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RICARDO BERNARDI SODER

RESSONÂNCIA MAGNÉTICA DE JOELHO EM ADOLESCENTES JOGADORES DE FUTEBOL ASSINTOMÁTICOS: UM ESTUDO CONTROLADO

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Tese de Doutorado apresentada ao curso de Pós-graduação em Medicina /Pediatria e Saúde da Criança da Pontifícia Universidade Católica do Rio Grande do Sul, como parte dos requisitos necessários à obtenção do título de Doutor em Medicina, área de concentração: Pediatria.

Orientador: Prof. Dr. Matteo Baldisserotto

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Dedico este trabalho aos meus pais, Plínio e Lorita, que sempre me apoiaram e permitiram que eu chegasse até aqui.

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ARTIGO ORIGINAL 1 – PUBLICADO NA AMERICAN JOURNAL OF ROENTGENOLOGY (AJR 2011; 196:W61–W65)

Ressonância Magnética de joelho em adolescentes jogadores de futebol assintomáticos: um estudo controlado

RESUMO

OBJETIVO: O joelho é a articulação mais frequentemente lesada durante a prática de futebol por jovens atletas com idade entre 12 e 15 anos. A ressonância magnética (RM), por sua vez, é um método de imagem bastante acurado no diagnóstico de lesões relacionadas ao esporte. O objetivo deste estudo transversal de casos e controles foi avaliar os joelhos de jogadores de futebol adolescentes assintomáticos utilizando uma ressonância magnética de campo aberto.

MÉTODOS: Foram avaliados 56 joelhos de 28 adolescentes assintomáticos do sexo masculino com idade entre 14 e 15 anos. Os participantes foram divididos em dois grupos pareados por idade e peso: jogadores de futebol (28 joelhos) e controles (28 joelhos). Todos os exames foram realizados em uma RM de campo aberto com 0.35 tesla e avaliados por dois radiologistas experientes, cegados para os 2 grupos em estudo. As seguintes anormalidades forma acessadas: derrame articular; edema ósseo medular; e anormalidades meniscais, ligamentares, tendíneas e cartilaginosas.

RESULTADOS: No grupo de jogadores de futebol, 18 joelhos (64,2%) tinham uma ou mais alterações à RM, sendo que, no grupo controle, apenas nove joelhos (32,1%) tiveram uma ou mais anormalidade (p = 0,003). A prevalência de edema ósseo medular foi maior no grupo de jogadores de futebol (14 joelhos, 50%), sendo detectada em apenas um joelho (3,5%) do grupo controle (p = 0,0001). Outras alterações de imagem sem diferença estatística significativa foram encontradas nos dois grupos: edema coxim adiposo infrapatelar, cistos poplíteos e cistos gangliônicos.

CONCLUSÃO: Edema ósseo medular é uma anormalidade prevalente encontrada na RM de joelho de jovens atletas jogadores de futebol. Os achados de RM devem ser interpretados com cautela e com estreita correlação clínica.

PALAVRAS-CHAVE: Edema, Estudos de Casos e Controles, Adolescente, Traumatismos do Joelho, Imagem por Ressonância Magnética, Futebol, Medicina Esportiva.

MRI of the Knee Joint in Asymptomatic Adolescent Soccer Players: A Controlled Study

ABSTRACT

OBJECTIVE: The knee is the joint that is most frequently injured in boys 12–15 years old who practice soccer, and magnetic resonance imaging (MRI) is an accurate method of diagnosing sports-related injuries. The objective of this cross-sectional case-control study was to evaluate the knees of asymptomatic adolescent soccer players using open MRI.

METHODS: We evaluated 56 knees of 28 asymptomatic male adolescents 14–15 years old. Participants were divided into two groups and paired by age and weight: soccer players (28 knees) and control subjects (28 knees). All the examinations were performed using a 0.35-T open-field MRI unit and were evaluated by two experienced radiologists blinded to study groups. The following abnormalities were evaluated: joint effusion; bone marrow edema; and meniscus, ligament, tendon and cartilage abnormalities.

RESULTS: In the group of soccer players, 18 knees (64.2%) had one or more MRI abnormalities, whereas in the control group nine knees (32.1%) had at least one MRI abnormality ($p = 0.003$). The prevalence of bone marrow edema was much greater in the group of soccer players (14 knees, 50%), whereas the same abnormality was found in only one knee (3.5%) in the control group ($p = 0.0001$). Other abnormalities that were not statistically significant with regard to study group were also found in the two groups: infrapatellar fat pad edema, popliteal cysts, and ganglion cysts.

CONCLUSION: Bone marrow edema is a prevalent abnormal finding on MRI scans of knees of asymptomatic adolescent soccer players. MRI findings should be interpreted cautiously and in close correlation with clinical findings.

KEYWORDS: Edema, Case-Control Studies, Adolescents, Knee Injuries, Magnetic Resonance Imaging, Soccer, Sports Medicine

ARTIGO ORIGINAL 2 – PUBLICADO NA BRITISH JOURNAL OF SPORTS MEDICINE, 2011

Ressonância Magnética de joelho em adolescentes nadadores de elite assintomáticos: um estudo controlado

RESUMO

OBJETIVO: A natação é uma atividade esportiva amplamente difundida, sendo considerada uma forma ideal de exercício, com pouco ou nenhum impacto sobre os joelhos. No entanto, lesões por microtrauma repetitivo ou uso excessivo podem frequentemente afetar a articulação do joelho de jovens atletas nadadores de nível competitivo. As lesões iniciais geralmente são assintomáticos por um período de tempo considerável antes de causarem desconforto ou dor articular. O objetivo do presente estudo foi avaliar por ressonância magnética (RM) os joelhos de jovens atletas assintomáticos nadadores de elite e compará-los com um grupo controle pareado por idade e peso, que não pratica nenhum esporte de impacto regularmente.

MÉTODOS: Realizamos um estudo transversal controlado para avaliar 54 joelhos de 27 adolescentes assintomáticos com 14 a 15 anos de idade, pareados por idade e peso. Os participantes foram divididos em dois grupos: 13 atletas nadadores de elite e 14 controles. Todos os exames foram realizados em uma RM de campo aberto com 0.35 tesla e avaliados por dois radiologistas experientes, cegados para os 2 grupos em estudo. As seguintes anormalidades forma acessadas: derrame articular; edema ósseo medular; e anormalidades meniscais, ligamentares, tendíneas e cartilaginosas.

RESULTADOS: Um ou mais achados de imagem anormais foram detectados em 18 joelhos do grupo de nadadores (69,2%, p = 0,013). Os achados mais prevalentes nos atletas de natação foram edema do coxim gorduroso infrapatelar (53,8%, p = 0,049), seguido de edema da medula óssea (26,9%, p = 0,022), edema da gordura pre-femoral (19%, p = 0,022) e derrame articular (15,3%, p = 0,047).

CONCLUSÃO: A prevalência de anormalidades de imagem detectadas pela RM foi significativamente maior nos joelhos dos adolescentes nadadores de elite. Esta alta prevalência de achados de imagem positivos em nadadores de elite assintomáticos pode corresponder a alterações benignas ou lesões pré-clínicas, que devem ser melhor avaliadas em um estudo longitudinal de seguimento.

PALAVRAS-CHAVE: Edema, Estudos de Casos e Controles, Adolescente, Traumatismos do Joelho, Imagem por Ressonância Magnética, Natação, Medicina Esportiva.

Magnetic Resonance Imaging of the knee in asymptomatic adolescent swimmers: a controlled study.

ABSTRACT

OBJECTIVE: Swimming is a widespread sporting activity generally regarded as an ideal form of exercise, which has little or no impact on the knees. However, overuse or repetitive microtrauma injuries may often affect the knee joint of young competitive swimmers. These early lesions are frequently asymptomatic for a considerable period of time before causing discomfort or joint pain. The aim of the present study is to use MRI to evaluate the knee joints of asymptomatic young elite swimmers, comparing them to age and sex-matched controls that do not practice any impact sports regularly.

METHODS: We perform a cross-sectional controlled study to evaluate 54 knees of twenty-seven asymptomatic male adolescents aged 14 to 15 years, paired by age and weight. Participants were divided in two groups: 13 elite swimmers and 14 control adolescents. We performed all the exams using a 0.35-Tesla open-field MRI unit and evaluated by 2 experienced radiologists blinded to study groups. The following abnormalities were evaluated: joint effusion; bone marrow edema; and meniscus, ligament, tendon and cartilage abnormalities.

RESULTS: One or more imaging abnormalities were detected in 18 knees in the group of swimmers (69.2%; p=0.013). The most prevalent findings in the athletes were infrapatellar fat pad edema (53.8%; p=0.049), followed by bone marrow edema (26.9%; p=0.022), edema of prefemoral fat pad (19%; p=0.022) and joint effusion (15.3%; p=0.047).

CONCLUSION: Significantly more MRI abnormalities were found in the knee joints of asymptomatic adolescent elite swimmers. This high prevalence of positive imaging findings in swimmers may correspond to benign changes or pre-clinical lesions, which should be evaluated in a follow-up study.

