados.

Inicialmente, a análise da acurácia diagnóstica foi realizada em cada parâmetro avaliado (VISA-P, APID e história) de forma isolada em relação ao teste de referência (ultrassonografia). Apenas para o VISA-P (n=43) foi realizada a análise por atleta envolvido (no caso de escore abaixo de 80 pontos) ou não envolvido (com escore acima de 80 pontos). Para o APID e história de dor no tendão patelar foram considerados ambos membros inferiores (n=86) na análise individual de cada teste. Em seguida, as possíveis combinações entre os parâmetros descritos foram testadas, para assim ser apresentada a combinação de maior acurácia diagnóstica. O membro inferior envolvido ou mais sintomático (no caso de atleta com resultado positivo) ou o membro dominante (para os casos negativos) foram considerados na análise do APID e da história de dor no tendão patelar combinada com o VISA-P (n=43). Finalmente, foi analisada a acurácia do parâmetro de melhor performance considerando o ajustamento pela idade e pelo tempo de prática esportiva dos atletas participantes. Os pontos de corte selecionados para idade e tempo de prática foram baseados na média da amostra (25 anos e 10 anos respectivamente).

2.3 ESTUDO 3

2.3.1 Contextualização breve

Este estudo explorou quais fatores relacionados à articulação do quadril e ao complexo do pé são associadas a ocorrência da tendinopatia patelar. O foco da investigação sobre variáveis associadas a sobrecarga do tendão patelar tem sido direcionado a características antropométricas e fatores da articulação do joelho. Dessa forma, para uma melhor compreensão do mecanismo de lesão do tendão patelar, outros fatores devem ser explorados, como os relacionados as articulações do quadril e do pé. Além disso, a análise por meio da árvore de classificação e regressão permite explorar possíveis interações entre os fatores investigados e o desfecho que podem agregar informações importantes no entendimento de processos patológicos no tendão patelar.

2.3.2 Amostra

Foram convidados atletas das modalidades de voleibol e basquetebol de ambos os sexos para avaliações pré-temporadas promovidas pelo LAPREV – CENESP - UFMG. Atletas com alta demanda de saltos (líberos não participaram) que praticavam esporte ao menos 12 horas semanais de forma regular e que participavam de competições oficiais eram elegíveis de participação. Os participantes com dor e sensibilidade no tendão patelar (confirmado por médico do esporte ou fisioterapeuta) e pontuação menor que 80 no questionário VISA-P (n=59) foram identificados com tendinopatia patelar. Aqueles com Osgood-Schlatter, dor anterior no joelho não relacionada ao tendão patelar (ambos confirmado por médico do esporte ou fisioterapeuta por meio de exame clínico), história de cirurgia nos membros inferiores e/ou infiltração no tendão patelar (ambos descritos pelo atleta ou fisioterapeuta) foram excluídos da amostra inicial para evitar viés (n=41). Além disso, atletas com história de dor no tendão patelar isolada (negativos no VISA-p e no teste de agachamento no plano inclinado descendente) foram excluídos para evitar a presença de participantes assintomáticos com anormalidades no tendão patelar no grupo sem TP (n=41). De forma similar, atletas com pontuação no VISA-P entre 80 e 95 pontos foram excluídos para garantir um grupo sem TP formados por atletas sem qualquer queixa do tendão patelar (n=39). Atletas com pontuação no VISA-P acima de 95 pontos, APID negativo e sem história de dor no tendão patelar foram identificados sem tendinopatia patelar (n=133). De acordo com os critérios mencionados, foram convidados 313 atletas para a avaliação pré-temporada, 121 foram excluídos e 192 atletas (47 mulheres e 145 homens) foram considerados para análise. Todos os participantes assinaram o termo de consentimento livre e esclarecido aprovado pelo Comitê de Ética da Universidade Federal de Minas Gerais (nº ETIC 493/2009) para participação no estudo.

2.3.3 Procedimentos

Na avaliação pré-temporada, os atletas preencheram dois questionários: VISA-P para caracterizar o perfil funcional (VISENTINI *et al.*, 1998) e um de caracterização do perfil de lesões pregressas e atuais (incluindo histórico de intervenções cirúrgicas e de história pregressa de dor no tendão patelar relacionada a prática física nos últimos 6 meses) adaptado de Fuller et al (2006).

Além disso, realizaram o teste APID com o fim de determinar a reatividade do tendão patelar quando colocado em situação de maior imposição de carga mecânica (ZWERVER *et al.*, 2007). O atleta realizou um agachamento unipodal, com cada membro inferior, em uma rampa de 30º de inclinação. O examinador registrou se o atleta sentiu dor ou não no tendão patelar durante o teste.

Após este procedimento, os atletas realizaram a avaliação pré-temporada com os testes distribuídos em estações de forma sequencial. As seguintes medidas foram realizadas: alinhamento perna-antepé (APA), amplitude de movimento (ADM) de dorsiflexão, ADM passiva de rotação medial do quadril, flexibilidade da banda iliotibial (BIT), torque isométrico dos rotadores laterais e dos abdutores do quadril. Todos os testes foram previamente descritos detalhadamente na sessão de metodologia do Estudo 1 (página 15 a 23 da presente tese). Essas variáveis independentes foram selecionadas para identificar a contribuição de fatores relacionados as articulação do quadril e do pé na sobrecarga do tendão patelar.

2.3.4 Análise Estatística

Estatística descritiva foi realizada para caracterizar a amostra em relação as variáveis independentes e demográficas. Para capturar quais fatores e interações estão associados à ocorrência da TP foi utilizada a *Classification and Regression Tree* (CART). Esse modelo multivariado e não-paramétrico desenvolve uma árvore de decisão, que representa graficamente a associação entre as variáveis preditoras e a variável desfecho (BREIMAN *et al.*, 1984). O crescimento da árvore ocorre por meio de divisões binárias sucessivas do conjunto inicial de dados até que futuras divisões não sejam possíveis (BREIMAN *et al.*, 1984). Em cada divisão, todas as variáveis independentes são avaliadas e todos os possíveis pontos de corte (no caso de variável do tipo contínua) são considerados (BREIMAN *et al.*, 1984). Assim, se estabelece aquele fator que melhor divide os dados em subgrupos (nodos) cada vez mais homogêneos (BREIMAN *et al.*, 1984; LEMON *et al.*, 2003). Nesse sentido, as divisões subsequentes a divisão inicial identificam possíveis interações entre as variáveis preditoras que explicam a tendinopatia patelar (LEMON *et al.*, 2003).

Para o desenvolvimento do modelo de predição, a variável desfecho foi dicotomizada em presença e ausência de tendinopatia patelar, baseado nos parâmetros apresentados anteriormente. Os critérios utilizados para promover as partições e, consequentemente, o desenvolvimento da árvore: mínimo de 8 participantes em cada nodo para realizar a divisão; mínimo de 4 participantes para gerar um nodo e um índice Gini de 0.0001 para maximizar a homogeneidade dos nodos. Foi estabelecido um máximo de 4 níveis de profundidade e um procedimento de *pruning* foi adotado para evitar partições super-ajustadas. Os custos de classificação considerados simétricos entre as categorias e a probabilidade de ocorrência da TP foi baseada em dados da literatura (40% positivo e 60% negativo) (COOK *et al.*, 2001; LIAN *et al.*, 2005; LIAN *et al.*, 1996).

A área abaixo da curva *receiver-operating characteristic* (ROC) foi determinada para verificar a acurácia do modelo de classificação. Um nível de significância $\alpha = 0.05$ foi estabelecido para indicar se o modelo identificou de forma acurada as categorias (área abaixo da curva estatisticamente diferente de 0.05). Além disso, foram calculados o *odds ratio* (OR) e a razão de prevalência (RP) em cada nodo terminal do modelo para explorar a força de associação dos fatores/interações reveladas pela CART.

3 ARTIGOS

3.1 ARTIGO 1:

Factors Associated with the Presence of Patellar Tendon Abnormalities in Athletes

Abstract

Objective: To investigate the association between lower limb alignment, range of motion/flexibility and muscle strength with the presence of patellar tendon abnormalities (PTA) in athletes. **Design**: This was a cross-sectional study. **Method**: Thirty-one male basketball and volleyball athletes were assessed for ankle dorsiflexion range of motion (ROM), shank-forefoot alignment (SFA), iliotibial band flexibility, hip external rotators and abductors isometric torque, passive hip internal rotation ROM and patellar and knee alignment in the frontal plane. Ultrasonographic evaluation of hypoechoic areas and thickness of patellar tendons were performed in longitudinal and transverse planes. A receiver operating characteristic (ROC) curve was used to determine clinically relevant cut-off point for each variable. When the area under the curve was statistically significant, the Odds Ratio (OR), Prevalence Ratio (PR) and 95% confidence intervals were calculated to indicate the strength of the association between the independent variable and the presence of PTA. **Results**: ROC curve showed that iliotibial band flexibility (p=0.006), SFA (p=0.013) and Arno angle (p=0.046) were associated with PTA. Cut-off points were established and only the OR and PR of iliotibial band flexibility (OR=8.61; PR= 5.26) and SFA (OR=6.25; PR= 4.42) were statistical significant. **Conclusions**: Athletes with iliotibial band above -0.02°/kg or SFA above 24° had, respectively, five and four times more chance to have PTA compared to athletes under these cut-off point values. These results suggest that such factors could contribute to patellar tendon mechanical overload. Therefore, iliotibial band flexibility and SFA should be considered in pre-season screening of volleyball and basketball athletes.

Keywords: patellar tendinopathy; injury; sport; ultrasonography, alignment, flexibility

Introduction

Sport modalities that include a great amount of jumping and landing, such as volleyball and basketball, may result in overload of the patellar tendon.[1,2,3] The presence of patellar tendon ultrasonographic changes are associated with patellar tendon pain and dysfunction (i.e. injuries or symptoms that required time off from training and/or decreased performance such as patellar tendinopathy) and have often been found to be indicative of tissue damage.[4,5,6] Cook et al[7] reported that 22% of the athletes that had PTA on ultrasound have no clinical symptoms. Although these athletes have no symptoms, they may still have tissue damage and the potential to develop chronic dysfunction and eventually tendon rupture.[4,6] Thus, it is suggested that in the presence of PTA, even in the absence of symptoms, an athlete should receive proper attention by the team's medical staff.

Tendon overload depends on the amount of stress applied to the musculoskeletal system.[8,9] Thus, factors related to landing pattern (i.e. foot alignment, passive hip stiffness) could be involved in the mechanism of development of this condition.[10,11,12] Landing requires adequate capacity of the musculoskeletal system (i.e. proper strength and stiffness) to deal with ground reaction forces.[11,12] The knee, as an intermediate joint in the kinetic chain, depends on the mechanical behavior of hip and ankle to mitigate and properly distribute forces imposed to the lower limbs during landing.[10,13] Forces that act on the knee joint (i.e. medial-lateral and rotational forces) could stress specific portions of the patellar tendon, interfere with the capability of tissue remodeling (because of tendon overload) and promote a degenerative process. Increased varus foot alignment [12,13,14] and limited ankle dorsiflexion[15], for example, can promote excessive pronation of the foot in landing and predispose tibial internal rotation and increased patellar tendon tension. Moreover, excessive tibial internal rotation can induce femur internal rotation.[14] Adequate hip external rotators strength and proper stiffness could control this excessive lower limb internal rotation and minimize patellar tendon overload.[12] Therefore, factors related to load transfer and dissipation mechanisms during landing could be associated to the development of patellar tendon abnormalities identified via ultrasound (i.e. hypoechoic areas).

There is still limited evidence on factors associated with PTA although this information could provide the basis for the development of effective preventive programs and enhance care attitudes of programs focused on minimizing patellar tendon overload. Cook et al[8] showed that posterior thigh flexibility and female players with high vertical jumps appear to be at increased risk of abnormal tendon morphology. A recently published study identified relationships between lower limb factors (i.e. hip ROM in stop-jump task landing and quadriceps flexibility) and the presence of PTA in pre-elite basketball athletes.[9] Given that elite basketball and volleyball athletes have the highest prevalence of patellar tendinopathy among other athletes, future studies aiming at effectively minimizing patellar tendon overload should target these population.[1,3]

Injury prevention in jumping sports requires measures to avoid excessive load of the patellar tendon that in turn could interfere with the athletes' performance and compromise their career. Identification of factors associated with the process of tendon damage could support the development of appropriate strategies to prevent such injuries. Thus, the purpose of this study was to investigate the association between lower limb alignment, range of motion/flexibility and muscle strength with patellar tendon morphological abnormalities in basketball and volleyball athletes.

Methods

This cross-sectional study included 18 volleyball and 13 basketball elite male athletes recruited from two sport teams that participated in a preseason assessment at the University. All athletes had to be able to fully participate in their team's activities at the time of assessment.

All athletes were submitted to a preseason assessment and ultrasound evaluation of the patellar tendon of both lower limbs. During the ultrasound assessment, if an athlete had signs of knee pathologies, other than those related to the patellar tendon, he was excluded. In addition, athletes that missed any part of the preseason assessment were also excluded from the study. The Universidade Federal de Minas Gerais Ethics in Research Committee approved the study's procedures (Approval Report number 0493.0.203.000-09) and all participants signed an informed consent.

