THE PORTUGUESE TRAIL RUNNER

Musculoskeletal injuries, morphologic, physiologic and neuromuscular profile

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PALAVRAS CHAVE: TRAIL RUNNING, EPIDEMIOLOGIA, LESÕES MUSCULO-ESQUELÉTICAS, COMPOSIÇÃO CORPORAL, PERFIL FISIOLÓGICO, FORÇA MUSCULAR E RÁCIOS ISOCINÉTICOS.

KEY-WORDS: TRAIL RUNNING, EPIDEMIOLOGY, MUSCULOSKELETAL INJURIES, BODY COMPOSITION, PHYSIOLOGICAL PROFILE, MUSCULAR STRENGTH AND ISOCINETICS RATIOS.

"Ninguém é melhor nem pior do que ninguém. Com trabalho, dedicação e respeito conseguimos grandes feitos. No Trail, nem sempre é vencedor quem chega primeiro, cada um de nós tem a sua vitória".

(Luís Mota, atleta de ultra-trail running, entrevista Louzan Trail 2014)

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Introdução Geral

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ADS - Athletes from different sports

ADS - Atletas de diferentes desportos

ATRP - Associação de Trail Running de Portugal

BIA - Bioimpedance Analysis

BIA - Análise de bioimpedância

BMC – Bone Mineral Content

BMD – Bone Mineral Density

BMI – Body mass index

CA – Chronological age

CI – Confidence intervals

CO2 – Carbon Dioxide

con – Concêntrico

CUTR - Competitive Utra Trail Runners

DXA – Dual energy X-Ray Absorptiometry,

DXA - Absorciometria de Raio-X de dupla energia

ecc – Excêntrico

FFM – Fat-free mass

FFQ - Food Frequency Questionaire

FM – Fat mass

HR – Heart Rate

IMC- Índice de massa corporal

ITRA - International Trail Running Association

KE - Knee Extensors

KF - Knee Flexors

Km- kilometers

K-S – Kolmogorov-Smirnov

LBM – Lean Body Mass

LLLM –Lower Limbs Lean Mass

LST – Lean Soft Tissue

min - Minutes

NTR - National Trail Runners

O2 – Oxygen

Pτ - Peak torque

QFA – Questionário de Frequência Alimentar

RER – Respiratory Exchange Ratio

RTR - Regional Trail Runners

RUTR - Recreational Ultra Trail Runners

SPSS – Statistical Package for the Social Sciences

STROBE - Strengthening the Reporting of Observational Studies in Epidemiology

TR - Trail Running

UTR - Ultra Trail Running

UTR_ R - Regional Ultra Trail Runners

UTR_N - National Ultra Trail Runners

VO2 - Oxygen Uptake

VO2max - Maximal Oxygen Uptake

VO2peak - Peak Oxygen Uptake

vs – Versus

τ – Torque

Resumo

O **objetivo** do presente trabalho foi o de caraterizar os atletas masculinos de trail running portugueses através de conjunto de parâmetros epidemiológicos, morfológicos, fisiológicos e neurofuncionais. Foram realizados **dois estudos transversais,** organizados em cinco artigos. O **primeiro estudo**, teve uma abordagem epidemiológica retrospetiva (12 meses). A amostra foi composta por 403 atletas de TR. Os resultados do artigo 1 revelaram que 72,7% dos atletas tiveram uma lesão musculoesquelética e o nível participativo, influenciou a severidade da lesão, a taxa de lesão e interferiu com a necessidade de parar de correr/treinar pelo menos um dia. A maioria lesões reportadas nas extremidades inferiores localizaram-se nos tornozelos/pés e nos joelhos (artigo 2). Foram identificados como potenciais determinantes de lesão significativa das extremidades inferiores o IMC, o volume de treino semanal e o treino regular em montanha. O **segundo estudo**, recorreu a uma amostra por conveniência composta por 44 corredores de ultra-trail (UTR) e teve como objetivo traçar um perfil descritivo multidimensional. O artigo 3, realçou que o UTR nacional (UTR-N) apresenta uma menor massa gorda. A avaliação das vias metabólicas (artigo 4) realçou que os UTR-N obtiveram um melhor desempenho aeróbio. Por último (artigo 5), pretendeu avaliar o perfil isocinético dos músculos da articulação do joelho dos UTR e compará-los com 28 atletas de diferentes desportos. A exigência do trabalho excêntrico dos flexores do joelho no UTR, pode explicar os maiores rácios funcionais de extensão e o equilíbrio das razões de força agonista e antagonista. **Conclui-se** o nível de participação dos atletas de TR pode implicar diferenças na severidade das lesões, na composição corporal e nos valores de aptidão aeróbia. A exigência do trabalho excêntrico dos flexores do joelho, podem explicar os maiores rácios funcionais de extensão, e o equilíbrio das reações de força agonista e antagonista.

Palavras-Chave: TRAIL RUNNING, EPIDEMIOLOGIA, LESÕES MUSCULO-ESQUELÉTICAS, COMPOSIÇÃO CORPORAL, PERFIL FISIOLÓGICO, FORÇA MUSCULAR E RÁCIOS ISOCINÉTICOS.

Abstract

The objective of the present work was to characterize Portuguese male trail runners in a set of epidemiological, morphological, physiological, and neurofunctional parameters. Two cross-sectional studies were performed, organized in five articles. The first study used a retrospective epidemiological approach (12 months). The sample was composed of 403 trail runners. The results revealed that 72.7% of the athletes had a musculoskeletal injury, and their participative level influenced the severity of the injury (Article 1). The majority of injuries reported in the lower extremities were located in the ankles/feet and knees (Article 2). Body mass index, weekly training volume, and regular mountain training were identified as potential determinants of significant lower extremity injuries. The second study used a convenience sample composed of 44 ultra-trail runners (RTU) and aimed to draw a multidimensional descriptive profile. Article 3 emphasized that the national RTUs (RTU-N) have a lower fat mass. The evaluation of metabolic pathways (Article 4) highlighted that the RTU-Ns obtained a better aerobic performance. Finally, the author evaluated the isokinetic profile of the knee joint muscles of RTUs and compare them with 28 athletes from different sports (Article 5). The demand of the eccentric work of the knee flexors in RTUs may explain the higher functional extension ratios and the balance of the agonist and antagonist force ratios. The author concluded that the level of participation of regional trail runners may imply differences in the severity of injuries, body composition, and aerobic fitness values. The demand of the eccentric work of the knee flexors can explain the greater functional ratios of extension as well as the balance of the agonist and antagonist force reactions.

KEY-WORDS: TRAIL RUNNING, EPIDEMIOLOGY, MUSCULOSKELETAL INJURIES, BODY COMPOSITION, PHYSIOLOGICAL PROFILE, MUSCULAR STRENGTH AND ISOCINETICS RATIOS.

Capítulo 1

Introdução Geral

1.1 O Trail Running

O trail running (TR) é uma modalidade desportiva apelativa por ser realizada em trilhos que não tenham sido alterados pelo homem, permitindo um contato próximo com a natureza e respeito pelo ambiente. Estas particularidades associadas ao tipo de terreno (gradiente de inclinação/desnível e tecnicidade do percurso), à distância e à altimetria do percurso/trilho (1,2) que a diferencia de outras formas de corrida (maratonas ou corta-mato). A facilidade de acesso à participação de eventos, originou a organização de um elevado número de competições com a designação de "trail running". Nestes eventos, verifica-se uma elevada presença de pessoas que vai desde atletas, organizadores, voluntários, patrocinadores, acompanhantes e/ou familiares criando um impacto positivo em termos sociais e económicos nos locais que acolhem as competições (3,4).

Associado ao crescimento exponencial de corredores da modalidade, observou-se, igualmente um aumento no número de associações desportivas/clubes em termos nacionais, tornando o TR acessível a atletas não profissionais e acolhendo participantes de diferentes estratos sociais(5,6). É usual, encontrar-se nos grupos de participantes, atletas praticantes de outras modalidades desportivas. Contrariamente a outras modalidades de corrida (maratonas ou corta mato), o TR não é uma disciplina reconhecida pela IAAF (*International Association of Athletics Federation*). No entanto, o seu rápido crescimento levou a que, em 1996, se fundasse a Associação Americana de Trail Running (*American Trail Running Association - ATRA*), seguida um pouco por todo o mundo pelo aparecimento de outras associações (1,7). As diferentes organizações tiveram como base um conjunto de valores e princípios, ajustados às caraterísticas culturais de cada país, para definirem com clareza o TR.

Em 2016, foi criada a Associação Internacional de Trail Running (ITRA), com o intuito de representar e reunir consenso às diferentes comunidades de TR, dos cinco continentes (1). Esta teve também como objetivo melhorar a qualidade da organização e segurança nas corridas, saúde e bem-estar dos participantes, bem como, como aprofundar o desenvolvimento do TR para garantir um diálogo construtivo entre os organismos nacionais e internacionais com interesse neste desporto (1).

Foram definidos critérios, para reunir consenso, entre as organizações locais, associações nacionais e internacionais, sobre designações, características e definições da corrida. Estes critérios parecem não ter sido suficientes, pelo que, em março de 2018, a ITRA voltou a implementar um conjunto de informações, nomeadamente sobre categorização da corrida com o objetivo de agrupar os eventos de forma coerente (1). Os critérios apresentados não foram baseados apenas no terreno, mas também na distância, referindo que é obrigatório haver um mínimo de prova realizada em estrada pavimentada ou de asfalto (inferior a 10% do total da prova) e também ter em consideração o gradiente de inclinação existente no percurso escolhido. Outras categorias definidas foram: a quantificação da inclinação, o valor médio de elevação do percurso (altimetria), assim como o critério de "*finisher*", ou seja, o tempo estimado para a prova do atleta vencedor. As provas podem ser realizadas de dia ou de noite, e se forem provas de endurance podem realizar-se em ambas as situações (1). Para todos os eventos é consensual a informação adicional de que o praticante de TR deve ser autónomo, entre pontos de abastecimento, no que diz respeito a roupa, comunicações, comida e bebida/hidratação e deve ser informado também de que não pode poluir ou destruir a natureza no espaço que acolhe o evento (1).

1.2 O Trail Running em Portugal

Portugal, em 2012, fundou a sua associação (Associação Portuguesa de Trail Running - ATRP) após a criação da ATRA (7). A qual definiu critérios e parâmetros pelos quais os organizadores dos eventos de TR se devem reger. São sobretudo baseados nos critérios definidos pela ITRA. Em maio de 2019 a ATRP foi integrada como "associado extraordinário" da Federação Portuguesa de Atletismo, para que a ATRP e seus associados obtenham os meios e apoios necessários, bem como ajudar a regulamentar e a consolidar o reconhecimento da modalidade.

Em Portugal a designação do TR de acordo com a distância, tem a seguinte categorização (tabela 1.1):

Tabela 1.1 - Classificação por categorias de acordo com a ATRP

Categoria	**Distância (km)**
Trail curto	0 a 21,0975 km
Trail longo	21.0975 a 42,195 km
Trail ultra M	42 a 69 km
Trail ultra L	70 a 99 km
Trail ultra XL ou endurance	Superior a 100 Km

Podem participar nas provas do circuito da ATRP os atletas que tenham idade superior ou igual a 18 anos. Os eventos são organizados em diferentes níveis e nas classificações os resultados são categorizados de acordo com a data de nascimento, da seguinte maneira: Sub-23 (18 a 22 anos); Sénior (23 a 39 aos); M-40 (40 a 44 anos); M-45 (45 a 49 anos); M-50 (50 a 54 anos); M-55 (55 a 59 anos) e M-60 (acima de 60 anos) (7).

Um breve olhar sobre o número de participantes e registos de corridas a nível Nacional pode dar uma ideia do rápido crescimento da modalidade nas últimas duas décadas. A ATRP divulgou, em 2013, esta era composta por 900 associados e que, atualmente, este número é de cerca de 1500 atletas (ATRP). Em Portugal existem perto de 120 associações que desenvolvem iniciativas de promoção desta modalidade. Os atletas de TR podem participar em termos individuais ou por equipas/coletivo (não federadas) nas competições locais/regionais e/ou nas que pertençam ao Circuito Nacional da ATRP ou mesmo no calendário Internacional da ITRA. Num evento de TR, seja qual for a distância e características, podem encontrar-se tipos de corredores com objetivos e níveis de preparação/aptidão física diferentes, desde que reúnam as condições físicas e económicas para se inscrever e, muitas vezes, apenas com o intuito de finalizarem a prova (serem "*finishers*") e não propriamente de a ganharem (6). Assim sendo, existe então, um elevado número de atletas com diferentes níveis de participação, desde profissionais vs. amadores ou principiantes vs. experientes.

1.3 As lesões músculo-esqueléticas decorrentes da corrida de longas distâncias

Nos últimos anos, devido ao elevado do número de corredores, parece ter havido a necessidade de se aprofundar alguns aspetos relacionados com os praticantes e a modalidade, observando-se um aumento de publicações. Os praticantes de TR são considerados atletas de longas distâncias (8). Encontram-se estudos que pretendem, criar um perfil do atleta, incluindo caracterização de aspetos pessoais, estilo de vida, parâmetros relacionados com o treino(2,5,9), outros têm o intuito de identificar potenciais fatores de risco de saúde (9–13).

Considerada como uma modalidade que explora os limites do desempenho humano, exige portanto, treino e preparação específica para os diferentes eventos.(14) O maior enfoque da investigação parece relacionado com a performance (15–18), com a determinação de prevalência e incidência de lesões (11,19) e com a identificação de fatores de risco de lesões relacionadas com a corrida (12,20).

Na literatura consultada, a performance está descrita como sendo dependente de dois pressupostos. Primeiro, fatores relacionados com a preparação da corrida: treino, preparação/condição física e mental (6,21,22). Segundo, fatores decorrentes durante a corrida, tais como, a resposta fisiológica e neuromuscular, a condição física e emocional do atleta (9,13,23). O acréscimo de conhecimento de cada um destes aspetos permitirá elevar a qualidade de desempenho do atleta e gerar informação que poderá ser utilizada para definir planos de treino e/ou de competição com o intuito de minimizar o risco de lesões.

As lesões associadas à corrida são, atualmente, outro dos aspetos estudados, porque o elevado número de corredores (recreativos e competitivos) não pára de aumentar (24–26). Recentemente, Malliaropoulos, Merty e Tsaklis (2015), descreveram uma prevalência de 82,2% de lesões em corredores de ultra-trail resultantes da corrida/treino. Outros autores sugerem os níveis de participação originam diferentes risco de exposição a lesões (27). Encontram-se estudos que demonstram uma oscilação entre 37% a 56% de taxa de incidência de lesões resultantes da corrida em atletas recreativos, que treinam com regularidade e que participam ocasionalmente numa corrida de longa distância (28). As lesões decorrentes da corrida acabam por ter um custo negativo para o atleta, que pode ter necessidades de alterar ou suprir atividades do quotidiano devido à lesão. Algumas destas lesões levam à necessidade de procurar um profissional de saúde (médico, fisioterapeuta (e/ou enfermeiro) para avaliação e tratamento da lesão (26,28). Estes profissionais avaliam a lesão realizando uma mensuração de risco aceitável, desejando uma ausência de recidiva ou agravamento. O que poderá significar que alguns atletas aptos para regressarem à prática da modalidade, sejam mantidos mais tempo afastados do que deveriam por aplicação de critérios mais conservadores ou baseados em estudos de modalidades parecendo similares não exprimem a realidade do TR.

1.3.1. Definição de lesão

A definição de uma lesão decorrente da corrida varia de acordo com a pesquisa efetuada. Contudo, os autores são consensuais ao referir que as etiologias são multifatoriais, já que, na maioria das situações, é difícil identificar a causa exata das lesões (28,29). As lesões envolvem, frequentemente, o sistema músculo-esquelético (9,25,30). Porém, a ausência de consenso da definição de "lesão" e dos critérios associados, dificulta a comparação de resultados entre estudos, uma vez que a definição utilizada irá influenciar o número, os rácios e os tipos de lesões reportadas.

A maioria dos autores define lesão como sendo "*qualquer ocorrência (sintoma ou lesão) resultante da prática desportiva que impossibilite o atleta de realizar a atividade",* podendo afetar um ou mais segmentos (31–34). Esta definição apenas abrange lesões que restrinjam a prática da modalidade, eliminando a possibilidade de se incluir lesões, que ao serem resultantes da prática da modalidade, têm interferência noutras vertentes pessoais e sociais do praticante. São exemplo de lesões não consideradas, habitualmente, nos estudos epidemiológicos, as que são autodiagnosticadas e tratadas pelo indivíduo, sem parar de correr (35–37). Apesar da multiplicidade de definições, a literatura refere que esta se deve basear em três domínios (26,28,38,39):

1. Presença de um sintoma ou lesão numa qualquer região anatómica resultante da prática desportiva;

2. Redução ou ausência de dias de atividade desportiva;

3. Procura de avaliação, ou tratamento clínico (médico ou de outro profissional de saúde).

As revisões sistemáticas mencionam uma elevada oscilação de valores de incidência das lesões associadas à corrida, entre 19% a 79%, sendo que estas variações estão dependentes da região anatómica afetada (12,25) e das características associadas à lesão (mecanismo, severidade e tipo de tecido afetado) (24,34). Uma clara definição de lesão e dos critérios de classificação que a caraterizam permite aos estudos epidemiológicos contribuírem com informação crucial para o desenvolvimento da prevenção de lesões, tratamento e estratégias de reabilitação (40).

1.3.2 Severidade da lesão

A classificação de acordo com a sua severidade tem sido descrita com base nos critérios definidos por van Mechelen, Hlobil e Kemper (32):

- Natureza e tipo de lesão;
- Duração e natureza do tratamento;
- Tempo de paragem desportiva;
- Tempo de paragem no trabalho;
- Incapacidade permanente;
- Custo associado.

A maioria dos estudos sobre lesões, mesmo em outras modalidades, baseia-se na ausência de tempo de prática desportiva a partir da data da ocorrência da lesão até à data em que retoma em plenitude a atividade (32,38). Sendo este critério o mais utilizado pela facilidade em se recorrer ao tempo de ausência de prática desportiva a partir da data da ocorrência da lesão, através dos registos dos treinadores ou dos próprios atletas (41). Normalmente, agrupam-se as lesões em detrimento dos períodos de pausa desportiva, sendo esta divisão associada à gravidade da mesma.

A classificação de gravidade da lesão desportiva de acordo com o Sistema Nacional de Notificação de Lesões (*National Athletic Injury/lllness Reporting System* - NAIRS) refere três categorias:

- Trivial - ausência de treino de 1 a 7 dias;
- Moderadamente grave - ausência de treino entre 8 dias a 21 dias;
- Grave - ausência de treino superior a 21 dias ou lesão permanente.

No entanto, o Conselho da Europa (1989) e outros autores (32,42–44), propõem uma definição de severidade mais extensiva, não se referindo apenas ao tempo de incapacidade e/ou de restrição, que a lesão desportiva provoca no atleta, ou na identificação da região anatómica afetada, mas numa definição que tenha pelo menos uma das seguintes consequências: a redução da quantidade ou do nível de atividade desportiva; a necessidade de avaliação ou tratamento clínico (por um médico ou outro profissional de saúde); ou que tenha efeitos sociais ou económicos adversos.

É, relativamente escassa, a literatura que classifica a severidade utilizando uma combinação de fatores (tempo, tipo, local) de caraterização da lesão (20,28,45), ou que se baseie em aspetos funcionais (41) e não apenas em número de dias de ausência de treino/competição. Uma classificação fica limitada se ficar reduzida aos critérios como tempo de paragem ou necessidade de intervenção médica (28,32). Nomeadamente, porque não contempla os atletas lesionados que, não tendo recorrido de imediato aos cuidados de um profissional de saúde, procuram-nos mais tarde ou, aqueles em que não havendo restrição da participação desportiva, sofreram interferência no desempenho das atividades diárias e/ou no trabalho, em consequência da lesão. A classificação também pode sofrer influências consoante a região do corpo afetada e/ou tipo de tecido afetado pela lesão (31,40).

Neste estudo, utilizou-se uma classificação de severidade que combina um conjunto de critérios que já foram utilizados em estudos epidemiológicos associados a outros desportos (28,42,46). Para esta Tese foram definidos dois tipos de lesões associados à severidade. A **lesão ligeira**, todo e qualquer sintoma/lesão resultante da corrida (treino/competição) mas que não levou o atleta a evitar atividades diárias, a ser examinado ou tratado por um profissional de saúde e necessidade de paragem de correr (treino/competição). A **lesão significativa**, todo e qualquer sintoma/lesão que surge devida à corrida (treino/competição) e que teve impacto no atleta nos seguintes aspetos, levou o atleta a evitar atividades diárias, a ser examinado ou tratado por um profissional de saúde e/ou a ter de parar de correr (treino/competição).

1.3.3. Mecanismo de lesão

A definição do tipo de lesão, normalmente, está associada ao mecanismo que a originou. A lesão aguda, é definida como qualquer sintoma/queixa com início súbito onde o atleta consegue definir o momento específico ou relacionar com uma situação claramente identificável (32). Esta ainda se pode dividir em micro- e macro- traumática, sendo esta última considerada consoante a participação de terceiros ou não, e ter a designação de direta ou indireta (46). No TR, o desempenho e a interação com o ambiente levam a que o atleta esteja exposto a situações momentâneas, identificáveis e de exigência excessiva que resultam numa lesão aguda ou traumática (46,47). Apesar dos atletas estarem expostos a situações que podem originar lesões agudas, a literatura demonstra que, das 75% das lesões relacionadas com a corrida 28,7% foram agudas (48).

A lesão de "sobre uso" ocorre quando um esforço mecânico repetido ou excessivo é exercido sobre uma determinada estrutura do sistema músculo-esquelético (24,46) originando repetição de stress, que resulta em dano (microtraumatismo), sem causa identificável. O atleta não consegue identificar o mecanismo responsável pela condição, às vezes pode ser o resultado de uma lesão aguda que não foi corretamente reabilitada ou com sintomas residuais (49). A lesão de "sobre uso" pode surgir associado a uma inflamação ou outra lesão das estruturas músculo esqueléticas, causada por um uso/carga excessivo(a) ou não habitual, que ultrapassa o limite das possibilidades de adaptação e reparação das estruturas anatómicas (46). A literatura demonstra que das 75% lesões decorrentes da corrida 59,4% foram lesões de uso excessivo (48). As estruturas anatómicas mais expostas a tensões excessivas, agudas ou por repetição, parecem ser os tendões, as bainhas sinoviais dos tendões, os ligamentos ou os músculos (46). Na revisão sistemática Van Mechelen (1992) descreve que 54% a 74% de todas as lesões resultantes da corrida tiveram como causa o uso excessivo. A identificação precoce deste tipo de lesão e, consequentemente, identificação da causa da sobrecarga nas estruturas, permite que o dano seja controlado e o seu impacto minimizado. A correta identificação da condição e posterior tratamento ajuda na redução da gravidade da lesão (28). Por vezes, o tratamento pode implicar apenas a introdução de pequenas modificações no programa de treino (tipo, duração e intensidade) ou de planear exercícios de fortalecimento e de flexibilidade com o objetivo de corrigir desequilíbrios musculares (28,50,51).

1.3.4 Fatores de risco da lesão

O aparecimento da lesão pode ainda estar associado a um conjunto de fatores que afetam os padrões de lesão e a incidência de lesões em corredores (28). Existem vários fatores (extrínsecos/externos ou intrínsecos/internos) que podem estar associados às lesões. São considerados **fatores extrínsecos** os aspetos situacionais como os métodos de treino (distância; duração; frequência; ritmo e intervalo), treino delineado por um treinador; o tipo de superfícies/terreno de treino; ou ambientais (altimetria, humidade, temperatura) ou os equipamentos como o tipo de calçado (52,53).

Os **fatores intrínsecos**, por outro lado, são os que possuem uma etiologia imputável ao organismo e podem ser associados à idade e nível de experiência, à composição corporal (peso; índice de massa corporal); tipo de dieta e fatores psicológicos (52,53). Há autores que consideram os seguintes fatores como suscetíveis de originar lesão na extremidade inferior: a força muscular, a flexibilidade e alguns aspetos antropométricos comuns como altura e/ou tipo do arco plantar, diferença no comprimento das extremidades, o desalinhamento inter-segmentar da extremidade inferior (ângulo-Q e consequente alinhamento varo/valgo do joelho) (12,28). Muitos dos aspetos aqui referidos poderão ser modificáveis desde que identificados precocemente.

Deve-se realçar que muitos pesquisadores identificam vários aspetos que contribuem para as lesões em corrida, porém há uma falta de evidências conclusivas sobre alguns dos fatores identificados (52). Analisados os resultados que pretendem identificar e verificar uma associação de risco, alguns dos fatores foram apresentados como tendo uma ação protetora (53). Assim, a aquisição de conhecimentos com a identificação de fatores de risco e de proteção modificáveis e não-modificáveis para lesões relacionadas com a corrida é importante, na medida em que pode ajudar no tratamento e na prevenção de lesões.

1.3.5. Localização e tipo de tecido afetado pelas lesões

As regiões anatómicas mais frequentes de ocorrência das lesões resultantes da corrida estão bem descritos (12,25). Existindo consenso na literatura que identifica a extremidade inferior como sendo a região mais exposta (11,28,51,54).

Algumas das revisões sistemáticas referem que a maioria das lesões (82,2%) são devido ao uso excessivo das estruturas anatómicas (impacto e movimentos repetidos) em atletas de corrida de longa distância (10,11,28). Segundo Hreljac e Ferber (54), o local predominante das lesões da extremidade inferior é o joelho, cuja incidência específica de localização varia de 7,2% a 50,0%. As lesões em ambas as extremidades inferiores (9,0% a 32,2%), tornozelos/pés (5,7% a 39,3%) e da perna (3,4% a 38,1%) são comuns, e os valores variam de acordo com as distâncias e tipo de atleta (10,24,54).