KEYWORDS: Edema, Case-Control Studies, Adolescents, Knee Injuries, Magnetic Resonance Imaging, Swimming, Sports Medicine

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CAPÍTULO I

1 REFERENCIAL TEÓRICO

1.1 INTRODUÇÃO

Durante as últimas décadas, a prática de esporte e de atividades físicas tem se tornado extremamente popular. A crescente participação de crianças e adolescentes em esportes competitivos tem acarretado uma alta incidência de lesões osteoarticulares em um esqueleto ainda imaturo e não preparado para suportar treinamentos rigorosos de um atleta de elite. Esta sobrecarga estrutural aliada a pouca habilidade e baixo nível técnico iniciais tem um impacto significativo sobre o sistema locomotor, sendo o joelho e o tornozelo as articulações mais acometidas.[1,2] Nos jovens atletas de elite, independentemente da modalidade esportiva, existem dois tipos ou mecanismos principais de lesão: a lesão traumática aguda e a lesão por uso crônico excessivo do sistema musculoesquelético ainda imaturo, denominada lesão por *overuse*.[3-6] Lesões traumáticas agudas são por definição resultado de um evento agudo identificável, causado por uma força desproporcional que, na maioria das vezes, produz sintomas imediatamente. Em contraste, lesões por *overuse* são causadas por traumas de repetição sem um evento agudo

identificável, que excedem a capacidade de recuperação do esqueleto, sendo pouco associadas a sintomas.[7, 8]

O presente estudo, por incluir apenas atletas de futebol assintomáticos com 14 e 15 anos de idade, tem por objetivo estudar preferencialmente lesões por *overuse*, visto que a grande maioria das lesões traumáticas agudas produz sintomatologia articular imediata, no momento do trauma. Portanto, o enfoque do presente trabalho é ampliar o conhecimento sobre as lesões osteoarticulares assintomáticas, relacionadas ao uso crônico excessivo do joelho por atletas de futebol oriundos de um clube profissional de Porto Alegre.

1.2 FISIOLOGIA DO FUTEBOL DE ALTO NÍVEL

O desempenho do atleta que pratica futebol de alto nível é influenciado por diversos fatores, tais como biomecânica do movimento, técnica, tática, desenvolvimento mental e físico. Esforços para melhorar o desempenho do jogador de futebol durante treinamentos são concentrados principalmente na técnica e na tática, porém são diretamente dependentes do preparo e da resistência física do atleta. Durante uma partida de futebol, o atleta percorre cerca de 10 a 12 quilômetros, intercalando atividades aeróbicas e anaeróbicas com períodos de repouso e de extrema atividade física, onde utiliza 80 a 90% de sua capacidade aeróbica máxima a cada 90 segundos aproximadamente.[9, 10]

Durante 90 minutos, o jogador necessita correr, saltar, chutar, combater o adversário, mudar de direção abruptamente, acelerar, desacelerar, sustentar contrações para manter seu equilíbrio e controlar a bola para superar seu oponente. Para atingir este alto desempenho, o atleta é submetido a treinamentos rigorosos e complexos, que visam aumentar a capacidade aeróbica, aperfeiçoar fundamentos básicos do futebol, melhorar a habilidade e simular situações reais de jogo.

O emprego de métodos de treinamento corretos e balanceados, adaptados à capacidade física, estrutural e mental de cada atleta, é de extrema importância para alcançar alto desempenho e, consequentemente, progredir técnica e taticamente. Atletas de futebol bem preparados do ponto de vista técnico, físico e mental são menos propensos a desenvolverem lesões musculoesqueléticas, visto que suportam melhor a sobrecarga de exercícios e conseguem evitar lesões.[8] Outro fator essencial na prevenção de lesões é saber contrabalançar a quantidade e a intensidade dos treinamentos com o tempo de recuperação entre as atividades físicas ou partidas de futebol, objetivando evitar lesões por *overuse*, muito comuns em jogadores de futebol jovens e imaturos do ponto de vista musculoesquelético.[11]

1.3 LESÕES DE JOELHO NO FUTEBOL COMPETITIVO

De maneira geral, considerando os esportes competitivos de alto impacto articular, existe uma proporção de duas lesões traumáticas agudas para cada lesão por *overuse*.[12] Estudos avaliando apenas jogadores de futebol de elite com idade inferior a 18 anos têm demonstrado uma incidência ainda maior de lesões traumáticas agudas comparativamente às lesões por *overuse.* Baxter-Jones et al, avaliando prospectivamente jogadores de futebol de elite com idade inferior a 16 anos, encontrou lesões traumáticas agudas em cerca de 80% dos atletas, sendo o joelho o local mais acometido. Em contraste, lesões por *overuse* foram descritas em apenas 20% dos jogadores de futebol deste estudo, sendo, porém, de maior severidade quando comparadas às lesões traumáticas agudas.[13] Recentemente, Brink et AL, em estudo longitudinal semelhante demonstrou uma menor discrepância entre lesões agudas e lesões por *overuse* (62% versus 38%, respectivamente)[8] Resultados similares foram obtidos com jogadores de elite adultos, observando-se 73% de lesões agudas versus 27% de lesões por *overuse,* sendo o joelho o terceiro local mais acometido.[14] Por fim, Ekstrand et AL, em grande estudo de coorte que avaliou 31 times da liga profissional européia de futebol, ratificou os achados prévios (69% de lesões agudas versus 31% por *overuse*, apontando o joelho como segundo local mais lesado.[15]

As lesões traumáticas agudas, bastante conhecidas no meio científico e extremamente comuns durante a prática recreativa ou competitiva de futebol

por crianças e adultos, são caracterizadas por sintomas articulares imediatos e por um fator causal bem definido. Em contrapartida, as lesões por *overuse,* muito discutidas e estudadas atualmente na literatura médica, devido ao aumento progressivo da prática de esportes competitivos, é um tipo especial de lesão que tende a ocorrer em atletas de elite, especialmente em jovens iniciantes, como é o caso dos jogadores de futebol juniores. Em geral, as lesões por *overuse* são muito comuns durante treinamentos intensos e frequentes de futebol[16] assim como em atividades esportivas que empregam movimentos de repetição, tal como na natação de alto nível. Estas lesões de instalação crônica e insidiosa resultam de um alto estresse fisiológico sobre um esqueleto ainda imaturo, incapaz de absorver e recuperar adequadamente os repetidos microtraumas que o joelho do jovem atleta de futebol é submetido.[6, 13, 17, 18] Le Gall et al, em estudo longitudinal de 10 anos avaliando adolescentes franceses, jogadores de futebol de elite, demonstrou que lesões por *overuse* têm uma certa preferência por atletas mais jovens, com idade inferior a 14 anos, visto que estes indivíduos possuem um esqueleto mais imaturo e estão mais propensos a lesões relacionadas ao crescimento ósseo.[16] O mesmo estudo ainda constatou que atletas com idade inferior a 14 anos apresentaram lesões de maior gravidade e em maior número, especialmente durante treinamentos, enquanto que, no grupo de jogadores mais velhos, as lesões de joelho foram menos graves e ocorreram mais comumente durante partidas de futebol. Segundo os autores, essa diferença pode ser explicada pelo treinamento excessivo para a idade, pela fragilidade da estrutura óssea do atleta mais

jovem, pela menor coordenação motora e menor capacidade de evitar lesões ou pela sua técnica menos apurada, predispondo conseqüentemente a um número maior número de lesões.

1.4 DIAGNÓSTICO POR IMAGEM DAS LESÕES ASSINTOMÁTICAS DE JOELHO NO ESPORTE DE ALTO IMPACTO

Os métodos de imagem utilizados por muitas décadas para a avaliação do sistema músculo-esquelético foram a radiografia convencional e a cintilografia. Mais recentemente, a ultrassonografia e a ressonância magnética foram incluídas nos protocolos diagnósticos para avaliação das lesões relacionadas ao esporte.[19] A ressonância magnética (RM) é uma modalidade diagnóstica sem radiação ionizante, com alto detalhamento anatômico, amplamente utilizada para acessar o sistema musculoesquelético e que possui alta acurácia no diagnóstico de patologias do joelho, tais como contusão óssea, derrame articular, lesão ligamentar, cartilaginosa e tendínea.[20-23] Devido a sua alta acurácia para avaliação do joelho, alguns cirurgiões ortopédicos de grandes centros têm preferido a RM como método diagnóstico pré-cirúrgico de escolha, deixando a artroscopia diagnóstica em plano secundário.[24] Além disso, a RM tem demonstrado alterar o raciocínio diagnóstico e o planejamento terapêutico nos traumas agudos de joelho, muito comuns durante a prática esportiva

recreativa ou competitiva, possibilitando uma redução no número de procedimentos artroscópicos desnecessários e um aumento na acurácia diagnóstica.[25]

O crescente avanço tecnológico na área de diagnóstico por imagem não-invasivo, em especial a RM, juntamente com o acesso facilitado da população a estas novas tecnologias, tem ocasionado um aumento significativo na frequência de achados de imagem anormais em indivíduos assintomáticos. Em atletas e indivíduos que praticam esporte regularmente, estudos têm mostrado uma alta prevalência de lesões musculoesqueléticas assintomáticas detectadas incidentalmente, cujo significado clínico e potencial evolutivo ainda são incertos.[20,26-28] Estudos semelhantes que avaliaram o joelho de atletas assintomáticos adultos, incluindo jogadores de basquetebol, ginastas e maratonistas, encontraram também uma ampla variação na prevalência de achados de imagem positivos na RM.[29-31] O conhecimento das anormalidades de imagem que podem ocorrer sem sintomatologia clínica é de extrema importância para o manejo adequado do esportista, visto que torna factível a detecção precoce de alterações articulares ainda incipientes e reversíveis.[32] Durante a avaliação por imagem de um atleta de elite assintomático, é importante ressaltar que a subvalorização de alguma lesão potencialmente deletéria ou a implementação de um tratamento ou intervenção cirúrgica desnecessária pode acarretar danos irreparáveis a sua carreira.[32] Nesse sentido, a avaliação rápida e precisa de possíveis lesões assintomáticas, detectadas incidentalmente pela RM, é de crucial importância e tem por objetivo

a prevenção, diagnóstico e tratamento precoces destas lesões osteoarticulares ainda em estágio inicial.