Initially, a total of 48 athletes were assessed during preseason evaluation and were invited to undergo ultrasound examination. Forty-three athletes attended this exam in which four basketball athletes were identified with Osgood-Schlatter disease and were excluded.[15] Another eight athletes were excluded due to incomplete preseason assessment data (in case of absence of at least one measure). Therefore, thirty-one male athletes, with a mean age of 25.26±6.6 years, body mass of 90.74±11.2 kilograms and height of 1.95±0.09 meters, participated in this study. VISA-P (*Victoria Institute of Sport Assessment*) questionnaire was collected in all athletes for characterization of patellar tendon pain and dysfunction.[16]

The following measures were collected as part of this study and pre-season assessments on both legs: shank-forefoot alignment (SFA), ankle dorsiflexion range of motion (ROM), iliotibial band flexibility, hip external rotators (ER) and abductors isometric strength, passive hip internal rotation (IR) ROM, frontal plane patellar alignment and frontal plane knee projection angle. A pilot study with 10 participants (not included in the present study) and 2 days interval between measurements was performed in order to determine the intra and inter-ratter reliability (of two examiners in each measure) for each test.

SFA was measured with the athlete in prone. The shank was bisected and a metal rod was placed with a strap on the forefoot for photographic record (Figure 1a), according to Mendonça et al[13]. Three photos of each foot were taken and the measurement of the intersection between shank bisection and forefoot inclination (represented by the metal rod) were performed in a two-dimensional analysis software (Simi Motion Twinner® - Figure 1b) to determine the mean angle for SFA ($ICC_{3,3}$=0.93-intra rater reliability and 0.90-inter rater reliability)).[13]

To assess ankle dorsiflexion ROM the athlete was positioned facing a wall and was instructed to move the knee towards a vertical line drawn on the wall without removing the heel off the floor as described by Bennell et al[17]. Ankle dorsiflexion was measured using an inclinometer positioned 15 centimeters from the tibial tuberosity (Starrett ®). This measure was performed 3 times on each leg and the average was considered for analysis ($ICC_{3,3}$=0.98(intra rater reliability) and 0.92(inter rater reliability)).

Iliotibial band flexibility was measured with the participant in side lying. The examiner performed the modified Ober test protocol described by Reese & Bandy[18] (Figure 1c). Measures were taken with an inclinometer (Starrett ®) positioned proximal do lateral femoral condyle. Three measures of each leg were obtained. The mean was normalized by body mass (degrees/Kg). Positive values were assigned to hip abduction and negative values to hip adduction ($ICC_{3,3}$=0.99(intra rater reliability) and 0.94(inter rater reliability)).

To assess hip ER and abductors isometric strength the examiner used a handheld dynamometer (microFET2; Hoggan Health Industries, Inc, West Jordan, UT). For hip abductors assessment, the dynamometer was positioned proximal to the knee joint following the protocol described by Bittencourt et al[12] (ICC=0.94(intra rater reliability) and 0.90(inter rater reliability)). For hip ER strength measurement, the handheld dynamometer was placed superiorly to the medial malleolus with the athlete in prone position and 90^o of knee flexion[19] (ICC=0.98(intra rater reliability) and 0.90(inter rater reliability)). The same protocol of abductors test was used, except that we performed a progressive contraction to avoid excessive compensatory movements (i.e trunk and pelvis rotation, and hip adduction) that could add bias to the test. Muscle torque was calculated as the product between the mean of three strength measures and the distance from the location to of the dynamometer to the greater trochanter (for abductors test) and from the femoral condyles (for external rotators test). Torque values were normalized by body mass (Nm/kg).

Passive hip IR ROM was assessed with the participant positioned in prone with 90° of knee flexion and the pelvis stabilized by a strap using the protocol described by Carvalhais *et al.*[20] The passive movement of hip internal rotation, produced by the weight of the leg and foot of the athlete, was allowed until passive structures and hip muscular tension stopped this movement. Therefore, passive hip IR ROM test is inversely related to hip external rotators passive stiffness.[20] Three measures were conducted on each leg with an inclinometer positioned five centimeters from the tibial tuberosity. The mean of three measures was normalized using body mass (degrees/kg) ($ICC_{3,3}$=0.99(intra rater reliability) and 0.99(inter rater reliability)).

To access patellar alignment and knee projection angle in the frontal plane, reflective markers were placed on the anterior superior iliac spine, femoral condyles, middle point of patellar base and inferior pole, anterior tibial tuberosity and the middle point of malleolus of both lower limbs. Frontal plane patellar alignment (McConnell and Arno Angles) was assessed according to the protocol described by Mendonça et al [21] ($ICC_{3,3}$=0.90(intra rater reliability) and 0.85(inter rater reliability)). In order to measure the frontal plane knee projection angle, the athletes performed three one-leg squats until they reached 60^o of knee flexion (defined by each individual) and three countermovement jumps as described by Bittencourt et al[12] ($ICC_{3,3}$=0.88(intra rater reliability) and 0.83(inter rater reliability)). All angles were calculated using the Simi Motion Twinner® software.

The ultrasound examination was conducted with the athletes positioned in supine with knees flexed and feet flat on the exam table. A high-resolution equipment, Volusom ® GE 730 ®, with a linear transducer with 12 to 19 Hz frequency (mode B), was used by a single examiner. Both patellar tendons were analyzed with the same parameters adopted by Warden et al[22]. A positive diagnosis was confirmed when tendon hypoechoic regions and thickness were identified. Test-retest reliability of the ultrasound examination was conducted in a pilot study with six participants. Kappa coefficient of 0.72 (0.08 to 1.4), p = 0.047 demonstrated good test-retest reliability.

A receiver operating characteristic (ROC) curve was used to determine a clinically relevant cut-off point for each lower limb variable. The cutoff point was selected based on the largest distance from the reference line and sensitivity and specificity values[15]. If the area under the ROC curve was statistically significant (α =0.05) the Odds Ratio (OR), Prevalence Ratio (PR) and 95% Confidence Intervals (CI) were calculated to evaluate the strength of the association of the lower limb alignment, range of motion/flexibility and strength factors with PTA at ultrasound.

Results

Eight athletes had bilateral PTA identified at ultrasound (16 positive knees) and twenty-three had negative results for PTA (46 negatives for PTA on ultrasound). Athletes with PTA had mean age of 29.69±7.1 years, height of 1.92±0.9 meters, weight of 86.18±6.5 kilograms, time of sports practice of 13.92±6.5 years and VISA-P questionnaire of 77.0±21.5 points. Athletes without PTA had mean age of 22.96±5.2 years, height of 1.97±0.9 meters, weight of 93.11±12.5 kilograms, time of sports practice of 10.42±4.3 years and VISA-P questionnaire of 91.9±13.0 points.

Iliotibial band flexibility, Arno angle and SFA had significant area under ROC curve (area = 0.247; p= 0.006, area=0.316; p=0.046 and area = 0.728; p= 0.013, respectively). Hip abductors and external rotators torque (area = 0.582; p= 0.371 and area = 0.351; p= 0.104, respectively), ankle dorsiflexion ROM (area = 0.352; p= 0.108), McConnell angle (area = 0.434; p= 0.476), frontal plane knee projection angle (area = 0.443; p= 0.537 for landing and area = 0.525; p= 0.783 for single-leg squat) and passive hip IR ROM (area = 0.566; p= 0.476) didn't show a significant area under ROC curve. Table 1 indicates the area under the curve for all variables.

The iliotibial band flexibility cutoff point identified was -0.02^{o}/kg (45% sensitivity; 40% specificity), the SFA cutoff point was 24^{o} (66% sensitivity; 64% specificity) and the Arno angle cutoff point was -2.47^{o} (40% sensitivity; 35% specificity). Table 2 shows that 81.2% of legs with PTA had iliotibial band flexibility under - 0.02^{o}/kg, 87.5% had SFA above >24^{o} and 62.5% had Arno angle under -2,47^{o} (negative values indicates patellar medial rotation). However, only iliotibial band and SFA had significant OR and PR. For iliotibial band flexibility the OR was 8.61 (2.2-42.8) and PR was 5.26 (1.6-16.6). SFA had an OR of 6.25 (1.4-44.6) and PR of 4.42 (1.1-17.7).

Discussion

The results of ROC curve showed that iliotibial band flexibility, Arno angle (patellar medial rotation) and SFA (varus alignment) were associated to PTA. Cutoff points for each variable were obtained using ROC curves. OR and PR were calculated but only iliotibial band flexibility and SFA presented statistical significance. Athletes with iliotibial band under -0.02^{o}/kg or SFA above 24^{o} had five or four times more chance, respectively, to have PTA compared to those athletes with values under the cutoff point. These results revealed that iliotibial band flexibility and SFA are key factors related to patellar tendon overload injuries and should be considered on the development of rehabilitation and preventive programs for patellar tendon pain and dysfunction.

Some findings in longitudinal studies are conflicting about the predictive value of ultrasound in identifying patellar tendon changes.[2] However, it cannot be ignored that PTA indicates some level of tissue damage.[6] It is possible that the inconsistencies in the literature are due to differences in severity of the hypoechoic area evaluated.[4] When the tissue damage is mild (initial stages), it is possible for the tendon to adapt and recover during the sport season.[2] On the other hand, moderate to severe hypoechoic changes are likely to indicate an inability of the tendon to adapt or recover.[4] Comin et al[4] reported that only moderate to severe hypoechoic areas are associated with patellar tendon dysfunction. Interestingly, the athletes with PTA in the present study had lower scores of the VISA-P questionnaire (VISA-P=77), indicating that besides the PTA these individual had signs of tendon pain and dysfunction (patellar tendinopathy)

Iliotibial band flexibility is usually investigated as a factor related to patellar alignment[23,24]. Few studies discuss the iliotibial band role in musculoskeletal injuries[25,26]. The results of ROC curve revealed a cut off point of -0.02^{o}/kg, which is clearly a neutral hip position. Values under this cut-off point indicate a tendency towards hip adduction during Ober's test since the band did not resist the movement generated by the lower limb weight. Athletes with iliotibial band flexibility under -0.02^{o}/kg have five times more chance to have PTA. A possible mechanism that could explain this direction is the iliotibial band connections with the patellar retinaculum[26]. Due to this connection a considerable role of the band would be to promote adequate patellar stabilization. In this sense, a stiffer iliotibial band could increase patellar stabilization by means of proper retinaculum tensioning.[26] Therefore, athletes with iliotibial band flexibility under the cutoff point could have under stabilized patella, which would promote excessive patellar movement or imbalanced force distribution through the patellar tendon, which could overload this structure during landing activities.

Foot misalignments have been indicated as a risk factor for musculoskeletal injuries such as patellofemoral pain.[27] Monaghan et al[28] showed that forefoot angle predicts rearfoot and forefoot eversion (amplitude and duration) during walking. Excessive foot pronation leads to tibia internal rotation which could be a source of patellar tendon overload.[14] The present study identified an OR of 6.25 (1.4-44.6) and PR of 4.42 (1.1-17.7) for the occurrence of PTA in athletes with SFA higher than 24^{o}. Mendonça *et al.*[13] established a normative data of 13.9^{o} for SFA in athletes of various sports modalities. Probably, a SFA of 24^o could produce excessive internal tibial and femoral rotation during landing and/or running activities, which would lead to lateral traction of the patellar tendon[11,27] and unequal force distribution in this structure. This mechanism could potentially lead to tendon damage and pathology.[6] Moreover, increased varus foot alignment leads to excessive foot pronation and makes the foot complex too flexible to work as a stiff lever for propulsion.[14,29] Probably, high forefoot varus may alter the movement pattern necessary to produce proper sport gesture.[29] This altered movement pattern, if repetitively performed, may result in excessive patellar tendon stress.

The small number of participants included in the analyses was a limitation of the present study. Frontal plane patellar medial rotation (Arno angle) was associated to PTA (p=0.046). Arno angle inform about patellar tendon alignment relative to the patella.[21] Mendonça et al[30] showed that athletes with patellar tendinosis had higher Arno angle in the involved and non-involved lower limb. As expected, patellar misalignment could overload the patellar tendon especially in athletic populations[30]. However, OR and PR derivation did not achieved statistical significance for this variable potentially due to a small statistical power.

A key point of this study was applying low cost measurements that can be easily implemented in any environment. These characteristics enhance the applicability of the study. The tests used are well described in the literature and the examiners had excellent reliability after training. We suggest the inclusion of iliotibial band flexibility and SFA at preseason screening assessment given its potential for PTA development and/or patellar tendinopathy. However, prospective cohort studies are needed to investigate the role of these factors in PTA development and to analyze the efficacy of preventive approaches based on the modification of the factors indicated in the present study. The results could guide clinical decision making related to PTA prevention and rehabilitation in athletes that could be at risk of developing patellar tendon morphologic abnormalities.

Conclusion

Iliotibial band flexibility and SFA were strongly associated to PTA evaluated using ultrasound. ROC curves demonstrated cut off points of -0.02^o/kg and 24^o respectively for iliotibial band flexibility and SFA. Athletes presenting iliotibial band flexibility under -0.02^o/kg had 5.2 times more chance to have PTA and athletes with SFA above 24^{o} had 4.4 times more chance to have PTA compared to those under these cutoff points.