Da análise da literatura, os tecidos moles são também as estruturas comumente afetadas por lesões relacionadas com a corrida. Os tecidos associados referenciados com maior risco são os ligamentos, tendões e cartilagens, porque a sua adaptação à carga mecânica é lenta, comparativamente aos músculos (46). Os diagnósticos clínicos mais identificados são os seguintes: síndrome da banda iliotibial, síndrome do stress tibial (shin-splints, periostite medial da tíbia), síndrome da dor patelo-femoral, tendinite do Aquiles e fascite plantar (24,46,55,56). Outras, não tão frequentes, mas que são reportadas na literatura associadas a corredores de endurance, são as fraturas de stress (57). Estas lesões podem variar desde inflamação a degeneração estrutural e muitas são resultantes de sobre uso das estruturas

(46,56). As lesões agudas, apesar de não serem tão frequentes, são maioritariamente associadas a lesões em estruturas: musculares (ruturas, cãibras); ligamentares (entorses) ou cutâneas (bolhas e abrasões) (25,46) e podem, ocasionalmente, surgir associadas a situações mais traumáticas como a lesão óssea (fraturas) (10,46,57,58).

1.4 As principais características do atleta de trail running

1.4.1 Características demográficas (idade e sexo)

O atleta de TR está descrito na literatura como sendo um corredor com uma idade um pouco superior atletas de outras distâncias (5,59–61). Na verdade, a maioria dos corredores (homens e mulheres) de longas distâncias, têm em média, entre 40 e 49 anos de idade (59,61).

A percentagem de participação de acordo com o sexo apresenta uma diferença acentuada. Os estudos indicam que cerca de 80% dos participantes em ultramaratonas são homens (17,62,63) sendo que este número parece não sofrer alterações nas últimas décadas. Isto não acontece com o número de mulheres inscritas nas corridas de longas distâncias, pois a tendência nos últimos anos é de uma maior participação (cerca de um aumento de 10% em 1998 e de 16% em 2011) nas ultramaratonas (64,65). As diferenças antropométricas e fisiológicas inerentes às características humanas, fazem com que os homens sejam tendencialmente mais rápidos do que as mulheres. De acordo com a literatura, sabe-se que os homens têm maior quantidade de massa muscular e um coração com maiores dimensões. Estas características proporcionam vantagem aos homens, devido ao maior débito cardíaco e consequentemente maior volume sanguíneo o que lhes confere maior capacidade de oxigenação (61,66). Mas o estudo da performance também se relaciona com o aspeto idade. O estudo da idade nestes atletas tem sido alvo de alguma investigação, sendo consensual que, a média de idade onde se obtém a melhor performance ocorre entre os 30 e os 40 anos, nos homens e entre os 30 e os 54 anos, nas mulheres (59,64,67,68). Por outro lado, a idade também é fator de afastamento de alguns atletas da modalidade, em corridas mais curta e rápidas, como os 1500-m (média de idade 21,1 ± 3,4 anos), ou as maratonas com 42-Km (média de idade 25,4 ± 3,4 anos) (69). Em estudos recentes, identificou-se uma relação entre idade a diminuição de performance e o aumento do tempo necessário para realizar uma corrida, sendo apontado o intervalo de idades entre os 40 e os 50 anos, para que o declínio de desempenho seja mais visível (66). Nas mulheres a diminuição da performance é mais evidente depois dos 44 anos e nos homens depois dos 54 anos (64).

1.4.2 Composição e tamanho corporal

Alguns dos estudos sobre corredores de longas distâncias, referem que o atleta apresenta características antropométricas que parecem potenciar a sua capacidade em realizar distâncias superiores às maratonas (17,70–72). Pode dizer-se que o corredor de longas distâncias é caraterizado por apresentar pequenas quantidades de massa gorda e menores dimensões das circunferências nas extremidades (15,73–75). Estudos transversais, mostram que os corredores de longas distâncias têm um índice de massa corporal dentro dos parâmetros normais, tendo os homens tendência a excesso de peso comparativamente às mulheres presentes nos mesmos estudos (76). Estudos transversais corroboraram o papel negativo da massa gorda no desempenho (2,8) e na velocidade da corrida, havendo evidência de que esta é responsável por cerca de 10% a 12% da variação da velocidade do atleta (17). Contudo, a massa gorda também é uma forma biológica de armazenamento de energia e existe um nível mínimo recomendado para atletas de eventos longa distância (77,78), e que as características físicas (quantidade de massa gorda e peso corporal) são referidos em simultâneo com o desempenho (velocidade e tempo para terminar uma corrida) (79,80).

O impacto da participação em corridas de longas distâncias sobre o tecido ósseo ainda não é muito estudado. Por exemplo, a revisão de literatura de Tenforde e Fredericson (81), mostrou que as modalidades que envolvem cargas de grande impacto (ginástica, voleibol) ou de alto impacto ocasional, promovem maior composição mineral óssea, densidade mineral óssea e levam a alterações na geometria óssea, em regiões específicas do atleta (81). Por outro lado, estudos em corredores de diferentes distâncias revelaram que, os que praticam em distâncias curtas, estão sujeitos a forças de grande impacto num curto espaço de tempo, o que promove o aumento da densidade óssea quer em todo o corpo quer em regiões especificas, tais como as extremidades inferiores (82). Acredita-se que o conteúdo mineral e a densidade óssea aumentam como consequência do exercício e exposição à carga (57,83–86). Curiosamente, as revisões de literatura mostram que os atletas de longas distâncias apresentam valores baixos de densidade mineral óssea (57). Estas modalidades obrigam a um consumo excessivo de nutrientes que são importantes para a saúde óssea (cálcio, vitamina D). As corridas de longas distâncias colocam, muitas vezes, o atleta em risco de desidratação, fadiga extrema, dano ósseo e tecidular (57,87). De acordo com Hoffman e Krishnan (10) os atletas de ultramaratonas, após terem intensificado o treino de corrida para em mais do que 3 vezes por semana, apresentaram fraturas de stress relacionadas com a corrida.

1.4.3 Vias metabólicas e fatores neuromusculares

O TR é um desporto de endurance descrito como sendo maioritariamente dependente da contribuição do sistema aeróbio. O consumo máximo de oxigénio é um indicador das adaptações centrais que permite inferir a capacidade, que o atleta tem, de responder fisiologicamente ao exercício prolongado (2,88,89). É ainda, definido como a "maior taxa à qual o oxigénio pode ser captado e utilizado pelo corpo durante o exercício físico intenso" (88). A par deste indicador, também a concentração de lactato sanguíneo é considerada um bom preditor do desempenho em corrida de longas distâncias (90,91). Os atletas de longas distâncias parecem ter concentrações mais baixas quando comparadas com corredores de distâncias mais curtas (91). Presume-se que, o atleta que apresente valores mais baixos de concentração de lactato sanguíneo, tem melhor desempenho de corrida. O desempenho nos desportos de maior resistência requer consistentemente valores máximos elevados de consumo de oxigénio (92). Esta ideia é fundamentada na literatura em artigos de revisão e descrita em estudos com modalidades de longa distância como a ultramaratona (69,93,94). Outro indicador frequentemente utilizado, é a frequência cardíaca. Os monitores de análise de frequência cardíaca são acessíveis e acabam por ser uma ferramenta científica básica que ajuda no controlo indireto do sistema cardiovascular. De uma maneira simples o atleta pode controlar e regular o esforço durante a prova/treino ajustando a velocidade da corrida com base nos valores de frequência cardíaca (95). A frequência cardíaca é também um indicador utilizado pelos treinadores na prescrição de exercício (96).

Existem informações muito limitadas sobre a contribuição do metabolismo anaeróbio ou da influência da atividade muscular e da velocidade de transformação da energia, de ATP intramuscular e fosfatos de alta energia para a potência mecânica, durante as corridas de longa distância. O contributo deste metabolismo parece ser menor em eventos de longa distância comparativamente a corridas mais rápidas (97) ou com desportos com esforços e gestos balísticos ou de força explosiva (98), onde ocorre elevadas taxas de produção de força em curtos espaços de tempo. Legaz-Arrese et al. (99) obtiveram resultados semelhantes na avaliação de indicadores anaeróbios de atletas que corriam diferentes distâncias (desde 100-m até 42-km). Estes referiram que o desempenho eficaz, mesmo durante as longas distâncias, esteve relacionado com a quantidade de contração muscular e tipo de fibras envolvidas na atividade, mas também com a capacidade de oxigenação do tecido muscular (99). Uma das caraterísticas da corrida de trail são os percursos irregulares, com desníveis e piso diverso (riachos e pedras de diferentes dimensões, etc.) que, por vezes, levam o atleta a realizar movimentos explosivos e rápidos (saltos, sprints) (100), havendo para isso uma contribuição do sistema anaeróbio. Este esforço está relacionado com determinantes periféricos e com a capacidade de o sistema muscular responder ao incremento de esforço, num curto tempo. Para estes atletas, o treino e a sua preparação não pode restringir-se à componente aeróbia, mas também devem incluir incremento no desempenho anaeróbio (97,101–103).

Os fatores neuromusculares podem ser estudados através de avaliações de força, recorrendo a protocolos no dinamómetro isocinético. O joelho tem sido identificada como sendo a região anatómica mais associada às lesões relacionadas com a corrida, por esta razão, os estudos centralizam a avaliação do desempenho funcional em torno desta articulação (71,91,104). Na avaliação isocinética da função muscular do joelho, o máximo de força (pico de torque -PT) gerado pelos extensores e flexores e a relação de PT entre flexores-extensores estão entre os parâmetros isocinéticos mais comumente utilizados. Assim sendo, a força desenvolvida pela extremidade inferior parece ser um fator determinante para que o atleta possa superar o desafio de correr longas distâncias, em condições específicas, tais como a elevação e tecnicidade do terreno (105,106). Por outro lado, a força também tem sido relacionada com a economia da corrida (107) mas também pela implicação que possa ter no aparecimento de lesão, nomeadamente, se houver déficit de força e/ou se verifique a presença de desequilíbrios musculares (104,108).

Como já referimos anteriormente, o TR tem nas suas caraterísticas percursos com descidas e subidas que parecem originar maior esforço mecânico nas estruturas musculares, da extremidade inferior (66,104). Em geral, os músculos das extremidades inferiores produzem maior trabalho mecânico durante a corrida em declive positivo (subidas), enquanto que durante a corrida em declive negativo (descidas) a dissipação da energia é predominante (109). Após a corrida em declive prolongada, a diminuição da função neuromuscular dos extensores do joelho parece estar associada à fadiga metabólica em subidas e a danos mecânicos em descidas, relacionados principalmente com ações musculares concêntricas e excêntricas, respetivamente (110). As descidas, são foco de estudo, por serem consideradas como sendo causadoras de alterações neuromusculares (periféricas e centrais) agudas (66,111,112). De acordo com alguns autores, os dois principais determinantes do desempenho dos corredores ultra-trail são: o tempo do esforço, associado a provas muitas vezes de 4 ou mais horas; e a elevada quantidade de trabalho excêntrico imposto nos extensores do joelho durante a fase negativa do percurso da corrida (66,113). Reforçando a ideia de que a força muscular e o equilíbrio da ação muscular, dos extensores e flexores do joelho, podem ser importantes para o desempenho em corrida e para a prevenção de lesões (114,115). Tem sido referido que o desequilíbrio excessivo entre os grupos musculares recíprocos predispõe a articulação e o grupo muscular mais fraco à lesão (116). As razões convencionais e funcionais resultantes do PT dos grupos musculares à mesma velocidade angular, são utilizados para descrever a função do joelho, mas tem limitações (117). Em primeiro lugar, na razão convencional, o PT concêntrico gerado pelo quadricípite é, normalmente, comparada com o PT gerado pelo seu antagonista, com o mesmo tipo de ação muscular, não traduzindo a relação que ocorre entre estes dois grupos, durante os movimentos funcionais (118). Em vez disso, a co-ativação antagonista ocorre excentricamente para controlar/conter a contração concêntrica agonista, ou vice-versa (117,119). A utilização da razão funcional permite analisar a combinação dos valores de torque máximo, obtido das ações musculares concêntricas e excêntricas (118). Em segundo lugar, estes valores são normalmente citados independentemente do ângulo articular em que ocorrem, o que ignora o efeito do comprimento muscular levando a que o potencial da dinamometria isocinética permaneça sub-explorado.

1.5 Fundamentação, objetivo e esquema da tese

Verifica-se que a quantidade de estudos publicados sobre TR, até agora, não parece fornecer informações claras sobre diferentes aspetos epidemiológicos, físicos e fisiológicos em atletas de trail running com níveis diferentes de participação. Mais concretamente, a caracterização das lesões músculo esqueléticas e, considerando as lesões significativas das extremidades inferiores que determinantes podem estar associados ao seu aparecimento. E, fazendo uso de metodologias precisas de avaliação direta, caraterizar os atletas de ultra-trail running no que diz respeito a parâmetros morfológicos, fisiológicos e neurofuncionais.

A maioria dos atletas, dedica muitas horas de treino para que possa estar nas condições ideais de participação nas provas. Os eventos diferem quer no grau de dificuldade quer nas distâncias. Estes parâmetros associados aos objetivos de cada corredor, origina a participação de atletas com diferentes níveis de participação, a nível regional/local, nacional ou internacional.

Face a estas particularidades, colocaram-se as seguintes questões:

- O tipo de participação pode traduzir diferenças no tipo e na localização de lesões?

- Que tipo de tecidos são mais afetados considerando o tipo de lesão e a sua distribuição por regiões anatómicas da extremidade inferior?

- Se a extremidade inferior é, tendencialmente, a mais afetada, que determinantes contribuem para a prevalência de lesões significativas?

- Será que o atleta que corre ultradistâncias e que se insere em níveis diferentes de participação, apresenta aspetos morfológicos e funcionais similares?

- E o atleta de ultra-trail running terá, pela especificidade da modalidade, uma resposta neuromuscular diferente de atletas que realizam outros desportos?

Como já foi referido anteriormente, efetivamente, esta modalidade, nos últimos anos, teve um acréscimo do número de participantes e do número de eventos. Os praticantes de TR, face às particularidades de modalidade, ficam expostos a fatores de risco extrínsecos e intrínsecos quando correm. A maioria dos fatores extrínsecos não são modificáveis, nomeadamente os que estão relacionados com o meio em que decorre o evento/corrida. No estudo aqui apresentado, numa primeira parte, houve a pretensão de identificar a prevalência das lesões músculo esqueléticas e, posteriormente, de dar a conhecer um conjunto de fatores que poderiam ser causadores de lesões. Numa segunda parte, tentou-se caraterizar o perfil dos corredores adultos masculinos de longa distância (ultra-trail). Deu-se a conhecer a composição corporal do atleta, os seus limites fisiológicos e funcionais, que também têm sido descritos como sendo fatores determinantes de lesões além de indicadores de performance.

Estes conhecimentos ajudarão quer os treinadores quer outros profissionais, bem como os próprios corredores, a desenvolverem estratégias e planos de treino adequados ao nível de participação e, consequentemente, a contribuir para a prevenção de lesões. Apesar de nem todas as lesões decorrentes da corrida, levarem o atleta a procurar avaliação e/ou tratamento por um profissional de saúde, o fisioterapeuta, foi identificado como sendo o profissional de saúde a quem, cerca de 90% dos corredores recorre se estiverem com lesões (9). Caberá a este profissional, especialista na reabilitação, delinear estratégias de intervenção, ajustadas ao tipo de atleta, sabendo que este poderá ter características específicas (9,50), por exemplo, se se considerar o nível de participação. Este estudo permite complementar os conhecimentos do fisioterapeuta, quer que trabalhe em contexto de clínica ou integrado em equipas multidisciplinares, por exemplo, integrado na seleção nacional de TR ou associações/clubes desportivas. O leque de informações aqui exposta, pretende facilitar a avaliação e posterior acompanhamento do corredor de TR. No caso de aparecimento de lesão, deve dotar o profissional de saberes na área da fisiologia do exercício e da saúde, que servem de auxílio na definição dum plano de intervenção terapêutica. O fisioterapeuta avalia e define a sua intervenção, no sentido da prevenção da incapacidade ou da lesão, bem como no tratamento de condições patológicas relacionadas com a prática desportiva (http://www.apfisio.pt). As técnicas de intervenção utilizadas são muito variadas, desde as terapias manuais, exercícios terapêuticos e/ou à utilização de agentes físicos e termoterapia (120).

O presente trabalho teve como objetivos:

1. Determinar a prevalência e caracterizar de lesões músculo esqueléticas, de acordo com o nível de participação, em atletas Portugueses de trail running. - artigo 1
2. Caracterizar as lesões músculo esqueléticas nas extremidades inferiores, determinar a ocorrência e identificar os determinantes das lesões significativas nas extremidades inferiores em atletas de trail running portugueses. - artigo 2
3. Examinar a composição corporal dos corredores de ultra-trail e, adicionalmente, comparar dois grupos, de acordo com o nível de participação (Regional vs Nacional). - artigo 3
4. Descrever a aptidão aeróbia e anaeróbia dos atletas adultos masculinos ultra-trail running, de acordo com o seu nível de competição (Regional vs Nacional). - artigo 4
5. Elaborar um perfil de força isocinética das ações musculares do joelho de corredores de ultra-trail Portugueses, em comparação com atletas de diferentes desportos. - artigo 5

O documento aqui apresentado está elaborado de acordo com o modelo escandinavo e apresenta-se dividido em capítulos.

O **primeiro capítulo** diz respeito à introdução geral sobre a modalidade e o atleta de TR e termina com os objetivos do projeto de investigação.

O **segundo capítulo**, fornece uma descrição dos procedimentos e amostras estudadas, bem como os materiais e métodos utilizados para a avaliação dos atletas e registo de dados.

O **terceiro capítulo,** apresenta os artigos originais, procurando responder aos objetivos da proposta, no que diz respeito aos atletas de TR. Iniciou-se com o estudo retrospetivo (caso-controlo), que pretendeu caracterizar a prevalência e tipologia das lesões músculo esqueléticas relacionadas com o TR, numa população masculina de atletas portugueses. Apesar do significativo aumento da participação das mulheres nesta modalidade, os homens correspondem à maioria dos participantes e têm mais experiência de treino e de participação em competição, em eventos de corridas de longa distância. Apenas por estas razões, se restringiu o estudo à população masculina tendo como expectativa a obtenção de informação detalhada e importante para o trabalho subsequente. O estudo final é observacional e é composto por três artigos. Estes pretendem facultar informações que ajudem a conhecer o atleta que participa em eventos com distâncias superiores a 42-km (ultra-trail running) no que diz respeito à sua morfologia, resposta das vias metabólicas e parâmetros neuromusculares.

No **último capítulo**, serão apresentadas a discussão geral e as conclusões, com as principais implicações clínicas e eventuais aspetos práticos, que podem ser utilizados para futuras pesquisas e intervenções no âmbito da fisioterapia.

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Capítulo 2

Considerações Metodológicas

2.1 Caracterização dos estudos e amostra

Este projeto assenta em dois estudos; o primeiro com uma abordagem descritiva epidemiológica retrospetiva, e o segundo, com um desenho descritivo comparativo transversal. O projeto foi previamente aprovado por duas comissões de ética (Universidade do Porto: CEFADE 17.2017; Universidade de Coimbra: CE/FCDEF-UC/00102014).

O questionário concebido para o estudo descritivo epidemiológico (primeiro estudo: artigo 1 e 2), foi disponibilizado no período de janeiro de 2018 a abril de 2019. O método de amostragem em "bola de neve" foi aplicado e destinado a recrutar atletas voluntários que praticam trail running. Este estudo segue as diretrizes da STROBE para relatar recrutamento, exposição, recolha de dados e resultados de estudos observacionais (1).

A recolha de dados, necessária para o segundo estudo, foi realizada no Laboratório Integrado da Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra e no laboratório de Imagiologia de um Hospital Privado de Coimbra (segundo estudo: artigo 3 a 5). Os procedimentos deste estudo seguiram as normas éticas recomendadas para investigação científica com humanos (2). As diferentes fases de medições e recolhas foram supervisionadas por um investigador qualificado e experiente, respeitando os protocolos definidos a cada equipamento específico.

Foi ainda elaborado, para ambos os estudos, um consentimento informado com a descrição do estudo, objetivos e procedimentos (quando se justificasse). Ficou também claro que podiam desistir em qualquer altura do processo de recolha de dados (questionário ou laboratório).

2.1.1 Cálculo de amostra

Para o primeiro estudo (epidemiológico), o tamanho da amostra foi determinado usando uma prevalência estimada de 80% de lesões (conforme estudos de revisão sistemática, mencionados), assumindo uma margem de erro de 5% com intervalo de confiança de 95%.(3,4). Assim o tamanho da amostra foi calculado de acordo com a fórmula: n = [z2 * p * (1 - p) / e2] / [1 + (z2 * p * (1 - p) / (e2 * N))] (onde, n = número de participantes da amostra, z = 1.96 para um intervalo de confiança (α) de 95%, p = 0.80, e = 0.05); N= 1500). Utilizando estes pressupostos, o tamanho mínimo da amostra seria de 307 atletas.

Foram considerados válidos para participarem no estudo 403 atletas de trail running masculinos com idade compreendida entre 18 e 62 anos. A maioria dos participantes (67.0%) era casado (maritalmente ou em união de facto). Relativamente ao nível mais elevado de ensino 53.8% referiam ter um nível de estudos superiores completos (licenciatura, mestrado ou doutoramento); por outro lado, 38.0% descreveram que o tempo despendido por semana no seu local de trabalho se situava entre as 40 a 44 horas semanais (tabela 2.1.).

Tabela 2.1 - Estatística descritiva para a totalidade da amostra (n=403).

Variável	*N*	Percentagem valida (%)
Nível de ensino/escolaridade		
Ensino básico 2º e 3º ciclos (6º e 9º anos)	35	8.7
Ensino secundário (12º anos)	151	37.5
Estudos superiores (licenciatura, mestrado, doutoramento)	**217**	53.8
Situação profissional		
Empregador/a	22	5.5
Trabalhador/a por conta própria	48	11.9
Trabalhador/a por conta de outrem	**313**	77.7
Desempregado/a	6	1.5
Estudante	14	3.5
Horas de trabalho por semana		
1 a 4 horas	6	1,5
5 a 14 horas	15	3,7
15 a 29 horas	15	3,7
30 a 34 horas	17	4,2
40 a 44 horas	**153**	38,0
45 ou mais horas	93	23,1

A distribuição dos participantes por escalões foi a seguinte: Sub23 (4.0%); Sénior (40.9%), M40 (28.3%); M45 (16.1%); M50 (6.2%); M55 (3.5%) e M60 (1.0%). Desta amostra, 83.9% dos participantes disseram estar inscritos ou pertencer a uma associação desportiva e 77.7% não têm um profissional especializado ou recebem orientação para programar o treino. De acordo com o nível de participação, 53.6% referiram participar em eventos a nível Nacional e Internacional e 46.4% participam em eventos locais, sendo assim classificados no grupo de nível Regional.

Para o **segundo estudo**, a amostra utilizada foi obtida com base numa amostragem de conveniência. O tamanho da amostra foi semelhante ao de estudos anteriores com corredores de longas de distâncias (5–8). Esta amostra foi composta por atletas que aceitaram participar, que cumpriram os critérios de inclusão e que se disponibilizaram a comparecer no laboratório. As características e definição de critérios de inclusão estão definidos em cada um dos artigos. No total participaram 44 atletas de UTR portugueses e 28 atletas de diferentes desportos que foram recrutados no Estádio Universitário de Coimbra. Os atletas de outros desportos foram incluídos apenas para no artigo 5.

Na Tabela 2.2. estão resumidas as características básicas de cada estudo em relação ao desenho, amostragem e variáveis estudadas.

Tabela 2.2.- *Desenho, amostragem e variáveis estudadas nos estudos realizados.*

<table>
<tr><th></th><th>Artigo</th><th>Desenho</th><th>Caraterísticas da amostra</th><th>Idade</th><th>Variáveis estudadas</th></tr>
<tr><td rowspan="2">Primeiro Estudo</td><td>Artigo 1</td><td rowspan="2">Descritivo epidemiológico
Estudo retrospetivo de Caso-controle</td><td rowspan="2">403 participantes masculinos de trail running portugueses</td><td rowspan="2">18 a 62 anos</td><td>Prevalência de lesões músculo esqueléticas; nível participação; localização das lesões, caraterização das lesões</td></tr>
<tr><td>Artigo 2</td><td>Determinantes das lesões da extremidade inferior, caraterização das lesões e tecido afetado</td></tr>
<tr><td rowspan="3">Segundo Estudo</td><td>Artigo 3</td><td rowspan="3">Transversal</td><td rowspan="2">44 atletas masculinos de ultra trail running</td><td rowspan="2">23 a 53 anos</td><td>Antropometria; tamanho e composição corporal; frequência alimentar</td></tr>
<tr><td>Artigo 4</td><td>Antropometria; tamanho e composição corporal; vias metabólicas (aptidão aeróbia e capacidade anaeróbia)</td></tr>
<tr><td>Artigo 5</td><td>42 atletas de ultra trail running (UTR) e 28 atletas de diferentes desportos (ADS)</td><td>18 a 53 anos</td><td>Força muscular isocinética; articulação do joelho; rácios</td></tr>
</table>

2.2 Instrumentos

2.2.1. Questionário de lesões músculo esqueléticas do praticante de trail running

Para o **estudo 1** utilizou-se um questionário, redigido em português, elaborado com base em estudos epidemiológicos em atletas de corrida de longas distâncias. O pré-teste do questionário foi aplicado a um grupo de atletas de trail running e, posteriormente, foram feitos alguns ajustes finais, após análise dos comentários e respostas. O questionário foi construído utilizando o software de pesquisa online (Google-Forms©). O link foi posteriormente enviado para endereços eletrónicos de equipas/associações desportivas nacionais (continente e ilhas); federações de atletismo, pedindo a cada associado e atleta de trail para convidar outros e partilhar o link (https://forms.gle/tanvXhXB448V9tkA9). O questionário podia ser disponibilizado mediante pedido (*"por favor contacte o autor correspondente"*). O questionário esteve disponível entre janeiro de 2018 até abril de 2019.