1.5 ACHADOS ANORMAIS NA RESSONÂNCIA MAGNÉTICA DE JOELHO EM JOGADORES DE FUTEBOL E ATLETAS DE ELITE ASSINTOMÁTICOS

As seguintes anormalidades de imagem podem ser observadas no joelho de atletas de elite assintomáticos:

a) Edema ósseo:

Até onde se sabe, não foram publicados estudos utilizando RM para avaliar a presença de edema ósseo nos joelhos de jogadores de futebol assintomáticos. Entretanto, o edema ósseo, detectado incidentalmente através da RM, tem sido descrita em outras modalidades esportivas de alto nível há mais de 20 anos.[28,33,34] Este achado anormal, observado em atletas assintomáticos pela RM, tem despertado a atenção da comunidade científica sobre a relação existente entre estas alterações de imagem e a presença ou ausência de dor articular em esportistas. Em estudo conduzido por Major et al,[28] avaliando o joelho de jogadores de basquetebol assintomáticos antes do início

da temporada de competições, demonstrou áreas de edema ósseo em mais de 40% dos indivíduos avaliados. Segundo os autores, este achado incidental de edema ósseo provavelmente está relacionado à transmissão de carga axial através dos meniscos para o osso subcondral, resultando em microfraturas e/ou contusões ósseas. Outros autores relacionaram o edema ósseo à presença de hemorragia, edema ósseo ou líquido, achados que também podem ser encontrados em diversas patologias acometendo o joelho.[35] Este tipo de edema ósseo (figuras 1 e 2) está geralmente associado à lesão de joelho por *overuse,* comum em atletas jovens assintomáticos e jogadores de futebol de alto nível. Além disso, este edema ósseo sem dor pode, em alguns casos, evoluir desfavoravelmente para fratura de estresse (figura 3), principalmente naqueles atletas de elite que persistem com treinamentos rigorosos, sobrecarregando sobremaneira as articulações dos joelhos.

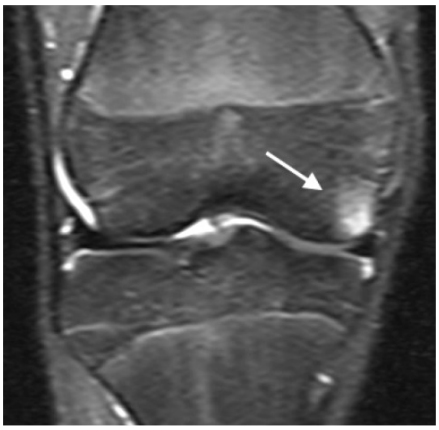

Figura 1 - Atleta assintomático: Imagem coronal STIR mostrando edema ósseo no côndilo femoral medial. Fonte: Soder et al, AJR 2011

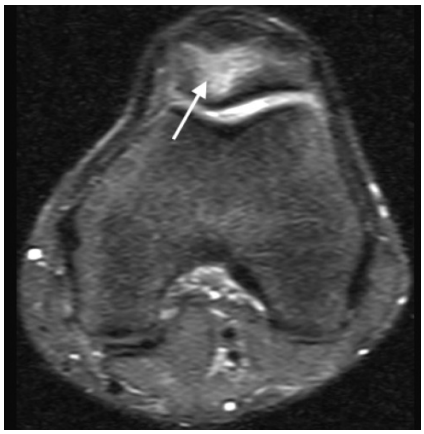

Figura 2 - Atleta assintomático: Imagem axial STIR mostrando edema ósseo na patela. Fonte: Soder et al, AJR 2011

Figura 3 - Atleta assintomático: Imagem coronal STIR mostrando hipersinal linear no platô tibial, sugerindo fratura de estresse. Fonte: Soder et al, AJR 2011

b) Anormalidades nos Coxins Gordurosos:

Não existem trabalhos na literatura utilizando RM de joelho para avaliar alterações nos coxins gordurosos em atletas de futebol assintomáticos. A maioria dos estudos disponíveis que avaliaram os coxins gordurosos por RM examinaram indivíduos com dor anterior no joelho.[36-38] Anormalidades da gordura prefemoral têm sido descritas em atletas e não atletas.[36, 37] Na RM, alterações no coxim gorduroso prefemoral estão relacionadas a sinal de gordura, sinal intermediário (similar à intensidade de sinal do músculo ou cartilagem) e sinal de líquido. Acredita-se que exista um pinçamento da gordura prefemoral durante a extensão do joelho, da mesma forma como ocorre com a gordura infrapatelar em atletas. Foi demonstrada associação significativa entre dor anterior no joelho e hipersinal em T2 da gordura quadricipital, ao nível do recesso suprapatelar (figura 4).[37]

Anormalidades da gordura infrapatelar de Hoffa podem ser causadas pelo pinçamento durante os movimentos repetidos de flexão e extensão do joelho, por lesões secundarias à injúria/ruptura ligamentar ou por trauma direto.[38] Estas alterações comumente são acompanhadas por dor no compartimento anterior do joelho e aumento de volume na região infrapatelar. Nas imagens de RM, pode-se observar hipersinal da gordura de Hoffa, com ou sem derrame articular associado (figura 5). Outra localização possível do edema dos coxins gordurosos é na porção súpero-lateral da gordura infrapatelar (figura 6). Neste caso, além das causas supracitadas, o edema nesta topografia também pode ser explicado pelo mal-alinhamento da patela em relação à tróclea femoral, o que levaria a uma instabilidade fêmoro-patelar transitória, com consequente pinçamento da porção lateral e superior da gordura de Hoffa.[39]

Figura 4 - Imagem sagital ponderada em DP com saturação de gordura mostrando aumento de volume e edema da gordura quadricipital. Fonte: Roth et al, AJR 2004

Figura 5 - Imagem sagital ponderada em T2 com saturação de gordura mostrando espessamento e edema da gordura de Hoffa (setas). Fonte: Saddik et al, Skeletal Radiol 2007

Figura 6 - Atleta assintomático: Imagem sagital STIR mostrando edema da porção súpero-lateral da gordura de Hoffa (seta). Fonte: Soder et al,AJR 2011

c) Derrame articular:

Até o presente estudo, nenhum trabalho avaliou a presença de derrame articular em jogadores de futebol assintomáticos. Apenas o estudo conduzido por Major et al descreveu derrame articular nos joelhos de atletas de basquetebol assintomáticos pela RM, tendo observado uma prevalência de 35% desta alteração nos jogadores estudados. Contrariamente, Kaplan et al, em estudo semelhante, não detectou derrame articular de joelho pela RM em jogadores profissionais de basquetebol. Outros estudos utilizando RM de joelho avaliaram cadáveres e indivíduos sintomáticos com desarranjos internos, objetivando correlacionar o volume de líquido articular com a presença ou ausência de lesões no joelho.[40-42] Kolman et al, estudando derrame articular nos joelhos de pacientes com e sem desarranjo interno através da RM, encontrou um valor preditivo negativo de 86% utilizando um ponto de corte de 10 mm (diâmetro anteroposterior ao nível do recesso suprapatelar lateral – figura 7 e 8), com sensibilidade de 92% e especificidade de 60%. Apesar disso, este estudo demonstra limitações que impedem o emprego disseminado deste ponto de corte na prática clínica para avaliação dos derrames articulares pela RM. Por não existir uma medida fisiológica de líquido articular que possibilite a diferenciação de joelhos com e sem patologia, esta mensuração ainda é alvo de questionamentos.[40, 41]

Figura 7 - Imagem sagital ponderada em DP com saturação de gordura mostrando derrame articular no recesso suprapatelar. Fonte: Kolman et al, Skeletal Radiol 2004

Figura 8 - Atleta assintomático: Imagem sagital STIR mostrando derrame articular no recesso suprapatelar e edema da gordura prefemoral. Fonte: Soder et al, submetido para BJSM.

d) Anormalidades nas Plicas Sinoviais:

O estresse crônico e repetitivo que o joelho do atleta é submetido pode ocasionar alterações nas plicas sinoviais. Alem do presente estudo, que descreveu edema da plica sinovial infrapatelar em atletas assintomáticos de futebol (figura 9), apenas Major et al avaliou jogadores de basquetebol assintomáticos por RM, onde descreveu anormalidades de imagem envolvendo a plica sinovial infrapatelar (figura 10). Os demais estudos que avaliaram anormalidades em plicas sinoviais foram realizados em pacientes com dor anterior no joelho (figura 11).[43-46] De maneira geral, alterações nas plicas sinoviais são caracterizadas por espessamento e inflamação da plica, podendo ou não estar associadas a derrame articular.[47] As alterações acometendo a plica sinovial podem ser agudas ou crônicas, dependendo do tipo de esporte praticado, assim como da frequência e intensidade dos treinamentos. Atividades físicas com flexão e hiperextensão do joelho podem ocasionar o pinçamento da plica sinovial contra o côndilo femoral, sendo o principal mecanismo de injúria, ocorrendo geralmente em esportes caracterizado por saltos e corridas.[43-45]

Figura 9 - Atleta assintomático: Plica infrapatelar alterada (seta). Imagem sagital STIR. Fonte: Soder et al, AJR 2011

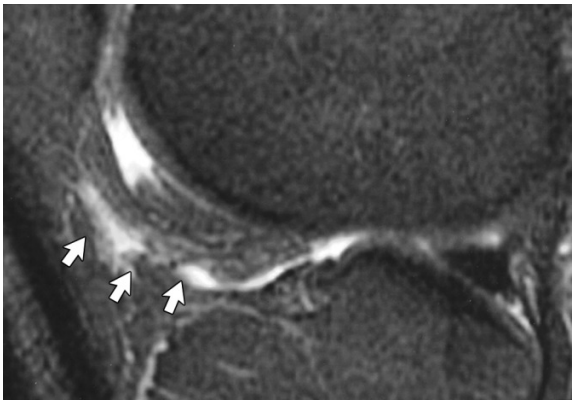

Figura 10 - Atleta assintomático: Plica infrapatelar alterada (setas). Imagem sagital focada ponderada em T2 com saturação de gordura. Fonte: Major et al, AJR 2002