Practical Implications

- The study results showed that iliotibial band flexibility and SFA were associated to patellar tendon abnormalities. The cutoff points indicted could be used to Identification of athletes' risk profile (pre-dysfunction status) could lead to earlier intervention that may minimize the occurrence of chronic dysfunctions.
- Foot orthoses could increase energy absorption by the ankle joint, especially when landing from a jump and should be prescribed to those athletes with high SFA to minimize stress on the patellar tendon[15,28]. Increasing iliotibial band flexibility could be prescribed with the goal to minimize patellar tendon stress, however; the relationship between this variable and PTA need to be further investigated.
- This study indicates the need to further investigate the effectiveness of interventions aiming at modifying the lower limb alignment, range of motion/flexibility and strength factors explored in this study. Prospective studies should test the recommendations described above and follow-up the athletes with risk for patellar tendon abnormalities throughout the season.

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Tables

Table 1: Demographic data and preseason assessment data comparison of athletes with and without PTA (BMI= body mass index; CI = confidence interval of 95%; ER= external rotation; IR= internal rotation; M= mean; min-max = minimum – maximum; PTA=patellar tendon abnormality; ROM=range of motion; SD= standard deviation; VISA-P = questionnaire score).

Variable	**Sample mean**	**With PTA**	**Without PTA**	**ROC curve**		**P-value**
				area	**CI (95%)**	
Ankle dorsiflexion ROM (^{o})	38.54 (5.65)	35.66 (6.4)	39.49 (5.3)	0.352	0.16-0.53	0.108
Passive hip IR ROM (^{o}/kg)	0.34 (0.12)	0.34 (1.0)	0.31 (0.1)	0.566	0.38-0.74	0.476
Iliotibial band flexibility (^{o}/kg)	-0.01 (2.86)	-1.69 (0.64)	0.56 (0.40)	0.247	0.11-0.38	0.006[a]
Hip ER torque (Nm/kg)	0.37 (0.12)	0.30 (0.05)	0.36 (0.1)	0.351	0.20-0.49	0.104
Hip abductors torque (Nm/kg)	1.61 (0.29)	1.65 (0.3)	1.55 (0.2)	0.582	0.37-0.78	0.371
Shank-forefoot angle (^{o})	22.18 (9.71)	26.33 (4.7)	19.44 (9.7)	0.728	0.58-0.86	0.013[a]
McConnell angle (^{o})	1.13 (4.84)	0.47 (3.4)	1.52 (4.8)	0.434	0.27-0.59	0.476
Arno angle (^{o})	-1.21 (7.02)	-3.36 (4.9)	0.01 (6.8)	0.316	0.18-0.45	0.046[a]
Knee alignment-Landing(^{o})	-1.37 (4.30)	-2.30 (3.1)	-1.35 (4.4)	0.443	0.28-0.60	0.537
Knee alignment-Squat(^{o})	3.95 (3.57)	3.56 (2.7)	3.74 (3.7)	0.525	0.36-0.68	0.783

a. Indicates $p<0.05$

Table 2: Athletes with and without PTA comparison of ankle dorsiflexion ROM, shank-forefoot alignment and iliotibial band flexibility (CI= confidence interval; PTA=patellar tendon abnormality).

Variable	**With PTA**	**Without PTA**	**Odds ratio (CI $_{95\%}$)**	**Prevalence ratio (CI $_{95\%}$)**
Iliotibial band flexibility			8.61 (2.2-42.8) [b]	5.26 (1.6-16.6) [b]
Low (< -0.02°/kg)[a]	13	15		
High (> 0.02°/kg)	3	31		
Shank-forefoot alignment			6.25 (1.4-44.6) [b]	4.42 (1.1-17.7) [b]
High (> 24°)[a]	14	24		
Low (< 24°)	2	22		
Arno angle			2.5 (0.7-8.8)	2.03 (0.8-4.8)
Low (< -2.47°)[a]	10	18		
High (> -2.47°)	6	28		

a. Indicates the group exposed

b. Indicates statistical significance

Figure and figure legends

Figure 1: Measurements of the factors associated to PTA. Shank-forefoot alignment test: 90^{o} of dorsiflexion (measured with goniometer) position for photographic record with metal rod fixed on forefoot (metatarsal) (A); Shank-forefoot alignment analysis: intersection between shank (dotted line) bisection and metal rod projection (continuous line) (B); and Iliotibial band flexibility – Modified Ober test (C).

3.2 ARTIGO 2:

The Accuracy of the Patellar Tendon Clinical Test to Identify Athletes with and without Tendon Abnormalities: Who Should Undergo an Eccentric Protocol?

Abstract

Study Design: Cross-sectional

Objectives: to determine the diagnostic accuracy of a clinical test to identify athletes with patellar tendon abnormalities

Background: Some athletes may have pain without patellar tendon abnormalities (PTA) and would therefore not benefit from treatments based on eccentric training. Clinical tests for PTA identification could optimize the diagnostic process to confirm, or not, the presence of tissue degeneration and, thus, guide proper treatment management.

Methods: Forty-three athletes, older than 18 years, without lower limb surgery in the past 6 months, who participate in sports activities, completed the VISA-P questionnaire, performed the single-leg decline squat (SLDS) test and provided information about patellar tendon pain history. Moreover, they were submitted to ultrasound examination for PTA identification. The sensitivity, specificity, positive and negative predictive values, likelihood of positive and negative tests, accuracy and diagnostic Odds of the VISA-P, history, the SLDS and of the composite of these (Patellar Tendon Clinical Test) tests were computed.

Results: The Patellar Tendon Clinical Test (PTCT) had 79% of accuracy and showed the best performance compared to each test used in isolated form. Moreover, PTCT had the best balance between sensitivity (75%) and specificity (81.5%). PTCT was better to identify PTA presence in athletes older than 25 years old (90% of sensitivity and 90% of predictive positive value) and in individuals with the time of sports practice above 10 years (83% of sensitivity and predictive positive value).

Conclusion: PTCT was an accurate method for PTA identification, which could be used to guide the best intervention approach. Athletes with positive results in the PTCT had more chance to have PTA if they were at least 25 years old, compared to athletes with negative PTCT. Therefore, PTCT may contribute to the establishment of the best intervention program.

Level of Evidence: screening, level 4

Key Terms: *patellar tendinopathy, accuracy, sensitivity, specificity*

Introduction

Patellar tendinopathy is a prevalent sport injury, frequently induced by excessive tendon overloading and characterized by localized tendon pain with morphologic abnormalities[5,16,22]. Jumping frequency, training volume and amount of match exposure are described as risk factors for patellar tendinopathy[1,20]. The recommended conservative treatment for this injury has been the implementation of an eccentric training protocol, which is thought to promote tissue remodeling by means of controlled tendon stress[16,23]. However, some patients may not respond to this conservative approach and the evidence on the benefits of eccentric training remains limited[27]. It is possible that some non-responding athletes may have pain without the presence of patellar tendon abnormalities (PTA) and, therefore, they are not the ones that should benefit from eccentric training. It is clear that treatment choices must be defined based on the identification of PTA presence (induce tendon overload) or absence (remove tendon load). Therefore, the proper clinical identification of athletes with or without PTA is crucial for rehabilitation effectiveness.

Imaging exams, such as ultrasonography, are normally used for PTA detection and should be incorporated in the athlete's assessment[26]. However, this procedure may not be accessible in some sports teams[26]. Training time wasted with ultrasound exams, costs with equipment, hiring of image technicians or the cost of athletes' transportation to a specialized clinic may impede the implementation of ultrasound assessment for all sports team members. Clinical measures such as the VISA-P (*Victoria Institute of Sport Assessment*) questionnaire and the single-leg decline squat test (SLDS) are suggested as means of identifying individuals with patellar tendon pathology (i.e. pain, inflammation, and limited function)[24,25,29]. Therefore, VISA-P and SLDS are frequently used as a screening method to establish the best applicable treatment protocol. However, the diagnostic accuracy of these tests to identify individuals with PTA has not been yet reported, which would be necessary to validate the use of the VISA-P questionnaire and SDLS test as screening methods.

PTA occurrence seems to be related to presence of pain and also to athlete's load exposition (i.e. patellar tendon pain history, age, years of sport practice)[21]. Tissue metabolism decreases with aging and contributes to the declining of the tendon mechanical properties, such as elasticity and tensile strength[19]. Hence, the tendon has inferior capability to tolerate loading, as well as delayed tissue-repairing abilities[19]. These changes make the tendon more susceptible to develop morphologic abnormalities[15]. Therefore, athletes' age and years of sports practice may also help to inform about cumulative loading that could affect tendon mechanical adaptation[9].

The development of screening methods to accurately identify the presence of PTA can guide the rapid establishment of proper care. In addition, the simplicity and low cost nature of clinical screening assessments may provide time and cost effective approaches to assess a large number of individuals within a sports medicine environment. Accordingly, the purpose of this study was to determine the diagnostic accuracy of a clinical test developed to identify athletes with patellar tendon abnormalities.

Materials and Method

Study design:

This cross-sectional study was approved by The University's Ethics in Research Committee (Approval Report number 0493.0.203.000-09). The study design and report is in accordance to the *Standards for Reporting of Diagnostic Accuracy* [2].

Study sample:

Initially, fifty-two athletes from sports modalities with high PTA prevalence[8,13,30] (volleyball, basketball, soccer and running), were recruited by telephone. To be eligible for the study participants had to be older than 18 years, not have had lower limb surgery in the past 6 months, and be fully participating in sports activities. All athletes who agreed to participate in the study (n=47) read and signed a consent form. Athletes identified, at the ultrasound examination, with Osgood-Schlatter or Sinding-Larsen-Johansson diseases, were excluded from the study (n=4). Forty-three athletes (volleyball (n=26), basketball (n=14), soccer and running (n=3)) were suitable for analysis. The study's sample had 38 men and 5 women, with mean age of 24.8 ± 6.7 years, weight of 87.6 ± 13.7 kilograms, height of 1.93 ± 0.1 meters and time of sports practice of 11.01 ± 5.4 years. Figure 1 demonstrates the study's flow diagram to illustrate the recruitment procedure.

Procedures:

Ultrasound examination, VISA-P questionnaire, SLDS test and information about patellar tendon pain history were collected in a two-day period to avoid modification in the athletes' clinical status. The reference test (ultrasound examination) was the last one to be carried out and was performed by a different single examiner (L.M.O.F) to avoid any bias during data collection. The results obtained in the other three measurements were kept confidential by the examiner in charge (R.A.B.) and they were transferred to a researcher (L.D.M.) not involved in data collection.

SLDS test consisted of a single leg squat (performed until 30^{o} of knee flexion), which was performed once (eccentric and concentric phases) with each lower limb, in a 30^{o} decline ramp[29]. The goal was to evaluate the tendon reactivity in this task. Therefore, the presence of patellar tendon pain indicated a positive test. After this test, the VISA-P questionnaire was applied to characterize the athletes' functional profile and to classify the severity of the patellar tendon symptoms[24,25]. The questionnaire is self-administered and has eight questions (seven answers scaled from 0 to 10 and one scaled from 0 to 30). Six questions are related to patellar tendon pain in functional/sports tasks (i.e. sitting, squatting, jumping) and two are related to the level of sports performance. Scores under 80 are usually used as indicative of patellar tendinopathy [7,18,26] and this parameter was adopted in the present study to indicate patellar tendon dysfunction. A time limit was not established for the athletes to complete the questionnaire.

Before the examiner R.A.B. applied the VISA-P questionnaire and the SLDS test in all participants, a reliability analysis was performed with 7 subjects, six men and one woman (mean age of 38.57 ± 18.8 years; weight of 78.57 ± 13.01 kilograms; height of 1.73 ± 0.10 meters). In this reliability study, the same examiner applied twice the VISA-P questionnaire and the SLDS test with an interval of 4 days between the two measurements. The procedures used in the second evaluation were the same adopted in the first assessment. The results showed excellent intra-rater reliability, with an $ICC_{3,3}$ of 0.99 for VISA-P and Kappa of 1, $p < 0.0001$, for SLDS.

The history of patellar tendon pain in all athletes was registered separately for each leg. Pain history was considered positive when the athlete had progressive patellar tendon pain related to sports practice that interfered with his/her performance in the past 6 months (traumatic cases and those related to growth spurt were excluded)[26]. After providing information regarding the patellar tendon pain history, the athletes were submitted to an ultrasound examination, which was performed by a specialist physician (L.M.O.F.), who did not have access to the other tests results. The athletes were placed in supine position in a treatment table, with knees flexed and feet supported. A high-resolution 12 to 19-MHz linear transducer ultrasound (Volusom® 730 GE®, General Electric Company, United Kingdom) was used. The examiner analyzed the entire extension of both patellar tendons of the participants in the longitudinal (sagittal) and transverse (axial) planes. The transducer was kept perpendicular to the tendons to avoid false-positives results due to anisotropy[26]. Tendon thickness, echogenicity and texture were evaluated. In addition, other findings related to patellar tendinopathy, such as bursa distention, tendon rupture and bony peri-insertional prominence, were investigated [26]. The subjects were asked not to provide any information about the presence of symptoms to the ultrasound examiner. A positive diagnosis of PTA was given when a tendon had hypoechoic regions and thickness reduction with or without intra-tendinous swelling (Figure 2). After the ultrasound examination, four athletes were excluded from the study, because they had signs associated to Osgood-Schlatter.