O questionário foi apresentado ao participante com uma breve explicação da natureza e objetivos do estudo, bem como considerações éticas dos dados (anonimato e confidencialidade). No final desta explicação foi solicitado a autorização de participação para assim se poder dar continuidade e acesso às partes constituintes do questionário.

Num primeiro momento, as questões elaboradas tinham como intuito reunir informação sobre dados sociodemográficos, incluindo sexo, data de nascimento, altura e peso. Num segundo momento, construiu-se um conjunto de perguntas relacionadas com o trail running, tais como, anos de experiência, nível de participação (nacional ou regional), volume do treino semanal (frequência, duração/tempo, distância, tipo de superfície utilizada), treino orientado por treinador e tipo de superfície de terreno mais frequente (estrada plana, estrada com elevação ou montanha).

Na última parte do questionário, encontrava-se um conjunto de questões que tinham como objetivo obter informações sobre lesões músculo esqueléticas relacionadas com a corrida de trail, dos últimos 12 meses. Estas questões tiveram como base o Questionário Nórdico Músculo-esquelético, utilizado internacionalmente para analisar sintomas de lesões músculo esqueléticas em diferentes populações. As perguntas incluíram a ocorrência de lesões nos últimos 12 meses, com identificação do seu local em dez regiões anatómicas (cabeça, pescoço, ombros, cotovelos, punhos/mãos, região torácica, região lombar, ancas/coxas, joelhos, tornozelos/pés). No caso de respostas afirmativas de ocorrência de lesão, eram recolhidos outros aspetos que permitiram caraterizar as lesões, tais como a severidade da lesão; tipo de lesão (aguda ou de uso excessivo) e tipo de tecido lesionado (pele, osso, músculo, articulação e nervo) isto feito através de uma listagem de um conjunto de diagnósticos/lesões músculo esqueléticas relacionadas com a corrida de trail mais comuns. Houve ainda outras questões que pretendiam mostrar se a lesão afetava (restringia ou modificava) o indivíduo em aspetos pessoais ou desportivos, como por exemplo, evitar atividades do dia-a-dia, treinar e/ou competir. Também se solicitou a identificação do número de dias de "perda" da participação; a classificação do grau de dificuldade percecionado durante a corrida; e, por último, se houve necessidade de avaliação e/ou tratamento por parte de um profissional de saúde.

2.2.2. Avaliação multicompartimental do atleta de ultra-trail running

Para a realização do **Estudo 2**, os atletas realizaram um conjunto de avaliações no Laboratório do Estágio Universitário de Coimbra. Para obtenção dos dados da Absorciometria de Raio-X de Dupla Energia, a recolha foi feita num laboratório de imagiologia num Hospital Privado da cidade de Coimbra. Para todos os sujeitos foram utilizados os mesmos instrumentos de medida e os dados recolhidos foram registados em fichas individuais.

ANTROPOMETRIA

A antropometria do corpo todo foi efetuada por um único investigador, adotando procedimentos estandardizados (9). Para estas medições os atletas foram aconselhados a ficarem com o mínimo de roupa e descalços.

- Estatura

O atleta assumia a posição antropométrica de referência: de pé ou sentado, consoante a medição, permanecendo imóvel, encostando-se ao estadiómetro e preservando as extremidades superiores naturalmente ao lado do tronco, e solicitando uma inspiração profunda. Para a recolha recorreu-se a um estadiómetro da Harpenden portátil com mesa específica (modelo 98.603, Holtain Ltd, Crosswell, UK) com uma precisão de 0.1cm (10). O comprimento das extremidades inferiores foi estimado pela diferença entre a estatura e a altura sentado.

- Massa corporal

A medição foi realizada utilizando uma balança portátil SECA (modelo 770, Hannover, MD, USA) com valores expressos em quilogramas (kg) e com a precisão de 0.1 kg. Os atletas eram mantidos numa posição estática, olhando um ponto na horizontal e com as extremidades superiores posicionadas naturalmente a longo do corpo. As medições eram repetidas duas vezes para verificação.

COMPOSIÇAO CORPORAL

- **Pletismografia de Ar Deslocado**

Para avaliação da composição corporal através da pletismografia de ar deslocado, utilizou-se o equipamento Bod Pod Body Composition System (modelo Bod Pod 2006, Life Measurement Instruments, Concord, CA, USA). Para obtenção dos dados conectou-se uma balança eletrónica ao computador do pletismógrafo. A calibração do equipamento foi realizada antes de cada teste utilizando um cilindro de 50.255 L. Os atletas usaram equipamento adequado ao teste, calções de banho e touca de lycra. Os atletas foram avaliados duas vezes consecutivas, consideradas como suficientes caso diferença fosse inferior a 150 ml. Se fosse necessária uma terceira avaliação, iniciava-se uma nova rotina de calibração do equipamento.

O volume médio de ar nos pulmões e tórax, durante a respiração corrente normal, foi estimado a partir do sexo, idade estatura e massa corporal, para cada sujeito de forma a que fosse possível obter o valor do volume corporal. A densidade corporal foi calculada dividindo a massa corporal (kg) pelo volume corporal (L). A percentagem de massa gorda foi estimada utilizando a equação de Siri (1961), (%MG = [(4,95/D) – 4,50] x 100) para adultos (11). A percentagem de massa gorda foi convertida (em kg) para determinar a massa gorda. A massa livre de gordura foi estimada pela subtração da massa gorda à massa corporal.

- Impedância Bioelétrica

Para análise da impedância bioelétrica utilizou-se o equipamento BIA 101 (System Analyzer, Akern, Florence, Italy). Este método, não invasivo, permite realizar uma estimativa bicompartimental sobre a composição corporal, a partir da medida de resistência (Rz) e de reactância (Xc). A passagem de uma corrente elétrica de baixa intensidade (800 µA) e de frequência constante (50 kHz) (10). Foram efetuadas duas medições para cada atleta. A aplicação da técnica tetrapolar consistiu em deitar os atletas numa marquesa, na posição de supino, afastando as extremidades do hemicorpo direito e, posteriormente, colocar 2 elétrodos na mão e 2 elétrodos pé, respetivamente. A estimativa das variáveis de composição corporal (massa celular e do índice de massa celular corporal, água corporal total, água intracelular e água extracelular, massa gorda, massa isenta de gordura, massa muscular, taxa de metabolismo basal) foi efetuada com recurso à aplicação informática Bodygram - version 1.3 (Akern Srl, Florence, Italy).

- Absorciometria de Raio-X de Dupla Energia

Para avaliação da composição corporal através da Absorciometria de Raio-X de Dupla Energia, foi utilizado o equipamento Lunar DPX-MD+ (Software: enCORE version 4,00,145, GE Lunar Corporation, 726 Heartland Trail, Madison, WI 53717-1915 USA. Os atletas foram posicionados em decúbito dorsal na marquesa, para permitir que o equipamento realizasse um scanner da totalidade do corpo do indivíduo, iniciando da cabeça para os pés (12) Este procedimento permitiu, posteriormente, obter medições específicas dos diferentes segmentos corporais. A recolha e interpretação dos dados foram efetuadas sempre pelo mesmo técnico num laboratório certificado de uma unidade privada hospitalar.

- Avaliação da frequência alimentar

Recorreu-se ao questionário de frequência alimentar (QFA) para avaliar a ingestão de alimentos relativa aos últimos 12 meses do ano. O QFA foi desenhado de acordo com Willett et al. (13) e adaptado para a população portuguesa pelo Serviço de Higiene e Epidemiologia da Faculdade de Medicina da Universidade do Porto (14). Através de um conjunto de questões o QFA permitiu obter a frequência e a quantidade (porções) de ingestão de cerca de 86 alimentos, possibilitando ainda a quantificação de outros que não se encontrem discriminados na listagem, mas que ao fazerem parte do consumo habitual foram reportados/adicionados pelos atletas. O QFA inclui oito grupos de alimentos (I – produtos lácteos; II – ovos, carnes e peixes; III – óleos e gorduras; IV – pão, cereais e similares; V – doces e pastéis; VI – hortaliças e legumes; VII – frutos; VIII – bebidas e miscelâneas). Usando uma escala de nove opções (de "nunca ou menos de uma vez por mês"; "uma a três vezes por mês"; "uma vez por semana"; "duas a quatro vezes por semana"; "cinco a seis vezes por semana"; "uma vez por dia"; "duas a três vezes por dia"; "quatro a cinco vezes por dia"; "seis ou mais vezes ao dia"). Os valores finais resumem a quantidade de calorias e nutrientes (colesterol, fibras, etanol e cálcio, percentagens de proteínas, hidratos de carbono e gorduras) (14,15), que são considerados componentes principais a nível molecular e que igualmente permitem avaliar a composição corporal dos atletas.

AVALIAÇÃO DE DESEMPENHO DAS VIAS METABÓLICAS

- Desempenho aeróbio

A capacidade aeróbia máxima foi determinada através de um teste de corrida incremental, utilizando o tapete rolante motorizado (Quasar, HP Cosmos, Alemanha). A calibração e as medições do ar ambiente foram realizadas antes de cada sessão de testes, de acordo com as diretrizes do fabricante. Antes de cada teste, o fluxo e o volume foram calibrados através da utilização de uma seringa com capacidade de 3 L (Hans Rudolph, Kansas City, EUA). O analisador de gases (CO2 e O2) foi calibrado com o kit (Cosmed, UN1956, 560L, 2200 psi, 70^{o}F), utilizando gases de concentrações conhecidas. A frequência cardíaca (FC) foi medida durante todo o teste com um monitor de FC, disponível comercialmente (Polar Electro, Finlândia), conectado ao sistema analisador de gases. No final do teste foi efetuada a recolha de sangue, do primeiro dedo da mão direita, de 25 µl para avaliar a concentração de lactato utilizando uma lanceta descartável (UniStik 2 Extra). A concentração de lactato foi medida com um analisador portátil (Lactate Pro2 Analyzer, Arcay, Inc.). Os procedimentos protocolares iniciaram-se com um aquecimento de dois minutos, iniciou-se a uma velocidade de 8 $km.h^{-1}$, com uma inclinação do tapete rolante de 2%, para familiarizar os atletas com os equipamentos (em particular o aparelho da ergo-espirometria). O teste iniciou-se com a velocidade de 10 $km.h^{-1}$ com um incremento de carga que se traduziu num aumento de 1 $km.h^{-1}$ em cada minuto. Este aumento foi efetuado até à exaustão voluntária do atleta (16). A perceção de exaustão foi obtida com recurso à escala de Borg CR-10. A capacidade aeróbica máxima era confirmada se o atleta atendesse aos seguintes critérios: relação de troca respiratória (RER) superior a 1,05; FC dentro dos 5% do valor máximo previsto para a idade; plateau no consumo de oxigénio apesar do aumento da intensidade do exercício; perceção de exaustão; a concentração de lactato sanguíneo ser superior ou igual a 8 mmol.L, no período de recuperação imediatamente após o esforço máximo (17).

- Desempenho anaeróbio

Para a avaliação do desempenho anaeróbio foi realizado o teste de 30 segundos, de Wingate. Para realização do teste utilizou-se uma bicicleta ergométrica Monark AB (modelo 824E Peak Bike, Varberg, Sweden), com sensor ótico, ligado a um computador. Antes de se iniciar o teste calculou-se a resistência a ser aplicada, que foi fixada em 0,075 kg por unidade de massa corporal. Ajustou-se o posicionamento na bicicleta em função do tamanho corporal do atleta. A altura do banco deveria permitir que o membro inferior deveria ficar ligeiramente abaixo da extensão máxima no momento final, após um ciclo completo de movimento. Após estes procedimentos, iniciou-se o protocolo estandardizado de aquecimento (18), consistindo em pedalar durante três minutos a 60 rpm, seguido de um conjunto de exercícios de alongamento das extremidades inferiores no tapete. Antes de se dar início ao teste máximo, os sujeitos pedalaram normalmente a uma velocidade constante de 60 rpm sem resistência, até atingirem o "steady-state" durante cinco segundos. É dado o sinal ao indivíduo para se preparar e começa-se uma contagem decrescente que dá início ao teste. O investigador indica o começo do teste com a palavra "já". O atleta inicia o exercício/pedalar em máximo esforço para atingir o pico máximo de rotações e, consequentemente, de potência mecânica, acontecendo esta, habitualmente, nos primeiros 5 a 6 segundos (19). Após este período, o atleta é incentivado pela equipa de avaliadores a manter um desempenho o mais elevado possível, pedalando o mais rápido que conseguir sem se levantar do assento, até ao limite temporal de 30 segundos (20). No final dos 30 segundos, e para que o atleta possa recuperar do esforço, este continua a pedalar contra uma carga de (0.50 kg, com cesto apoiado), durante alguns minutos.

AVALIAÇÃO DA FUNÇAO NEUROMUSCULAR

- Força muscular isocinética

Recorreu-se a um dinamómetro isocinético (Biodex System 3, Biodex Medical Systems, Shirley, NY, EUA), respetivo *software* (Biodex System 3, Biodex Medical Systems, Shirley, NY, EUA) e procedimentos padronizados de recolha e análise de dados (21), para avaliar as ações musculares concêntricas e excêntricas (recíprocas) dos extensores e flexores do joelho do membro inferior dominante. A calibração standard foi realizada de acordo com as diretrizes do fabricante. O protocolo de aquecimento realizou-se com o atleta a pedalar num ciclo-ergómetro Monark (Ergomedic 814E, Monark, Varberg, Suécia) durante 5 minutos, entre 50 a 60 rpm com uma resistência equivalente a 2% da massa corporal. Seguido de exercícios no tapete de alongamento estático de baixa intensidade, mantidos durante 20s, para os músculos extensores e flexores do joelho. Os indivíduos foram sentados no isocinético respeitando as configurações standard da cadeira (encosto inclinado a 85°), estabilizados com fitas de fixação a nível dos ombros, cintura e coxas. O eixo de rotação do dinamômetro foi alinhado visualmente com o epicôndilo lateral do joelho (eixo anatômico de rotação). O comprimento do braço da alavanca do dinamômetro foi ajustado no nível do maléolo medial para que a almofada de resistência ficasse fixa à perna. O alinhamento correto do eixo de rotação foi verificado movendo passivamente a articulação através de toda a amplitude de movimento (fixada em 90° e inclinada em 0°). A extensão completa do joelho foi utilizada para definir o ângulo de referência anatómica de 0^{o} de extensão. A amplitude de movimento do teste foi definida de 5^{o} a 90° de flexão do joelho. Para correção do efeito da gravidade sobre o membro e braço da alavanca foi determinado o peso dos mesmos a partir da posição de 30^{o} de flexão do joelho. Os indivíduos foram solicitados a manter uma posição de teste padronizada com os braços cruzados sobre o tórax (sem agarrar os cintos) e cada mão sobre o ombro contralateral (22). Os indivíduos receberam feedback verbal e visual para encorajar à contração voluntária máxima durante o teste (23).

O protocolo do teste consistiu num conjunto máximo de cinco repetições contínuas a cada velocidade de $60^{o}.s^{-1}$ e $180^{o}.s^{-1}$ no modo concêntrico e no modo reativo excêntrico. A configuração da almofada foi definida como zero ("duro") para minimizar a desaceleração no final da amplitude de movimento. Todas as repetições começaram com a posição inicial de 90º de flexão do joelho. Para cada repetição concêntrica, o sujeito foi orientado para empurrar o braço da alavanca para cima (extensão) e puxar o braço da alavanca para baixo (flexão). Para cada repetição excêntrica, o sujeito foi instruído a contrariar a extensão do joelho, tentando fletir o joelho e opor-se à flexão do joelho tentando estender o joelho, por toda a amplitude de movimento.

Para cada velocidade angular e tipo de ação muscular, o conjunto máximo de cinco repetições contínuas foi antecedido por um conjunto submáximo de três repetições contínuas para familiarização com o equipamento e os procedimentos de teste. Cada repetição incluiu o movimento alternado de extensão e flexão do joelho. Um período de repouso de 60 segundos foi estipulado entre cada conjunto de repetições. Utilizando diferentes velocidades angulares e para uma amplitude de movimento de 85º, a taxa de amostragem de 100 Hz permitiu a recolha de dados em ângulos específicos. Os dados foram analisados com o software Acqknowledge, versão 4.1 (Biopac Systems, Inc., Goleta, CA, EUA). Após inspeção visual das curvas isocinéticas, considerou-se os torques isocinéticos verdadeiros aqueles que estavam dentro do intervalo de confiança de 95% da pré-definida velocidade angular. O valor de pico de torque (PT) da melhor de cinco repetições (melhor curva realizada por extensores de joelho (KE) e flexores de joelho (KF) foram retidos para análise nos modos concêntrico (con) e excêntrico (ecc). Os valores de torque (τ) e pico de torque (Pτ) foram expressos em Newton.metro (N.m). Foram obtidos os seguintes parâmetros (em cada velocidade angular), que se apresentam com evidencia de fiabilidade (24), para posterior análise estatística:

- Pτ de ambos os grupos musculares (KE and KF) nas suas ações musculares (con e ecc): Pτ_KEcon; Pτ_KEecc; Pτ_KFcon; Pτ_KFecc;
- Rácio Convencional (Pτ_KFcon / Pτ_KEcon);
- Rácio funcional de extensão (Pτ_KFecc / Pτ_KEcon);
- Rácio funcional de flexão (Pτ_KFcon / Pτ_KEecc);
- τ do KF no ângulo do Pτ do KE: τ_KFcon no ângulo do Pτ_KEcon; τ_KFecc no ângulo do Pτ_KEcon; τ_KFcon no ângulo do Pτ_KEecc;
- Rácio do ângulo-específico convencional (τ_KFcon at angle of Pτ_KEcon / Pτ_KEcon)
- Rácio do ângulo-específico funcional de extensão (τ_KFecc at angle of Pτ_KEcon / Pτ_KEcon);
- Rácio do ângulo-específico funcional de flexão (τ_KFcon at angle of Pτ_KEecc / Pτ_KEecc).

2.3 Análise estatística

A análise estatística foi definida com base na amostra utilizada de acordo com os objetivos específicos de cada estudo e subsequente artigo (Tabela 2.3.). O nível de significância estabelecido foi de 0.05 (25). As análises estatísticas foram realizadas utilizando o programa Statistical Package for the Social Sciences – SPSS, versão 25 para Windows (SPSS Inc., IBM Company, Armonk, NY, EUA).

A estatística descritiva foi calculada para a amostra total (amplitude, média, erro padrão da média, intervalo de confiança de 95% da média e desvio padrão). A normalidade foi determinada pelo teste de Kolmogorov-Smirnov. Para a análise de comparação entre os grupos, foi utilizado o *teste-t* para amostras independentes (25). A magnitude dos efeitos foi observada através dos valores *d de Cohen* (26) e foram interpretados da seguinte forma: trivial (0,000 a 0,1999); pequeno (0,200 a 0,599); moderado (0,600 a 1,199); grande (1,200 a 1,999); muito grande (2,000 a 3,999) e quase perfeito (≥4,000).

Tabela 2.3. - *Procedimentos estatísticos utilizados de acordo com os estudos.*

Análise	Estudo 1		Estudo 2		
	Artigo 1	Artigo 2	Artigo 3	Artigo 4	Artigo 5
Descritivo	X	x	x	X	x
Teste *t- student*	X		x	X	x
Magnitude do efeito de Cohen	X		x	X	x
Teste do *Qui quadrado*	X	x			
Modelo de regressão logística binária, baseado no método *Enter*		x			
Crude Odds ratio bruto e ajustado (à idade*) Odds Ratios*		x			

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Capítulo 3

Artigos originais

Artigo 1

Musculoskeletal Injuries in Male Portuguese National and Regional Trail Runners

Lesões músculo esqueléticas em corredores de trail running masculinos nacionais e regionais portugueses

Musculoskeletal Injuries in Male Portuguese National and Regional Trail Runners

Abstract: Trail-running is a rising popular unprofessional sport were participants can run at local or national events. This growth has a high risk of injuries associated. Definitions of injury, severity, and running exposures, together with criteria for classifying injuries in terms of location, type, and seriousness need to be included in order to understand the personal and sports implications. Different participation levels should be taken into consideration to evaluate trail running injuries in order to properly implement effective training and health interventions.

Objective: This study aimed to determine prevalence and characterize running musculoskeletal injuries in Portuguese Trail Runners according to the participation level (national: NTR vs. regional: RTR).

Methods: The study was an observational case-control design. An online questionnaire was administered. Participation level, trail running history and injury characteristics, from the past 12 months, were obtained. Descriptive statistics were used. Independent t-tests and Pearson Chi-Square test were used to evaluate and to determine associations.

Results: The sample included 403 male Portuguese trail runners aged between 18 to 62 years. The prevalence of trail running injuries was of 72.7%; 75% of injuries were considered significant and 25% slight. NTR self-reported a greater number of injuries. Injury proportion was higher at RTR than at NTR according to significant injuries. Injury rate (per 1000hours, 1000km) was higher at RTR for significant and slight injuries. The most common injury locations were ankles/feet (26.2%) and knees (26.0%). Significant injuries affected mostly the ankles/feet (32.1%) and slight injury affected the knees (27.1%), both with a greater prevalence at the NTR. There is no association between participation level and injury type and seriousness. Significant injuries were mostly the result of overuse (64.8%) and translate into more running time-loss (serious injuries: 37.0%) affecting the lumbar region and lower extremity, in both groups.

Conclusions: Participation level could determine different results in injury type, severity, running time-loss, the need to avoid daily activities and to require a clinical professional. Running injuries do not always result in running time loss, the presence of slight injury should be considered at epidemiological studies, they could be considered for a runner with a history of previous injury. RTR are exposed to a smaller amount of weekly running volume, but nevertheless have a higher significant injury rate, and from those the majority are resulting from an acute mechanism.

Keywords: prevalence, trail running injuries, participation level, anatomical region, injury severity.

Introduction

Trail running participation has grown exponentially in recent years (1,2) and includes many types of runners at competitions or training. According to their participation level, the runner can present distinct training volumes and characteristics that should be considered in epidemiologic studies. Some run to win, while others run to test their limits. Running is associated with health benefits but also exposes the runner to injuries (3)**.** At all participation levels, injuries end up having a negative cost for the runner, such as the restriction of going to work (4), or requiring medical or other health professional assessment/treatment (4–7). Reading There are different types of runners, and the criteria used by each author categorized them differently according to their training or competition purpose, or used a classification based on a mathematical algorithm (1). Some studies described runners as *recreative* and *competitive* (6,8–10); or as *novice* (11) and *masters* runners (12). To van Mechelen (1992) the injury rate of recreational athletes who trained regularly and occasionally participated in long-distance races ranged from 37% to 56%, the majority of their injuries resulted from running (13). Notably, the majority of trail athletes ran in their free time. Previous research also found that some runners preferred regional/local races and others preferred the national or international competitions. The events found in diverse regions have various tracks characteristics as defined by the measures defined by the ITRA: distance and positive and negative elevation. The characteristics of the tracks and the easy access to the events encourages athletes to run in different participation level during the year (14,15). Depending of the level of participation, some authors reported a wide variety of prevalence and incidence rates, of running injuries (16).

Most **running injuries** are often related to musculoskeletal problems (10,11,17) and affect largely the lower extremity (1,13,18). Systematic reviews mentions an incidence of injuries associated with sports between 19% to 79% depending on the anatomical region (3,10). For what we can see, the incidence, prevalence or injury rate are dependent on the definition of injury. From the literature it can be seen that most of studies report injuries reflecting the number of days with absence at training/competition (4,19–21), and this criteria is associated with the seriousness of the injury (22). The use of time-loss definition allows comparisons and the use of documentation based on registered information by the athlete or coach (23). Since 2006 there is a consensus of papers accepting and recognising three different injuries definitions (“any physical complaint”, “medical attention injury” and “time-loss injury”) but the “time-loss” definition is the one most commonly used (23). Injury seriousness classification is based on sports time-loss, due to its consequence for an individual (22). Not all injuries have as consequence of a long period of missed training or competing, namely in the case of a semiprofessional athletes were it should may also be considered the impact that the injury has on time lost to work (24). The use of a definition based on sport time-loss will reduce the incidence rate of injuries, and for this reason it is important to use a definition based on functional level and not sports time- loss (23). It is supposed that some runners are exposed to injuries that have no implication in sports time-loss (25). Through the use of “time-loss” criteria it is almost impossible to understand how many athletes have suffered injuries that were interpreted as not significant and avoiding an evaluation of the true impact in the tissue. The type of injury is related to cause and location (20,22) and the consequences that they bring are different according to the type of sports. Recently, Malliaropoulos, Merty and Tsaklis (1), described prevalence of injury of 82.2% due to overuse at ultra-trail running athletes. For any athlete, it is important to be fully recovered from any and all injuries prior to a running event. A recent systematic review identified, with a strong evidence, that the history of previous injuries was a potential determinant of running injuries in long distance runners. The athletes with a history of injury may be more likely to be reinjured and this could be related to the fact that the repair tissue was not completely healed (3,13). The lack of clarity in the descriptors used to define running injuries, leads to a greater difficulty profiling injury into this specific population.