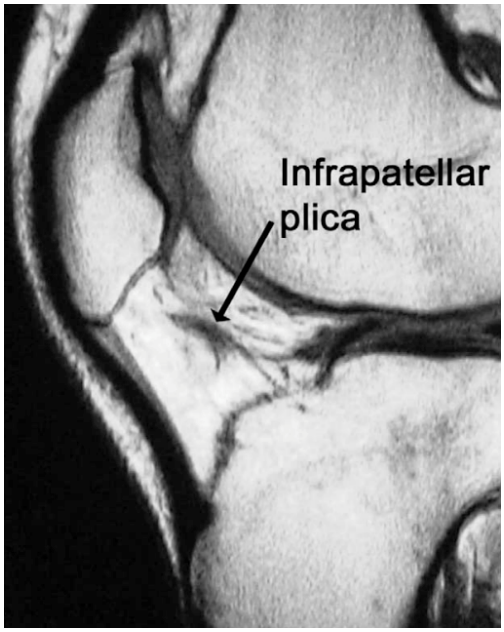

Figura 11- Plica infrapatelar espessada (seta) Imagem sagital ponderada em T1. Fonte: K.A.L Peace et al, Clinical Radiol 2006

e) Lesões de Menisco:

Nenhum estudo avaliou patologia meniscal em joelhos de jogadores de futebol assintomáticos por RM. Apesar disso, estudos prévios realizados em atletas assintomáticos de basquetebol, futebol americano, ginastas e maratonistas encontraram uma prevalência de lesões meniscais silenciosas que variou entre 9 e 20%.[27,32,33,48] Em crianças e adolescentes que praticam esporte competitivo, é pouco comum encontrar qualquer tipo de lesão meniscal, salvo naqueles atletas que já apresentam alguma anormalidade meniscal congênita, tal como menisco discóide, ou quando existe injúria ligamentar associada.[49] A avaliação dos meniscos medial e lateral em crianças e adolescentes pela RM

requer certo cuidado, devido a sua maior vascularização em relação aos adultos, gerando um hipersinal fisiológico intra-substancial, que pode simular ruptura (figura 12).[41, 50, 51] Em termos gerais, os critérios para determinar lesão de menisco pela RM basicamente são alteração de sinal intra-substancial e alteração na morfologia/contornos do menisco, sendo classificados em 3 graus distintos.[52] Lesões grau I são caracterizadas por aumento de sinal intra-substancial irregular, que não se estende para a superfície articular. As lesões grau II geralmente estão associadas a processo degenerativo e caracterizam-se por aumento de sinal intra-substancial linear, que pode se estender até a margem capsular, sem determinar descontinuidade. Lesões grau III são caracterizadas por um aumento de sinal linear ou complexo que se estende até a superfície articular, com descontinuidade em seus contornos, podendo inclusive estarem associadas a perda de substância ou fragmentação do menisco, com visualização de fragmentos longe do menisco de origem.

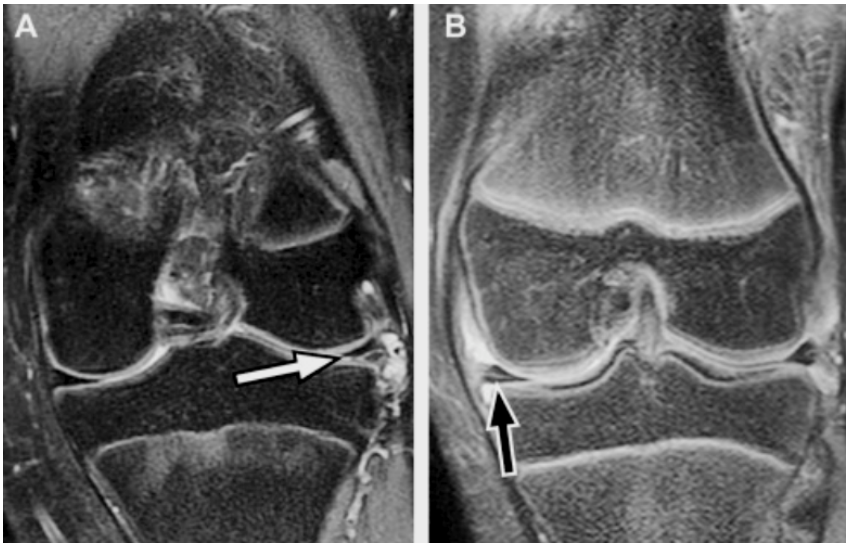

Figura 12 - Ruptura meniscal (A) versus vaso intrameniscal (B). Imagens coronais ponderadas em DP com saturação de gordura. Fonte: Sanchez et al, Magn Reson Imaging Clin N Am, 2009

f) Lesões da Cartilagem Articular:

Segundo a literatura, não foram encontrados estudos avaliando a cartilagem articular do joelho em jogadores de futebol assintomáticos por RM. Em uma revisão sistemática sobre lesões condrais de joelho, cuja amostra incluía 14% de atletas assintomáticos de basquetebol e maratonistas, a prevalência de lesões condrais de espessura total nestes indivíduos foi de 59%.[27-30, 53] Considerando todos os atletas incluídos no estudo, sintomáticos e assintomáticos, a prevalência do mesmo tipo de defeito condral foi de 36%. Isso demonstra que boa parte das lesões condrais pode ocorrer sem manifestação clínica. A RM é uma excelente ferramenta para a avaliação da cartilagem

articular. No entanto, um número considerável de lesões condrais pode permanecer indetectável pela RM até o procedimento artroscópico, especialmente as lesões cartilaginosas de espessura parcial.[54] A avaliação por imagem das superfícies condrais visa detectar defeitos de espessura parcial ou total, assim como alterações na espessura e na intensidade de sinal, que são caracterizadas por hipersinal no local da lesão.[41, 50, 51, 55] Há 4 graus de lesão condral identificados através da RM: grau I- irregularidade da cartilagem com edema; grau II – afilamento de mais de 50% da espessura da cartilagem, mas não de toda a sua espessura (figura 13).; grau III- lesão de toda a espessura da cartilagem, mas sem sinais de edema ósseo; e grau IV- lesão de toda a espessura da cartilagem, com sinais de acometimento ósseo subcondral.[7]

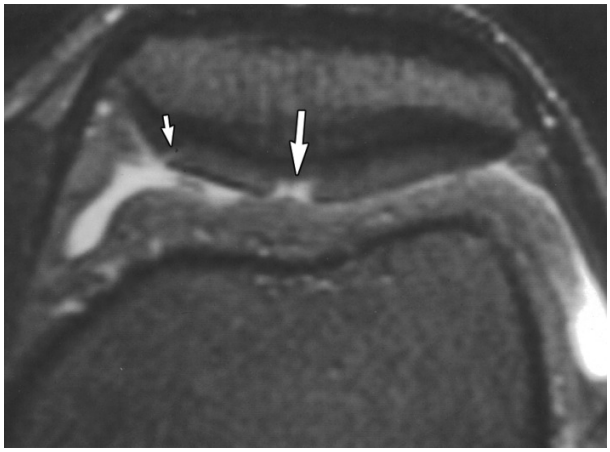

Figura 13 - Atleta assintomático: Imagem axial ponderada em T2 com saturação de gordura mostrando lesão grau II da cartilagem patelar. Fonte: Major et al, AJR, 2002

g) Anormalidades no Tendão Patelar ("Joelho do Saltador")

Alterações de sinal na RM acometendo a porção proximal do tendão patelar são bastante comuns no atleta de elite (figura 14), mesmo na ausência de sintomas.[46, 56] O joelho do saltador é uma patologia bastante comum em atletas jovens, principalmente quando sua atividade esportiva exige a extensão repetida e abrupta do joelho, como é o caso das lesões por *overuse*.[56] Major et al encontrou uma prevalência de 24% de anormalidades no tendão patelar, examinando jogadores de basquetebol assintomáticos, através da RM.[28] Estudos posteriores utilizando a ultrassonografia na avaliação do tendão patelar de atletas assintomáticos conseguiram detectar pequenas alterações tendíneas capazes de predizer quais atletas desenvolveriam posteriormente sintomas relacionados à lesão do tendão patelar, demonstrando a importância do diagnóstico por imagem no período pré-sintomático.[57, 58]

Figura 14 - Atleta assintomático: Imagem sagital T2 com saturação de gordura mostra espessamento do tendão patelar com focos de hipersinal intrassubstancial (seta). Os achados de imagem são compatíveis com joelho do saltador. Fonte: Major et al, AJR 2002

1.6 NOVAS PERSPECTIVAS

Atualmente, estudos apontam para uma nova direção: atletas assintomáticos de diversas modalidades esportivas têm apresentado anormalidades de imagem quando submetidos à RM e comparados à população em geral.[20, 27-32] Estas atividades esportivas, de maneira semelhante ao futebol,são caracterizadas pelo alto impacto articular, expondo o atleta de elite a lesões traumáticas de repetição que sobrecarregam cronicamente seu sistema musculoesquelético.

Embora a investigação por imagem de atletas sem queixas musculoesqueléticas relevantes seja incomum e inviável financeiramente na prática clínica, deve-se considerar que alterações de imagem insuspeitas detectadas pela RM podem sugerir algum tipo de intervenção preventiva ou terapêutica precoce a fim de evitar o desenvolvimento de deficiências funcionais no futuro. Por isso, entender melhor os achados incidentais de imagem em atletas adolescentes assintomáticos pode prevenir interpretações equivocadas, como a subvalorização ou supervalorização de certas anormalidades de imagem. Talvez em um futuro próximo, novos estudos longitudinais sejam capazes de demonstrar que a avaliação por imagem do esportista visando a detecção pré-clínica de qualquer anormalidade músculo esquelética seja uma

estratégia a ser adotada rotineiramente em benefício dos atletas e do esporte como um todo.