To verify the ultrasound examination test-retest reliability, a reliability study was carried out with 6 subjects, 4 women and 2 men (mean age of 23.0 ± 1.7 years, weight of 55.6 ± 3.7 kilograms and height of 1.6 ± 0.1 meters). The same procedures previously described were adopted in the reliability study. The examiner performed two ultrasound examinations with a rest period of 4 days between exams. A Kappa coefficient of 0.75 (p= 0.047) revealed a good test-retest reliability of ultrasound examination.

Data analysis:

An independent investigator (L.D.M.), blinded to the all test results, was responsible for the statistical analysis. Sensitivity, specificity, positive and negative predictive values, likelihood of positive and negative tests, accuracy and diagnostic Odds (95% of confidence interval) of VISA-P, history, SLDS and of the composite of tests (for each possible combination) were computed.

For SLDS test and patellar tendon pain history were considered both lower limbs (n= 86). For the combined analysis, the involved or more symptomatic lower limb (in case of positive results) or the dominant lower limb (in case of negative results) was used for SLDS test and pain history. After the individual accuracy analyses, all possible combinations among the tests were performed to find the most accurate composed test. Finally, this test combination had its accuracy investigated taking into account the athletes' age and years of sports practice to identify the association of these factors to PTA. The cutoff points used for age and sports practice experience were based on the sample mean (25 and 10 years, respectively).

Results

Out of the 43 athletes tested, 27 tendons were diagnosed with PTA and 59 tendons were classified as normal at ultrasound. The mean score of VISA-P questionnaire for athletes with PTA was 77.3 ± 23.5 and 92.5 ± 12.7 for those without PTA. Diagnostic accuracy analysis of each individual test and the most accurate combination of tests are presented in Table 1. The results revealed that the most accurate combination of tests to identify PTA presence and/or absence was found when the athlete had positive for VISA-P, or SLDS or tendon pain history (75% sensibility and 81% specificity). This combination was named the Patellar Tendon Clinical Test (PTCT). The occurrence of positive results in the VISA-P or SLDS or in pain history, which is indicative of athlete positive on PTCT, obtained the highest diagnostic accuracy (79%) compared to the tests performed individually (respectively 72%, 71% and 74%). For all comparisons performed, specificity values were higher than sensitivity, which indicates that the clinical tests investigated in the present study are more appropriate to identify true-negative cases of PTA (Table 1).

The contribution of age and years of sports practice to PTA identification was analyzed considering the PTCT (Table 2). It was observed that applying the PTCT in older athletes or in athletes with more years of sport practice sharply increased the test accuracy (88% and 84%, respectively). The results demonstrated that age and years of sports practice are independently associated to the occurrence of PTA. This is demonstrated by the fact that these variables had distinct odds from each other (Table 2) and from the sample's value (Table 1). Specifically considering athletes above 25 years old, PTCT was more accurate to identify PTA presence (90% of sensibility, 83% of specificity, positive predictive value = 90% and negative predictive value= 83%).

Discussion

The present study showed that the PTCT could be used accurately in clinical practice to identify athletes with PTA. Specifically, the PTCT presented a better performance and appropriate accuracy compared to the VISA-P, SLDS and patellar tendon pain history analyzed individually. Therefore, these tests should not be used solely to identify athletes with PTA. In addition, our results demonstrated that age and sports experience was independently associated to PTA occurrence. We recommend the use of PTCT for PTA occurrence especially in individuals older than 25 years because of the decreased false positive and false negative results.

The results of the present study may indicate that athletes above 25 years-old with positive PTCT could perform interventions based on eccentric protocols, shock wave therapy and/or the use of platelet rich of plasma (PRP) to enhance patellar tendon repair. Otherwise, if an athlete above 25 years old had negative PTCT, these interventions must be discarded from treatment regime. Recent studies about eccentric protocols efficacy for patellar tendinopathy founded confounding results. Visnes et al[23] investigated an eccentric decline squat protocol in athletes with patellar tendinopathy that had no ultrasound data reported in the study. The results revealed no effect on knee function of a 12-week program in volleyball players who continued to train and compete. However, Young et al[28] showed that pain and sport function improved using the same eccentric decline squat protocol in volleyball athletes who continued to play and had PTA. Probably, Visnes[23] study included athletes without PTA and, consequently, would not benefit from eccentric protocol. Kongsgaard et al[14] required an ultrasound exam to confirm tendon abnormalities and showed that slow resistance training had good short-term and long-term clinical effects accompanied by tendon properties improvement (e.g. PTA reduction and increased turnover and synthesis of the collagen network). Therefore, it seems that a heavier eccentric training is important for tissue remodeling and this intervention should be used only when PTA is identified, otherwise it could not be an effective intervention[23]. In this sense, the results of the present study demonstrated that the PTCT approach could be used to identify the occurrence of PTA and, therefore, help to select the correct treatment choice, as well as inclusion/exclusion criteria in studies that investigate the effects of eccentric training or another intervention to treat individuals with PTA.

The PTCT had 81% of specificity and a diagnostic odd of 13.2 (2.9 - 58), which indicates that an athlete considered negative for the PTCT have more chance to not have PTA, when compared to an athlete with positive PTCT. Moreover, the PTCT showed a good balance between sensitivity (75%) and specificity (81%) values, which indicates that the PTCT is a more accurate method than the other tests alone. Good predictive positive (70%) and negative (85%) values were also found, which reinforces the method's applicability. Out of the 16 athletes who had PTA, four (2 men and 2 women) were classified as negative in the PTCT. Two of these athletes were 18 years old (with 2 and 4 years of sport practice) and the other two were volleyball players of less demanding positions (setter and defender). The short time in sports practice and the small amount of jumping/landing demand of these players, indicate that they were not submitted to high tendon loading, which is necessary for developing symptoms[17]. Out of the 27 athletes without PTA at ultrasound, five were evaluated as positive PTCT. Two of these athletes had positive results in SLDS test, three were positive in VISA-P and none had patellar tendon pain history. It is possible that these 5 athletes had paratendon symptomatology without affecting the tendon's integrity[4,17]. These circumstances revealed the variability of patellar tendinopathy clinical presentation in athletes and demonstrated that the accuracy of symptoms related to PTA requires a more comprehensive strategy, as performed in the present study.

The analysis adjusted by age and years of sports practice revealed that these factors are independently associated to PTA occurrence. Older and more experienced athletes had a higher chance to have PTA probably due to load exposition over the years and tissue metabolism reduction[19]. The application of PTCT exclusively in athletes older than 25 years resulted in an accuracy of 88% (90% for sensibility and 83% for specificity). The positive predictive value of 90% reveals the precision of PTA positive athletes identification. Moreover, the diagnostic odds was 50.0, which indicates that an athlete older than 25 years who had a positive result in the PTCT had more chance to have PTA, when compared to an older athlete that scored negative in the PTCT. In this subgroup, the likelihood of positive and negative test revealed the best relationship among all tests analyzed (5.4 and 0.1, respectively), indicating moderate accuracy[10]. Therefore, apply PTCT in athletes above 25 years old can discriminate accurately the presence or absence of PTA. This criteria established a relationship between sensibility and specificity and has been frequently used in the literature as the main criteria to classify the diagnostic accuracy of a test[10,12,26].

The use of the PTCT in athletes with 10 or more years of sport practice revealed a diagnostic accuracy of 84% to PTA occurrence (83% for sensibility and 84% for specificity). The diagnostic odds was 27.5, which indicates that an athlete with 10 or more years of sport practice who had a positive PTCT has more chance to have PTA, when compared to a similar athlete with negative PTCT. The likelihood of positive and negative test values was 5.4 and 0.2, respectively, also revealing a moderate accuracy classification. The role of age and years of sport practice could be understood through the etiology related to patellar tendon overload. The existence of a long history of demand exposition might implicate in a higher chance for PTA occurrence [4,9,26]. Accordingly, especially in athletes older than 25 years, the PTCT could be considered an important screening tool for PTA presence.

The individual analysis of VISA-P questionnaire, SLDS test and patellar tendon pain history reveled sensitivity values of 50%, 44% and 37%, respectively. These results showed the failure of these tests to identify the true-positives athletes with PTA. Similarly, Warden et al[26] reported a lack of association between cross-sectional area of the hypoechoic region on ultrasound (gray scale) and either number of sporting hours per week, symptom duration, visual analog scale or VISA-P questionnaire score (all $r = -0.14$ to 0.15, $p = 0.43$ to 0.92) [26]. On the other hand, the specificity values for VISA-P, SLDS test and history in the present study were 85%, 83% e 91,5%, respectively. These data revealed a good capability of these procedures to identify participants without PTA (true-negatives). However, the diagnostic accuracy of a test depends on a good balance between sensitivity and specificity values[10,12]. Unfortunately, this was not the case for the VISA-P questionnaire, SLDS test and patellar tendon pain history, when considered solely.

Currently, is not clear whether the presence of PTA in athletes predicts tendon pathology (i.e. pain, inflammation, and limited function)[22]. Prospective studies founded athletes with PTA in the beginning of the season which develops pain and dysfunction, however, another ones improve patellar tendon morphology during the season[4,6,8,9,17]. However, it cannot be ignored that PTA signalizes tissue damage, even in its initial stages[11]. Probably, this inconsistency is related to the severity of the hypoechoic area, since mild tendon abnormalities can adapt and recover during the season. On the other hand, Comin et al[3] reported that moderate to high hypoechoic areas predict tendon-related disability in ballet dancers. This result supports the assessment of PTA, by means of PTCT. Therefore, the presence of PTA could indicate patellar tendon overload.

One limitation of the present study was the fact that the assessment was performed during the athletes' preseason. During this time period, the training load is in its initial stages and, thus, athletes with PTA have a higher chance of presenting themselves asymptomatic, when compared to midseason and/or end-season periods. Therefore, tests that rely on pain as the outcome (i.e. VISA-P and SLDS) could have better accuracy performance during later season stages. However, capturing asymptomatic athletes with PTA was an important feature of the study.

In circumstances in which the ultrasound examination may be costly or not accessible, the PTCT could be used as a clinic tool to define a particular subgroup with a higher chance to have PTA. Athletes above 25 years-old positive on PTCT had a higher chance of PTA presence. Otherwise, if a subject score negative on PTCT, the probability of PTA absence is higher. Thus, the PTCT can be applied as an economic strategy to define the specific individuals that should undergo ultrasound examination. The aggregate value of a test must be analyzed considering its incorporation in clinical practice. If the new method is less invasive, less time consuming and less costly, it is possible to critically accept the specific contribution of the method in question[10,12]. The PTCT fulfills these requirements. Moreover, the results of the present study reveled that an athlete older than 25 years old should perform eccentric protocol if positive in PTCT. Otherwise, a negative result on PTCT in athletes above 25 years indicated PTA absence and eccentric protocol should be discarded.

Conclusion

PTCT was an accurate method for identifying PTA occurrence, especially in older or experienced athletes, which could be used as a parameter to guide the best intervention approach. Athletes older than 25 years with positive results in the PTCT had more chance to have PTA and should perform eccentric protocol for tendon repair. A negative result on PTCT indicates a higher chance to PTA absence in athletes above 25 years and eccentric protocol should be discarded. For younger athletes (under 25 years old), a confirmatory ultrasound exam should be indicated only if they presented PTCT positive. Therefore, PTCT could be considered an clinical tool to identify the presence or absence of PTA, an economic option to define those athletes that should undergo ultrasound examination and, finally, a standard method to guide interventions based or not on tendon repair.

Findings: Athletes older than 25 years with positive results in the PTCT had 50 times more chance to have PTA compared to athletes with negative PTCT. Therefore, athletes older than 25 years with positive PTCT are more likely to benefit from rehabilitation based on eccentric protocols to improve tendon capability do absorb energy.

Implications: PTCT can be considered a useful tool to identify PTA presence or absence especially in athletes above 25 years old and guide the implementation of the proper intervention. Moreover, this test may be used to define which athletes should be submitted to an ultrasound assessment to confirm the presence of PTA. Therefore, PTCT is a clinical tool developed to minimize time and financial costs with ultrasound exam and also guide the implementation of interventions based on eccentric training.

Caution: The data of the present study were collected in athletes during preseason. The relationship between PTCT and PTA occurrence should be investigated during midseason and/or end-season periods when probably the athletes had higher training load (midseason) and/or more pain and dysfunction at the patellar tendon. Therefore, PTCT could be more accurate in these cases.

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Figures and Tables

TABLE 1. Accuracy of clinical tests and the Patellar Tendon Clinical Test (PTCT) in PTA identification.

Variable	VISA-P (+/-)†	SLDS (+/-)	History (+/-)	PTCT* (+/-)
With PTA	8/8	12/15	10/17	12/4
Without PTA	4/23	10/49	5/54	5/22
Accuracy (%)	72.1 (57-83)	71 (61-79)	74.4 (64-82)	79.1 (64-88)
Sensitivity (%)	50 (28-72)	44.4 (27-62)	37 (21-55)	75 (50-89)
Specificity (%)	85.2 (67-94)	83 (71-90)	91.5 (81-96)	81.5 (63-91)
Positive Predictive Value (%)	66.6 (39-86)	54 (34-73)	66.6 (41-84)	70.6 (46-86)
Negative Predictive Value (%)	74.2 (56-86)	76 (65-85)	76.1 (65-84)	84.7 (66-93)
Likelihood of positive test result	3.3 (1.6-7)	2.6 (1.7-4)	4.3 (2.1-9)	4 (2.5-6.3)
Likelihood of negative test result	0.5 (0.4-0.7)	0.6 (0.5-0.7)	0.6 (0.6-0.7)	0.3 (0.2-0.5)
Diagnostic Odds	5.75 (1.3-24)	3.9(1.4-10)	6.3 (1.9-21)	13.2 (2.9-58)

Values in parentheses indicate the confidence interval

* Most accurate composed = VISA or SLDS or History positive

† (+/-) indicates the frequency of athletes with positive/negative results in VISA-P, SLDS, history and PTCT.