Considering the trail runner and knowing that he is an unprofessional athlete, will the definition based only on time-loss be the most adequate? The trail runner who stopped working as a consequence of an injury during competition/training is or is not an injured athlete? The athlete that had to be treated by a physiotherapist, or other health professional, to recover a running related injury without stopping running, is or is not an injured athlete?

Although studies can support the understanding of the injury profile allowing appropriate interventions to reduce the risk of injury the epidemiology of injuries in trail running with different participation levels are scarce. Therefore, the **objectives** of this study were to be characterized, according to participation level, the musculoskeletal injuries in Portuguese Trail Runners, over a 12-month period. It was hypothesized that a **national trail runner** given the volume of training and the characteristics associated with the of competition tracks (distance, positive and negative elevation), is expected to be **more** exposed to injuries. The significant injuries are expected to result from overuse and not all injuries lead to a sports time-loss.

Materials and methods

1. Study design

An observational case-control study, regarding the previous 12 months, was conducted. The questionnaire was available from January 2018 to April 2019. This study was submitted and approved by the *Ethics Committee* of *University of Porto* (CEFADE 17.2017). This study follows the STROBE guidelines for reporting recruitment, exposure, data collection and results of observational studies (26).

2. Instrument

A **questionnaire, written in Portuguese,** was elaborated to obtain epidemiologic information (personal aspects, training, running and injuries characteristics). To gather injuries data, it was used the standardized Nordic Musculoskeletal Questionnaire, adjusting some words so that the responder might associate the injury to a trail running problem (ex. "Because of the problem/injury at the knee region how many days you have been unable to train/compete during the last 12 months").

This questionnaire had a pre-test carried out to a group of trail running athletes, asking for comments on the layout and content. Some final adjustments were made after examining their comments. The questionnaire was built on an online survey software (Google-Forms©) and the link was sent to e-mail lists through different running teams, athletic federations and running associations (for example Coimbra's District Athletics Association, Skyrunning), to social and professional networks, in Portugal (continent and islands). A snowball sampling method was applied and intended for voluntary recruit trail athletes that participate in trail events, asking every trail running participant to invite others to participate in the study and share the link (https://forms.gle/tanvXhXB448V9tkA9). The questionnaire could be made available on request ("please contact the corresponding author").

The **inclusion criteria** were defined as: being of Portuguese nationality; being male; to be older than 18 years; having at least 12-months of trail running experience; having participated and completed at least one trail event, in the past year. Each variable was examined for major outliers, and then was verify the accuracy of such data.

The questionnaire began with a full description of the nature and objectives of the study, as well as ethical considerations related to anonymity and confidentiality of the participants. In case of a negative response to the consent the survey would end. The questionnaire was composed with **three parts of questions**. **The first**, anthropometric data included: gender, age, weight and stature. **The second** was related to trail running experience; **participation level** (national and regional), weekly running training volume (frequency, duration/time, distance). Participation level was defined according to the participation at competition races. The athletes who regularly participate in races from the National and International Trail Circuit were considered "National". Those who choose local competitions because they are near his residence were considered "Regional".

The last **part** was composed of questions that were used to described the musculoskeletal trail running injuries, referred to the past 12-months, in ten anatomical regions (head, neck, shoulders, elbows, wrists/hands, thoracic region, low back region, hips/thighs, knees, ankles/feet). Responders were categorised as either injured or non-injured based on their response to the first question of the third part from the questionnaire: "*Have you had any complaint/symptom resulting from trail running training or competition during the past 12 months?"*

Injuries were reported using the following **definition** "*any musculoskeletal symptom or complaint sustained by an athlete*" (19,21,23) resulting from the trail running (competition or training), at one or more different anatomical regions.

Based on answers, the participants that had a presence of any injury were fixed into ALL group. As the study looked for **injury severity** further questions were presented to understand the personal and sports implications associated with running related injuries. Those who had not exhibited in any of the following factors: daily activity avoidance, running **time-loss** and the **clinical** attention, were **considered slight injuries**. In contrast, individuals who revealed as a consequence of running injury an inability to run for at **least one day** (19), and/or **avoid daily activities** and/or result in receiving **a health care** attention (clinicians, physiotherapists or nurses); were considered **significant injuries.**

To limit bias towards reporting severe injuries the injury definition need to incorporate both **slight and significant injuries**. This allowed to add injuries that are self-diagnose and treated by the individual without having to stop running (25,27,28) and usually are not considered in epidemiological studies. During a 12-months period, the participants could self-report slight or significant injuries because it can happen in different anatomical regions.

The most common injury definition used in papers is the time-loss definition. Considering, the length of the time that the individual need to stop the sports activity (22). The exact indication of time-loss gives a precise indicator of the significances of an injury to an athlete (7,20,29). In accordance with National Athletic Injury/lllness Reporting System (NAIRS), Schlatmann H, Hlobil H, van Mechelen W, et al. (1986) (22) classify the **seriousness of injuries according to sports time-loss**, into "***minor***" (1 to 7 days), ***"moderately serious"***' (8 to 21 days) and "***serious***" (over 21 days).

According to the mechanism of occurrence, the participants were classified with the following **type of injury:** overuse or acute. Overuse injuries have a gradual onset, without a specific, identifiable event responsible for their occurrence and can be a result of repetitive/accumulated load. The injury manifests itself or has a gradual appearance over a period of time. The athlete could not identify the mechanism responsible for the condition, sometimes it can be the result of an acute injury poorly rehabilitated with residual symptoms (21,30). The symptoms can be describe as pain, reduced function and/or performance (31). Acute injuries are defined as any physical complaint with a sudden onset that the athlete can relate to a specific clearly identifiable situation, normally resulting in a structural/tissue damage and/or functional integrity, at an anatomical region (7). Examples given for such injuries were ankle sprain, ligament injury, or fractures.

DATA ANALYSIS

Sample calculation

The sample size was determined using an estimated prevalence of 80% injuries (as reported in systematic review studies, mentioned above), a population of approximately 1500 trail runners (ATR indicator) and assuming a margin of error of 5% with 95% confidence interval(32,33). It was calculated using the formula: $n = [z^2 * p * (1 - p) / e^2] / [1 + (z^2 * p * (1 - p) / (e^2 * N))]$ (were, n = number of participants, z = 1.96 for a confidence interval (α) of 95%, p = 0.80, e = 0.05); N = 1500). Using these assumptions, the minimum sample size was 307 athletes.

Statistical analysis

The answers were transferred and analysed in an Excel database before exporting the results to the Statistical Package for the Social Sciences - SPSS, version 25 for Windows (SPSS Inc., IBM Company, Armonk, NY, USA) for statistical analyses.

Injury proportion was calculated by expressing the number of injured athletes and divided by the total number of athletes. The **injury rate** was calculated according two exposition parameters: time and distance of running. The injury rate per 1000h was calculated by expressing the number of injuries divided by the total number of athletes-hours (7,34,35). The injury rate per 1000km was calculated by expressing the number of injuries divided by the total number of athletes-kilometers (7,36). Calculation of the number of hours or amount of distance of running, during the 12-months were obtained by multiplying the average of a number of running hours or distance per week and then multiplying for 52 weeks (33,37).

Descriptive statistics using range, mean values and standard deviation were used at continuous variables. Distribution of simple frequencies (n) and percentages (%) was used to describe categorical variables. Normality was examined and confirmed for all variables and the Kolmogorov-Smirnov test was used. Independent samples t-tests and the Pearson Chi-Square test (or Fisher´s exact test when the assumption is not observed) was used to evaluate and to determine associations between independent variables (participation level and anatomical region) with dependent variables (injury occurrence, severity and type)

The magnitude of the effects **used Cohen´s value**. To measure strength of associations for dichotomous variables the **Phi test** was used. The significance level was established at 0.05 (38).

Results

A total of 403 Portuguese male trail runners provided usable data. The sample aged between 18 to 62 years (40.01±8.18 years) participated in this study. According to the participation level 53.6% are National trail runners (NTR) and 46.4% are Regional trail runners (RTR).

Table 1. summarizes the baseline trail runner characteristics, by participation level (national and regional). The results show that NTR had a significant lower weight than RTR (NTR: 71.85±8.00 kg and RTR: 75.89±9.34; p<0.001; t=-4.640; d=-0.468) with a small magnitude of effects. The results of the average of trail running volume (duration, time, distance) suggest statistically significant results, presenting the NTR higher average values.

------------------------table 1 -----------------------------

Descriptive epidemiological information, of trail running injuries according to the participation level and **injury severity** (significant and slight), is presented at **Table 2**. From the 403 trail runners 72.7% (n= 293) referred to have an injury (significant and slight), in the past 12-months, presented a rate of 1.20 injuries per total number of athletes and 161injured trail runners had belonged to the national participation level.

A total of 129 national trail runners self-reported having suffered a significant injury. The total number of injuries (significant and slight) was about 484. A total of 193 injuries was classified as significant, obtaining a ratio of 1.49 of significant injuries per injured athletes.

The injury proportion results from 0.73 (CI95%: 0.68-0.77) injuries per trail runner independent of the injury severity. The NTR has an injury proportion of 0.75 (per total number of athletes) greater than the RTR. Significant injury proportion at RTR (0.61) was higher than the NTR. The obtained injury rate, according to time (1000hours) and to distance (1000km), for all participants, was higher at the RTR according to injury severity (all, significant and slight).

------------------------ insert table 2 -----------------------------

As it described in **Table 3., t**here was no **association** between injury occurrence (all, significant and slight) and participation level to all participants (403). According to the presence of injuries, injured athletes with different participation level (NTR:161; RTR:132) do not manifested association between the need to avoid daily activities and the need to be seen or treated by health professional.

The relationship between these variables **was statistically significant**, $\chi 2$ (1, N =293) = 4.147, $p < 0.05$ at the injury occurrence and at the need to stop training or competing for at least one day. Results showed that **RTR** injured athletes were less likely to need to stop training or competing and NTR athletes were more likely to need to stop training or competing.

------------------------table 3 -----------------------------

The results obtained from the trail running injuries location, don't result into significant associations according to injury severity and the comparison by the participation level **(Table 4). T**he lumbar region (15.9%) and lower extremity (hips/thighs: 16.7%; knees: 26.0% and ankles/feet: 26.2%) are the anatomical regions with highest prevalence of trail running injuries. NTR revealed a superior number of injuries at ankles/feet (28.1%) and the RTR revealed a higher number of injuries at the knees (26.7%). The injuries classified as significant had a superior number (193) than the injuries in the NTR group. The knees were the location with more significant injuries in the RTR group (28.7%) and the ankles/feet were the anatomical location with more injuries in the NTR group (32.1%).

------------------------insert table 4 -----------------------------

Table 5. summarizes significant injury location, comparing injury type (acute and overuse) with participation level. The main injury type was caused from **overuse** (64.8%) from a total of 364 significant injures. The knees were the most affected overuse injury region reported by the NTR (38.1%). There were some anatomical regions that had no injuries in the last 12-months (such as elbows). A Chi-Square test examined the relationship between the variables. The relationship between these variables **was statistically significant**, $\chi 2$ (1, N =244) = 5.489, $p < 0.05$ only at lumbar region and were associated with overuse injuries. Results showed that NTR were less likely to have acute type injuries as it was observed in RTR. From the other associations, the injury type at the lower anatomical region (knees, ankles/feet) was as expected, higher in NTR and caused by overuse.

------------------------insert table 5 ----------------------------

The injury seriousness according to the sport time-loss associated with the participation level was presented at **Table 6.** From the **289 injuries** that lead to the need to stop training or competing at least for a day, the results showed that there was no **association** between injury seriousness and the participation level. The results presented a similar number of seriousness of injuries with minor (34.3%) and serious (37.0%) sports time-loss. Comparing the injury seriousness with the participation level, the results shows the lumbar region and the lower extremities with varying lengths of time without running, the period over 21 days with running time-loss being the greater occurrence as a result of a running related injury.

------------------------insert table 6 ----------------------------

Discussion

The data obtained in this study showed the prevalence of musculoskeletal injuries in male Portuguese trail runners (72.7%), over a 12-month period. From a health-related viewpoint, running provides beneficial effects on body mass, and for that reason, a long-distance runner is expected to have a distinct morphotype. Available studies regarding anthropometric characteristics and years of trail running experience, presented similar results to our general male trail runner sample (2,17,18,39). The anthropometric data revealed that the national trail runners (NTR) are younger, lighter and had a lower body mass index than the regional trail runners (RTR). According to participation level, the NTR referred more injured athletes and also more injuries reported. But the proportion and rates according to training volume, showed a superior number of Regional injured athletes and injuries per total number of athletes, even when the NTR presented a higher average of weekly running training volume (frequency, time and distance per week).The proportion of injuries are available at systematic reviews (39,40) and the rates are comparable to the ones presented at this study.

It was not possible to gather valid information about **participation level**, because the criteria used by each author reveals different types of classification. The classification defined at methodology is crucial. There can be found studies with *novice* or *professional; recreative* or *competitive* runners. From previous literature, it could be said that there are different **types of running population**, classified as: track and field runners (short, medium and long distance), long-distance, marathon, ultra- marathon and cross-country runners (40). Other authors, classifying them according to their training or competition purpose into: recreational or competitive (41), or used a classification based on a mathematical algorithm given credits to: sex, age, races and performance (1). There can be found runners in these categories running at national or regional trail running events. Independently of the type of classification, it seems that in this study, the NTR had similar anthropometric characteristics and training characteristics exposed by other authors using competitive trail runners. The training volume self-reported was generally higher in the Portuguese trail population. The RTR had less training frequency comparable with studies that used recreational runners such as was presented by Besomi et al. (2018). Is was expected that the NTR participated in races with a high level of difficulty or also participated at international events in order to obtain points and classification such a “competitive” runner. The RTR was expected to be like a “recreational” runner, running mostly for the pleasure and to be a finisher than for obtaining points or be a winner. For these reasons the differences observed in the volume of trail running training were acceptable.

Independently of the participation level, previous literature, has showed that runners are exposed to intrinsic and extrinsic risk factors related to running musculoskeletal injuries. These aspects are well developed as it was described at different systematic reviews (9,13,41). According to Hoffman and Krishnan (2014) the presence of injury is related to an annual period, and the incidence of injuries in ultramarathon runners was defined as around 52%, lower from those found at the present study (72.7% of injured trail runners). The participants used by the previous authors have a different training preparation and the race was performed with a great amount of running on asphalt, placing the runner to differently from a trail runner. Despite these studies, there is a lack of information according to the participation level of trail runners. In the present study, the NTR appears to have both higher **numbers of injured athletes** and **numbers of injures**. Estimating an injury proportion of 0.75 injured athletes per the total number of athletes of the sample. The average of the **number of injuries** per total number of trail runners was 1.22 for the NTR. The average of the number of injuries per number of injured athletes was higher at the RTR (1.67). It seems that the regional group was more susceptible to having a greater number of running injuries despite having less injured athletes with reference to all participants and also have small training volume (frequency, time, distance). For this reason, it was important to explore the results and analyse the ratios.

According to the injury **severity** (slight or significant injury), it seems that the NTR presented a greater number of significant injuries in an injured athlete. If the injuries are classified as slight, the RTR had a greater ratio (1.28). The presence of over 25 % of slight injuries is important when most studies associates the presence of an previous injury as a risk factor to injury (23). Junior, van Mechelen and Verhagen (29) reported in a prospective cohort study, that 24.4% of the running related injuries neither resulted in time loss nor medical attention.

Despite the NTR presented a greater number of injured athletes (n=161) when the injury proportion was explored according to the injury **personal and sports implications**, the proportion of significant injuries was superior in the RTR, and the slight injuries were higher at NTR. Some authors report the **injury rate** as a percentage of athletes with injury related to the total sample used (with and without injury), so there are no studies to support these results. The assessment of injury rates is a useful measurement, but the clear definition is needed to further comparisons. In the literature the running injuries proportion varies from 2.5 to 12.1 injuries per 1000h (13). Junior, van Mechelen and Verhagen (29) the injury rate of running injuries was 10.7 per 1000h of running (95 % CI 9.4–12.1), more specifically, for males, the injury rate was 11.3 (95 % CI 9.7–12.9). The presence of injuries is often related to the **training aspects** (13,17,41). The **weekly distance and frequency** are the factors most investigated. At the present study, the average of training volume seems to be higher in the NTR, using the measure of **running time** (injuries per 1000 hours) enables the comparison of the groups (37). In the present study, the injury rate was higher in NTR with 4.44 injuries per 1000 hours, but the trail runner has a higher exposition to running than the participants used in the systematic review of the van Mechelen (13). Recently, **Videbæk et al** (37) in a systematic review referred that the injury rate is an important measure to analyze studies. Also, from the literature review it could be said that long-distance runners had lesser running injuries per 1000hours (2.5) than the middle-distance runners (5.6). They also exposed that there was a greater rate of injuries, in novice runners (17.8) when compared to recreational runners (7.7) or to ultra-marathon runners (7.2). All of these rates presented superior values to the ones found in the present study, which can be partially explained by the type of runner's present. In the systematic review, Van Mechelen(13) refered the Van Galen and Diedericks (1990) study which reported an incidence rate of 3.6 injuries per 1000hours of running in the overall running population, but the lack of definition of the type of participants was scarce to support those with our findings.

In the present study, it was considered important to adjust the number of injuries to the number of kilometres (0.41 all injuries per 10000km of running), because the literature assumes an association of injuries with the **running distance**. In the description of the rate per participation level, it was clear that RTR had a greater ratio (of 0.50) when compared to NTR

(0.35). It demonstrates that RTR had more injuries than NTR according to the number of athletes exposed to the risk of being injured according to distance in 12-months. The RTR appears to have a greater number of injuries as it was previously described in the number of hours. From the literature, there is a lack of consensus, namely because they are different types of runners. Saragiotto et al (41) referred in a review article, that runners who train at a distance greater than 64km per week are more susceptible to have an injury as the consequence of running. **Videbæk et al** (37) in a systematic review referred that in the recreational group used in the Jakobsen et al. (1994) study, the ratio estimated was of 0.62 injuries, according to 1000km, identical to RTR. Knobloch et al (36) reported an injury rate of 0.08 per 1000km running exposure, from a sample with master runners that have an average of 65.2±28.3km/week and mean age of 42±9 years. Most of these participants run a half-marathon and marathon, which are asphalt/road running. The trail runner is exposed to running in an irregular the type of surface, which could be a potential explanation for the higher injury ratio. Once again, the type of surface and track used by these athletes can be the answer for the differences found and that restricts the comparison to the present study.

The participation level seems to be important to describe injury epidemiology. In the present study, th**e injury prevalence** was higher at NTR (32.0%). As a consequence of injury, it could have an impact on several personal factors mentioned previously (the need to avoid daily activities, the need of medical/health care attention and sport time- loss)(1,13,18). From the injured trail runners, the impact of the **need to avoid daily activities** was the same, according to the participation level (both NTR and RTR had 25.3%). This aspect appears to be important because the participation in trail running is related to health and well-being. The participants have to use their free time (out of work) to performed running and exercise (22). From an overall evaluation 50,5% of the injured participants affirmatively referred the need to avoid daily activities. It was difficult to find research that supports these results. According to van Mechelen (13) the absence from work or school as a consequence of running injuries range from 0 to 5%, but the analyses were for all participants and not only from the ones that have injuries.

Another consequence of running injuries is the **need of health care attention**. In the present study of the 180 injured athletes that needed health assistance the NTR had a greater number of athletes (34.8%) with the need to be seen or treated by a health professional. These values are similar for those found at the literature. According to Mechelen(13) some authors explained that more than 20 to 70% of all injuries leads to medical consultation or treatment, others referred that 31% of injuries lead the runner to search for medical care. For Hoffman and Krishnan (18), 60% of the ultra-marathons with running injuries need to go to the medical care system (not specified the service). Besomi et al (17) from the 1221 participants, 30.4% had health professional evaluation and 26.3% needed physiotherapy care after the injury. This was an important aspect, once for 90% of the participants recognized as being useful to seek a physiotherapist when they are injured. According to Yamato, Saragiotto and Lopes (42) over 79.2% needed medical consultation, 83.3% visited a health professional and 42.5% required surgery.

One of the last factors associated with injury was the **need to stop training or competing.** According to Hoffman and Krishnan(18), the percentage of running injured athletes that resulted in loss of training, of at least one day, were 64.6%. Lysholm and Wiklander (35) also Van Galen and Driedericks (cited in Van Mechelen(22)), with a more detailed description, for 56% of medical treated injuries lead to a training reduction or loss, as it did for the 40% of non-medical treated injuries. Other authors described that 44% of athletes need to stop running (13). In the present study, 71.3% of total trail runners need to stop their training or competition for at least a day, in consequence of the running injury and 51.22% were NTR. This aspect was the only one to demonstrate significative association according to the participation level. A significative association was observed between participation level and the need to stop training or competing, for at least one day. As several authors referred, the consequence of not being able to run is an important psychosocial factor to the athlete(22,23,29). The injury seriousness according to sport time-loss has a similar number of injuries with minor (1 to 7 days) and serious (over 21 days) of running time-loss. The length time presented at other studies is related to the location and type of injury. Yamato, Saragiotto and Lopes (42) 77.8% of the recreative runners reported the need to stop/interrupte running for over 7 days.

From the previous literature (1,13,18), the **most exposed anatomical location** for running injuries are the lower extremities. Most of the epidemiological studies define the knees has the anatomical region with more running injuries. The incidence could change according to the running populations, with an incidence of 15.0% (18), or 16.6% (12), or 25.0% (13) and a prevalence of 40.0% (1), but the cited researchers are related different types of runners (middle distance up to ultra-trail runners). In the present study, the main self-reported anatomical regions injured were: ankles/feet (26.2%), knees (26.0%); hips/thighs (16.7%) and lumbar region (15.9%). Consistent with the explanation that the lower extremity being the anatomical structure most expose to impact and repetitive movements, and the lumbar region exposed to the biomechanical adjustments that occur in the trunk during uphill and/or climbing (1). The knees and ankles/feet remain the most exposed anatomical regions to injury, the main contribution for this reason could be the type of terrain that the trail events have, forcing these regions to a more stressful condition.

Literature was still scarce according to the classification of **severity** (13,36,41). Previous epidemiological research referred the impact of an injury into sport time- loss, medical treatment and/or absence from work (13). The classification according to injury severity makes all the difference. The major injuries had a direct impact to the athlete, according to previously described factors and for these reasons it was analysed only at the major trail running injuries location. Looking into the injury severity, by anatomical regions, it there weren´t found significant differences according to participation level. In both major and minor injuries, the NTR self-reported a higher occurrence of injuries. The ankles/feet present a greater number of **major injuries** (32.1%) and the knees were referred to be the anatomical region with more minor injuries (27.1%). An explanation of these situations, could be that NTR had more years of trail running experience, running longer distances and more times per week, leading to shorter recovery periods. These results are consistent with other researches (12,13). And for this reason, it is important to analyse injuries, according to participation level, classification of severity but also the according to injury type (acute or overuse).

Most of running injuries are associated to with **overuse** as an explanation for the mechanism of injury. In the present study, the major injuries are due to overuse and NTR was the most affected group, self-reporting 64.8% of total overuse injuries. Similar results to those found by Ristolainen et al.(43) were from the 75% of running injuries 28.7% where acute and 59.4% were overuse injuries. Mechelen (13) describes a range of 54% to 74% of all injuries related to overuse cause, from research exposed at the systematic review. Malliaropoulos, Merty and Tsaklis(1), referred a prevalence of 82.2% overuse injuries in ultra-trail runners. This amount of injuries could be explained by the number of kilometres and hours of running that a trail runner has to perform. Knobloch, Yoon and Vogt (36) analysed the location of the injuries and likewise classified them according to the mechanism of injury (acute and overuse), and once again the results suggested that the lower extremity was more frequently involved with injury. Overuse injuries were also associated with the ankles and knee regions and the acute injuries were related to the ankles, identical to the present study. In the present study, the anatomical region mentioned as having more overuse injuries was the knees (38.1%) and it was observed in NTR. Another aspect was that NTR, like ultra-marathons, have a greater number of training hours and running distance, as also more years of running experience leading to a higher risk of overuse injury. In fact, the association reveals a risk of NTR to have more overuse injuries in the knees. Research mentioned that the runner, sometimes keeps training while in pain or without having treated the musculoskeletal problem, leading to the growth of the musculoskeletal problem severity (6,18). The runner doesn´t adjust his daily activities or avoids running until the problem grows, and for these reasons the injury could be associated with the ones classified as minor. Acute injuries are supposed to be more significant in the short-term and are the ones that leaded the athlete to seek health care services or may prevent the athlete to run (training or competing) (6), and for these reasons it could be associated with a major injury.

Limitations

The study contains some limitations associated with the fact that this was a self-reported questionnaire relying on the memory of the runner. Body mass index was calculated from self-reported height and weight rather than from direct observation. These direct analyses could result in bias, leading to a classification not according to the body composition (i.e. with the correct reference of amount of fat free mass and fat mass). The use of reliable instruments to categorize the athlete should be considered for future studies. The musculoskeletal injuries were reported but not evaluated by a health professional. The questionnaire does not explore the exact diagnosis of injuries, that would allow a better classification of injury. The results could not represent all the trail running population. Other limitations were related to the difficulty of finding literature to support some results due to the differences in the definition of injury, injury rate and proportion, participation level or the type of runner and outcomes used. However, the results and general conclusions seem to be strongly and well supported.