2 JUSTIFICATIVA

Estudos utilizando RM para avaliar atletas e não-atletas assintomáticos demonstraram a importância da estreita correlação clínico-radiológica, a fim de evitar a subvalorização ou supervalorização de alterações de imagem detectadas incidentalmente.[20,24,27,33,51,59-61] O diagnóstico precoce destas anormalidades de imagem em atletas de elite assintomáticos pode alertar o médico do esporte quanto à existência de lesões por *overuse*, possibilitando uma mudança ou readaptação na preparação física do atleta e, caso necessário, a instituição de um tratamento rápido e adequado.

Existem poucos estudos utilizando a RM para avaliar o joelho de atletas de elite assintomáticos.[28,33,34] Além disso, até o momento, nenhum estudo avaliou o joelho de jogadores de futebol assintomáticos com idade inferior a 18 anos, através da RM. Diante disso, o presente trabalho visa estudar, por RM, o joelho de adolescentes assintomáticos, jogadores de futebol de alto nível, comparando com um grupo controle de adolescentes que não pratica esporte de alto impacto.

3 OBJETIVOS

3.1OBJETIVO PRINCIPAL

Verificar se a prática competitiva de futebol por adolescentes assintomáticos está associada a alterações no joelho pela RM.

3.2 OBJETIVO SECUNDÁRIO

Comparar os achados de imagem em 2 grupos de adolescentes assintomáticos: jogadores de futebol e indivíduos controles que não praticam esporte de impacto.

4 HIPÓTESE

4.1 HIPÓTESE

Os autores sustentam a hipótese de que a RM será capaz de detectar uma maior prevalência de lesões osteoarticulares no joelho dos jogadores de futebol.

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CAPÍTULO II

ARTIGO ORIGINAL

MRI of the Knee Joint in Asymptomatic Adolescent Soccer Players: A Controlled Study

AMERICAN JOURNAL OF ROENTGENOLOGY (AJR 2011; 196:W61–W65)

Pediatric Imaging • Original Research

MRI of the Knee Joint in Asymptomatic Adolescent Soccer Players: A Controlled Study

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OBJECTIVE. The knee is the joint that is most frequently injured in boys 12–15 years old who practice soccer, and MRI is an accurate method of diagnosing sports-related injuries. The objective of this cross-sectional case-control study was to evaluate the knees of asymptomatic adolescent soccer players using open MRI.

SUBJECTS AND METHODS. We evaluated 56 knees of 28 asymptomatic male adolescents 14–15 years old. Participants were divided into two groups and paired by age and weight: soccer players (28 knees) and control subjects (28 knees). All the examinations were performed using a 0.35-T open-field MRI unit and were evaluated by two experienced radiologists blinded to study groups. Bone marrow signal, articular cartilage, meniscus, and fat pad abnormalities and the amount of fluid were assessed.

RESULTS. In the group of soccer players, 18 knees (64.3%) had one or more MRI abnormalities, whereas in the control group nine knees (32.1%) had at least one MRI abnormality ($p = 0.03$). The prevalence of bone marrow edema was much greater in the group of soccer players (14 knees, 50%), whereas the same abnormality was found in only one knee (3.6%) in the control group ($p = 0.0001$). Other abnormalities that were not statistically significant with regard to study group were also found in the two groups: infrapatellar fat pad edema, popliteal cysts, and ganglion cysts.

CONCLUSION. Bone marrow edema is a prevalent abnormal finding on MRI scans of knees of asymptomatic adolescent soccer players. MRI findings should be interpreted cautiously and in close correlation with clinical findings.

Keywords: bone marrow edema, case-control studies, children, knee injuries, MRI, soccer injuries, sports medicine

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WEB
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Soccer is the most popular and widely played sport worldwide, especially among children and adolescents [1]. The knee is the joint that is most frequently injured in boys 12–15 years old who practice soccer [2]. The optimal imaging tool in the evaluation of knee injuries is MRI, which has been shown to be an accurate method of diagnosing sports-related injuries, such as bone contusion; joint effusion; and cartilage, ligament, meniscus, and tendon lesions [3–7].

MRI studies of asymptomatic adults to evaluate different regions of the musculoskeletal system have shown the importance of the correlation between clinical examination and MRI findings [8–12]. High percentages of abnormalities have been found in the general population and in athletes without compatible clinical symptoms. MRI studies that evaluated the knees of asymptomatic adult athletes, including basketball players, gymnasts, and marathon runners, have shown wide variations in the prevalences of abnormalities [3, 8, 13–15]. The differences between the clinical and radiologic findings justify studies of groups of asymptomatic athletes, so minor bone and articular lesions may be detected early while still at a reversible stage.

According to a previous study of asymptomatic National Basketball Association players conducted by Walczak et al. [13], baseline MRI studies of the knee may be clinically useful to prevent injury and improve diagnostic accuracy, which may reduce the amount of time athletes cannot play in games or practice and may accelerate rehabilitation after injury. Moreover, MRI scans to evaluate athletes with new symptomatic lesions in the future may be compared with the baseline scans obtained when the athlete was still asymptomatic. Finally, MRI screening may provide a better understanding of bone changes found incidentally that may often be misinterpreted as abnormalities or as

causes of symptoms in symptomatic individuals who play sports often.

MRI to evaluate the knees of asymptomatic adult or adolescent soccer players may be a useful and innovative technique for the early detection of osteoarticular lesions. This study compared MRI findings of knees of asymptomatic adolescent soccer players with those of adolescents who did not practice impact sports regularly, matched according to age and sex.

Subjects and Methods

This study was approved by the ethics in research committee of the institution where it was conducted. An informed consent form was signed by all participants and their legal guardians.

Participants

This cross-sectional controlled study, conducted from October to November 2009, enrolled 28 volunteer adolescent boys whose knees were examined separately, in a total of 56 MRI scans. The athlete group comprised 28 MRI examinations of 14 asymptomatic soccer players born in 1994 or 1995 who had been recruited to join the junior section of a professional soccer team. The control group comprised 28 MRI examinations of 14 asymptomatic adolescent boys matched to players according to age and weight and who did not practice any impact sport.

All soccer players followed an intense practice routine that consisted of circuit training workouts with aerobic and anaerobic exercises with and without the ball supplemented by running (sprinting and jogging), plyometric and isometric exercises, and soccer training skills (kicking, ball control, heading, dribbling, passing, and tackling) ranging from 3 to 3.5 hours per day for 5 days a week. All control group participants practiced sports only sporadically in school at a frequency not greater than once a week for less than 1 hour each time. No study participant was referred to MRI examination because of clinical problems.

The inclusion criteria for the soccer players were being asymptomatic, being an athlete in the junior section of a soccer team, being 14 or 15 years old, and having practiced soccer on a team for the past 3 years at a minimum frequency of five times a week. The exclusion criteria were a history of surgery or any traumatic knee lesion that led to discontinuation or decreased frequency of soccer practice, osteoarticular abnormalities or malformations, a history of chronic disease (e.g., diabetes; hypertension; rheumatic, cardiac, renal, respiratory, or neurologic disease; chronic liver disease), and a body mass index (BMI) of greater than 25.

The inclusion criteria for the control group were being asymptomatic and being 14 or 15 years old. The exclusion criteria were practice of impact sports more than once a week in the previous 6 months, a history of surgery or any traumatic knee lesion that led to the interruption of daily activities, osteoarticular abnormalities or malformations, a history of chronic disease (diabetes; hypertension; rheumatic, cardiac, renal, respiratory, or neurologic disease; chronic liver disease), and a BMI of greater than 25.

The asymptomatic status of athletes was confirmed by means of extensive questioning, adapted from a previous questionnaire [16], in which the following were investigated: pain, functional limitations, mechanical symptoms, and any discomfort in the knees in the 6 months preceding MRI examination.

MRI

All MR examinations were performed using a 0.35-T open-field magnet (Magnetom C, Siemens Healthcare) and a transmit-and-receive knee coil. The standardized imaging protocol included STIR images (TR/TE, 4,750/19; inversion time, 140 milliseconds) in the axial, coronal, and sagittal planes; fast spin-echo (FSE) proton density images (1,660/19) in the sagittal plane; FSE T1-weighted images (525/19) in the sagittal plane; and 3D gradient-echo images in the axial plane (500/23; flip angle, 30°). The imaging parameters were a matrix of 256 × 128, slice thickness of 3.5 mm with an interslice gap of 0.8 mm, and a field of view of 16 cm.

The images were evaluated to detect abnormalities. The following abnormalities were evaluated: joint effusion; bone marrow edema; and meniscus, ligament, tendon, and cartilage abnormalities. Abnormalities were classified by structure as follows: ligaments, rupture or change in thickness or signal intensity on T1-weighted, proton density–weighted, or STIR weighted sequences; meniscus, changes or discontinued outline of the articular surface or changes in signal intensity on proton density–weighted and STIR weighted sequences; articular cartilage, increased signal intensity, changes in contour or surface smoothness, or reduced thickness on 3D gradient-echo and STIR weighted sequences; bone marrow edema, increased signal intensity on STIR or decreased signal on T1-weighted sequences in comparison with adjacent bone; tendons, changes in signal intensity on T1-weighted, proton density–weighted, and STIR weighted sequences or changes in thickness in comparison with normal tendon segments; and joint effusion, classified as absent when there was < 5 mm of synovial fluid in the suprapatellar bursa and as present when there was ≥ 5 mm [17].

Image Analysis

All images acquired from the 56 examinations were saved on a workstation for later analysis.

Two radiologists with 5 years' experience in musculoskeletal imaging evaluated all examinations independently. Observers were blinded to study groups. In cases of disagreement, the findings were discussed until the observers reached a consensus.

Statistical Analysis

A Microsoft Excel spreadsheet was used to store data, and statistical analyses were conducted using a software package (SPSS, version 13.0, SPSS). Results were statistically significant at a p value of < 0.05. The Fisher's exact test was used to evaluate differences in frequency of changes between the two groups. Interobserver agreement was assessed using kappa statistics.