TABLE 2. Analysis adjusted by age and years of sports practice in PTA identification through Patellar Tendon Clinical Test.

Variable	≤ 25 years (+/-)	> 25 years (+/-)	<10 years of sports practice (+/-)	≥10 years of sports practice (+/-)
With PTA	2/3	10/1	2/2	10/2
Without PTA	4/17	1/5	3/11	2/11
Accuracy (%)	73 (53-86)	88 (65-96)	72 (49-87)	84 (65-93)
Sensitivity (%)	40 (11-76)	90 (62-98)	50 (15-85)	83 (55-95)
Specificity (%)	81 (60-92)	83 (43-96)	78 (52-92)	84 (57-95)
Positive Predictive Value (%)	33 (9-70)	90 (62-98)	40 (11-76)	83 (55-95)
Negative Predictive Value (%)	85 (63-94)	83 (43-96)	84 (57-95)	84 (57-95)
Likelihood of positive test	2.1 (0.2-14)	5.4 (0.7-39)	2.3 (0.4-12)	5.4 (1.9-15)
Likelihood of negative test	0.7 (0.3-1.4)	0.1 (0.0-0.8)	0.6 (0.2-1.7)	0.2 (0-0.5)
Diagnostic Odds*	2.8 (0.3-23)	50 (2-977)	3.6 (0.3-38)	27.5 (3.2-233)

* It reveals association of age and sports practice on PTA because stratas had distinct odds from each other (sub-groups) and from the sample's value (Diagnostic Odds = 13.2).

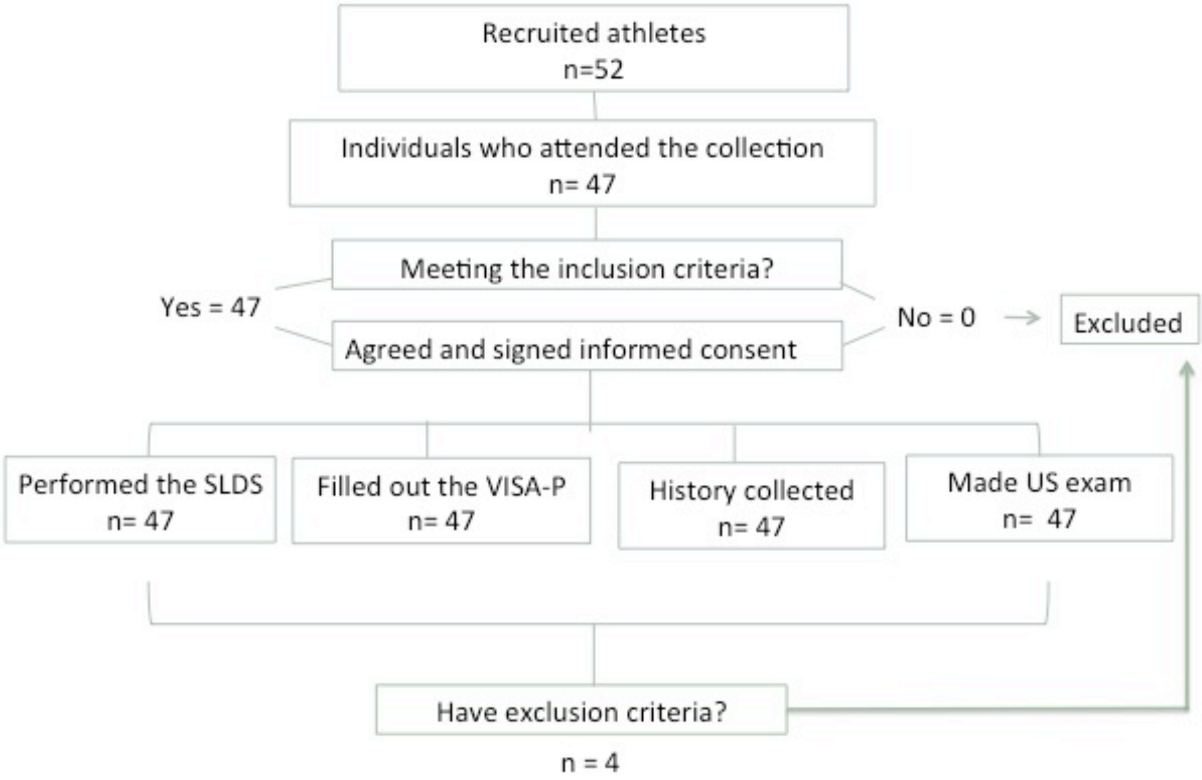

FIGURE 1. Flow diagram of diagnostic accuracy study

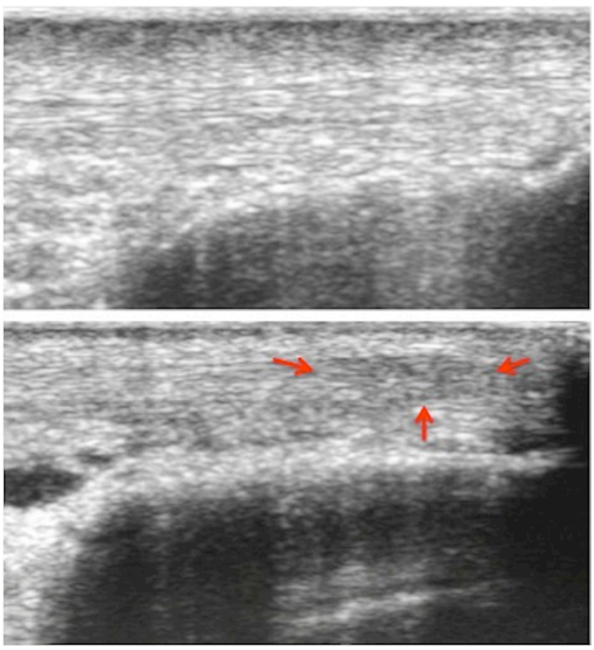

FIGURE 2. Ultrasound images of patellar tendon normal (above) and with abnormalities (below). The arrows indicate a hypoechoic area.

3.3 ARTIGO 3:

Identifying Hip and Foot Contribution to the Occurrence of Patellar Tendinopathy (Jumper's knee) in Athletes: a Classification and Regression Tree Approach

ABSTRACT

Background: Patellar tendinopathy (jumper's knee) have a high prevalence in elite basketball and volleyball athletes, affect sports participation and even lead to the end of a sport career. The investigation about patellar tendinopathy focus mostly in the individuals' anthropometric characteristics and on factors related to the knee joint (local factors). However, hip and foot joints influence knee movement pattern and, consequently, the forces distribution on the knee joint and the patellar tendon. Objective: to identify the contribution of factors related to hip and foot joints to the occurrence of patellar tendinopathy (jumper's knee) in volleyball and basketball athletes. To accomplish this purpose the Classification and Regression Tree (CART) analysis was used. Design: observational study. Setting: Preseason screening at the Universidade Federal de Minas Gerais. Participants: Male and female volleyball and male basketball athletes. Methods: Preseason assessment included shank-forefoot alignment (SFA), ankle dorsiflexion range of motion (ROM), iliotibial band flexibility, passive hip medial rotation (MR) ROM, hip lateral rotators (LR) and abductors isometric strength. The tests were distributed as a test battery and the athletes performed the strength tests lastly. Athletes with tenderness and/or pain at the inferior pole of the patella and VISA-P under 80 points (n=59) were identified with patellar tendinopathy (PT). Results: The classification tree selected hip LR torque, SFA, ankle dorsiflexion ROM and passive hip MR ROM as predictors for PT in athletes. The model predicted correctly 43 of the 59 athletes with PT (72.9% sensitivity) and 94 of the 133 athletes without PT (70.7% specificity). The area under the ROC curve was

0.77 (95% confidence interval: 0.70 - 0.84; standard error 0.03; $p<0.0001$) revealing that the classification of the athletes into positive or negative PT using this model was not by chance. Conclusions: Hip and foot factors contribute to PT occurrence in volleyball and basketball athletes. CART developed an accurate model and showed that an isolated factor wasn't able to predict PT occurrence and that interaction between hip and foot factors need to be considered in further investigation of PT etiology.

Keywords: patellar tendon, injury, lower extremity, factors.

INTRODUCTION

Patellar tendinopathy (jumper's knee) is a clinically identified overload injury associated to jumping activities[1]. Elite volleyball and basketball athletes have a prevalence rate of this disorder around 40%[2-4] and the treatment is challenging[5]. Understanding the mechanisms that result in patellar tendinopathy is mandatory, because symptoms may last for years, affect sports participation and even lead to the end of a sport career[6]. However, the investigation about patellar tendinopathy focus mostly in the individuals' anthropometric characteristics and on local factors related only to the knee joint[7-10]. A systematic review published by van der Worp *et al.*[11] indicated nine risk factors (weight, body mass index (BMI), waist-to-hip ratio, leg-length difference, arch height of the foot, quadriceps flexibility, hamstring flexibility, quadriceps strength and vertical jump performance) for patellar tendinopathy. The authors revealed that there was no strong or moderate evidence that any investigated risk factor was associated with patellar tendinopathy[11]. Considering other knee injuries (patellofemoral pain, ACL) some studies pointed out the contribution of non-local factors related to the hip and foot joints to the occurrence of these injuries[12-19]. In this sense, it is possible that factors related to these joints could also play a role in patellar tendon overload and, consequently, contribute to the patellar tendinopathy occurrence.

The literature suggests that hip and foot segments can contribute to development of some knee injuries, since alterations in these segments can modify movement and alignment of tibiofemoral and patellofemoral joints, resulting in overload of some knee structures[13-21]. This argument is reinforced by evidence that some individuals with patellofemoral pain had increased hip adduction[17] and excessive femoral internal rotation[22] during some activities. For example, Dierks et al[17] founded that runners with patelofemoral pain syndrome had weaker hip abductor muscles that were associated with an increase in hip adduction during running. Moreover, Souza et al[22] showed that altered patellofemoral joint kinematics in females with PFP was the result of excessive internal rotation of the femur during a single-limb squat. Therefore, forces that act on the knee joint could stress specific portions of the patellar tendon, interfere with the capability of tissue remodeling (because of tendon overload) and promote the degenerative process. Limited ankle dorsiflexion and increased varus foot alignment[13, 14], for example, lead to excessive pronation of the foot in landing increased patellar tendon tension due to tibial medial rotation. Moreover, excessive tibial medial rotation could medially rotate the femur during landing[23]. In this case, an adequate hip external rotators strength and proper stiffness could control this excessive lower limb internal rotation and minimize patellar tendon overload[24]. Therefore, the presence of muscle strength weaknesses, alterations in mobility and/or flexibility and misalignment of hip and foot joints influence knee movement pattern and, consequently, the forces distribution on the knee joint and the patellar tendon[17, 24, 25].

As multi factors could affect the knee joint mechanics and contribute to patellar tendon overload, statistic methods that consider interactions between the independent variables and outcome are appropriate. Athletes with patellar tendinopathy have factors that could interact in different ways and, consequently, more than one injury mechanism could be identified[11, 26]. The classification and regression tree (CART) is a tree-building technique that may uncover interactions and identify those related to injury occurrence[27]. Therefore, the CART could be used to identify how factors related to hip and foot contribute to patellar tendinopathy occurrence: if the association is revealed throughout interactions or not. The purpose of this study was to identify the contribution of factors related to hip and foot joints to the occurrence of patellar tendinopathy (jumper's knee) in volleyball and basketball athletes. To accomplish this purpose the Classification and Regression Tree (CART) analysis was used.

METHODS

Male and female volleyball (no libero player) and male basketball athletes were invited to a preseason screening at the university. The eligibility for participation was regular sports practice of at least 12 hours per week in the last season. Athletes with tenderness and/or pain at the inferior pole of the patella (confirmed by sports physician or physical therapist) and VISA-P under 80 points (n=59) were identified with patellar tendinopathy (PT)[26, 28, 29]. Individuals diagnosed with Osgood-Schlatter disease, anterior knee pain not related to patellar tendon (both confirmed by sports physician or physical therapist throughout clinical exam), history of lower limb surgery and/or patellar tendon steroid injection (both described by the athlete and physical therapist) were excluded from the initial sample to avoid bias (n = 41). Moreover, athletes with only patellar tendon pain history positive (negative on VISA-P and single-leg decline squat) were excluded to avoid asymptomatic participants with patellar tendon abnormalities in non-PT group (n=41). Similarly, athletes with VISA-P score between 80 and 95 points were excluded to guarantee a non-PT group formed by athletes without any patellar tendon complain (n=39)[28]. Athletes with VISA-P questionnaire above 95 points, single-leg decline squat (SDS) negative and no patellar tendon pain history made up the group of individuals without PT (n=133)[28, 30, 31]. According to these criteria, we invited 313 athletes to preseason screening, 121 were excluded and 192 athletes (47 women and 145 male) were considered for analysis. All participants read the consent form approved by the University's Ethics Committee (n^{o} ETIC 493/2009) and sign if they agreed to participate.