Conclusion

This was the first Portuguese study of musculoskeletal injuries of trail runners and examined them according to participation level (national and regional). Participation level could result into different injury locations, type, severity and seriousness, because runners were exposed to different training hours, frequencies and distances. It seems that the increase in exposure (as it happens with the NTR) could lead to a decrease in injury rate (per hours and distance) but increases the injury proportion as a result of the cumulative effect of increasing exposure. These aspects could explain the following aspects. The RTR had more injuries per injured athletes (1.63). This aspect could explain why the RTR, who was expected to need less days of running time loss, showed the opposite. Moreover, the NTR had a greater number of significant overuse injuries, as well as a higher serious time-loss period. Perhaps these results could be related to the hight number of hours and distance of training/competing, as well as more years of experience. Not surprisingly, the most affected anatomical region was the lower extremity (ankles/feet; knees; hips/thighs). RTR are exposed to a smaller amount of weekly running volume, but nevertheless have a higher significant injury rate, and from those the majority are result from an acute mechanism. A significative association was observed between participation level and the need to stop training/competing, for at least one day. Running injuries do not always result in running time loss, in fact the association reveals that it would be expected that the NTR have the need to stop training/competing and/or have felt the need to avoid daily activities because of the running injuries. Sports and health professionals involved with trail runners should be aware of the fact that the participation level determine different injury types, severities and locations.

Further studies are required to explain the injuries associated with trail running, specifically to classify the anatomical structure affected (muscle, tendon, ligaments, joints) and to identify determinants of injuries in order to define programs of prevention.

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Table 1 - Characteristics of the trail runners by participation level and comparison between groups (National vs. Regional) (n = 403).

Characteristics	Participation level		Comparison			
			Independent samples t-test		Magnitude of effects	
	National n = 216 (53.6%)	Regional n = 187 (46.4%)	t - value	p	d†	Qualitative
Age (years)	39.98 ± 8.60 (18.00 - 62.00)	40.04 ± 7.68 (19.00 - 62.00)	-0.075	(0.940)	0.007	Trivial
Weight (kg)	71.85 ± 8.00 (54.00 - 94.00)	75.89 ± 9.34 (58.00 - 110.00)	-4.670	(<0.001)	0.468	Small
Stature (cm)	175.16 ± 6.13 (160.00 - 194.00)	176.06 ± 5.83 (161.00 - 189.00)	-1.505	(0.133)	0.151	Trivial
Body mass index (kg/m²)	23.40 ± 2.08 (18.52 - 30.37)	24.45 ± 2.47 (18.39 - 32.37)	-4.590	(<0.001)	0.464	Small
Trail running experience (years)	5.98 ± 3.10 (1.00 - 23.00)	5.23 ± 3.74 (1.00 - 25.00)	2.195	(0.029)	0.220	Small
Average weekly running training frequency (days/week)	4.94 ± 1.33 (3.00 - 7.00)	3.88 ± 1.34 (2.00 - 7.00)	7.936	(<0.001)	0.796	Moderate
Average weekly running time (hours/week)	7.55 ± 2.23 (4.00 – 15.00)	4.92 ± 1.88 (2.00 – 12.00)	12.821	(<0.001)	1.271	Large
Average weekly running distance (km/week)	66.74 ± 19.82 (30.00 - 140.00)	45.35 ± 16.11 (20.00 - 90.00)	11.945	(<0.001)	1.179	Moderate

Quantitative variables: mean ± standard deviation (minimum – maximum). p (significance level).

†Cohen's d for the mean difference.

Table 2 – Descriptive epidemiologic measures of trail running related injuries by participation level (National and Regional) and injury severity (All, Significant and Slight).

	Total number of athletes	Number of injured athletes	Number of injuries	Injury proportion Number of injured athletes/ Total number of athletes (95% CI)	Injury rate (per 1000h) Number of injuries/ Total number of athletes-hours (95% CI)	Injury rate (per 1000km) Number of injuries/ Total number of athletes-kilometers (95% CI)	Number of injuries/ Total number of athletes	Number of injuries/ Number of injured athletes
All injuries	403	293	484	0.73 (0.68 - 0.77)	3.65 (3.32 - 3.97)	0.41 (0.37 - 0.44)	1.20	1.65
National	216	161	263	0.75 (0.69 - 0.80)	3.10 (2.73 - 3.48)	0.35 (0.31 - 0.39)	1.22	1.63
Regional	187	132	221	0.71 (0.64 - 0.77)	4.44 (3.86 - 5.03)	0.50 (0.44 - 0.57)	1.18	1.67
Significant injuries	403	244	364	0.61 (0.56 - 0.65)	2.74 (2.46 - 3.03)	0.31 (0.27 - 0.34)	0.90	1.49
National	216	129	193	0.60 (0.53 - 0.66)	2.28 (1.95 - 2.60)	0.26 (0.22 - 0.29)	0.89	1.50
Regional	187	115	171	0.61 (0.55 - 0.68)	3.44 (2.92 - 3.95)	0.39 (0.33 - 0.45)	0.91	1.49
Slight injuries	403	97	120	0.24 (0.20 - 0.28)	0.90 (0.74 - 1.07)	0.10 (0.08 - 0.12)	0.30	1.24
National	216	58	70	0.27 (0.21 - 0.33)	0.83 (0.63 - 1.02)	0.09 (0.07 - 0.12)	0.32	1.21
Regional	187	39	50	0.21 (0.15 - 0.27)	1.01 (0.73 - 1.28)	0.11 (0.08 - 0.14)	0.27	1.28

CI: confidence intervals.

Table 3 – Injury occurrence, daily activities avoidance, need for health-care attention, time-loss and comparison by participation level (National vs. Regional).

		Total number of athletes 403 (100)	Participation level		Comparison	
			National 216 (53.6)	Regional 187 (46.4)	χ^2 (p)*	ϕ (p)‡
Injury occurrence (all injuries) 484 injuries	Yes	293 (72.7)	161 (40.0)	132 (32.8)	0.788 (0.375)	-0.044 (0.375)
	No	110 (27.3)	55 (13.6)	55 (13.6)		
Injury occurrence (significant injuries) 364 injuries	Yes	244 (60.5)	129 (32.0)	115 (28.5)	0.132 (0.716)	0.018 (0.716)
	No	159 (39.5)	87 (21.6)	72 (17.9)		
Injury occurrence (slight injuries) 120 injuries	Yes	97 (24.1)	58 (14.4)	39 (9.7)	1.972 (0.160)	-0.070 (0.160)
	No	306 (75.9)	158 (39.2)	148 (36.7)		
		Total number of athletes 293 (100)	National 161 (54.9)	Regional 132 (45.1)	χ^2 (p)*	ϕ (p)‡
Need to avoid daily activities 202 injuries	Yes	148 (50.5)	74 (25.3)	74 (25.3)	2. 959 (0.085)	0.100 (0.085)
	No	145 (49.5)	87 (29.7)	58 (19.8)		
Need to be seen or treated by a health professional 261 injuries	Yes	180 (61.4)	102 (34.8)	78 (26.6)	0.556 (0.456)	-0.044 (0.456)
	No	113 (38.6)	59 (20.1)	54 (18.4)		
Need to stop training or competing for at least 1 day 289 injuries	Yes	209 (71.3)	107 (51.2)	102 (48.8)	4.147 (**0.042**)	0.119 (**0.042**)
	No	84 (28.3)	54 (18.4)	30 (10.2)		

*Pearson Chi-Square test; †(p) Fisher's Exact Test; ‡Phi test. p (significance level).
Categorical variables: frequency (percentage).

Table 4 - Trail running related injuries location (10 anatomical regions) by injury severity (Significant and Slight) and comparison by participation level (National vs. Regional).

Injury location	Significant injuries					Slight injuries				
	Total number of athletes	Participation level		Comparison		Total number of athletes	Participation level		Comparison	
		National	Regional	χ^2 (p)*	ϕ (p)‡		National	Regional	χ^2 (p)*	ϕ (p)‡
Head	6 (1.6)	2 (1.0)	4 (2.3)	0.422†	0.050 (0.316)	5 (4.2)	4 (5.7)	1 (2.0)	0.378†	-0.059 (0.234)
Neck	12 (3.3)	8 (4.1)	4 (2.3)	0.396†	-0.046 (0.357)	9 (7.5)	2 (2.9)	7 (14.0)	0.088†	0.095 (0.056)
Shoulders	13 (3.6)	5 (2.6)	8 (4.7)	1.238 (0.266)	0.055 (0.266)	13 (10.8)	8 (11.4)	5 (10.0)	0.341 (0.560)	-0.029 (0.560)
Elbows	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA	3 (2.5)	2 (2.9)	1 (2.0)	1.000†	-0.023 (0.649)
Wrists/Hands	1 (0.3)	0 (0.0)	1 (0.6)	0.464†	0.054 (0.282)	3 (2.5)	2 (2.9)	1 (2.0)	1.000†	-0.023 (0.649)
Thoracic region	5 (1.4)	2 (1.0)	3 (1.8)	0.667†	0.031 (0.540)	3 (2.5)	2 (2.9)	1 (2.0)	1.000†	-0.023 (0.649)
Lumbar region	63 (17.3)	34 (17.6)	29 (17.0)	0.004 (0.949)	-0.003 (0.949)	14 (11.7)	10 (14.3)	4 (8.0)	0.275†	-0.068 (0.173)
Hips/Thighs	62 (17.0)	32 (16.6)	30 (17.5)	0.116 (0.733)	0.017 (0.733)	19 (15.8)	9 (12.9)	10 (20.0)	0.311 (0.577)	0.028 (0.577)
Knees	97 (26.6)	48 (24.9)	49 (28.7)	0.869 (0.351)	0.046 (0.351)	29 (24.2)	19 (27.1)	10 (20.0)	1.785 (0.182)	-0.067 (0.182)
Ankles/Feet	105 (28.8)	62 (32.1)	43 (25.1)	1.696 (0.193)	-0.065 (0.193)	22 (18.3)	12 (17.1)	10 (20.0)	0.008 (0.927)	-0.005 (0.927)
Total number of injuries	364 (100)	193 (100)	171 (100)	NA	NA	120 (100)	70 (100)	50 (100)	NA	NA

*Pearson Chi-Square test; †(p) Fisher's Exact Test; ‡Phi test. p (significance level).

Categorical variables: frequency (percentage).

NA (not applicable).

Table 5 – Significant injuries location (10 anatomical regions) by injury type (Acute vs. Overuse) and comparison by participation level (National vs. Regional).

Injury location	Participation level	Injury type		Comparison	
		Acute	Overuse	χ^2 (p)*	ϕ (p)‡
Head	National	2 (33.3)	0 (0.0)	0.400†	0.707 (0.083)
	Regional	1 (16.7)	3 (50.0)		
Neck	National	1 (8.3)	7 (58.3)	1.000†	0.213 (0.460)
	Regional	0 (0.0)	4 (33.3)		
Shoulders	National	0 (0.0)	5 (38.5)	1.000†	-0.228 (0.411)
	Regional	1 (7.7)	7 (53.8)		
Elbows	National	0 (0.0)	0 (0.0)	NA	NA
	Regional	0 (0.0)	0 (0.0)		
Wrists/Hands	National	0 (0.0)	0 (0.0)	NA	NA
	Regional	1 (100)	0 (0.0)		
Thoracic region	National	0 (0.0)	2 (40.0)	0.100†	-1.000 (0.025)
	Regional	3 (60.0)	0 (0.0)		
Lumbar region	National	6 (9.5)	28 (44.4)	5.489 (**0.019**)	-0.295 (0.019)
	Regional	13 (20.6)	16 (25.4)		
Hips/Thighs	National	8 (12.9)	24 (38.7)	1.594 (0.207)	-0.160 (0.207)
	Regional	12 (19.4)	18 (29.0)		
Knees	National	11 (11.3)	37 (38.1)	2.209 (0.137)	-0.151 (0.137)
	Regional	18 (18.6)	31 (32.0)		
Ankles/Feet	National	30 (28.6)	32 (30.5)	0.002 (0.964)	-0.004 (0.964)
	Regional	21 (20.0)	22 (21.0)		
Total number of injuries		128 (35.2) of 364	236 (64.8) of 364		

*Pearson Chi-Square test; †(p) Fisher's Exact Test; ‡Phi test. p (significance level).

Categorical variables: frequency (percentage).

NA (not applicable).

Table 6 – Time-loss injuries location (10 anatomical regions) by injury seriousness (Minor, Moderately serious, Serious) and comparison by participation level (National vs. Regional).

Injury location	Participation level	Injury seriousness			Comparison	
		Minor (1 to 7 days)	Moderately serious (8 to 21 days)	Serious (over 21 days)	χ^2 (p)*	ϕ (p)‡
Head	National	2 (33.3)	0 (0.0)	0 (0.0)	1.000 †	0.500 (0.472)
	Regional	2 (33.3)	1 (16.7)	1 (16.7)		
Neck	National	3 (42.9)	1 (14.3)	0 (0.0)	1.000 †	0.091 (0.809)
	Regional	2 (28.6)	1 (14.3)	0 (0.0)		
Shoulders	National	1 (33.3)	1 (33.3)	0 (0.0)	1.000 †	1.000 (0.223)
	Regional	0 (0.0)	0 (0.0)	1 (33.3)		
Elbows	National	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
	Regional	0 (0.0)	0 (0.0)	0 (0.0)		
Wrists/Hands	National	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
	Regional	1 (100)	0 (0.0)	0 (0.0)		
Thoracic region	National	0 (0.0)	0 (0.0)	0 (0.0)	NA	NA
	Regional	0 (0.0)	3 (100)	0 (0.0)		
Lumbar region	National	10 (21.3)	7 (14.9)	5 (10.6)	1.816 (0.403)	0.197 (0.403)
	Regional	10 (21.3)	5 (10.6)	10 (21.3)		
Hips/Thighs	National	7 (14.9)	7 (14.9)	8 (17.0)	1.338 (0.512)	0.169 (0.512)
	Regional	5 (10.6)	7 (14.9)	13 (27.7)		
Knees	National	12 (14.6)	8 (9.8)	22 (26.8)	1.832 (0.400)	0.149 (0.400)
	Regional	15 (18.3)	10 (12.2)	15 (18.3)		
Ankles/Feet	National	17 (18.3)	18 (19.4)	18 (19.4)	0.046 (0.977)	0.022 (0.977)
	Regional	12 (12.9)	14 (15.1)	14 (15.1)		
Total number of injuries		99 (34.3) of 289	83 (28.7) of 289	107 (37.0) of 289		

*Pearson Chi-Square test; †(p) Fisher's Exact Test; ‡Phi test. p (significance level).

Categorical variables: frequency (percentage).

NA (not applicable).

Prevalence and Determinants of Lower Extremity Musculoskeletal Injuries in Male Portuguese Trail Runners

Prevalência e Determinantes das Lesões Músculo Esqueléticas na Extremidade Inferior em Corredores de Trail Masculinos Portugueses

Prevalence and Determinants of Lower Extremity Musculoskeletal Injuries in Male Portuguese Trail Runners

Background: Long-distance running has raising in popularity in the last years. Running injuries prevalence and classification can differ depending on the definition. The objective of this study was to profile injury epidemiology at specific lower extremity regions and identify potential determinants of significant injuries in male Portuguese trail runners.

Methods: This study was an observational case-control design. A 12-month retrospective online questionnaire was applied. Injury location, severity, type and tissue type were described. A binary logistic regression model was constructed (with odds ratios and their 95% confidence intervals) of possible determinants using the dependent variable lower extremity significant injury.

Results: Portuguese trail runners presented 62.5% running injuries at lower extremities**.** Descriptive aspects showed that the ankles/feet and knees had the highest prevalence of injuries. Injury proportion, injury rate per 1000 hours and per 1000 km was higher in the ankles/feet region. Injury severity distributed slight injuries at the knees (7.2%) and significant injuries at the ankles/feet (26.1%). Serious knee injuries were those that result in a greater loss of **running time**, but the worst **perceived degree of difficulty** was associated with serious injuries to the hips and thighs. Muscle was the most common type of **tissue injury**. Most running injuries resulted from **overuse**. Statistically significant **potential determinants** (adjusted for age) of **significant lower extremity injuries** were associated with BMI lower than 25 kg/m^2 (odds ratio= 2.085; 95%CI: 1.320 - 3.209; p≤0.001) than those who have a BMI higher than 25kg/m^2; average weekly training distance between 40km and 70km/week (odds ratio= 1.791; 95%CI: 1.114 - 2.878; p=0.016) than those who train less than 40km/week and having a schedule for usual mountain training (odds ratio= 1.689; 95%CI: 1.061 - 2.689; p=0.027) than those who don´t train at the mountain. Important associations at **specific lower extremity anatomical regions** were also found.

Conclusions: Injuries are prevalent amongst Portuguese trail runners, particularly to the knees and ankles/feet. Weight-management plans to adjust body composition, weekly running distance and usual mountain training are potential factors that should be taken into consideration when the results are used to predict running injurie, as well as whether athletes, coaches and sports professionals intend to define training plans and health professionals propose preventive or rehabilitative programs.

Keywords: prevalence, determinants, lower extremity musculoskeletal injuries, severity, time loss, type, tissue type**.**

Introduction

Trail running is gaining popularity as a regular outdoor sport activity mostly with the health benefits association (1). On the other side, researchers have found, during one year of running, almost 80% of long-distance runners will experience an injury (2) especially at lower extremities (1,3,4). The knees were the more common anatomical location of running injury incidence reported by authors (2,5–7).

The outcome of an injury such location, cause, severity and cost (8,9) can explain the individual response to injury. According to Wiese-Bjornstal (10), both personal factors and social context affect athletes' responses to sport injuries. For instance, an acute injury is more likely to be seen or treated for by a health professional and to restrict some daily activities closer to the onset, whilst runners with **overuse** injuries are more likely to report these consequences spread over time (8). Even then, the majority of injures are associated with the overuse mechanism, being the tissue exposed to low-grade forces exceeding their tolerance (9,10) and not allowing the reparation and adaptation of the **musculoskeletal structures** (11–13). It seems that the greater the distance of running training more exposed are the muscle structures to overuse injuries at lower extremity (hip, quadriceps and calf muscles) (13).

Sometimes individuals may not be conscious of their injury and what will be the consequence to continuing running despite the presence of symptoms (14). Some runners can change their training restricting running activity for one or more days, given the definition of injury seriousness according to the length of running time lost (15), but many others continue running while having slight injuries (16). Most papers, almost with no exception, are consensual with using the time-loss injury definition (9,15,17), leaving out the athlete injured that did a self-diagnosis and treated his injury without medical assessment (14). The examination of a physical complaint, after training or competition, depend on the availability of medical support (9). Commonly, the trail runner is not a professional athlete, and for this reason the access to medical evaluation could be limited. Likewise, not all injuries lead to medical care. It was found that runners who were evaluated for health professional 56% result in running reduction or time-loss; but the ones that were non-medically assisted only 40% resulted on reducing or stop running (15,18). Another aspect that expounded musculoskeletal structures to different types of loads is the type of running surfaces/terrain used by the athlete. This exposition couldn´t be necessary harmful. Several authors(19–21), referred that the greater use of trail running or softer surfaces (off-road) rather than others/hard (asphalt, concrete) may protect from some certain structures, namely if they run for several hours at the same terrain.

Running injury prevalence, definition and classification can differ depending on the methodology of the study, type of runner and running modality (3,12). Determination of injury factors are study of interest, namely, to define programs of prevention for health and sports professionals. **Intrinsic and extrinsic risk factors** have been proposed for lower extremity running injuries (1,3,22). Extrinsic factors such participation level, running distance per week or during the event, years of experience, environment and type of running surface, and intrinsic factors such demographic and biomechanical characteristics (age, leg length, anatomical alignment of the lower extremity) and history of previous injuries are considered risk for both male and female runners. Some of the previous factors have a protective influence, but not supported by the literature (1,23).

Further studies are recommended to summarize knowledge about lower extremity running injuries and the determinants of running injuries. Thus, the **objective** of this study was to profile injury epidemiology (prevalence, location, severity, type and tissue type) at specific lower extremity regions and identify potential determinants of significant injuries in Portuguese male trail runners, over a 12-month period. It was hypothesized that significant injuries were expected to be the result of overuse. Injury tissue type should be different according to the anatomical region and respective biomechanical loads exposed during long distance run. Factors regarding the Portuguese trail runner such as age, body mass index, running experience, weekly training volume, usual training track, having a training plan defined by a coach and participation level, could determine the presence of significant lower extremity musculoskeletal injuries.

Materials and methods

3. Study design

A **retrospective observational case-control study** was conducted to gather data on lower extremity musculoskeletal injuries. This study was submitted and approved by the *Ethics Committee* of *University of Porto* (CEFADE 17.2017). This study follows the STROBE guidelines for reporting recruitment, exposure, data collection and results of observational studies (24).

4. Participants

The **sample size** was determined using an estimated prevalence of 72.7% injuries (obtained at the first study). Assuming a margin of error of 5% with 95% confidence interval (25–27) to a population of approximately 1500 trail runners (ATR indicator). The sample size was calculated using the formula: $n = [z^2 * p * (1 - p) / e^2] / [1 + (z^2 * p * (1 - p) / (e^2 * N))]$ (were, n = number of participants, z = 1.96 for a confidence interval (α) of 95%, p = 0.727, e = 0.05); N = 1500). Using these assumptions, the minimum sample size was 238 athletes.

Inclusion criteria were defined has: being male; aged over 18 years, being of Portuguese nationality; having more than 12-months of trail running experience, and having completed at least one trail event, in the past year. Questionnaires that were incomplete, invalid or had duplicated answers were removed from the data. Each variable was examined for major outliers, and then the accuracy of such data was verified.

5. Instrument

A **questionnaire,** written in Portuguese, was designed based on previous studies (2,28,29). The pre-test of the questionnaire was applied to a group of trail runners. A few final adjustments were made after examining their comments and responses. The questionnaire was built using the online survey software (Google-Forms©). The link was sent to e-mail lists through the national (continent and islands) teams and running federations and associations, asking every trail runner to invite others and share the link (https://forms.gle/tanvXhXB448V9tkA9). The questionnaire could be made available on request ("please contact the corresponding author"). The questionnaire was available from January 2018 to April 2019. The questionnaire initiated with a full explanation of the nature and purposes of the study, as well ethical considerations of the data treatment (anonymity and confidentiality).

Descriptive epidemiological aspects data was collected including gender, age, weight and stature. Trail running information: years of trail running experience, echelon, participation level (national and regional), weekly running volume (frequency, time, distance), training plan by coach and the usual type of training surface (road, road with gradient, mountain).

Questions related to injuries included the **occurrence** in the last 12-months, with identification of anatomical **location** (hips/thighs, knees, ankles/feet); type of **injury** (acute or overuse) and injury **tissue type** (skin, bone, muscle, joint and nerve). Other outcomes related to **injury severity**, namely personal and sports consequences associated with the running injury (the need to avoid daily activities, the need for **clinical** attention, the need to stop training or competing). Also, the classification of the **perceived degree of difficulty** during running.

Primary analyses

To answer the modified questions of the Nordic Musculoskeletal Questionnaire **injury was defined as** "any musculoskeletal symptom or complaint sustained by an athlete" (9,30,31), resulting from trail running (competition or training), at a lower extremity, in the last 12 months. Based on the answers, the participants with any injury were fixed into ALL group. The athletes that have reported an injury than according to **injury severity**, were sorted into:

a) Slight: the participant considered an occurrence of “any musculoskeletal symptom or complaint sustained by an athlete” resulting from trail running (competition or training), at lower extremity, in the last 12 months, that **didn’t cause** personal and sports consequences such as the need to avoid daily activities, the need for **health care** attention, the need to stop training or competing.

b) Significant: the participant considered an occurrence of “any musculoskeletal symptom or complaint sustained by an athlete” resulting from trail running (competition or training), at lower extremity, in the last 12 months **and had at least one of the following aspects**: the athlete had to **stop the sport activit**y (running time loss) for at **least one day** (31); and/or **needed to avoid daily activities** and/or **needed to be seen or treated by a health care professional** (clinicians, physiotherapists or nurses).

The need of stop the running activity usually is associated with **a time-loss definition** (15,32), and is defined with different classifications according to the length of period during which the individual needed to stop the sports activity (15). In accordance with National Athletic Injury/illness Reporting System (NAIRS), Schlatmann et al. (1986) cited in Van Mechelen (15) classify **injury seriousness is classified according into sports time-loss as:** “***minor***” (1 to 7 days), ***“moderately serious”***' (8 to 21 days) and “***serious***” (over 21 days).

Injury type

Acute injury was associated with a sudden condition or force applied at the time of injury to the tissue (muscle, tendon, ligament, and bone) that overcomes the threshold of the structure. The symptoms appear practically instantly. **Overuse injury** was referred to as the one that occur over a period of time, consistently due to repetitive loads on the tissue. The symptoms present themselves gradually. As little or no pain/discomfort might be experienced in the early stages, the athlete may not identify the mechanism responsible for the condition (13,15,28).

Injury tissue type

The participants selected from a list of most common medical diagnostics the one that was considered the most impactful to the individual in the past 12 months. Then it was categorized by the tissue type affected according to the classification of sports injuries presented by Brukner & Khan's Clinical Sports Medicine (33). The classification of biological **tissue type** was categorized according to the type of injury and identification of following structures: as skin, bone, muscle (including tendon), joint (including cartilage, ligament, fascia and bursa) and nerve (34–36). The aggregation of different tissue was based on the anatomical features and function (36).

6. Data Analysis

Data was described using descriptive statistics range, mean and standard deviation and percentages. Injury proportion and rate were measures of prevalence.

Injury proportion was estimated by the total number of athletes who had at least one injury during the past 12 months divided by total number of athletes.