Results

Participant Characteristics

The study and control groups had similar baseline demographic characteristics. The mean age of the group of players and that of the control group was 14.86 ± 0.55 years (SD) and 14.85 ± 0.43 years, respectively; mean weight, 57.80 ± 7.85 kg and 58.50 ± 6.90 kg; and mean height, 1.68 ± 0.07 m and 1.67 ± 0.06 m. BMIs ranged from 15.00 to 22.10 in the group of players and from 17.01 to 21.72 in the control group.

Clinical examination revealed that none of the 28 participants had pain or any other type of knee symptom.

Knee Abnormalities

The analysis of all 56 knees of the two groups revealed that 27 (48.2%) had one or more abnormalities detected using MRI.

In the group of 14 soccer players, 28 knees were examined and MRI revealed one or more abnormalities in 18 (64.3%) of the knees. The most frequently seen abnormality was bone marrow edema, which was found in 14 knees (50%) in the medial femoral condyle (Fig. 1), patella (Fig. 2), and tibial plateau in order of greater frequency. One of the athletes had bone marrow edema in the tibial plateau of both knees, and the imaging features were similar to those found in stress fracture, such as subtle periosteal edema, marrow edema, and fracture lines that are often not seen on radiographs. This athlete was under clinical observation; a conventional radiograph was also obtained but showed no abnormality. He remained asymptomatic and his physical activities were not discontinued.

Fig. 1—15-year-old asymptomatic male soccer player. Coronal STIR MR image (TR/TE, 4,750/19; inversion time, 140 milliseconds) shows bone marrow edema (*arrow*) in medial femoral condyle.

Fig. 2—14-year-old asymptomatic male soccer player. Sagittal STIR MR image (TR/TE, 4,750/19; inversion time, 140 milliseconds) shows bone marrow edema (*arrow*) in patella.

The second most prevalent abnormality was edema in the infrapatellar fat pad (Hoffa fat pad), which was seen in 10 of the 28 knees (35.7%). In nine knees (32.1%), edema in the infrapatellar fad pad ran along the infrapatellar plica (Fig. 3). Only two knees (7.1%) had edema in the superolateral portion of the infrapatellar fat pad (Fig. 4). In one of the knees, edema was detected in those two regions of the infrapatellar fat pad. Other less frequent abnormalities were also found in the knees of the soccer players, such as ganglion cysts in two knees (7.1%), patellar tendinitis in one knee (3.6%), and a small popliteal cyst in one knee (3.6%).

In the control group composed of 14 asymptomatic individuals, 28 knees were examined and MRI revealed one or more abnormalities in only nine (32.1%). The most frequent finding was edema of the infrapatellar fat pad, which was seen in seven of the 28 knees (25.0%). Edema ran along the infrapatellar plica in four knees (14.2%) and the superolateral portion of the infrapatellar fat pad in four knees (14.3%). One of the knees had edema in the two portions of the infrapatellar fat pad. Small popliteal cysts were found in two knees (7.1%). In contrast to the study group, only one knee in the control group (3.6%) had bone marrow edema, which was found in the medial femoral condyle.

The Fisher's exact test revealed a statistically significant difference in the overall frequency of abnormalities between the two groups ($p = 0.03$) because of the greater prevalence of abnormalities in the group of adolescent soccer players. The difference in frequency of bone contusion between groups was also statistically significant ($p = 0.0001$) and was much greater in the group of soccer players. The differences between the two study groups with regard to other knee abnormalities were not statistically significant.

Evaluation of the 56 MRI examinations did not reveal any meniscus, ligament, or cartilage abnormalities and revealed no joint effusions. There was no correlation between the knee abnormalities and dominant leg in the soccer players and control subjects. Interobserver agreement (κ) was 0.82 for all evaluations.

None of the athletes in this study had any knee symptoms during the 6-month follow-up period after the end of the study. Athletes with abnormal findings were under observation by their soccer club health care department. The abnormalities found using MRI were reported to the sports physician responsible for the athletes in the club. No athlete received additional treatment because of our study findings.

Discussion

The main finding in this study was that asymptomatic adolescent soccer players already had some type of bone abnormality that could be detected by MRI. This may change the way imaging findings are interpreted and valued for soccer players who undergo MRI to investigate any suspected trauma or osteoarticular lesion. The isolated finding of bone marrow edema without compatible symptoms may, depending on the context, have no clinical importance. Previous studies that evaluated the spine, the shoulder, and the knee of asymptomatic athletes and nonathletes using MRI

Fig. 3—15-year-old asymptomatic male soccer player. Sagittal STIR MR image (TR/TE, 4,750/19; inversion time, 140 milliseconds) shows infrapatellar fat pad edema (*arrow*) along infrapatellar plica.

Fig. 4—14-year-old asymptomatic boy in control group. Sagittal STIR MR image (TR/TE, 4,750/19; inversion time, 140 milliseconds) shows edema (*arrow*) in superolateral portion of infrapatellar fat pad.

TABLE 1: Knee Abnormalities: MRI Findings in 56 Knees

Abnormality	No. (%) of Subjects		p^a
	Soccer Players (n = 28)	Control Group (n = 28)	
One or more abnormalities	18 (64.2)	9 (32.1)	0.03
Bone marrow edema	14 (50.0)	1 (3.6)	0.0001
Infrapatellar fat pad edema	10 (35.7)	7 (25.0)	NS
Ganglion cyst	2 (7.1)	—	NS
Popliteal cyst	1 (3.6)	2 (7.1)	NS
Menisci	—	—	NS
Ligaments	—	—	NS
Articular cartilage	—	—	NS
Joint effusion	—	—	NS

Note—Dash (—) indicates that MRI revealed 0 abnormalities. NS = not significant.
[a]Significant difference at $p < 0.05$.

found that this imaging technique may detect several musculoskeletal changes without clinical significance [3, 8–13, 18].

Bone marrow edema is a focal signal of abnormality in the subchondral bone marrow, and its appearance is thought to represent microtrabecular fractures, hemorrhage, and edema of the marrow without disruption of the adjacent cortices or overlying articular cartilage [19]. Bone marrow edema is the result of repetitive microtrauma caused by direct bone impact during sports practice that is not completely absorbed by the buffering system (i.e., menisci and articular cartilage) and is transmitted to the underlying bone [3, 7]. Other authors suggest that bone marrow edema may be a precursor of stress fractures, as shown in a study conducted by Major [20]. This theory may explain why one of the soccer players had more severe bone marrow edema in the tibial plateau of both knees and an imaging appearance similar to that of a stress fracture. This finding, not seen on MRI of the other asymptomatic athletes, shows that more severe bone abnormalities may also be detected when using MRI to examine asymptomatic athletes. This difference between the two study groups may be explained by the high intensity of exercising and impact in the group of highly trained athletes in comparison with the study group of students who practiced sports only sporadically.

Asymptomatic soccer players may have bone marrow edema, which can be detected using MRI, and this knowledge may be extremely useful in the evaluation of symptomatic soccer players. Bone edema detected using MRI has often been implicated as the cause of knee symptoms; however, as seen in this study, it may also be found in asymptomatic individuals. Therefore, the clinical significance of bone edema in symptomatic soccer players should be interpreted in close correlation with the lesion site seen on MRI scans and the site of symptoms, such as pain and increased sensitivity, reported by the patient.

Another relatively frequent but not statistically significant abnormality in the group of soccer players and in the control group was edema of the infrapatellar fat pad, which was found in 35.7% and 25.0% of the knees, respectively. Two patterns of distribution and position were seen for edema of the infrapatellar fat pad: In soccer players, it ran mainly along the infrapatellar plica, whereas in the control group, it was found at an equal frequency in the superolateral portion of Hoffa fat pad and along the infrapatellar plica. There are several possible explanations for the presence of edemas of the infrapatellar fat pad, but the one most often accepted is that edema results from impingement of the infrapatellar fat pad or plica between adjacent bone structures as a consequence of excessive knee hyperextension or rotation and repetitive microtrauma, which causes edema and inflammation of the infrapatellar plica [21, 22]. Another possible explanation is patellar maltracking, which may lead to transitory and repetitive impingement of the superolateral portion of the infrapatellar fat pad between the lateral femoral condyle and the patella and may result in a change in signal intensity in this area [23]. Also, falls on the knee and direct trauma from the soccer ball may be possible causes of signal intensity changes seen in the infrapatellar fat pad.

This study did not detect any joint effusion or meniscus, ligament, or cartilage lesion in the knees of the asymptomatic boys enrolled in the study. The fact that no cartilage lesion was found in the 56 MRI scans may be characteristic of asymptomatic soccer players in this age group. However, the sensitivity of low-field MRI (0.35-T) in detecting cartilage lesions, in comparison with meniscus and ligament lesions, is lower than that of high-field units [24], which may be one of the limitations of this study. Therefore, further studies should be conducted using high-field MRI magnets to evaluate the prevalence of possible cartilage lesions in the knees of asymptomatic adolescent soccer players.

The impact of these lesions on asymptomatic athletes may be established only in longitudinal studies conducted over several years to determine whether chronic osteoarticular lesions, such as osteoarthritis, in these athletes will eventually develop. This may justify some type of intervention in physical preparation or maybe in a physical therapy program.

Although the soccer players enrolled in this study did not have any complaints of pain or history of trauma in the 6 months that preceded MRI, competitive athletes are accustomed to bearing pain to remain training and not lose their place on the main team, which makes us believe, as Major and Helms [3] reported, that these athletes are probably asymptomatic. Another limitation of this study is that most athletes suffer falls that are undocumented even if the athlete is questioned. Therefore, we cannot rule out the possibility that some of these lesions were not caused by other types of trauma mechanics.