Preseason assessment included shank-forefoot alignment (SFA), ankle dorsiflexion range of motion (ROM), iliotibial band flexibility, passive hip medial rotation (MR) ROM, hip lateral rotators (LR) and abductors isometric strength. The tests were distributed as a test battery and the athletes performed the strength tests lastly.

Shank-forefoot alignment (SFA)

SFA was measured with the athlete positioned prone on a treatment table. A digital camera was placed on a tripod at 90^o to the right end of the treatment table. The shank was bisected (on the tibial plateaus and malleolus) and a metal rod was placed on the forefoot for photographic record (Figure 1a), according to Mendonça et al[32]. The examiner positioned the foot in neutral ankle dorsiflexion/plantar flexion and requested the athlete to actively maintain this position for photographic record (Figure 1b). Three photos were taken in each foot and the measurement of the intersection between shank bisection and forefoot inclination (represented by the metal rod) were performed in a two-dimensional analysis software (Simi Motion Twinner® - Figure 1c) to determine the mean angle for SFA (Intraclass Correlation Coefficient $(ICC)_{3,3}$=0.93(intra) and 0.90(inter))[32]. Positive values were assigned to varus alignment and negative ones to valgus alignment.

Insert figure 1 about here

Ankle dorsiflexion ROM

To assess ankle dorsiflexion ROM the athlete was positioned facing a wall and was instructed to move the knee forward until it touched a perpendicular line drawn on the wall without lifting the heel off the floor (Figure 2a) as described by Bennell et al[33]. The participant selected each foot position to permit the maximal ankle dorsiflexion ROM without trunk rotation. Then an inclinometer was placed 15 centimeters from the tibial tuberosity (Starrett ®) to access ankle dorsiflexion ROM. Three trials were performed on each leg and the average was considered for analysis ($ICC_{3,3}$=0.98(intra) and 0.92(inter)).

Insert figure 2 about here

Passive hip MR ROM

The examiner applied the protocol described by Carvalhais et al[34], in which the passive movement of hip medial rotation, produced by the weight of the leg and foot of the athlete, was allowed until passive structures and hip muscular tension stop this movement (Figure 2b). Therefore, it was determined as the position in which the torque produced by the mass of the lower leg and foot was equal to the passive-resistance torque generated further hip medial rotation and indicates hip passive stiffness during medial rotation (19). The participant was positioned in prone on a treatment table with 90° of knee flexion and the pelvis stabilized by a strap. If the examiner observed muscle contractions the measurement was disregarded and repeated. Three measures were carried out with an inclinometer positioned five centimeters from the tibial tuberosity. The mean of the three measures was normalized by athlete's body mass to allow comparison between participants (degrees/kg) ($ICC_{3,3}$=0.99(intra) and 0.99(inter)).

Iliotibial band flexibility

Iliotibial band flexibility was measured with the participant on a treatment table in side lying position. The examiner performed the modified Ober test protocol described by Reese & Bandy[35] (Figure 2c). The examiner sustained the tested limb weight as the participant was instructed to keep all muscles relaxed. Then, the examiner flexed, abducted, laterally rotated the participant's hip and when the hip was extended and kept in neutral rotation, the examiner withdrew the lower limb support to assess the iliotibial band flexibility. Measures were taken with an inclinometer (Starrett ®) positioned distal to lateral femoral condyle three times and normalized by body mass to be considered for analysis (degrees/Kg). Positive values were assigned to hip abduction and negative ones to hip adduction ($ICC_{3,3}$=0.99(intra) and 0.94(inter)).

Hip LR and abductors isometric strength

To assess hip LR and abductors isometric strength the examiner used a handheld dynamometer (microFET2; Hoggan Health Industries, Inc, West Jordan, UT). For hip abductors strength assessment (ICC=0.94(intra) and 0.90(inter)), we followed the protocol described by Bittencourt et al[25] with the dynamometer positioned proximal to the lateral femoral condyle (Figure 3a). The participant was positioned in side lying with the pelvis stabilized by a strap and three trials of maximal hip abduction isometric contractions were performed with 15 seconds of interval between then. The participants received verbal encouragement to guarantee maximal effort. Muscle torque was calculated as the product between the mean of three strength measures and the distance from the greater trochanter to the location of the dynamometer. For hip LR strength measurement (ICC=0.98(intra) and 0.90(inter)), the handheld dynamometer was placed proximal to the medial malleolus with the athlete in prone position with a strap stabilizing the pelvis and 90^{o} of knee flexion[36] . The same protocol[25] of abductors test was used, except that we performed a progressive contraction to avoid excessive compensatory movements (i.e trunk and pelvis rotation, and hip adduction) that could invalidate the test (Figure 3b). Three trials were performed with 15 seconds of interval between then and the participants received verbal guidance to guarantee the progressive contraction. Muscle torque was calculated as the product between the mean of three strength measures and the distance from the medial femoral condyle to the location of the dynamometer. Torque values were normalized by body mass (Nm/kg).

Insert figure 3 about here

The athletes were assessed bilaterally and none of the examiners who performed the preseason screening tests knew the clinical diagnosis of the participants. The data of the injured lower limb (for athletes with PT) and the dominant lower limb (for athletes without PT) were considered for the analysis.

Statistical Analysis

Descriptive statistics were used to characterize the sample in relation to PT (outcome variable), iliotibial band flexibility, hip abductors torque, hip LR torque, passive hip MR ROM, ankle dorsiflexion ROM and SFA (independent variables or potential factors related to the occurrence of PT). Classification and Regression Tree (CART) was used to determine which factors and interactions would be related to the occurrence of PT. The decision tree is constructed by recursive partitioning of the initial set of data, until further divisions are not possible or until pre-established criteria for tree growth are reached[27, 37]. This multivariate, nonparametric classification (regression) model consider all possible independent variables and cut-off points for each partition[27, 37].

The criteria used to produce the partitions and, consequently, tree development, were: minimum of 8 participants in each node to make a division; minimum of 4 participants to generate a node and a Gini indice of 0.0001 to maximize the nodes homogeneity. A maximum depth of 4 levels was established and a pruning procedure was applied to avoid over-fitting partitions. The classification cost was considered symmetric between categories and PT probability was based on the literature (40% positive PT and 60% negative PT)[2, 3, 4].

The area under receiver-operating characteristic (ROC) curve was determined in order to verify the accuracy of the prediction model. A significance level of 0.05 was established to indicate if the model was accurate to predict the outcome categories (area under ROC curve statistically different from 0.5). Moreover, odds ratio (OR) and prevalence ratio (PR) were performed on each terminal node to explore the strength of associations revealed by the final CART model.

RESULTS

Table 1 shows minimum and maximum values of each demographic and independent variables collected of the sample and of the athletes with and without PT.

Table 1: Descriptive demographic and independent variables data of the sample and athletes with and without PT (y=years, m=meters, kg= kilograms, ^{o} = degrees, N= newtons, Min= minimum, Max= maximum, PT= Patellar Tendinopathy)

Variables	Min-Max	Sample	with PT	without PT
Age (y)	15 - 37	17.85 (4.72)	18.25 (0.69)	17.68 (0.38)
Time of practice (y)	1 - 20	5.12 (4.64)	5.71 (0.62)	4.86 (0.39)
Height (m)	1.53 - 2.13	1.86 (0.10)	1.85 (0.01)	1.86 (0.09)
Body mass (kg)	51.40 - 125	76.47 (13.58)	75.32 (1.88)	76.56 (1.26)
BMI	16.18 - 30.37	21.73 (2.48)	21.70 (0.29)	21.79 (0.24)
VISA-P	39 - 100	90.32 (14.83)	68.73 (1.14)	99.70 (0.08)
Ankle dorsiflexion ROM (^{o})	23.66 - 54.33	39.52 (6.26)	39.48 (0.79)	39.89 (0.58)
Passive Hip MR ROM (^{o}/kg)	0.12 - 1.05	0.45 (0.19)	0.49 (0.02)	0.44 (0.16)
Iliotibial band flexibility (^{o}/kg)	-0.24 - 0.24	-0.05 (0.06)	-0.06 (0.00)	-0.05 (0.00)
Hip LR torque (Nm/kg)	0.09 - 0.81	0.33 (0.13)	0.30 (0.01)	0.35 (0.01)
Hip abductors torque (Nm/kg)	0.58 - 2.65	1.51 (0.36)	1.49 (0.05)	1.50 (0.03)
SFA (^{o})	-3.68 - 46.64	22.31 (9.22)	23.38 (1.16)	21.93 (0.87)

The classification tree selected hip LR torque, SFA, ankle dorsiflexion ROM and passive hip MR ROM as predictors for patellar tendinopathy (jumper's knee) in athletes (Figure 4). Hip LR torque was the first factor selected. In this case torque values under or equal to 0.31 Nm/kg associated with SFA under or equal 16.67^o was associated with the absence of PT (78.9%; n=15; node 3). However, when SFA was above 16.67^o and associated with passive hip MR ROM above 0.62^o/kg (approximately 43^o), 11 athletes had PT (73.3%; node 8). All athletes (n=6; 100%; node 12) with passive hip MR ROM between 0.58^o/kg and 0.62^o/kg didn't have PT. Otherwise, passive hip MR ROM under 0.58^o/kg the CART indicated PT presence (n=20; 44.4%; node 11).

Athletes with hip LR torque above 0.315 Nm/kg associated with ankle dorsiflexion ROM above 42.33^o, (n=30; 96.8%; node 6) did not have PT. On the other hand, if ankle dorsiflexion ROM remained between 38.83^o and 42.33^o, 12 athletes (54.5%) had PT (node 10). Interestingly, ankle dorsiflexion under 38.83^o indicated absence of PT (n=43; 79.6%; node 9).

Insert figure 4 about here

The CART model predicted correctly 43 of the 59 athletes with PT (72.9% sensitivity) and 94 of the 133 athletes without PT (70.7% specificity). The total prediction of the model was 71.4% and the area under the ROC curve was 0.77 (95% confidence interval: 0.70 - 0.84; standard error 0.03; $p<0.0001$) revealing that the classification of the athletes into positive or negative PT using this model was not by chance. For each terminal node, OR and PR were calculated to indicate the strength of the association (prediction). Table 3 shows that node 6, 8, 10 and 11 revealed statistical significance.

Table 3: OR and PR of each terminal node of the CART model

Node	OR	PR
Node 3	0.57 (0.15-1.73)	0.66 (0.26-1.62)
Node 6	0.05 (0.00-0.32)*	0.08 (0.01-0.62)*
Node 8	7.30 (2.28-27.64)*	2.70 (1.83 - 3.99)*
Node 9	0.48 (0.21-1.00)	0.58 (0.32-1.04)
Node 10	3.11 (1.24-7.93)*	1.97 (1.25-3.10)*
Node 11	2.20 (1.09-4.43)*	1.67 (1.09-2.55)*
Node 12	-	-

* indicates statistical significance

DISCUSSION

The results revealed that hip LR torque, SFA, ankle dorsiflexion ROM and passive hip MR ROM classified accurately 72.9% of athletes with PT and 70.7% of athletes without PT. CART model did not indicate an isolate factor able to predict PT occurrence, instead, interactions were revealed and associated to athletes with and without PT. Hip LR torque under 0.31 Nm/kg, SFA above 16.67^o and passive hip MR ROM above 0.62^o/kg was strongly associated to PT occurrence. On the other hand, the profile most associated to non-PT occurrence was hip LR torque above 0.31 Nm/kg and ankle dorsiflexion ROM above 42.33^o. Therefore, the results presented by CART revealed that hip and foot factors can contribute to patellar tendinopathy occurrence.

The first variable selected by CART was hip LR torque with a cut-off point of 0.31Nm/kg (close to the sample mean = 0.33 Nm/kg). Proper strength of these muscles may contribute to energy absorption during landing and control the excessive medial rotation of the femur[38]. Willy & Davis[36] improved single-leg squat mechanics by means of hip strengthening (lateral rotators and abductors), decreasing femur medial rotation, hip adduction and contralateral pelvic drop in healthy females. Moreover, Khayambashi et al[39] reported that hip lateral rotators and abductors strengthening decreased pain (visual analogue scale) and improved function (Western Ontario McMaster Universities Osteoarthritis Index - WOMAC) in patellofemoral pain (maintained 6 months postintervention). Similarly, an adequate hip LR torque that maintains a proper femur alignment probably minimize patellar tendon overload in jumping activities and, consequently, diminished pain and dysfunction. Hip LR torque by itself did not explain PT occurrence, then CART selected another variable. The majority of the athletes with hip LR torque under 0.31 Nm/kg and SFA under 16.67^{o} did not have PT (node 3). Even with a tendency of hip LR weakness, if the athletes did not have misalignment of the foot complex (which generally enhance the demand on the lower limbs, because of the imposed medial rotation), the patellar tendon pathology may not occur[13, 40].