Injury rate was estimated per 1000 hours and 1000 kilometers of training to normalize the risk of injury across the athletes. According to time of running (per 1000 hours) injury rate was calculated by expressing the number of injuries divided by the total number of athletes-hours (5). According to the running distance (per 1000 km) the injury rate was calculated by expressing the number of injuries divided by total number of athletes-kilometers (13). Calculation of number of hours or amount of running distance, during the 12-months was obtained by multiplying the average number of running hours or distance per week and then multiplying for 52 weeks (25,37).

A **binary logistic regression model, based on the Enter method,** was used to examine the relative contribution of the predicted risk factors to the **significant** lower extremity musculoskeletal injuries (overall and specific anatomical regions). Regression calculation was performed for lower extremity injuries for all and specific anatomical regions (hips/thighs, knees, ankles/feet) across significant injuries. Contributing variables included in the model were: age; body mass index; trail running experience; average weekly running training frequency; average weekly running time; average weekly running distance; usual mountain training; training plan by a coach and participation level. Crude odds ratio and adjusted (for age group) odds ratios and corresponding 95% confidence intervals were estimated. Statistical significance $p<0.05$ was used to enter the model (38).

The statistical analyses were performed with the Statistical Package for the Social Sciences - SPSS, version 25 for Windows (SPSS Inc., IBM Company, Armonk, NY, USA).

Results

A total of 403 Portuguese male trail runners with a mean age of 40.01±8.18 years (range: 18-62 years), completed the questionnaire. The mean value of mass index was 23.89±2.33 kg/m^2 (range: 18.39 to 32.37 kg/m^2). According to trail running experience, runners have an average 5.63±3.43 years of trail running experience. The volume of training was described has followed: 4.45± 1.43 days of weekly running training (range: 2 to 7 days), 6.33±2.45 hours of weekly running (range 2 to 15 hours) and 56.81±21.08 km of running per week (range: 56.81 to 21.08 km). **Table 1** shows a more detailed information (with subdivisions) regarding the previous variables. Trail runners have a usual mountain training (77.7%) and according to participation level 53.6% are considered national trail runner.

________________________/insert table 1 here /___________________________

An **injury proportion** of 0.63 (95%CI: 0.58-0.67) injuries per trail runner was calculated. The obtained **injury rate** was 2.52 (95%CI: 2.25-2.79) injuries per 1000 hours and 0.28 (95%CI: 0.25-0.31) injuries per 1000km of trail running. The higher injury proportion observed was of 0.52 (95%CI: 0.47-0.56) injuries classified as significant (table3). The average of number of all lower extremity injuries per injured trail runners was 1.33. According to the severity, it was obtained the following average: significant injuries per injured trail runner was of 1.27 and slight injuries per injured trail runner was 1.11. The average number of injuries per trail runners according to anatomical region and injury severity can be analyzed in **table 2.**

________________________/ insert table 2 here /___________________________

In total, 252 (62.5%) of the 403 trail runners reported at least one injury during the last year in the lower extremity. Concerning **the injury severity,** most trail runners 208

(51.6%) reported the occurrence of a significant injury. These injuries were self-reported in the ankles/feet (26.1%) and slight injuries were self-reported in the knees (24.1%). It seems that 50% of injured trail runners didn´t need to avoid daily activities as a consequence of trail running injury at the lower extremity. Contrarily, 59.9% injured trail runners referred the need to be seen or treated by a health care professional and 71.4% to stop training or competing for at least a day, related to trail running injury at the lower extremity**.** The ankles/feet were the regions that reflected a significant interference with daily activity (48.8%), lead to a stop in running or competing (73.2%) and the needed to be seen/treated by a health professional (59.1%) **(Table 3).** The categorization of the injury seriousness into three groups, revealed that the knees are the anatomical location that lead to a greater period without running or competing (84.2±60.5 days) in a range from 30 to 300 days. Remarkably, the injuries located at hips/thighs are the ones that were perceived with a worst degree of difficulty (8.1±1.8 points).

________________________/insert table 3. /___________________________

The total (403) trail runners reported a frequency of 334 injuries between significant (264) and slight (70) injuries. The significant injuries (264), were almost equally distributed between acute (100 injuries) and overuse (164 injuries) with trail running injuries distributed by different tissue type (skin, bone, muscle, joint and nerve). The **distribution of the acute injuries in an anatomical region** was 20 injuries at the hips/thighs, 34 injuries in the knees and 58 injuries at the ankles/feet. In addition. The distribution per location of the overuse injuries was 57 injuries at the hips/thighs, 92 injuries in the knees and 69 injuries at the ankles/feet.

Looking only to the anatomical distribution of the significant injuries, according to injury severity. The injuries that were considered acute have an equal distribution (50.0%) at hips/thighs and occur in the muscle and joint tissue. The significant injuries with a superior prevalence at the joint tissue were both in the knees (62.1%) and in the ankles /feet (90.2%). Considering the significant injuries reported as overuse, the muscle tissue was the most affected in the hips/thighs (69.0%), in the knees (48.5%) and in ankles/feet (35.2%) by injuries related to trail running (**table 4).**

________________________/insert table 4. /__________________________

The **Table 5. and 6.** shows the relationship between lower extremity **significant injuries** and potential determinants: age, BMI, trail running experience, average of weekly training frequency, time and distance, usual mountain training, training plan advised by a coach and the participation level, obtained from the application of the binary logistic regression model.

There were found significant associations, adjusted by age (method Enter) that trail runner that have BMI inferior to 25kg/m2 had 2.058 more chances ($p \leq 0.001$) of having a lower extremity significant injury than higher BMI; and had 2.275 more probabilities ($p = 0.004$) of having an ankles/feet significant injury compared with those who have a higher BMI;

Considering the average of weekly training distance, trail runner with an average between 40km to 70km had 1.791 odds ($p=0.016$) of having **a lower extremity** significant injury compared with those who had a weekly running inferior to 40km and who had a weekly running distance higher than 70km. Trail runner with an average higher than 70km per week had 3.150 odds ($p=0.009$) of having a **hips/thighs** significant injury compared with those who had a weekly running inferior to 40km, and who had an average weekly running training distance between 40km to 70km. Trail runner with an average between 40km to 70km had 2.014 odds ($p=0.019$) of having an **ankles/feet** significant injury compared with those who had a weekly running inferior to 40km and who had a weekly running distance higher than 70km.

Regarding a usual mountain training, trail runner had 1.689 more probability of having a **lower extremity** significant injury (p=0.027) than those who usually don´t train at the mountain. Trail runner had 2.111 more probability of having a **knees** significant injury (p=0.003) than those who usually don´t train at the mountain; and had 1.811 more probability of having a **ankles/feet** significant injury (p=0.018) than those who usually don´t train at the mountain.

Comparing these values with crude odds ratio, the significant associations were present at the same covariates. Other potential determinants doesn´t show significant associations to explain the probability of lower extremity significant injury.

________________________/insert table 5. and 6. /___________________________

Discussion

Thus, the objective of this study was to profile injury epidemiology (prevalence, location, severity, type and tissue type) at lower extremities as well as to identify potential determinants associated with significant running injuries in male Portuguese trail runners, over a 12-month period. The prevalence of lower extremity injuries of the Portuguese trail runner was 62.5%, higher than 21.6% incidence in participants who ran long distances presented by van Poppel et al.(4) but acceptable, according to the reviews used as reference, that suggested a large range of prevalence (24% to 77%) of lower extremity injuries (5) depending of the distance running. Despite the most common anatomical injury location documented being the knee (1,4,7,36) our trail runners have a similar prevalence in the ankles/feet (31.5%) and knees (31.3%) anatomical regions. These could be explained by the irregular and soft surfaces used to run, contrarily to the exposure of the long-distance runners used in some of the reference studies (such ultra-marathon). For this reason, the increased number of injuries at the ankles/feet can occur by the exposition to more irregular running surfaces/terrain, like mountain running, without hard surfaces like road or flat tracks. The knee having a small difference of injury rate and proportion, should also be considered as a potential anatomical location at risk. The different injury definitions and methodological research design resulted in a surprising disparity of injury rate at literature.

During a race, runners could experience a musculoskeletal injury with diverse severities, whether slight or significant. Determining injury severity is an important step towards defining programs of injury rehabilitation or prevention. In the present study, injury proportion and the injury rate of significant injuries per distance was as well superior at ankles/feet region. Running injuries may lead the runner to drop out (permanently or for a period of time) decrease performance or to restriction in maintaining an active lifestyle (8,10). Additionally, and yet important is the impact of injuries in daily activities. It was exposed that injuries at ankles/feet injuries reflected major interference with daily activities (48.8%), this could be related with the greater amount of acute injuries reported at this anatomical region.

The severity combined with the mechanism will determine the impact of the running injury into the athlete and the tissue affected. According to Kluitenberg et al. (8) runners with acute injuries are more likely to be seen or treated for a health professional and to restring some activities closer to the onset, whilst runners with overuse injuries are more likely to report these consequences extend a period of time. Being the trail running a long-distance sport activity combined with an irregular soft surface, this explain partially why the most common significant injury is associated with overuse (12). The amount of training volume (mean hours and distance) could explain the superior prevalence of overuse running injuries at the knees. The fact of the runner usually use mountain to train also could explain the higher risk of acute injuries at the ankles/feet. Although they have lower prevalence may be associated with rapid and intense loads and for this reason, they affected the joint tissue type. These findings are consistent with Knobloch, Yoon and Vog (13) were the distance of running training resulted in muscle overuse injuries at lower extremity (hip, quadriceps and calf muscles), and the acute injury was most common in the ankle follow by knee ligaments and tendon ruptures. They also describe the overuse injuries has the most frequent (than the acute). Tendon injury at ankle was predominant, followed muscular knee pain and ligaments tears at ankles.

At the presented study the injured tissue type most affected by the majority of injuries were muscle (including tendon) and joint (including cartilage, ligament and bursa). The overuse injury was located at the muscle tissue (69.0%). The acute injury was mostly located at the joint tissue type (62.1%). The tissue type is affected could be explained to the mechanical load imposed during trail running (training or competition) where the nature of running surfaces/terrain used by the athlete places stress to different musculoskeletal structures. Hoffman and Krishnan (2) referred that the greater amount of trail running surfaces (off-road) rather than others (asphalt, concrete) may protect from some certain structures, namely if they have to run for several hours, at the same terrain. Trail runner reported that usually uses mountain running tracks to train. This sort of surfaces expounds the musculoskeletal structures to different types of loads. Inclination, technicity, jumps and escalade can be a part of training/competition track. Muscle and joint structures are the most exposed to loads, Poppel et al.(20) as well as Macera (21) found an association of hard surfaces with running injuries. They suggest that the softer surfaces, like those used by trail runners, provide more shock absorption protecting the structures.

The need of health care attention is another consequence of running injury. At the present was observed that 59.9% of tail runners seek or need treatment from a health professional. These values are similar from those found at the literature. According Hoffman and Krishnan(2) 60% of the ultra-marathons with running injuries needed to use medical care (not specified the service) and Besomi et al. (39) referred that 30.4% had health professional evaluation and 26.3% need physiotherapy care after the injury. Van Mechelen (5) cited that 20 to 70% of all injuries leads to medical consultation or treatment. Although, neither author studied this need according to anatomical regions, the present study the injuries placed at ankles/feet were those how suggest a higher need to be seen/treated for health professional (59.1%), this result could be related with the greater prevalence of injuries at this particular anatomical region.

It was exposed that running injuries could lead to the need of stop running (training or competing) or to restring running activity for one or more days. This was consistent with studies such, Hoffman and Krishnan(2) were the percentage of running injured athletes that resulted in loss training of at least one day were 64.6%. It is known that not all injuries lead to medical care. It was found at literature that runners who were evaluated for health professional 56% resulted in running reduction or running time lost and from the ones that were non-medical assisted the number decreases and 40% of runner had to reduce or stop running (15,18). In the present study although, the prevalence of significant injuries occurs at the ankles/feet the amount of overuse injuries was fixed at the knees. This aspect can explain the following result, the serious injury placed at the knee, revealed a greater amount of time without running (84.3±60.5 days, range: 30-300 days) and with an important perceived degree of difficulty. It was found at literature, that as consequence of running injuries (not only at lower extremity) an average of 10.1 days of absence at daily activities (5), but the analyses were for all sample and not only from the ones that have injuries and doesn´t referred the running time loss, other author presented according to self-reported data an average of 13.8 days (range: 0-240 days) of missed training time due to running injury (2). When a trail runner stays without run, the primary consequence is his well-being because the runner use their free time to performed running and exercise (15), and for this reason is important assess the number of running days affected by an injury.

From the possible determinants of lower extremity significant injuries, there was some that, contrarily to systematic revisions studied, were not obtained associations. For instance the age was a factors described by some authors has being associated with an increased risk for running injuries (6,31), but even their results referred a limited evidence of the association. The present study couldn´t associate age to lower extremity significant injury.

Body mass index was another risk factor for running injuries, referred at literature. The van der Worp Maarten et al. (6) review considered the studies with low-quality and for that reason there was a limited evidence that BMI is a risk factor. Buist et al. (31) found an association with higher BMI but referred that "heavier persons" may have a higher risk of running injuries. From the present study, the runner that had a BMI inferior to 25kg/m2 appears had 2.087 (95% CI: 1.340-3.251; p= 0.001) probabilities for having a lower extremity significant injury or 2.297 (95%CI: 1.309-4.032; p=0.004) chances of having an ankles/feet running injury, than those with superior BMI. The findings could lead to think that heavyweight is protective. The fact that the BMI is resultant of a direct measure of body mass index based on height and weight self-reported by the participants. This could lead to bias, because more weight could be associated with greater amount of fat free tissue. For this reason, the results should be carefully interpreted, and for future research it will be important the use multidimensional evaluations whether regarding valid methods and techniques to characterized body size and body composition.

Running experience was associated with risk of injuries several (20,21,31). For these authors participants who were running less than 3 years were 2.2 (21) or the runner that had less than 5 years of running experience were 1.77(20) times at higher risk of injury compared to the more experience ones. The present study, participants who had 5 to 6 years of trail running experience don´t have strong associations with injuries. Consistent with the van der Worp Maarten et al.(6) review where there was no evidence of the relationship between running experience and running injuries or that a more running experience was a risk to the knee and foot. This results confirm the state that being the running inexperience a major risk for sustaining an injury (5,31).

The weekly training frequency were also factors associated with running injuries (6,11). Descriptive analyses at present study, show an average of running training of 4 to 5 days per week. Macera et al.(21) reported that frequency of 3 to 7 times per week for men sample was associated with risk of running injuries. At the present study the average of weekly running frequency was not a potential determinant of significant injury. The explanation for this could be related with the characteristics of this type of runner. The volume of frequency of running training doesn´t reflects the training itself. The training plan (inclinations, speed, type of training) can be extrinsic factor related with the risk of running injuries. Other training aspects that research associates with risk of running injuries is the time of running. The systematic review from Videbaek et l. (37), referred an incidence of running injuries at ultra-marathon runners of 7.2 per 1000hours comparing with other type of runners, and considered this a useful measure to compare risk of injuries across studies. The van der Worp Maarten et al. (6) review found some studies that found an association of increasing hours of running per week to be protective against overall injuries and for knee and foot injuries. At the present study the number of hours was not determinant for lower extremity significant injuries. Descriptive results show that the participants have an occurrence of 2.52 injuries per 1000hours. Once again, the number of running hours that a trail runner does do not reflect the training plan.

The weekly training distance is cited as being the most important factor associated with running injuries and his related (5,6,10,11). Macera et al. (21) and Walter and Hart (40), found that weekly distance was an injury risk factor, the runner that train a distance higher than 64km per week were more likely to sustain an injury. Van Middelkoop et al. (22) concluded that among the weekly running distance of 40km was a strongest predictor also had a protective association for the occurrence of lower extremity running injuries. They did not find an increased risk for running injuries with increased weekly running distance. The present study showed a significant association of a trail runner with a weekly running distance. From the analyses of potential determinants, it was found a strong association by the weekly running distance between 40km until 70km to have a lower extremity and also a ankles/feet significant injury compared with those who had weekly running inferior to 40km and who had a weekly running distance higher than 70km. The hips/thighs are more exposed to injury if the trail runner had an average higher than 70km per compared with those who had a weekly running inferior to 40km, and who had an average weekly running training distance between 40km to 70km. The trail runner could run for several distances, short or ultra, and the influence of distance to the odds of lower extremity injuries changes according to the distance exposition and type of surface. And this could be the explanation for changing of the injury location according to the distance usual performed. The distance can overload the structures not allowing the structures to regenerate resulting in overuse injury (21,40).

Limited research considered the type of surface used during running. The studies use marathon participants and for this reason the type of surface is very different from those that a trail runner is exposed. Knobloch et al.(13) used a sample of master runners (marathon and ultramarathon) that had an average of weekly distance of 65.2±28.3km. For them, the type of surface had influence to kind of injury. The asphalt decreased the risk of tendon injury, the sand increased the risk of tendon injury. The sample almost doesn´t used the mountain to run (13). Stays the idea that running at hard surfaces increases mechanical shock and may overload joints and tendon while soft surfaces affects muscle (41) The trail runner has expected to run in soft surfaces, but also irregular ones. According to some authors, the irregular surfaces increases the risk of acute injuries at ankle and knee (5,13), has it can be used as explanation to the present results. Van der Worp et al. (6) review found only one study that related the hard surface protect thighs from running injuries, but the participants run at hard surface not being compareble to this study. Malliaropoulos et al.(10) expound that runnign in mountain was protective than training on asphalt/road due to the higher shock absotion and for the variation grading surface (climb and descents).

The training design is important to any type of running. According to Malliaropoulos et al. (10), the trail runners that followed a schedule that was individualized were found to be protective, with less running injuries. Limited research with the aspect "training plan by a coach" was found. At the present study, the use of a training plan by a coach does not interfere with (more or less) running injuries. Further investigation is necessary to complement this aspect.

The trail runner can run with different participation level. The level seems not to interfere with risk of running injuries. Is easy to be found races with different grades of difficulty, trail runners with different level of participation, can participate freely at any one (local, national or international) The physical condition and motivation to run, are two factors that could be associated whit participation level (39). At the national circuit the trail runner has a various running event that he could choose to run. The Portuguese and International Trail Running Association implemented a set of trail running categories in classify the races coherently. The criteria are not only terrain-based also distance-based. Other categories are inclination and average elevation of the course (42,43). Previous studies clearly demonstrate the great variety of type of runners included at the researche (middle distance or long distance runners), or classify them according to experience (novice and masters) or according to the running objectives (recreative and competitive)(36,37,39). The trail running for its dimension can have in the same event participants with large age range, and type of runner such competitors, recreative, novices or masters. This could be the explanation for the exponential growth of this modality.

The determinants selected to this study were all supported by previous literature, nevertheless not all were good predicts of lower extremity running injuries.

Limitations

The use of self-administered questionnaires has its limitations and is not representative of the studied population. It can be considered restraining that all injury outcomes were self-reported and thus may not be completely reliable. For future studies, it could be useful to register the correct medical diagnostic to better classify injury. It will be interesting to include information regarding other detailed training information. The association between training characteristics and running injuries seems to be complex, since methodological limitation could compromise comparisons. Such extrinsic factors that are difficult to collect (type of terrain: mountains, snow, sand dunes, river crossings, slot canyons), time of the day, inclination temperature, and humidity).

Conclusion

Trail runners are exposed to running conditions that make them different from other long-distance runners. The recurrent use of a mountain terrain to run and the fact that they do their own training plan, could explain the higher results of **running injury** prevalence, injury proportion and injury rate in the ankles/feet and the knees. To maintain the performance the trail runner is exposed to higher weekly distances, which lead to repetitive loads in anatomical structures in the lower extremities. This aspect can determine the more common overuse injuries and why is the muscle the most affected tissue. Although, the majority of injuries have occurred in the ankles/feet, with a direct impact in daily activities, running and also leading to the need to be seen/treated by a health professional, serious knee injuries were those that revealed the more sports time loss to the athlete. For these reasons the identification of potential determinants focuses on significant running injuries.

To our knowledge, this is the first publication using a classification of injuries not based only in time-loss, but also defining criteria based on the impact that injuries had in non-professionals athletes. Injuries are prevalent amongst Portuguese trail runners, especially in the knees and ankles/feet. Weight management plans to adjust body composition, weekly running distance and usual mountain training are potential factors that should be taken into consideration when the researcher, based on the results, predicts running injury factors. And if, athletes and sports professionals intend to define training plans and when health professionals propose preventive or rehabilitation programs.

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Table 1 - Characteristics of the Portuguese trail runners.

Characteristics	Total 403 (100)
Age group	
Under 23 (18 to 22 years)	16 (4.0)
Senior (23 to 39 years)	165 (40.9)
M40 (40 to 44 years)	114 (28.3)
M45 (45 to 49 years)	65 (16.1)
M50 (50 to 54 years)	25 (6.2)
M55 (55 to 59 years)	14 (3.5)
M60 (≥60 years)	4 (1.0)
Body mass index	
<18,5 kg/m^2	1 (0.2)
18,5 to 24,9 kg/m^2	288 (71.5)
25,0 to 29,9 kg/m^2	108 (26.8)
≥30 kg/m^2	6 (1.5)
Trail running experience	
1 to 2 years	50 (12.4)
3 to 4 years	111 (27.5)
5 to 6 years	134 (33.3)
7 to 8 years	54 (13.4)
≥9 years	54 (13.4)
Average weekly running training frequency	
2 to 3 days/week	120 (29.8)
4 to 5 days/week	184 (45.7)
6 to 7 days/week	99 (24.6)
Average weekly running time	
≤3 hours/week	45 (11.2)
>3 hours/week to ≤6 hours/week	186 (46.2)
>6 hours/week to ≤9 hours/week	119 (29.5)
>9 hours/week	53 (13.2)
Average weekly running distance	
≤40 km/week	103 (25.6)
>40 km/week to ≤70 km/week	221 (54.8)
>70 km/week	79 (19.6)
Usual mountain training (yes)	304 (75.4)
Training plan by a coach (yes)	90 (22.3)
Participation level	
National	216 (53.6)
Regional	187 (46.4)

Quantitative variables: mean ± standard deviation (minimum – maximum). Total participations (n= 403).

Table 2 – Descriptive epidemiologic measures of trail running related injuries by anatomical region (Lower Extremity, Hips/Thighs, Knees and Ankles/Feet) and injury severity (All, Slight and Significant), n = 403.

	Injury proportion Number of injured athletes/ Total number of athletes (95% CI)	**Injury rate (per 1000h)** Number of injuries/ Total number of athletes-hours (95% CI)	**Injury rate (per 1000km)** Number of injuries/ Total number of athletes-kilometers (95% CI)	**Number of injuries/ Total number of athletes**
All injuries				
Lower extremity	0.63 (0.58 - 0.67)	2.52 (2.25 - 2.79)	0.28 (0.25 - 0.31)	0.83
Hips/Thighs	0.20 (0.16 - 0.24)	0.61 (0.48 - 0.74)	0.07 (0.05 - 0.08)	0.20
Knees	0.31 (0.27 - 0.36)	0.95 (0.78 - 1.12)	0.11 (0.09 - 0.12)	0.31
Ankles/Feet	0.32 (0.27 - 0.36)	0.96 (0.79 - 1.12)	0.11 (0.09 - 0.13)	0.32
Slight injuries				
Lower extremity	0.16 (0.12 - 0.19)	0.53 (0.40 - 0.65)	0.06 (0.05 - 0.07)	0.17
Hips/Thighs	0.05 (0.03 - 0.07)	0.14 (0.08 - 0.21)	0.02 (0.01 - 0.02)	0.05
Knees	0.07 (0.05 - 0.10)	0.22 (0.14 - 0.30)	0.02 (0.02 - 0.03)	0.07
Ankles/Feet	0.05 (0.03 - 0.08)	0.17 (0.10 - 0.24)	0.02 (0.01 - 0.03)	0.05
Significant injuries				
Lower extremity	0.52 (0.47 - 0.56)	1.99 (1.75 - 2.23)	0.22 (0.19 - 0.25)	0.66
Hips/Thighs	0.15 (0.12 - 0.19)	0.47 (0.35 - 0.58)	0.05 (0.04 - 0.07)	0.15
Knees	0.24 (0.20 - 0.28)	0.73 (0.59 - 0.88)	0.08 (0.07 - 0.10)	0.24
Ankles/Feet	0.26 (0.22 - 0.30)	0.79 (0.64 - 0.94)	0.09 (0.07 - 0.11)	0.26

CI: confidence intervals. NA: not applicable.

Table 3 – Injury occurrence, daily activities avoidance, need for health-care attention, time-loss, seriousness and perceived degree of difficulty by anatomical region (Lower Extremity, Hips/Thighs, Knees and Ankles/Feet).