In conclusion, bone marrow edema is a common finding on MRI of clinically asymptomatic youth soccer players and is the most prevalent change. Bone marrow edema was practically absent on MR studies of the control group. Therefore, MRI detection of bone marrow edema may not always be associated with symptoms in soccer players. Conversely, a finding of bone marrow edema on an MR scan of a symptomatic soccer player should be considered in case the site of symptoms is associated with the location of the imaging abnormalities.

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ANEXO

ARTIGO ORIGINAL 2

Magnetic Resonance Imaging of the knee in asymptomatic adolescent swimmers: a controlled study.

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Original article

MRI of the knee in asymptomatic adolescent swimmers: a controlled study

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ABSTRACT

Background Swimming is a widespread sporting activity generally regarded as an ideal form of exercise, which has little or no impact on the knees. However, overuse or repetitive microtrauma injuries may often affect the knee joint of young competitive swimmers. These early lesions are frequently asymptomatic for a considerable period of time before causing discomfort or joint pain.

Purpose The aim of the present study is to use MRI to evaluate the knee joints of asymptomatic young elite swimmers and to compare them with age- and sex-matched controls who do not practice any impact sports regularly.

Study design Cross-sectional case–control study.

Material and methods The authors performed a cross-sectional controlled study to evaluate 54 knees of 27 asymptomatic male adolescents aged 14–15 years, paired by age and weight. Participants were divided in two groups: 13 elite swimmers and 14 control adolescents. The authors performed all the exams using a 0.35-T open-field MRI unit and evaluated by two experienced radiologists blinded to study groups. The images were evaluated to detect the presence or absence of abnormalities.

Results One or more imaging abnormalities were detected in 18 knees in the group of swimmers (69.2%; p=0.013). The most prevalent findings in the athletes were infrapatellar fat pad edema (53.8%; p=0.049), followed by bone marrow edema (26.9%; p=0.022), edema of prefemoral fat pad (19%; p=0.022) and joint effusion (15.3%; p=0.047).

Conclusion Significantly more MRI abnormalities were found in the knee joints of asymptomatic adolescent elite swimmers. This high prevalence of positive imaging findings in swimmers may correspond to benign changes or preclinical lesions, which should be evaluated in a follow-up study.

INTRODUCTION

Swimming is a popular recreational sport activity that has been frequently employed as a medical therapy all over the world. Many physicians have recommended this low-impact aerobic exercise to relieve symptoms of patients with degenerative knee joint lesions as a complementary preoperative and postoperative treatment.[1] It can be used as an adjuvant therapy for patients undergoing orthopaedic treatments and surgery because this activity provides muscle building and cardiovascular training.[2] As complementary to pretreatment- and post-treatment, swimming improves posture and spinal alignment, by reducing pressure along the vertebral column and by relaxing muscles. As well, it has been indicated for obese people to weight loss since this low-impact activity does not overload knee joints.

In contrast to recreational swimming, competitive swimmers frequently face overuse-related pain and musculoskeletal injuries. Most of them start high-performance swimming at an early age and maintain these training workouts over many years, which are associated with repetitive movements and microtraumas that may evolve to deleterious osteoarticular lesions.[3–5]

The most common osteoarticular lesions affect the shoulder and in general are caused by impingement of the supraspinatus and biceps tendons against the overlying coraco-acromial arch. The knee joint is the second most common cause of complaints in competitive swimmers and has been frequently compromised by injuries linked to different biomechanical patterns based on the swimming style or related to rigorous practice techniques adopted by some athletes.[4 6] The vast majority of knee injuries has been found in elite athletes who swim breaststroke or butterfly styles. There are differences in leg movements between swimming styles. The leg motion in the breaststroke is the most damaging for the knee. This swimming style causes stress on the medial compartment of the knee joint.[6] Most of these lesions are caused by the whip kick movement, which places a valgus load on the lateral aspect of the knee and commonly affects the medial and the patellofemoral compartments.[4]

Although swimming is traditionally associated with upper limb injuries, it is also associated with lower limb symptoms including knee pain.[6] MRI is useful for diagnosing musculoskeletal swimming injuries. MRI is the most accurate imaging method for the diagnosis and confirmation of osteoarticular lesions associated with sports practice, such as bone marrow oedema (BMO), joint effusion, as well as cartilage, ligament, tendon and meniscal lesions.[7–12]

Because of a high percentage of incidental MRI abnormalities in the general population and in some athletes who have no compatible complaints, it is often recommended that clinicians correlate examination findings with imaging findings.[11 13–19] Studies that focused on the knee joints of asymptomatic adult athletes, including basketball players, gymnasts and marathon runners, reported a range of positive imaging findings.[7 11 13 20–23] This clinico-radiological discrepancy suggests that new studies in asymptomatic athletes should be conducted for preclinical detection and treatment of early and

still reversible osteoarticular changes. Furthermore, abnormal preclinical and incidental imaging findings may suggest an early intervention in order to avoid the development of future functional disabilities. To our knowledge, there has been no such study of incidental imaging findings in the knees of asymptomatic swimmers.[5 18 24] Therefore, we used MRI to evaluate the knee joints of asymptomatic young elite swimmers and we compared those data with findings in age- and sex-matched controls who do not practice any impact sports regularly.

METHODS

This study was approved by the Ethics in Research Committee at the institution where it was conducted.

Patients

This cross-sectional controlled study, conducted from October to November 2009, enrolled 27 volunteer male adolescents whose knees were examined separately, which totalled 54 MRI scans. The athlete group comprised 26 MRI exams of 13 asymptomatic elite swimmers recruited from a local team that competed in national championships. All participants in the group of elite swimmers followed an intensive practice routine of at least 3 h and 30 min per day 5 days a week, ranging from 20–25 h per week of pool training and 5 h of dry-land training involving flexibility and resistance work. Training sessions were graded into four levels of physical intensity: low-intensity aerobic, anaerobic threshold, maximal aerobic and maximal lactic. The control group comprised 28 MRI exams of 14 asymptomatic adolescent boys matched to swimmers according to age and weight and who did not practice any impact sports. The individuals of the control group practiced sports only sometimes in school at a frequency not greater than once a week for less than 1 h each time. All participants and their guardians provided informed consent to participate in the study.

The inclusion criteria for the group of swimmers were (1) being asymptomatic, (2) being an athlete in the junior section of a swimming association, (3) being 14 or 15 years old and (4) having practiced swimming in the team for the last 3 years at a minimum frequency of 5 times a week. Exclusion criteria were (1) history of surgery or any traumatic knee lesion that led to practice discontinuation or decreased frequency; (2) osteoarticular abnormalities or malformations and history of chronic disease (diabetes, hypertension, rheumatic, cardiac, renal, respiratory or neurological disease, chronic liver disease) and (3) body mass index (BMI) greater than 25.

The inclusion criteria for the control group were (1) being asymptomatic and (2) being 14 or 15 years old. The exclusion criteria were (1) practice of impact sports more than once a week in the last 6 months; (2) history of surgery or any traumatic knee lesion that led to the interruption of daily activities; (3) osteoarticular abnormalities or malformations and history of chronic disease (diabetes, hypertension, rheumatic, cardiac, renal, respiratory or neurological disease, chronic liver disease) and (4) BMI greater than 25.

Magnetic resonance imaging

All the exams were performed using a 0.35-T open-field magnet (Magnetom C; Siemens, Erlangen, Germany) and a transmit-receive knee coil. The following protocol was used: short tau inversion recovery (STIR) images (TR/TE, 4750/19, inversion time= 140 ms) in the axial, coronal and sagittal orientations, fast spin-echo proton density images (TR/TE, 1660/19) in the sagittal plane and fast spin-echo T1-weighted images (TR/TE, 525/19) in the sagittal plane. A matrix of 256 × 128, a slice thickness of 3.5 mm with an interslice gap of 1.1 mm and a field of view of 16 cm were utilised.

The images were evaluated to detect presence or absence of abnormalities. The following abnormalities were evaluated: joint effusion, bone marrow edema, and meniscus, ligament, tendon or cartilage abnormalities. Changes were analysed and structures were classified as abnormal if they met to the following criteria:

1. ligaments – rupture or changes in thickness or in signal intensity in proton density (PD)- and STIR-weighted sequences;
2. meniscus – changes or discontinued outline of the joint surface or changes in signal intensity in the PD- and STIR-weighted sequences;
3. articular cartilage – increased signal intensity, changes in outlines or reduced thickness;
4. bone marrow – increased signal intensity in the STIR-weighted sequences in comparison with adjacent bone;
5. tendons – changes in signal intensity in PD- and STIR-weighted sequences or changes in thickness in comparison with normal tendon segments;
6. joint effusion – absent when there was less than 5 mm of synovial fluid in the suprapatellar bursa and present when there was 5 mm or more, classified as small, moderate or large amount.
7. infrapatellar and prefemoral fat pad – changes in signal intensity in PD- and STIR-weighted sequences.

Image analysis

All images acquired from the 54 exams were saved in a workstation for later analysis. Two radiologists with at least 5 years of experience in musculoskeletal imaging evaluated all exams independently. Observers were blinded to study groups. In case of disagreement, the findings were discussed until a consensus was reached.

Statistical analysis

Data were stored in a Microsoft Excel spreadsheet and analysed using the Statistical Package for the Social Sciences, version 13.0 (SPSS, Chicago, Illinois, USA). Results were statistically significant at a 'p' value ≤0.05. The Fisher's exact test was used to evaluate differences in frequency of changes seen between the two groups. Interobserver agreement was assessed using 'κ' statistical test.

RESULTS

Participant characteristics

Baseline demographic characteristics were similar in the study and control groups. Mean age in the group of swimmers and in the control group was 14.73 ± 0.52 and 14.85 ± 0.43 years (mean ± SD); mean weight, 57.80 ± 7.85 and 58.50 ± 6.90 kg and mean height, 1.69 ± 0.08 and 1.67 ± 0.06 m. All individuals were male. BMI ranged from 17.79 to 23.43 in the group of players and from 17.01 to 21.72 in the control group.