The majority of athletes with hip LR torque under 0.31 Nm/kg, SFA above 16.67^{o} and passive hip MR ROM above 0.62^{o}/kg had PT (n=11, 73.3%, node 8). PR indicated that athletes with this profile have 2.7 times more chance to have PT. Moreover, this profile (hip LR weakness, high SFA and high passive hip MR ROM) was highly associated with PT (OR=7.3). High varus SFA leads to tibial medial rotation and patellar tendon traction[13, 41]. This mechanism of patellar tendon traction could be enhanced if hip lateral rotators strength and stiffness were unable to control femur medial rotation during landing[36]. The patellar misalignment (medialization of the superior pole of the patella and lateral rotation in the frontal plane) promoted by femur medial rotation during landing could result in distinct forces on medial and lateral portions of the patellar tendon and induces pathologic processes[41, 42]. Therefore, lower limb medial rotation allowed by hip factors and high varus foot alignment in conjunction could overload the patellar tendon during landing.

The distribution of athletes in node 11 seems to be balanced between the presence and absence of PT. However, PR values indicated that this profile (hip LR weakness, high SFA and a tendency to low passive hip MR ROM) is associated with PT occurrence, with about 1.67 times more chance to have this pathology. Probably, passive hip stiffness needs to be in an intermediate range to enhance energy absorption, minimize the chance of patellar tendon overload and, consequently, of PT occurrence[25]. According to this perspective, all athletes in node 12 (hip LR torque under 0.31 Nm/kg, SFA above 16.67^o and passive hip MR ROM between 0.58^o/kg and 0,62^o/kg.) were identified without PT (n=6). Intermediate passive hip MR ROM could contribute to an adequate knee joint alignment during landing which probably is a more efficient movement pattern to energy absorption[34]. For example, a high passive hip MR ROM would change the knee movement pattern and probably lead to patellar tendon overload [39, 20]. Otherwise, an athlete with a low passive hip MR ROM would decrease the capability of energy absorption in the hip joint and maybe enhance the necessity of energy dissipation on the knee joint and probably overloaded the patellar tendon[6]. However, the analysis about the intermediate passive hip MR ROM is limited, because it was not possible to calculate OR and PR values in node 12 (because no athlete in this node had PT). These results reveal a non-linear relationship between passive hip MR ROM and PT occurrence, because high or low values of this variable were identified in athletes with PT.

The majority of the athletes with hip LR torque above 0.31 Nm/kg and unrestricted ankle dorsiflexion ROM (above 42.33^o) did not have PT (node 6). PR values showed that this profile is highly associated to non-PT occurrence, about 12.5 times more chance to non-injury. Ankle dorsiflexion restriction has been indicated in the literature as risk factor for PT and the cut-off point selected by CART was similar to the one already reported[14, 43]. Backman & Danielson[14] indicated a cutoff point for ankle dorsiflexion range of 36^o for basketball athletes (higher-risk of 18.5% for the dominant leg and 29.4% for the non-dominant leg) and Malliaras et al[43] indicated a cut-off point of 45^o for volleyball athletes (relative risk =1.8 - 2.8). This result of the present study revealed an important profile to non-PT occurrence.

The CART revealed that athletes with ankle dorsiflexion ROM between 38.83° and 42.33° (node 10) had PT in a greater proportion compared to non-PT. Despite this apparently small difference of athletes distribution in node 10, OR and PR values showed a significant association to PT occurrence. Athletes with hip LR torque above 0.31 Nm/kg and ankle dorsiflexion between 38.83° and 42.33° had 2 times more chance to have PT. This result indicated that, despite hip LR strength, ankle dorsiflexion restriction could contribute to patellar tendon overload[14, 43]. Interestingly, CART indicated that athletes with more restricted ankle dorsiflexion (under 38.83°, node 9) did not have PT (without statistical significance revealed in OR and PR derivation). Eleven of the 59 athletes with PT (18.64%) and 43 of the 133 athletes without PT (32.33%) were classified in node 9. Most of the athletes in node 9 were male (47 males and 7 females) from a specific sport club (n=36) and practiced volleyball (39 volleyball and 15 basketball). Probably, other factors not investigated in the present study (as training characteristics/routine, coach experience[44] and jumping load control[1] may contribute to non-injury in these 43 athletes.

The results of the present study should be interpreted with caution, because a causal relationship cannot be established by the methods used (cross-sectional study). Prospective investigations need to be conducted to determine if interventions on the variables identified as associated with PT are effective. However, hip and foot variables explored in the present study added information about patellar tendinopathy associated factors and permitted the development of an accurate classification model. Moreover, the cut-off points defined by CART model could be used to guide clinicians to plan treatment and/or prevention programs for athletes with PT or at risk of developing this injury.

CONCLUSION

Hip and foot factors contribute to patellar tendinopathy (jumper's knee) occurrence in volleyball and basketball athletes. CART developed an accurate model for PT occurrence that revealed interactions between hip LR torque, SFA, ankle dorsiflexion and passive hip MR ROM. The results of this study showed that an isolate factor wasn't able to predict PT occurrence and that interaction between hip and foot factors need to be considered in further PT etiology investigation.

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FIGURES

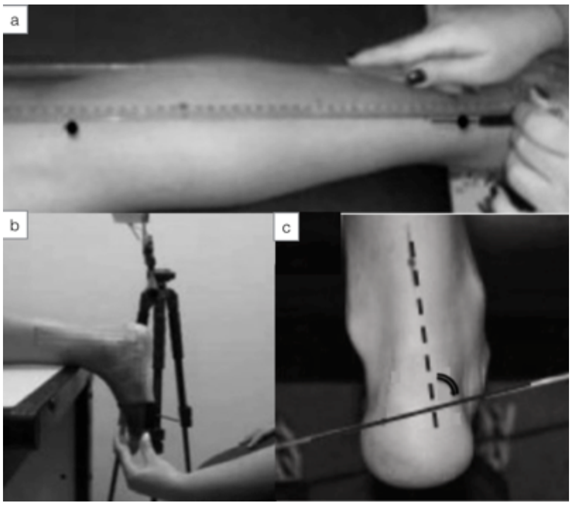


Figure 1: Procedures to SFA: shank bisection (a), neutral dorsiflexion position for photographic record (b), quantification of SFA angle (c).

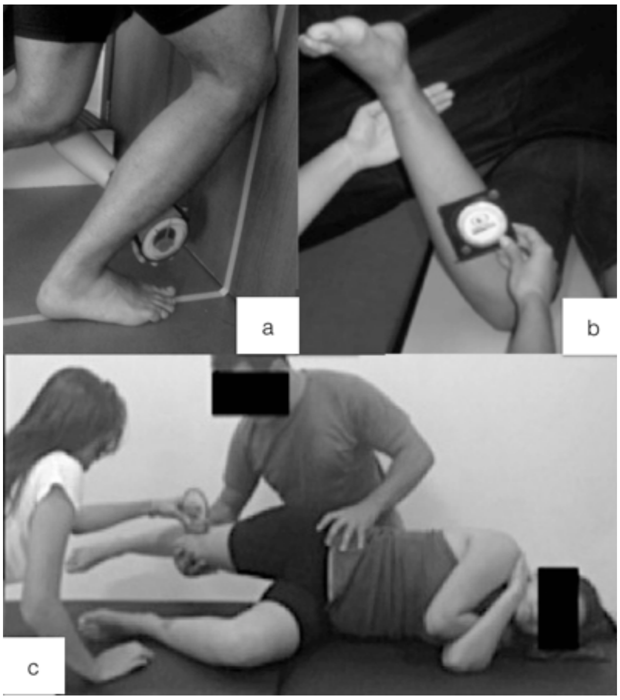


Figure 2: Participant's position and procedures to assess the ankle dorsiflexion ROM (a), passive hip MR ROM (b) and iliotibial band flexibility (c).

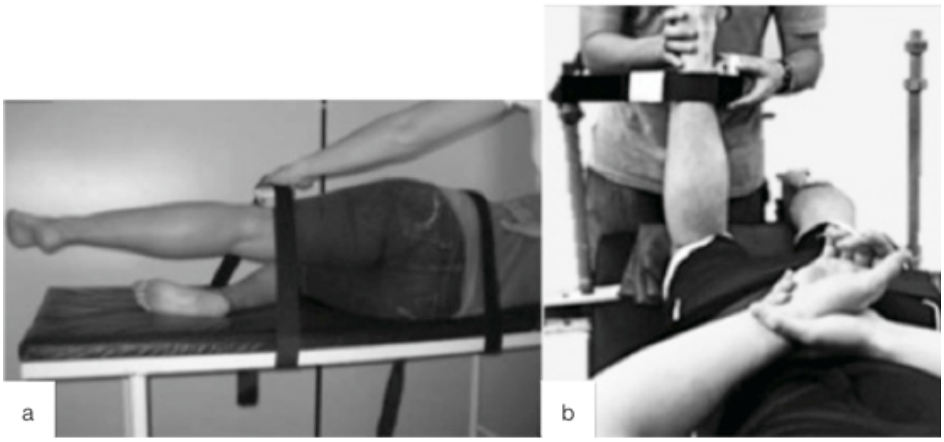
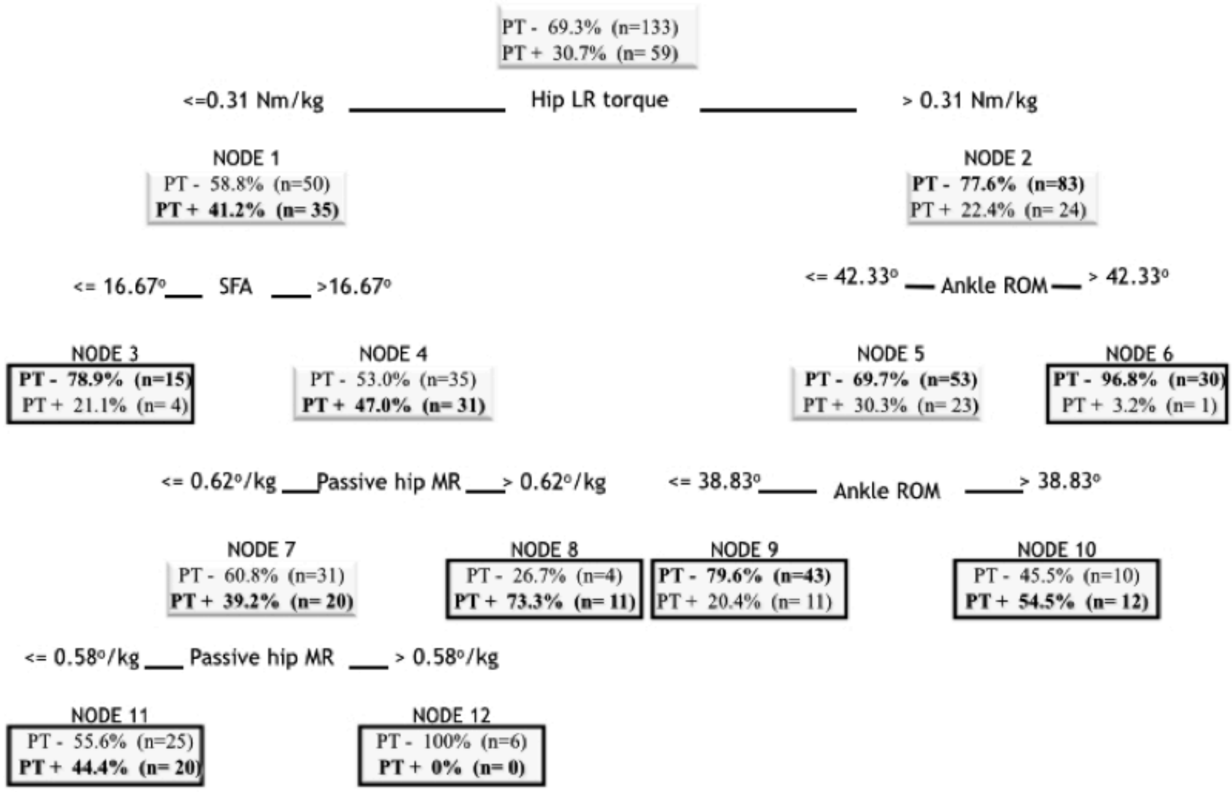


Figure 3: Position and procedures to hip abductors (a) and hip LR (b) isometric strength assessment

Figure 4: Classification tree model for Patellar Tendinopathy.



The bold category in each node corresponds to the predicted one. Classification rules for PT presence: node 8 is hip LR torque under 0.31 Nm/kg, SFA above 16.67^{o} and passive hip MR ROM above 0.62^{o}/kg; node 10 is hip LR torque above 0.31 Nm/kg and ankle dorsiflexion ROM between 0.38^{o} and 42.33^{o}; node 11 is hip LR torque under 0.31 Nm/kg, SFA above 16.67^{o} and passive hip MR ROM under 0.58^{o}/kg. Classification rules for PT absence: node 3 is hip LR torque under 0.31 Nm/kg and SFA under 16.67^{o}; node 6 is hip LR torque above 0.31 Nm/kg and ankle dorsiflexion ROM above 42.33^{o}; node 9 is hip LR torque above 0.31 Nm/kg and ankle dorsiflexion ROM under 38.83^{o}; node 12 is hip LR torque under 0.31 Nm/kg, SFA above 16.67^{o} and passive hip MR ROM between 0.58^{o}/kg and 0,62^{o}/kg. Abbreviations: PT (Patellar Tendinopathy), LR (lateral rotators), ROM (range of motion), SFA (shank-forefoot alignment), MR (medial rotation).