			Lower extremity 403 (100)	Hips/Thighs 403 (100)	Knees 403 (100)	Ankles/Feet 403 (100)
Injury occurrence (all injuries) 334 lower extremity injuries		Yes	252 (62.5)	81 (20.1)	126 (31.3)	127 (31.5)
Injury occurrence (slight injuries) 70 lower extremity injuries		Yes	63 (15.6)	19 (4.7)	29 (7.2)	22 (5.5)
Injury occurrence (significant injuries) 264 lower extremity injuries		Yes	208 (51.6)	62 (15.4)	97 (24.1)	105 (26.1)
			Injured athletes 252 (100)	Injured athletes 81 (100)	Injured athletes 126 (100)	Injured athletes 127 (100)
Need to avoid daily activities 154 lower extremity injuries		Yes	126 (50.0)	37 (45.7)	55 (43.7)	62 (48.8)
Need to be seen or treated by a health professional 191 lower extremity injuries		Yes	151 (59.9)	46 (56.8)	70 (55.6)	75 (59.1)
Need to stop training or competing for at least 1 day 222 lower extremity injuries		Yes	180 (71.4)	47 (58.0)	82 (65.1)	93 (73.2)
Injury seriousness	Minor (1 to 7 days)	Perceived degree of difficulty (points)*	Hips/Thighs (n= 12) Knees (n=27) Ankles/Feet (n= 29)	5.3 ± 2.5 (2 - 10)	5.7 ± 2.5 (0 - 10)	5.3 ± 2.5 (0 - 10)
		Time-loss training or competition (days)		3.0 ± 2.2 (1 - 7)	4.4 ± 2.0 (1 - 7)	3.7 ± 2.0 (1 - 7)
	Moderately serious (8 to 21 days)	Perceived degree of difficulty (points)*	Hips/Thighs (n= 14) Knees (n=18) Ankles/Feet (n= 32)	6.7 ± 2.1 (2 - 9)	6.7 ± 2.2 (2 - 10)	6.1 ± 2.8 (0 - 10)
		Time-loss training or competition (days)		14.6 ± 3.3 (8 - 21)	15.8 ± 3.9 (8 - 21)	15.8 ± 4.7 (8 - 21)
	Serious (over 21 days)	Perceived degree of difficulty (points)*	Hips/Thighs (n= 21) Knees (n=37) Ankles/Feet (n= 32)	8.1 ± 1.8 (5 - 10)	7.4 ± 2.7 (0 - 10)	7.3 ± 3.0 (0 - 10)
		Time-loss training or competition (days)		64.3 ± 43.7 (30 - 180)	84.2 ± 60.5 (30 - 300)	43.3 ± 21.3 (25 - 90)

Quantitative variables: mean ± standard deviation (minimum – maximum). Categorical variables: frequency (percentage).

*Numeric Rating Scale is 0 to 10 points, best to worst.

Table 4 – Injuries location (Hips/Thighs, Knees and Ankles/Feet) by injury severity (Slight and Significant), type (Acute and Overuse) and tissue type (Skin, Bone, Muscle, Joint and Nerve).

Injury location	Injury tissue type	Injury severity and type			
		Slight injuries		Significant injuries	
		Acute (n = 16)	Overuse (n = 54)	Acute (n = 100)	Overuse (n = 164)
Hips/Thighs	Skin	2 (50.0)	-	-	-
	Bone	-	-	-	2 (4.8)
	Muscle	2 (50.0)	8 (53.3)	10 (50.0)	29 (69.0)
	Joint	-	7 (46.7)	10 (50.0)	10 (23.8)
	Nerve	-	-	-	1 (2.4)
	Total	4 (100)	15 (100)	20 (100)	42 (100)
Knees	Skin	-	-	3 (10.3)	-
	Bone	-	1 (4.2)	2 (6.9)	3 (4.4)
	Muscle	-	13 (54.2)	6 (20.7)	33 (48.5)
	Joint	5 (100.0)	10 (41.7)	18 (62.1)	31 (45.6)
	Nerve	-	-	-	1 (1.5)
	Total	5 (100)	24 (100)	29 (100)	68 (100)
Ankles/Feet	Skin	1 (14.3)	2 (13.3)	-	8 (14.8)
	Bone	1 (14.3)	4 (26.7)	2 (3.9)	6 (11.1)
	Muscle	-	5 (33.3)	3 (5.9)	19 (35.2)
	Joint	5 (71.4)	4 (26.7)	46 (90.2)	18 (33.3)
	Nerve	-	-	-	3 (5.6)
	Total	7 (100)	15 (100)	51 (100)	54 (100)

Categorical variables: frequency (percentage). Slight injuries (n = 70). Significant injuries (n = 264).

Table 5 – Potential determinants of lower extremity significant injuries.

Dependent variables	Covariates	Crude odds ratios (95% CI)	p	Adjusted odds ratios (95% CI)†	p
Lower extremity	Age group (≥40 years*)				
	<40 years	1.357 (0.915 - 2.012)	0.129	NA	NA
	Body mass index (≥25 kg/m2*)				
	<25 kg/m2	**2.087 (1.340 - 3.251)**	**0.001**	**2.058 (1.320 – 3.209)**	**0.001**
	Trail running experience (<5 years*)				
	≥5 years	1.046 (0.702 - 1.559)	0.823	1.084 (0.725 - 1.621)	0.695
	Average weekly running training frequency (<4 days/week*)				
	≥ 4 days/week	1.096 (0.715 - 1.680)	0.673	1.070 (0.696 - 1.644)	0.757
	Average weekly running time (≤6 hours/week*)				
	>6 hours/week	1.140 (0.768 - 1.693)	0.516	1.114 (0.749 - 1.658)	0.593
	Average weekly running distance (≤40 km/week*)				
	>40 km/week to ≤70 km/week	**1.784 (1.111 - 2.863)**	**0.017**	**1.791 (1.114 - 2.878)**	**0.016**
	>70 km/week	1.506 (0.835 - 2.716)	0.174	1.433 (0.790 - 2.597	0.236
	Usual mountain training (No*)				
	Yes	**1.714 (1.079 - 2.725)**	**0.023**	**1.689 (1.061 - 2.689)**	**0.027**
	Training plan by a coach (Yes*)				
	No	1.151 (0.720 - 1.839)	0.558	1.192 (0.743 - 1.913)	0.466
	Participation level (Regional*)				
	National	1.021 (0.690 - 1.510)	0.918	1.021 (0.689 - 1.512)	0.917

CI: confidence intervals. NA: not applicable.

*Reference category. †Adjusted for age group (method Enter).

Table 6 – Potential determinants of specific lower extremities anatomical regions significant injuries.

Dependent variables	Covariates	Crude odds ratios (95% CI)	p	Adjusted odds ratios (95% CI)†	p
Hips/Thighs injury	Age group (≥40 years*) <40 years	1.484 (0.862 - 2.554)	0.154	NA	NA
	Body mass index (≥25 kg/m²*) <25 kg/m²	1.586 (0.825 - 3.051)	0.167	1.551 0.805 - 2.990	0.190
	Trail running experience (<5 years*) ≥5 years	1.360 (0.770 - 2.401)	0.289	1.430 (0.805 - 2.538)	0.222
	Average weekly running training frequency (<4 days/week*) ≥ 4 days/week	1.931 (0.988 - 3.775)	0.054	1.879 (0.959 - 3.681)	0.066
	Average weekly running time (≤6 hours/week*) >6 hours/week	1.314 (0.764 - 2.260)	0.324	1.277 (0.740 - 2.203)	0.380
	Average weekly running distance (≤40 km/week*) >40 km/week to ≤70 km/week >70 km/week	1.899 (0.875 - 4,124) **3.307 (1.404 - 7,790)**	0.105 **0.006**	1.903 (0.876 - 4.136) **3.150 (1.331 - 7.453)**	0.104 **0.009**
	Usual mountain training (No*) Yes	0.620 (0.309 - 1.243)	0.178	0.603 (0.300 – 1.212)	0.155
	Training plan by a coach (Yes*) No	0.797 (0.427 - 1.488)	0.476	0.830 (0.442 - 1.555)	0.560
	Participation level (Regional*) National	0.910 (0.529 - 1.564)	0.733	0.910 (0.529 - 1.566)	0.733
Knees	Age group (≥40 years*) <40 years	1.274 (0.806 - 2.014)	0.299	NA	NA
	Body mass index (≥25 kg/m²*) <25 kg/m²	1.707 (0.986 – 2.955)	0.056	1.685 (0.973 - 2.920)	0.063
	Trail running experience (<5 years*) ≥5 years	0.932 (0.586 - 1.483)	0.767	0.957 (0.599 - 1.528)	0.853
	Average weekly running training frequency (<4 days/week*) ≥ 4 days/week	0.873 (0.533 - 1.430)	0.590	0.855 (0.521 - 1.403)	0.535
	Average weekly running time (≤6 hours/week*) >6 hours/week	1.034 (0.652 - 1.640)	0.888	1.014 (0.638 - 1.612)	0.952
	Average weekly running distance (≤40 km/week*) >40 km/week to ≤70 km/week >70 km/week	0.933 (0.546 - 1.592) 0.660 (0.323 - 1.346)	0.798 0.253	0.933 (0.546 – 1.594) 0.629 (0.306 – 1.290)	0.799 0.206
	Usual mountain training (No*) Yes	**2.135 (1.298 - 3,511)**	**0.003**	**2.111 (1.282 - 3.475)**	**0.003**
	Training plan by a coach (Yes*) No	1.474 (0.821 - 2.648)	0.194	1.521 (0.844 - 2.741)	0.163
	Participation level (Regional*) National	0.805 (0.509 - 1.271)	0.352	0.804 (0.509 - 1.271)	0.351
Ankles/Feet	Age group (≥40 years*) <40 years	1.221 (0.781 - 1.906)	0.381	NA	NA
	Body mass index (≥25 kg/m²*) <25 kg/m²	**2.297 (1.309 – 4.032)**	**0.004**	**2.275 (1.295 – 3.997)**	**0.004**
	Trail running experience (<5 years*) ≥5 years	0.997 (0.633 - 1.570)	0.990	1.020 (0.646 - 1.611)	0.933
	Average weekly running training frequency (<4 days/week*) ≥ 4 days/week	1.228 (0.747 - 2.020)	0.418	1.210 (0.734 - 1.993)	0.454
	Average weekly running time (≤6 hours/week*) >6 hours/week	1.122 (0.716 - 1.756)	0.616	1.105 (0.705 - 1.733)	0.664
	Average weekly running distance (≤40 km/week*) >40 km/week to ≤70 km/week >70 km/week	**2.011 (1.121 - 3.607)** 1.710 (0.838 - 3.487)	**0.019** 0.140	**2.014 (1.122 - 3.615)** 1.655 (0.808 - 3.389)	**0.019** 0.168
	Usual mountain training (No*) Yes	**1.828 (1.119 - 2.987)**	**0.016**	**1.811 (1.107 – 2.961)**	**0.018**
	Training plan by a coach (Yes*) No	0.831 (0.493 - 1.401)	0.487	0.848 (0.502 - 1.433)	0.538
	Participation level (Regional*) National	1.348 (0.859 - 2.115)	0.194	1.349 (0.859 - 2.118)	0.193

CI: confidence intervals. NA: not applicable. *Reference category. †Adjusted for age group (method Enter).

Body composition among long distance runners

Composição corporal em corredores de longa distância

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BODY COMPOSITION AMONG LONG DISTANCE RUNNERS

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Keyword:	Air displacement plethysmography, Bioimpedance, Dual energy x-ray absorptiometry

BODY COMPOSITION AMONG LONG DISTANCE RUNNERS

ABSTRACT

:

Purpose: The current study was aimed to examine body composition of the adult male ultra-trail runners (UTR) according to their level of participation (regional UTR-R, *vs.* national UTR-N). **Methods:** The sample was composed of 44 adult male UTR (aged 36.5±7.2 years; UTR-R: n=25; UTR-N: n=19). Body composition was assessed by air displacement plethysmography, bioelectrical impedance and dual energy X-ray absorptiometry. In addition, the Food Frequency Questionnaire (FFQ) was applied. Comparison between groups was performed using independent samples t-test. **Results:** Significant differences between groups contrasting in competitive level were found for chronological age (in years; UTR-R: 38.8±8.2 *vs.* UTR-N: 33.5±4.1); body density (in $L.kg^{-1}$; UTR-R: 1.062±0.015 *vs* UTR-N: 1.074±0.009); fat mass (in kg; UTR-R: 12.7±6.8 *vs* UTR-N: 7.6±2.7). **Conclusion:** UTR-N were younger presented higher values for body density and had less fat mass, although no significant differences were found for fat-free mass. The current study evidenced the profile of long-distance runners and the need for weight management programs to regulate body composition.

KEYWORDS:

Air displacement plethysmography; Bioimpedance; Dual energy x-ray absorptiometry

COMPOSIÇÃO CORPORAL EM CORREDORES DE LONGA DISTÂNCIA

RESUMO

Objetivo: O presente estudo foi objetivado para examinar a composição corporal dos corredores de ultra-trail (UTR) e, adicionalmente, comparar dois grupos de acordo com o nível de participação (Regional *vs* Nacional, respetivamente UTR-R e UTR-N). **Métodos:** A amostra foi composta por 44 corredores adultos masculinos (36.5±7.2 anos de idade; UTR-R: n=25; UTR-N: n=19). A composição corporal foi avaliada recorrendo à pletismografia de ar deslocado, bioimpedância elétrica e absorciometria de raios-X de dupla energia. Adicionalmente, foi utilizado o Questionário de Frequência Alimentar. A comparação entre grupos foi realizada com base na prova *t-student* para amostras independentes. **Resultados:** Foram encontradas diferenças significativas por nível de competição para as seguintes variáveis dependentes: idade cronológica (em anos; UTR-R: 38,8±8,2 *vs* UTR-N: 33,5±4,1); densidade corporal (em kg/L; UTR-R: 1,062±0,015 L/kg *vs* UTR-N: 1,074±0,009); massa gorda (em kg; UTR-R: 12,7±6,8 kg *vs* UTR-N: 7,6±2,7). **Conclusão**: Os UTR-N tendem a ser mais jovens e apresentam valores superiores de densidade corporal e consequentemente menores de massa gorda, sendo a massa isenta de gordura semelhante entre os grupos. O presente estudo determinou o perfil dos corredores adultos masculinos de longa distância (ultra-trail), realçando a importância de uma cuidadosa regulação da massa corporal.

PALAVRAS CHAVE:

Pletismografia de ar deslocado; Bioimpedância; Absorciometria de raio-X de dupla energia.

INTRODUCTION

Ultra-trail running is gaining social popularity and the number of participants is continuously increasing with competitions ranging between 42-99 km. The sport comprises intermittent intensities of effort (i.e., walking and running in a large spectrum of positive and negative slopes) at different contexts (type of floor, wind)[1]. As for many other sports, body composition has been considered a determinant factor, particularly because it requires the displacement of whole body corresponding to inertia for running, cycling and swimming[2,3]. A substantial inter-variability in morphology and body composition has been noted in the literature[4]. Previous studies[5,6] compared competitive runners with recreational runners or, alternatively, runners with athletes from other sports. The literature consistently suggests long distance runners characterized by small body size including body mass and its components[7,8]. Fat mass corresponds to biological form of energy storage and a minimum level is recommended for athletes of long events[9]. The optimal combination of body size, muscularity and fat should be viewed as sport-specific.

Cross-sectional studies with long distance runners corroborated the negative role of fat mass (FM) in running performance[1,4]. Although, the two-component model has been reported as the most common option to examine body composition, it should be recognized that fat-free mass (FFM) is composed by several other components, such as water, protein, mineral and glycogen[10]. An accurate assessment of body composition requires concurrent technologies to inform about fat mass, lean body mass, bone mineral content (BMC), body water (total, intra-cellular, extra-cellular) for the whole body and regions of interests (trunk, appendicular). Other models, termed 3-compartment and 4-compartment allow a better estimation of body composition although assumptions are required[10]. Information obtained from concurrent technologies (bioimpedance analysis, air displacement plethysmography, dual energy x-ray absorptiometry, respectively BIA, ADP, DXA) are often combined to produces more robust estimates [3,11,12].

Prolonged episodes of exercise oblige specific demands of nutrients and hydration. The diet, in parallel to training, has a relevant impact on body composition and ability to overcome fatigue[13,14,15]. By inference, the contribution of carbohydrate, protein, fat intake and micronutrients should be considered as part of the training by long-distance runners. It is consensual that the ingestion of carbohydrates before and during prolonged exercises would delay fatigue saving the hepatic and muscular glycogen by providing glucose directly to the active muscles and, more recently, emergent recommendations for improving performance includes lipid supplementation through the ingestion of medium-chain triglycerides during exercise or a high-fat diet during the days before competition[15]. Meantime, although body composition and diet are often recognized as crucial for long distance runners, the literature devoted to concurrent assessment of body composition in long-distance runners is still lacking, particularly by competitive levels. The present study was aimed to examine body composition of male adult ultra-trail runners (UTR) and, additionally, to compare participants by level of participation (regional versus national). Given the negative contribution of FM in long-distance anti-gravitational efforts, it was hypothesized that better athletes are characterized by lower levels of fat mass with fat-free mass adequately kept.

METHODS

Procedures and sample

The procedures of the current study fit the guidelines for research[16]. The project was previously approved by two Ethics Committee (University of Coimbra: CE/FCDEF-UC/00102014; University of Porto: CEFADE 17.2017). Participants were recruited by convenience. The sample corresponds to male runners who performed official competitions in Coimbra area and after being contacted demonstrated availability to visit the Coimbra University Stadium 2-4 weeks after the event for data collection. Their geographic origins covered seven districts. Participants individually signed an informed consent prior to data collection. All measurements were obtained by experienced technicians. The sample was composed of 44 adult male runners. Inclusion criteria were: experience in UTR for two or more years; participation in regional or national competitions organized by the *Portuguese Trail Running Association;* have concluded a minimum of five competitions in the previous season. Additionally, exclusion criterion was the presence of musculoskeletal injury affecting training time during the previous two months. Runners were divided according to their level of practice: regional ultra trail runners *vs.* national ultra trail runners, respectively (UTR-R and UTR-N). The regional level included runners without objectives for the nation-wide ranking while the national group includes those qualified for the nation-wide championship in addition to participation in international events during the past two seasons. The later athletes are systematically exposed to individual coaching with prescriptions for training, diet and recovering methods.

Anthropometry

Stature was measured with a portable stadiometer (Harpenden stadiometer, model 98.603, Holtain, Crosswell, UK). Measurements were performed to 0.1cm accuracy. Body mass was quantified using a portable scale (SECA balance, model 770, Hanover, MD, USA) with precision of 0.1kg.

Air-displaced plethysmography (ADP)

Body volume was assessed by air-displaced plethysmography (Bod Pod Body Composition System, model Bod Pod 2006, Life Measurement Instruments, Concord, CA, USA). The instrument was previously calibrated with a 50.255L cylinder following the procedures issued by the manufacturer. Participants were using lycra underwear and a swimming cap. Each individual repeated the test at least two times until a maximum variation of 150mL was obtained. Whole body volume was adjusted for estimated thoracic gas volume. Afterwards, body density was calculated dividing body mass (kg) by body volume (L). Percentage of fat mass was estimated from body density using the equation proposed for normal weight adults[17].

Bioelectrical impedance analysis (BIA)

Total body water was derived from electric bioimpedance analyser (Akern, model BIA101, Akern Srl, Florence, Italy) using specific software recommended by the manufacturer (Bodygram - version 1.3 Akern Srl, Florence, Italy). Participants were lying in the dorsal position and the electrodes placed on the hand and feet, passing an electric current with very low intensity (800µA) and with a constant frequency (50kHz).

Dual-energy x-ray absorptiometry (DXA)

DXA was used to estimate body composition of the whole body and lower limbs. The above-mentioned data were obtained using a LUNAR (Lunar DPX-MD+, Software: enCORE version 4.00.145, GE Lunar Corporation, Madison, WI, USA) with participants placed on the table of the equipment in dorsal decubitus position following the recommendations of the manufacturer. Data acquisition and analysis were performed by experienced technician in a certified laboratory.

Food frequency questionnaire (FFQ)

A self-administered questionnaire (FFQ) was applied to obtain seasonality, frequency and dose volume for 86 food items. The questionnaire was adapted for the Portuguese[18] and informs about the habitual consumption using a scale of nine options (from "*never or less than once a month*" to "*6 or more times per day*"). The final values summarize the amount of calories and macronutrients.

Analyses

Descriptive statistic was calculated for the total sample (range, mean, standard error of the mean, 95% confidence interval of the mean and standard deviation). Normality was examined. For the comparison between groups, independent samples t-test was used. The magnitude of the effects was interpreted as follows[19]: <0.20 (trivial); 0.20 to 0.59 (small); 0.60 to 1.19 (moderate); 1.20 to 1.99 (large); 2.00 to 3.99 (very large); ≥4.00 (extremely large). The significance level was established at 5%. Statistical analyses were performed using the Statistical Package for the Social Sciences - SPSS, version 25 for Windows (SPSS Inc., IBM Company, Armonk, NY, USA).

RESULTS

Table 1 summarizes descriptive statistics for the total sample. Comparisons of UTR according to competitive level are presented in Table 2. UTR-N were younger ($t= 2.808$; $p<0.01$; $d= 0.80$), have higher values for body density ($t= -3.369$; $p<0.01$; $d= -0.96$) and lower values for body volume ($t= 2.135$; $p<0.05$; $d= 0.67$) and, consequently for fat mass ($t= 3.425$; $p<0.01$; $d= 0.96$). No differences were diagnosed for fat-free mass by ADP, total body water by BIA or lean soft tissue derived from DXA. For all above-mentioned significant differences, the magnitude of the differences was moderate ($0.6<d<1.2$). Fat mass (in kg) was similar by two concurrent protocols as shown in Figure 1.

[Table 1 about here]
[Table 2 about here]
[Figure 1 about here]

DISCUSSION

The current study examined inter-variability by competitive level among male Portuguese ultra-trail runners characterized by low levels of fat mass. In addition, regional and national groups differed in body volume and consequently in body density with implications in mean values of estimated fat mass. Finally, although concurrent methods for assessing body composition did not fully agree, both air displacement plethysmography and DXA technology evidenced national runners having lower levels of fat mass.

The chronological age of the sample in the current study was similar to calculated in other studies dealing with long-distance runners[5]. The results of the current study suggested that stature and body mass are similar to data obtained from long-distance athletes such as marathon runners and 24-hour ultra-marathon runners[7]. Mean value of body fat percent of present study was substantially lower than 161-km ultra marathoners[20] and 65-km mountain ultra-marathon[4] even though the substantial inter-individual variability for fatness. Runners contrasting in competitive level demonstrated distinct values for body composition. As expected, UTR-N exhibited lower levels of fat mass and this was reasonably reported by different protocols: DXA and air displacement plethysmography suggesting both as valid options for weight management.

Estimates for body composition using ADP, BIA and DXA were within normal variation for athletes of similar sport events[21]. Both groups of UTR presented the same amount of fat free tissue, but UTR-R significantly carried lower values of body density (higher amount of fat). It is intuitively established that if a long-distance runner such as a marathon exceeds 15% of FM, he will probably perform at lower running pace[9]. Other important aspect in body composition refers to bone tissue (content, density). UTR are exposed to repetitive mechanical impacts believed to be positively associated with bone health parameters, although in the current study, the differences between groups for BMC (whole body and lower limbs) appeared negligible (see Figure 1). This suggests that the main benefits are probably observed between non-athletes and athletes with trivial to small variability explained by the intensity of the participation. However, low values of bone mineral density were reported among long-distance runners[22], which may be a consequence of stress including hormonal changes, overtraining, unbalanced diet and excessive low levels of fat mass. At an ultra-endurance event, such as an ultra-marathon, the runner could experience an average daily expenditure >8.600Kcal and at the end of the 5-day running event, the energetic cost approach 59.079Kcal[15]. Future studies need to examine the diet of professional and amateur UTR participants by using interviews to understand the complex system of erroneous prescription, intuitive beliefs (including supplements). It is possible that the questionnaire (FFQ) used in the present study does not capture all facts for athletes, aspect that can be considered a weakness of this study and should be the focus of future studies, probably covering a complete season. However, the UTR athletes are supposed to have a minimum knowledge about nutrition and hydration[15]. BIA was used in the current study and offers an estimate of total body water. Future studies may consider phase angle as an indicator of tissue integrity in relations to performance and fatigue.

Limitations of the present study must be recognized. The sample is not representative of Portuguese ultra-trail runners. Future research also needs to approach the diet using a multi-protocol approach (questionnaire, interview, diary reports). Nevertheless, this study has strengths. It combined methodologies to assess body composition and compared the athletes by competitive level. It was possible to profile long-distance runners and to identify the need for adequate weight management particularly body composition. All together, the study claims for more specific and effective training supervision including nutrition.

CONCLUSION

In summary, ultra-trail runners were characterized by low levels of body fat demanding for an accurate regulation of body weight including and adequate maintenance of fat-free mass. These goals require appropriate diet regarding total calories and also nutrients to maintain the integrity of bone and muscle tissues. Bioimpedance is more popularized than absorptiometry and plethysmography and emerged, in the current study, as a reasonable option for assessing body composition.

CONFLICT OF INTEREST

The authors do not have any conflict of interest.

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Table 1. Descriptive statistics for the total sample of male adult long-distance runners (n=44) and test for normality on chronological age, training experience, body size given by stature and body mass and indicators of body composition.