Clinical examination revealed that none of the participants reported pain or any other type of knee symptom.

Knee abnormalities

The analysis of all 54 knees of the two groups revealed that 27 of the 54 knees (50%) had one or more abnormalities detected by MRI.

In the group of athletes, composed of 13 elite swimmers, 26 knees were examined. MRI revealed one or more abnormalities in 18 (69.2%) of these 26 knees. The most frequent abnormality was signal change in infrapatellar fat pad (Hoffa's fat pad) found in 14 knees (53.8%). In 9 knees (34.6%), the infrapatellar fat pad edema ran along the infrapatellar plica. Eight knees (30.7%) had edema in the superolateral portion of the infrapatellar fat pad (figure 1). In three of the knees, the edema was detected in both the portions of the infrapatellar fat pad. The second most prevalent abnormality was bone bruising found in 7 knees (26.9%) in the medial femoral condyle (figure 2), the tibial plateau and the patella in order of greater frequency. The third most prevalent abnormality was edema in the prefemoral fat pad found in 5 knees (19.2%) (figure 3). Joint effusion was detected in 4 knees (15.3%) (figure 3). No meniscus, ligament or cartilage abnormalities were found in the evaluation of the MRI scans of swimmers.

In the control group, which comprised 14 asymptomatic individuals, 28 knees were examined. MRI revealed one or more abnormalities in only 9 (32.1%) of these 28 knees. The most frequent abnormality was infrapatellar fat pad edema, which was seen in 7 of the 28 knees (25%). The edema ran along the infrapatellar plica in 4 knees (14.2%) and was found in the superolateral portion of the infrapatellar fat pad in 4 knees (14.2%). One of the knees had edema in the two portions of the infrapatellar fat pad. Small popliteal cysts were found in two knees (7.1%). Differently from the study group, only one knee in the control group (3.5%) had bone marrow edema, found in the medial femoral condyle. No meniscus, ligament or cartilage abnormalities, and no joint effusions were found in the evaluation of the control group MRI exams.

The Fisher's exact test revealed a statistically significant difference in the overall frequency of abnormalities in the two groups ($p=0.013$) with a greater prevalence of abnormalities in the group of adolescent elite swimmers (table 1). The difference in frequency of infrapatellar fat pad edema, bone bruises, prefemoral fat pad edema and joint effusion between groups was statistically significant ($p<0.05$), and was much greater in the group of elite swimmers. The differences in other knee abnormalities were not statistically significant between the two groups of adolescent boys. Interobserver agreement was 0.82 (κ) for all evaluations.

DISCUSSION

The most important finding of the present study was that MRI of the knee joint revealed more imaging abnormalities in the asymptomatic elite swimmers than in the control group. Although swimming does not cause direct impact on the bone and ligament structures of the knee joint, it produces a chronically repetitive leg movement that may be associated with the imaging changes found in this study.[12]

Infrapatellar fat pad edema, found in more than half of the athletes (53.8%), may be related to the high rate of repeated knee joint extension movements during workout series, which can result in fat entrapment in the anterior femorotibial joint space. Similar findings have been shown in athletes who practice high-impact sports[8] and in some prospective reports evaluating non-athletic individuals. These studies have revealed that positive MRI findings are not always associated with symptoms,[25] although anterior knee pain may be related to MRI inflammatory signal changes along the infrapatellar plica[26] or suprapatellar fat pad.[27 28]

Similarly, prefemoral signal changes, found in 19% of the swimmers, have already been described in previous reports focusing on athlete and non-athlete individuals.[27 29] In these studies, MRI signal abnormalities were associated with fat signal, intermediate signal (similar intensity of muscle or cartilage) and fluid signal. They have suggested that the prefemoral fat pad may also be entrapped during knee extension in athletes along with the infrapatellar fat pad. Furthermore, when

Figure 1 A teenage asymptomatic male swimmer. Edema in the superolateral portion of infrapatellar fat pad (arrow). Sagittal STIR MR image (TR/TE, 4750/19).

Figure 2 A teenage asymptomatic male swimmer. Bone contusion in the medial femoral condyle (arrow). Coronal STIR MR image (TR/TE, 4750/19).

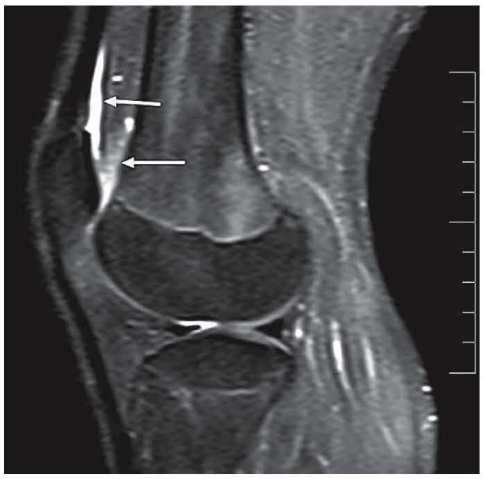

Figure 3 A teenage asymptomatic male swimmer. Prefemoral fat pad edema and joint effusion (arrows). Sagittal STIR MR image (TR/TE, 4750/19).

Table 1 Knee abnormalities – MRI findings

MRI abnormality	Swimmers (n=26)	Control group (n=28)	p Value
One or more abnormalities	18 (69.2%)	9 (32.1%)	0.013
Bone marrow edema	7 (26.9%)	1 (3.5%)	0.022
Prefemoral fat pad edema	5 (19.2%)	–	0.022
Infrapatellar fat pad edema	14 (53.8%)	7 (25%)	0.049
Joint effusion	4 (15.3%)	–	0.047
Menisci	–	–	NS
Ligaments	–	–	NS
Articular cartilage	–	–	NS

Significant difference at $p < 0.05$.
NS, not significant.

the signal corresponded to fat in this topography, there was no significant association with mass effect or knee pain, and this may be an explanation for this finding in asymptomatic patients in the present study.

Another frequent knee abnormality revealed by MRI was bone contusion, found in 26.9% of swimmers. This imaging finding has been described in athletes of several different sports[11 23 30] and has not been fully associated with symptoms, not even in elite athletes. Major and Helms[7] have found knee BMO in asymptomatic basketball players and have suggested that this abnormality may be assigned to the direct transmission of repetitive impact through articular cartilage to the underlying bone, which would cause this characteristic bone signal change. Another possible explanation for BMO in athletes has been reported by Vanhoenacker and Snoeckx[30] who suggested that as a physiological response to repeated stress, a biomechanical change occurs as a result of training which leads to the development of edema in certain knee compartments. Regarding elite swimmers, the source of joint stress may be related to repetitive knee flexion and extension during leg movements in freestyle, butterfly and backstroke, and also associated with medial impaction during the whip kick movement in the breaststroke. The clinical meaning of BMO has been a focus of discussion since it was first described by MRI many years ago.[31] Currently, there are still questions about the association between bone edema and knee pain.[32] Major and Helms[7] have raised a hypothesis that bone contusion in asymptomatic basketball players may be related to initial stress lesions at very early stages. Similarly, Lazzarini *et al*[33] have used MRI in order to determine whether running can cause BMO and have suggested it may be a result of the sports activity itself. Kornaat *et al*[11] also suggested BMO as a continuum injury that starts from physiologic response to biomechanical load and ends in stress fracture.

Joint effusions were revealed in 15.3% of swimmers. Previous reports have described minor joint effusions in asymptomatic subjects, who were not associated with sports practice or knee lesions.[34] In athletes, it has been described as an MRI finding in asymptomatic individuals.[23 24] Boks *et al*[24] have described difficulty to determine which volume of joint effusion would be physiological or pathological. On the other hand, larger cut-off points have been correlated with knee joint lesions. Although joint effusion can be frequently related to an underlying lesion (eg, cartilage lesion, meniscal tear or ligament injury), no such abnormalities were detected in the performed MRIs.

In this study, the athletes had practiced all swimming styles in a similar frequency, duration and intensity of workouts, because they had not yet specialised in one style. This may be one of the limitations of this study, because it was not possible to correlate an association between swimming style and MRI abnormalities. The cross-sectional design and the relatively small number of evaluated athletes were other possible study limitations. Certainly, a longitudinal study with a larger number of athletes would allow further inferences. Another limitation was the low-field magnet used in the present study, which has slightly less sensitivity for detection of cartilage lesions compared to high-field units.[20] Despite this, no cartilage lesion was found in any of the 56 scanned knees. To confirm these findings, a high-field magnet should be used in a subsequent study.

All evaluated athletes had regular check-ups by a physician in their swimming association. The observed imaging findings were described and reported to this physician in order to initiate a possible intervention.

In conclusion, the most prevalent abnormalities found in this study were infra- and suprapatellar fat pad edema, BMO and joint effusion. These results are consistent with previous studies in asymptomatic athletes of other sports.[7 11 13 20 21 35 36] The high prevalence of positive imaging findings detected in the group of asymptomatic swimmers may correspond to possible benign changes or preclinical lesions, potentially deleterious in the future. To address these specific questions, longitudinal cohort studies should be conducted to better understand the significance of these early imaging abnormalities revealed by MRI.

Competing interest None.

Patient consent Obtained.

Ethics approval This study was approved by the Ethics in Research Committee of the Hospital São Lucas of Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil.

Provenance and peer review Not commissioned; externally peer reviewed.

What is already known on this topic

Most of the previous reports have used MRI to evaluate knee joint abnormalities of asymptomatic athletes in different sport modalities, such as soccer, basketball and gymnastic. To the best of our know ledge, no study has evaluated MRI abnormalities of knee joints in asymptomatic young elite sw immers.

What this study adds

MRI can reveal preclinical imaging abnormalities in the knee joints of young elite swimmers. This advanced imaging technique can predict and prevent possible deleterious injuries. However, a follow-up longitudinal study is necessary to better understand the significance of these early MRI abnormalities detected in this group of elite swimmers.

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