4 CONSIDERAÇÕES FINAIS

A presente tese buscou identificar fatores relacionados aos segmentos locais e não locais associados a sobrecarga no tendão patelar em atletas. Foram considerados dois desfechos relacionados a sobrecarga no tendão patelar para identificar fatores associados 1) a um estágio pré-lesão (no caso da presença de anormalidades morfológicas do tendão patelar diagnosticadas por meio da ultrassonografia) e 2) a um estágio no qual a lesão está instalada (no caso de presença de dor no tendão patelar e disfunção clinicamente identificadas). Fatores relacionados à articulação do quadril e ao complexo do pé são comumente pouco explorados em atletas com tendinopatia patelar e foram explorados, uma vez que eles podem contribuir no mecanismo de lesão.

O Estudo 1 buscou investigar a associação entre alinhamento anatômico, amplitude de movimento articular/flexibilidade e força muscular dos membros inferiores com a presença de alterações morfológicas no tendão patelar em atletas de basquetebol de voleibol. Os resultados da área abaixo da curva ROC revelaram que varismo excessivo do alinhamento perna-antepé, flexibilidade da banda iliotibial e rotação medial da patela no plano frontal (ângulo de Arno) são associados a presença de alterações morfológicas no tendão patelar. Interessantemente, um fator local, um distal e outro proximal foram identificados revelando a contribuição de diferentes segmentos da cadeia cinética na sobrecarga do tendão patelar. Entretanto, o *odds ratio* e a razão de prevalência não indicaram significância estatística para a variável rotação medial da patela no plano frontal. Esse resultado pode estar relacionado a forma de mensuração do ângulo de rotação patelar. Possivelmente, os valores encontrados no Estudo 1 referente ao ângulo de Arno podem não estar se aproximando da magnitude da postura patelar nas situações de imposição de demanda no tendão patelar como na aterrissagem do salto vertical. Dessa forma, esse fato pode ter interferido na força de associação entre o ângulo de Arno e o desfecho. Atletas com a flexibilidade da banda íliotibial abaixo de -0.02^{o}/kg tiveram 5.2 vezes mais chance de apresentarem anormalidades no tendão patelar e atletas com varismo perna-antepé acima de 24^{o} tiveram 4.4 vezes mais chance de apresentarem anormalidades no tendão patelar. Nesse sentido, recomendamos que as variáveis flexibilidade da banda íliotibial, alinhamento perna-antepé e ângulo de Arno sejam considerados em estudos prospectivos que visam a identificação de fatores relacionados ao desenvolvimento de anormalidades morfológicas no tendão patelar.

O estudo 2 foi realizado com o objetivo de determinar a acurácia diagnóstica de um teste clínico desenvolvido para identificar atletas com alterações morfológicas no tendão patelar. Este passo foi necessário para minimizar a chance de indivíduos assintomáticos, mas com anormalidades no tendão patelar, serem alocados no grupo sem tendinopatia no terceiro estudo da presente tese. O resultados demonstraram que a combinação dos testes (questionário VISA-P ou agachamento no plano inclinado descendente ou história de dor no tendão patelar) denominado *Patellar Tendon Clinical Test (PTCT)* obteve a maior especificidade (81.5%) em relação a sensibilidade (75%), ou seja, o teste foi melhor para identificar os verdadeiros negativos (ausência de anormalidade no tendão patelar) no exame de ultrassonografia. Quando analisados atletas acima de 25 anos, os valores de especificidade (83%) e de sensibilidade (90%) indicaram que o PTCT é mais acurado na identificação de atletas com anormalidades no tendão patelar. Dessa forma, atletas com mais de 25 anos que tem resultados positivos no PTCT devem ser direcionados ao protocolo de intervenção voltado para a recuperação do tendão (treino excêntrico).

No estudo 3 o objetivo foi identificar a contribuição de fatores relacionados às articulações do quadril e do pé para a ocorrência de tendinopatia patelar (*jumper's knee*) em atletas de voleibol e basquetebol. A identificação daqueles com tendinopatia ocorreu quando os atletas tinham dor e sensibilidade no tendão patelar e uma pontuação menor que 80 no questionário VISA-P. Os atletas sem tendinopatia foram identificados por meio da combinação de testes (PTCT) avaliada no estudo 2. A CART desenvolveu um modelo acurado para a ocorrência de TP e revelou que um fator isolado não foi capaz de predizer a lesão. Quatro das seis variáveis investigadas foram selecionadas pela CART. As variáveis torque isométrico de rotadores laterais do quadril, ADM de dorsiflexão, alinhamento perna-antepé e ADM passiva de rotação medial do quadril interagiram para classificar atletas com e sem TP. Nesse sentido, interações entre fatores relacionados à articulação do quadril e ao complexo do pé devem ser considerados em investigações futuras sobre a etiologia da TP.

Os resultados da presente tese revelaram a participação de fatores não-locais nos dois desfechos analisados relacionados a sobrecarga do tendão patelar. No estudo 1 foram encontradas associações fortes da flexibilidade da banda íliotibial e do alinhamento perna-antepé com anormalidades morfológicas do tendão patelar. Interessantemente, o torque dos músculos rotadores laterais do quadril não foi associado a presença de anormalidades morfológicas do tendão patelar. Esse dado pode indicar que os dois desfechos analisados na presente tese podem apresentar diferentes mecanismos de ocorrência. Ressalta-se o caráter clínicos dos testes utilizados na investigação dos fatores elegidos que podem ser facilmente reproduzidos na prática do fisioterapeuta. Além disso, os resultados dos estudos 2 indicam não somente a acurácia do teste de agachamento no plano inclinado descendente e do questionário VISA-P aplicados frequentemente no contexto clínico em indivíduos com tendinopatia patelar, mas que a combinação de testes clínicos para a identificação da TP deve ser utilizada, ao contrário do que comumente é praticado. Algumas das interações entre o torque isométrico de rotadores laterais do quadril, ADM de dorsiflexão, alinhamento perna-antepé e ADM passiva de rotação medial do quadril reveladas no estudo 3 foram fortemente associadas a ocorrência da TP. Interessantemente, a flexibilidade da BIT não participou das interações reveladas pela CART. Isso reforça a hipótese de diferentes mecanismos para a ocorrência de tendinopatia patelar (*jumper's knee*) e de anormalidades morfológicas no tendão patelar. Dessa forma, a avaliação e intervenção dos fatores associados a ambos desfechos investigados, que são indicativos da sobrecarga do tendão patelar, deveria fazer parte da rotina dos fisioterapeutas que lidam com atletas de voleibol e basquetebol.

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Anexo I – Aprovação do Comitê de Ética e Pesquisa (COEP) -UFMG

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Parecer nº. ETIC 0493.0.203.000-09

Interessado(a): Prof. Sérgio Teixeira da Fonseca
Departamento de Fisioterapia
EEFFTO – UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 19 de novembro de 2009, após atendidas as solicitações de diligência, o projeto de pesquisa intitulado **"Avaliação dos fatores de risco para lesões músculo-esqueléticas em atletas"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

Av. Pres. Antonio Carlos, 6627 – Unidade Administrativa II - 2º andar – Sala 2005 – Cep 31270-901 – BH-MG
Telefax (031) 3409-4592 - email: coep@prpq.ufmg.br

Anexo II – Aprovação do adendo ao Projeto de Doutorado

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Projeto: CAAE - 0493.0.203.000-09

Interessado(a): Prof. Sérgio Teixeira da Fonseca
Departamento de Fisioterapia
EEFFTO – UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP analisou e aprovou, no dia 29 de fevereiro de 2012, as alterações, abaixo relacionadas, referentes ao projeto de pesquisa intitulado **"Avaliação dos fatores de risco para lesões músculo-esqueléticas em atletas".**

A inclusão de dois novos testes e de questionários padronizados:

1. Avaliação das propriedades mecânicas do tendão patelar;
2. Avaliação da amplitude de movimento da articulação do tornozelo;
3. Aplicação de questionários padronizados com fim de coletar o perfil funcional e psicológico do atleta de forma sistematizada.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

Av. Pres. Antonio Carlos, 6627 – Unidade Administrativa II - 2º andar – Sala 2005 – Cep:31270-901 – BH-MG
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Anexo III - TCLE

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO I

(Terminologia obrigatório em atendimento a resolução 196/96 - CNS-MS)

Pesquisador Responsável: *Prof. Dr. Sérgio Teixeira da Fonseca*

Você está sendo convidado a participar do projeto de pesquisa intitulado "**AVALIAÇÃO DOS FATORES DE RISCO PARA LESÕES MÚSCULO-ESQUELÉTICAS EM ATLETAS"**, do (a) aluno (a) Luciana De Michelis Mendonça, para a tese de Doutorado do programa de pós- graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional (EEFFTO) da Universidade Federal de Minas Gerais (UFMG), sob orientação do *Prof. Dr. Sérgio Teixeira da Fonseca*. **É necessário que você leia atentamente este termo antes de autorizar sua participação nesse estudo.**

O objetivo da pesquisa é determinar os fatores de risco para lesões musculares e ligamentares no esporte. Caso concorde em participar da pesquisa, a coleta dos dados será realizada no Minas Tênis Clube ou no LAPREV/UFMG. Você será medido(a), pesado(a) e responderá a questionários sobre seu perfil psicológico, funcional e de lesões. Em seguida, realizará alguns ou todos os testes descritos abaixo, de acordo com o esporte que você pratica, sua idade e características individuais, com cinco minutos de intervalo entre cada teste e uma pausa com lanche por 30 minutos na metade dos testes.

Teste do agachamento e salto vertical: serão fixados no seu corpo 16 marcadores reflexivos, utilizando micropore. Após a marcação você irá realizar cinco agachamentos com cada perna. Após 5 minutos você realizará cinco saltos consecutivos. Esses movimentos serão filmados para análise posterior com um software. Devido ao posicionamento da câmera seu rosto não será filmado, permitindo a identificação apenas por número.

Teste da força dos músculos do quadril: deitado de barriga para baixo sobre uma maca, você irá fazer força no sentido de rodar externamente seu quadril por 5 segundos com intervalo de 15 segundos entre três contrações ou até sentir desconforto e quiser interromper o teste. Após cinco minutos, você deitará de lado e fará força no sentido de elevar a perna com o mesmo protocolo do teste anterior

Avaliação do alinhamento do pé: deitado de barriga para baixo sobre uma maca, com os pés posicionados para fora dela, você irá sustentar seu tornozelo até 90º de flexão para o pesquisador fazer três fotografias do alinhamento do seu pé. O procedimento será repetido com o outro pé. As fotos serão analisada posteriormente com o software Simi Motion.

Avaliação da amplitude do tornozelo: Você ficará de frente a uma parede e será solicitado a encostar seu joelho na parede sem retirar o calcanhar do chão. Esse procedimento será feito com uma perna de cada vez por 3 vezes.

Flexibilidade dos músculos do quadril: você será posicionado de barriga para baixo com o joelho dobrado e irá relaxar a perna para o examinador medir com um dispositivo o ângulo de rotação da perna. Em seguida, você deitará de lado e um examinador irá elevar sua perna e levá-la posteriormente para depois acomodá-la. Esses testes serão realizados em uma perna de cada vez por 3 vezes.

Avaliação muscular isocinética: Você será posicionado em um aparelho (dinamômetro isocinético) para medir variáveis relacionadas ao desempenho muscular, como pico de torque, trabalho, potência e índice de fadiga. Os grupos musculares a serem avaliados serão os extensores e flexores do joelho.

Ponte com extensão unilateral do joelho: Você deitará sobre uma maca, com ambos os pés apoiados, e deverá levantar o quadril e esticar uma perna, sustentando a posição por 10 segundos ou até sentir desconforto. Em seguida, realizará o mesmo procedimento com a outra perna. O procedimento deverá ser realizado 3 vezes para cada perna.

Os riscos são mínimos. Você pode apenas sentir cansaço nas pernas ou no ombro durante o teste de força muscular e do agachamento. Não serão utilizados materiais perfuro-cortantes como seringas ou agulhas.

Os resultados desse estudo poderão contribuir na identificação dos fatores de risco para lesões no esporte possibilitando ações preventivas para reduzir o número e a severidade das lesões .

Sua participação é voluntária e não lhe trará nenhum gasto financeiro, nem lhe será paga nenhuma remuneração. Você poderá interromper a sua participação a qualquer momento, durante a coleta de dados, sem qualquer penalização ou prejuízo.

Sua identidade não será revelada em momento algum. Somente os pesquisadores e o orientador envolvidos terão acesso a seus dados, que serão apenas para fins de pesquisa.

Declaro que li e entendi as informações contidas acima e que todas as dúvidas foram esclarecidas. Este formulário está sendo assinado voluntariamente por mim, indicando meu consentimento em participar do estudo.

Belo Horizonte, _______de _________________de 20____.

____

____

Assinatura do voluntário Assinatura do pesquisador

Pesquisadores responsáveis:

Natalia F.N.Bittencourt Tel: 87882630 natalia@minastc.com.br

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Comitê de Ética em Pesquisa

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