Variable	units	Range		Mean			Standard deviation	Normality	
		Minimum	Maximum	Value	Standard error	(95%CI)		K-S value	*p*
Chronological age	years	23.3	53.2	36.5	1.1	(34.3 to 38.7)	7.2	0.081	0.20
Training experience	years	2	17	4.0	0.4	(3.10 to 4.8)	2.8	0.314	<0.01
Stature	cm	161.8	189.7	174.4	1.0	(172.3 to 176.5)	6.9	0.109	0.20
Body mass	kg	58.5	100.5	73.0	1.5	(70.1 to 76.0)	9.6	0.142	0.03
ADP									
Body volume	L	54.382	98.103	68.508	1.455	(65.574 to 71.441)	9.649	0.137	0.04
Body density	kg/L	1.025	1.088	1.067	0.002	(1.063 to 1.071)	0.014	0.232	<0.01
Fat mass	%	4.8	33.2	13.9	0.9	(12.0 to 15.8)	6.2	0.229	<0.01
	kg	3.0	33.4	10.5	0.9	(8.6 to 12.3))	6.0	0.186	<0.01
Fat free mass	kg	51.5	77.3	62.6	1.0	(60.5 to 64.7)	6.9	0.093	0.20
BIA									
Total body water	L	34.8	58.6	45.0	0.8	(43.4 to 46.6)	5.4	0.092	0.20
DXA – whole body									
BMC	g	2413	4128	3219	68	(3082 to 3356)	451	0.095	0.20
BMD	g/cm²	1.103	1.450	1.268	0.014	(1.234 to 1.296)	0.093	0.098	0.20
Fat tissue	kg	4.2	33.6	10.8	0.9	(8.9 to 12.6)	6.2	0.172	<0.01
Lean soft tissue	kg	48.3	72.3	58.6	0.9	(56.8 to 60.4)	5.9	0.102	0.20
DXA – lower limbs									
BMC	g	932	1635	1250	26	(1198 to 1303)	174	0.112	0.20
BMD	g/cm²	1.172	1.620	1.423	0.017	(1.388 to 1.458)	0.114	0.098	0.20
Fat tissue	kg	1.2	9.5	3.2	0.3	(2.7 to 3.8)	1.7	0.174	<0.01
Lean soft tissue	kg	16.9	25.1	20.6	0.3	(20.0 to 21.3)	2.2	0.098	0.20

ADP (air displacement plethysmography); BIA (bioelectrical impedance analysis); DXA (dual energy X-ray absorptiometry); BMC (bone mineral content); BMD (bone mineral density); 95% CI (95% confidence interval); K-S (Kolmogorov-Smirnov test); p (significance level)

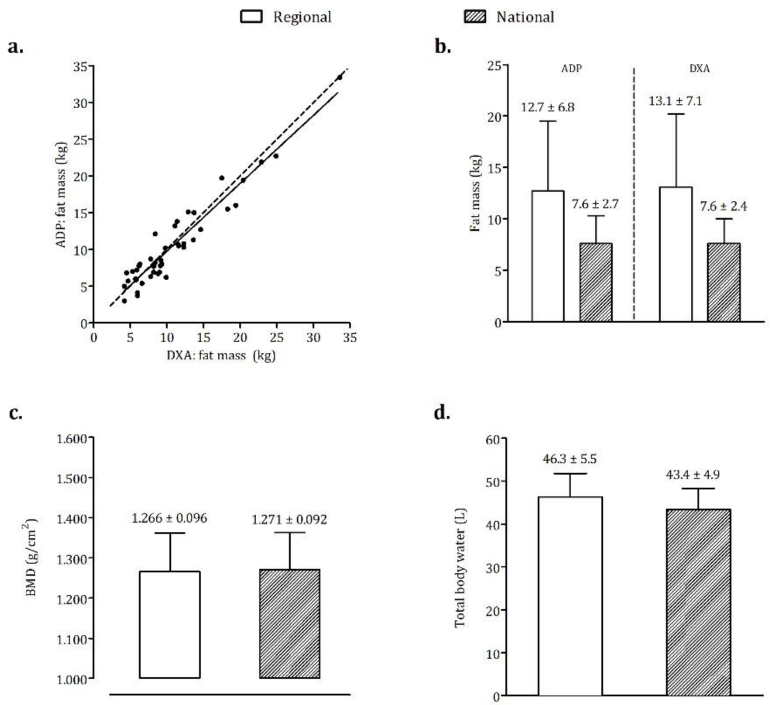

Figure 1. Agreement between estimated of fat mass (in kg) assessed by air displacement plethysmography (ADP) and DXA (dual energy x-ray absorptiometry) - panel a); variation of fat-mass (in kg) by competitive level (regional versus national UTR participants) according to above mentioned concurrent technologies – panel b); variation of bone mineral density and total body water by competitive level – panel c) and panel d), respectively.

Table 2. Mean and standard deviation by competitive group (Regional *vs* National) and comparisons between groups including magnitude effects of the mean differences on chronological age, training experience, body size given by stature and body mass and indicators of body composition plus diet nutrients (obtained from *Food Frequency Questionnaire*).

Y_i: Dependent variable		X: Independent variable		Comparison				
		Regional	National	Difference of means	t-student		Magnitude of effects	
		(n=25)	(n=19)	(95%CI)	t-value	*p*	d	(qualitative)
Chronological age	years	38.8±8.2	33.5±4.1	5.3 (1.5 to 9.1)	2.808	<0.01	0.80	(moderate)
Training experience	years	3.9±3.0	4.1±2.6	0.2 (-1.9 to 1.6)	-0.199	0.84	-0.07	(trivial)
Stature	cm	174.2±6.5	174.7±7.4	0.5 (-4.8 to 3.7)	-0.243	0.81	-0.03	(trivial)
Body mass	kg	75.4±10.5	69.9±7.6	5.5 (-0.2 to 11.2)	1.931	0.06	0.60	(moderate)
ADP: Body volume	L	71.110±10.611	65.085±7.106	6.025 (0.330 to 11.721)	2.135	0.04	0.67	(moderate)
ADP: Body density	L/kg	1.062±0.015	1.074±0.009	-0.012 (-0.020 to -0.005)	-3.369	<0.01	-0.96	(moderate)
ADP: Fat mass	%	16.2±6.8	10.8±3.7	5.4 (2.2 to 8.6)	3.388	<0.01	0.97	(moderate)
	kg	12.7±6.8	7.6±2.7	5.1 (2.1 to 8.1)	3.425	<0.01	0.96	(moderate)
ADP: Fat free mass	kg	62.8±6.7	62.3±7.4	0.4 (-3.8 to 4.7)	0.210	0.84	0.07	(trivial)
BIA: Total body water	L	46.3±5.5	43.4±4.9	3.0 (0.3 to 6.1)	1.829	0.07	0.57	(small)
DXA – whole body:BMC	g	3196±435	3250±482	-54 (-336 to 226)	-0.387	0.70	-0.12	(trivial)
DXA – whole body:BMD	g/cm^2	1.266±0.096	1.271±0.092	-0.005 (-0.063 to 0.052)	-0.188	0.85	-0.05	(trivial)
DXA – whole body:FT	kg	13.1±7.1	7.6±2.4	5.5 (2.4 to 8.6)	3.648	<0.01	1.01	(moderate)
DXA – whole body:LST	kg	58.5±6.0	58.7±6.0	-0.2 (-3.9 to 3.5)	-0.112	0.91	-0.03	(trivial)
DXA – lower limbs: BMC	g	1246±176	1257±176	-11 (-119 to 97)	-0.206	0.84	-0.06	(trivial)
DXA – lower limbs: BMD	g/cm^2	1.405±0.114	1.446±0.115	-0.040 (-0.110 to 0.030)	-1.158	0.25	-0.37	(small)
DXA – lower limbs: FT	kg	3.9±1.9	2.4±0.8	1.6 (0.6 to 2.5)	3.686	<0.01	1.04	(moderate)
DXA – lower limbs: LST	kg	20.7±2.4	20.6±2.1	0.2 (-1.2 to 1.5)	0.243	0.81	0.04	(trivial)
FFQ: Calories	kcal	2629±856	2323±755	306 (194 to 806)	1.234	0.22	0.38	(small)
FFQ: Proteins	%	21.2±4.8	21.7±3.5	-0.5 (-3.1 to 2.1)	-0.404	0.69	-0.12	(trivial)
FFQ: Carbohydrates	%	46.4±7.6	49.0±8.7	-2.5 (-7.5 to 2.5)	-1.016	0.32	-0.33	(small)
FFQ: total fat	%	33.7±4.9	30.8±5.5	2.8 (-0.4 to 6.0)	1.796	0.08	0.57	(small)
FFQ: saturated fat	%	8.8±1.9	8.5±2.8	0.3 (-1.1 to 1.7)	0.448	0.66	0.13	(trivial)
FFQ: monounsaturated fat	%	15.0±3.3	13.3±3.0	1.7 (-0.2 to 3.6)	1.762	0.09	0.55	(small)
FFQ: polyunsaturated fat	%	5.4±0.9	4.6±1.2	0.9 (0.2 to 1.5)	2.680	<0.01	0.79	(moderate)
FFQ: Cholesterol	mg	528±167	441±143	88 (-8 to 184)	1.841	0.07	0.57	(small)
FFQ: Fibres	g	37.0±16.6	56.5±97.8	-19.5 (-59.6 to 20.6)	0.981	0.33	-0.31	(small)
FFQ: Ethanol	g	8.9±6.3	8.8±8.8	0.1 (-4.5 to 6.5)	0.040	0.97	0.01	(trivial)
FFQ: calcium	mg	1149±562	1110±642	39 (-328 to 406)	0.215	0.83	0.07	(trivial)

ADP (air displacement plethysmography); BIA (bioelectrical impedance analysis); DXA (dual energy X-ray absorptiometry); BMC (bone mineral content); BMD (bone mineral density); FT (fat tissue); LST (lean soft tissue); FFQ (food frequency questionnaire); 95% CI (95% confidence interval); t (t-student test value); p (significance); d (d- Cohen value)

Physiological profile of adult male long-distance runners (ultra-trail): variation by level of participation (national versus regional)

Perfil fisiológico de corredores adultos masculinos de trail de longa distância (nacional versus regional))

AO- 5256_PREPRINT FRAN

Physiological profile of adult male long-distance runners: variation by level of participation (national versus regional)

Perfil fisiológico de corredores de longa distância adultos do sexo masculino: variação por nível de participação (nacional versus regional)

Short title: anaerobic and aerobic fitness in trail runners

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ABSTRACT

Objective: The current study was aimed to describe and identify the importance of different indicators of the aerobic and anaerobic fitness of male ultra-trail runners according to their level of participation (Regional versus National, respectively ultra-trail runners regional and ultra-trail runners national). **Methods:** Forty-four male ultra-trail runners were assessed (36.5±1.1 years). They were classified as regional (n=25) and national (n=19). Wingate test was used to assess the anaerobic pathway. In parallel, a progressive incremental running test was performed and ventilatory thresholds registered, in parallel to heart rate and lactate concentration at the end of the protocol. Comparison between groups was performed using independent samples t-test. **Results:** No significant differences were found between outputs derived from Wingate test. For aerobic fitness, while examining absolute values, differences were uniquely significant for VT2 (UTR.R: 3.78±0.32L.min-1 UTR-N: 4.03±0.40L.min-1 $p<0.05$). Meantime, when aerobic fitness was expressed per unit of body mass, differences were significant for VT2 (UTR-R: 50.75±6.23mL.kg-1min-1 UTR-N: 57.88±4.64mL.kg1min-1 $p<0.05$) and also VO2max (UTR-R: 57.33±7.66mL.kg-1min-1 UTR-N: 63.39±4.26mL.kg-1min-1 $p<0.05$). **Conclusion:** The current study highlighted the importance of considering physiological parameters derived from running protocols, preferably expressed per unit of body mass. In addition, regarding parameters of aerobic fitness, ventilatory thresholds 2 seemed to be the best single variable to distinguish trail runners of contrasting level of participation. Values of maximal oxygen uptake seemed of relative interest to distinguish long distance runners by level of participation.

Keywords: Exercise test, treadmill test, bicycle ergometry test, oxygen consumption

RESUMO

OBJETIVO: Descrever e identificar a importância de diferentes indicadores de aptidão aeróbia e anaeróbia de corredores de trilhas (*trail-running*) adultos do sexo masculino de acordo com seu nível de competição (regional versus nacional).**MÉTODOS:** Foram avaliados 44 corredores de trilha masculinos (36,5 ± 1,1 anos) classificados como regionais (n=25) e nacionais (n=19). O teste de Wingate foi utilizado para avaliar a via anaeróbia. Paralelamente, foi realizado um teste incremental e progressivo de corrida e registrou-se a adaptação ventilatória, bem como frequência cardíaca e concentração de lactato ao final do protocolo. A comparação entre os grupos foi realizada usando teste t de amostras independentes. **RESULTADOS:** Não foram encontradas diferenças significativas entre as variáveis derivadas do Wingate. Na aptidão aeróbia, examinando valores absolutos, as diferenças foram exclusivamente significativas para o limiar ventilatório-2 (regional: 3,78 ± 0,32 L.min-1 versus nacional: 4,03 ± 0,40 L.min-1 p <0,05). Após a aptidão física aeróbia ser expressa por unidade de massa corporal as diferenças foram significativas para o limiar ventilatório-2 (regional: 50,75 ± 6,23mL.kg-1min-1 versus nacional: 57,88 ± 4,64mL.kg-1min-1 p <0,05) e também VO2max (regional: 57,33 ± 7,66mL.kg-1min-1 versus nacional: 63,39 ± 4,26mL.kg-1min-1 p <0,05). **CONCLUSÃO**: O presente estudo destacou a importância de considerar parâmetros fisiológicos derivados de protocolos de corrida, preferencialmente expressos por unidade de massa corporal. Além disso, em relação aos parâmetros de aptidão aeróbia, o limiar ventilatório-2 pareceu ser a melhor e única variável para distinguir os corredores de trilha de diferentes níveis de participação.

Descritores: Exercício; Teste de Esteira Rolante; Teste Ergômetro de Bicicleta; Consumo de oxigênio

Introduction

Trail running is generally performed on hiking trails, often in mountainous terrain (both uphill and downhill). In contrast to cross country governed discipline International Association of Athletics Federation (IAAF) trail running is not recognized as a discipline of IAAF. The sport presents a large variation regarding the distances of the race that are considered short or ultra-long depending on the following criteria, <42km and >100km, respectively.(1) It is attracting new participants over the recent years.(2) Although the increasing popularity of trail running, research is still limited.

Aerobic fitness seems an obvious determinant of performance in middle and long distance runners.(3) Meantime, maximal oxygen uptake is considered of minor importance in downhill.(4) Variation in the characteristics of the competitions, particularly slope, may result in extraordinary demands for other metabolic pathways (*e.g*. anaerobic fitness). Activities during competitions were generally sustained at a wide range of intra and inter-individual variability regarding percentage of peak heart rate and oxygen uptake. A recent study(5) described the physiological profile of a 65km (4000m cumulative elevation gain) running mountain ultra-marathon based on 23 amateur participants. Heart rate (HR) was monitored during the race and intensity was expressed as Zone I (Ventilatory Threshold (<VT1), Zone II (VT_1-VT_2), Zone III (>VT_2). Race time in the cited study was 11.8 hours (±1.6h) and mean race intensities were as follows: 85.7% Zone I, 13.9% Zone II, 0.4% Zone III. This information about the intensity variation is crucial for training, nutrition, and strategy for competitors.

The literature devoted to the sport is covering topics such as muscular performance(6) and muscle damage,(7) central fatigue and sleep deprivation,(8) risk of musculoskeletal injuries.(9)

Recently, Yargic et al.,[10] examined the acute variation of molecules (IL-6, IL-15 and Hsp72) that have significant metabolic effects on glucose and fat metabolism after a long-distance trail run. Other recent study by Bjorklund et al.,[11] described biomechanical characteristics of short-distance trail runners and respective performances. The literature comparing ultra-trail runners (UTR) contrasting in their participation level (national versus regional, respectively UTR-N and UTR-R) is lacking. Efficiency of converting metabolic energy into mechanical power represents one of the main determinants of endurance performance.[12] In ultra-endurance triathlons mean HR intensities presented a gradient running < cycling < swimming.[13] Competitions often present large withdrawal rates[14] mainly due to inadequate pacing strategies (*i.e.* choice of exercise intensity) and, in the case of trail runners, changes in energy cost associated with different running conditions (particularly slope) make it very difficult to prescribe racing velocity.

OBJECTIVE

An intuitive interesting question is possible to be addressed for endurance trail runners: "why should fitness in prolonged endurance exercises, such as trail run, in which the oxygen consumption is not maximal, be determined by VO_{2peak}". Taking into consideration the previous information, the current study was aimed to determine the profile of regional and national trail runners and, additionally, to identify the importance of different indicators of aerobic and anaerobic fitness to distinguish athletes by level of participation. It was hypothesized that parameters related to metabolic pathways, other than maximal oxygen uptake emerged as relevant to distinguish long-distance runners by competitive level.

METHODS

Study design and Ethic requirements

This is a comparative cross-sectional study. It was conducted at the Laboratory of Biokinetics located in the Coimbra University Stadium. The study followed the ethical standards for Sports Medicine.[15] The proposal was previously approved by the Ethics Committee of the University of Coimbra (CE/FCDEF-UC/00102014). All participants signed an Informed Consent, and participation was voluntary and informed about the nature and objectives of the study.

Sample

Participants were recruited by convenience. Sample size was similar to previous studies with trail runners.[1,6,10,11] The final sample was composed of 44 adult male UTR (chronological age: 36.5±1.1 years). Inclusion criteria were as follow: - two or more years of participation and competition in the sports; - having participated in regional or national competitions organized by the Portuguese Trail Running Association; - a minimum of five competitions in the previous season. Exclusion criterion was the presence of musculoskeletal time-loss injury during the previous two months. The sample was divided into two groups according to their level of participation: regional and national, respectively UTR-R versus UTR-N. The group UTR-R included runners without official coaches and not oriented to achieve competitive objectives regarding the national ranking. In parallel, UTR-N group corresponds to participants who systematically train under the orientation of a coach and were qualified for the national ranking. Ultra-trail runners national also registered participation in international events. Information about training experience was obtained by interview.

Anthropometry

Body mass and stature were measured to the nearest 0.1kg and 0.1cm using a scale (SECA balance, model 770, Hanover, MD, USA) and a stadiometer (Harpenden stadiometer, model 98.603, Holtain, Crosswell, UK), respectively.

Aerobic fitness

Oxygen uptake was obtained using a motorized treadmill (Quasar, HP Cosmos, Germany) while the subjects performed an incremental running test. Before each test, flow and volume were calibrated using 3L capacity syringe (Hans Rudolph, Kansas City, MO). The gas analyzer (CO_2 and O_2) (Metamax Ergospirometry System, Cortex Biophysite GmbH) was also calibrated using the kit (Cosmed, UN1956, 560L, 2200 psi, 70F). Air temperature and humidity were measured using a digital weather portable station within thermo-hygrometer (Oregon Scientific, Model BAR913HGA, Tualatin, USA). All tests were performed at the same time of the day (in the mornings between 10 a.m. and 12 a.m.). The final lactate was measured with a portable analyzer (Lactate Pro2 Analyzer, Arcay, Inc.). Blood sample was collected, at the right thumb, at the recovery period immediately after the maximum effort: 25µl blood sample was obtained using a disposable lancet (UniStik 2 Extra lancets). The athletes started with two minutes running effort at velocity of 8 $km.h^{-1}$ with a constant 2% slope of the treadmill. A progression of 1 $km.h^{-1}$ was implemented every minute until the individual reached exhaustion without changing the slope.[16] Heart rate was registered using HR-monitor (model T81 - CODED, Polar Electro, Finland). Peak oxygen uptake was achieved when the athlete reached at least four from the five criteria: - respiratory exchange ratio (RER) higher than 1.05; -

maximal HR over 95% of maximum value predicted for age; - a plateau in VO_2 although an increase in running velocity; - perception of exhaustion (Borg CR10 Scale); - blood lactate concentration >8 $mmol.L^{-1}$. The following parameters were retained for subsequent analyses: VO_2 values (VT_1, VT_2, peak), maximal HR, RER and lactatemia at the end.

Anaerobic fitness

The 30-second Wingate Anaerobic Test (WAnT) was performed using a friction-loaded cycle ergometer (Monark AB, model 894E Peak Bike, Varberg, Sweden) connected to a microcomputer. The ergometer was calibrated as recommended by the manufacturer. Resistance was set at 0.075kg per unit of body mass. Participants started with a standardized 3-min warm-up, followed by a set of stretching exercises of the lower limbs. Before starting the test, the subjects pedaled at a constant rate of 60 rpm, with minimum resistance (basket supported) before the countdown that corresponded to the starting signal. Verbal standardized encouragement was given by observers. Wingate Anaerobic Test outputs retained for the present study were as follows: WAnT peak (WAnT-P) and WAnT mean (WAnT-M).

Statistics analysis

Reliability of anthropometric measurements was examined using technical error of measurement (TEM) and coefficients of variation (%CV). A subsample (n=13) was measured twice for the above-mentioned variables to determine TEM expressed in the same units as the variables and also as % of the pooled mean (%CV): stature (TEM= 0.37cm; %CV= 0.21) and body mass (TEM= 0.56kg; %CV =

0.81%). Quality control was not possible for this study for the two functional tests. Descriptive statistics were calculated for the total sample (mean, standard error of the mean, 95% confidence interval of the mean and standard deviation). Kolmogorov-Smirnov test was used to test normality. For the comparisons between groups, the independent samples t- test was used. The level of significance was 95%. All statistics were computed using the Statistical Package for the Social Sciences (SPSS) version 25 for Windows (SPSS Inc., IBM Company, Armonk, NY, USA) and figures obtained from GraphPad Prism version 5.03 software (GraphPad Software, La Jolla, USA).

RESULTS

Descriptive characteristics for the total sample on chronological age, training experience, stature, body mass, WAnT and aerobic outputs were summarized in Table 1. All variables, except for training experience, body mass and RER which were marginal dependent variables to the objectives of the current study. Briefly, the sample presented mean age of 36.5 years and experience, on average, 4 years of participation in the sport. Comparisons by level of participation did not suggest significant differences between UTR-R and UTR-N on training experience and stature (Table 2). Meantime, mean differences appeared as moderate in body mass with UTR-R being 5.5kg heavier than runners classified at national level (Figure 1).

Table 1. Descriptive statistics for the total sample (n=44) for chronological age, training experience, overall body size and outputs extracted from the Wingate test and treadmill progressive incremental running test

Variable	Unit	Mean			Standard deviation
		Value	Standard error	(95%CI)	
Chronological age	Years	36.5	1.1	(34.3 to 38.7)	7.2
Training experience	Years	4.0	0.4	(3.1 to 4.8)	2.8
Stature	Cm	174.4	1.0	(172.3 to 176.5)	6.9
Body mass	Kg	73.0	1.5	(70.1 to 76.0)	9.6
WAnT-P	Watt	820	24	(776 to 872)	157
WAnT-M	Watt	587	13	(562 to 615)	86
Oxygen uptake: VT_1	$L.min^{-1}$	2.93	0.06	(2.79 to 3.05)	0.4
Oxygen uptake: VT_2	$L.min^{-1}$	3.87	0.06	(3.75 to 4.00)	0.4
Oxygen uptake: Peak	$mL.min^{-1}$	4.32	0.06	(4.21to 4.43)	0.4
Maximal Heart rate	$beats.min^{-1}$	175	1.5	(172 to 178)	9
RER	$L.min^{-1}$ / $L.min^{-1}$	1.16	0.01	(1.14 to 1.16)	0.1
Lactate	$mmol.L^{-1}$	10.9	0.3	(10.23 to 11.6)	2.0

WAnT-P: (Wingate test peak output); WAnT-M (Wingate test mean output); VT_1 : first ventilatory threshold; VT_2 : second ventilatory threshold; RER:> respiratory exchange ratio; 95%CI: 95% confidence interval.

Table 2. Descriptive statistics (mean ± standard deviation) by competitive level and comparisons between groups for chronological age, training experience, anthropometry and outputs derived from the functional tests used to assess metabolic pathways.

Dependent variables		X: Independent variable			Comparison		
$Y_{i:}$	Units	Regional (n=25)	National (n=19)		Difference (95%CI)	*t* Student	
						t value	p
Chronological age	Years	38.8±8.2	33.5±4.1		5.3 (1.5 to 9.1)	2.808	<0.01
Training experience	Years	3.9±3.0	4.1±2.6		-0.2 (-1.9 to 1.6)	-0.199	0.84
Stature	Cm	174.2±6.5	174.7±7.4		-0.5 (-4.8 to 3.7)	-0.243	0.81
Body mass	Kg	75.4±10.5	69.9±7.6		5.5 (-0.2 to 11.2)	1.931	0.06
WAnT-P	Watt	816±164	824±150		-7.3 (-104.8 to 90.2)	0.151	0.88
WAnT-M	Watt	581±94	594±76		-13.6 (-66.8 to 39.6)	0.517	0.61
Oxygen uptake - VT_1	L.min^{-1}	2.95±0.32	2.96±0.48		-0.0 (-0.3 to 0.2)	-0.071	0.94
Oxygen uptake - VT_2	L.min^{-1}	3.78±0.32	4.03±0.40		-0.2 (-0.5 to -0.0)	-2.238	0.03
Oxygen uptake -peak	L.min^{-1}	4.26±0.35	4.40±0.36		-0.1 (-0.4 to 0.1)	-1.292	0.20
Maximal Heart rate	beats.min^{-1}	173±10	176±7		-3 (-9 to 2)	-1.360	0.25
RER		1.16±0.07	1.16±0.06		0.01 (-0.04 to 0.04)	-0.026	0.98
Lactate	mmol.L^{-1}	11.42±1.83	10.27±2.04		1.1 (-0.2 to 2.5)	1.691	0.10
Oxygen uptake - VT_1	mL.kg^{-1}.min^{-1}	39.56±5.15	42.45±5.73		-2.9 (-6.2 to 0.5)	-1.736	0.09
Oxygen uptake - VT_2	mL.kg^{-1}.min^{-1}	50.75±6.23	57.88±4.64		-7.1 (-10.6 to -3.7)	-4.156	<0.01
Oxygen uptake - peak	mL.kg^{-1}.min^{-1}	57.33±7.66	63.39±4.26		-6.1 (-9.8 to -2.3)	-3.287	0.02

WAnT-P: wingate test peak output ; WAnT-M: wingate test mean output; $VT_{1:}$ first ventilatory threshold; $VT_{2:}$ second ventilatory threshold; RER: respiratory exchange ratio ; 95%CI: 95% confidence interval; p: significance level.

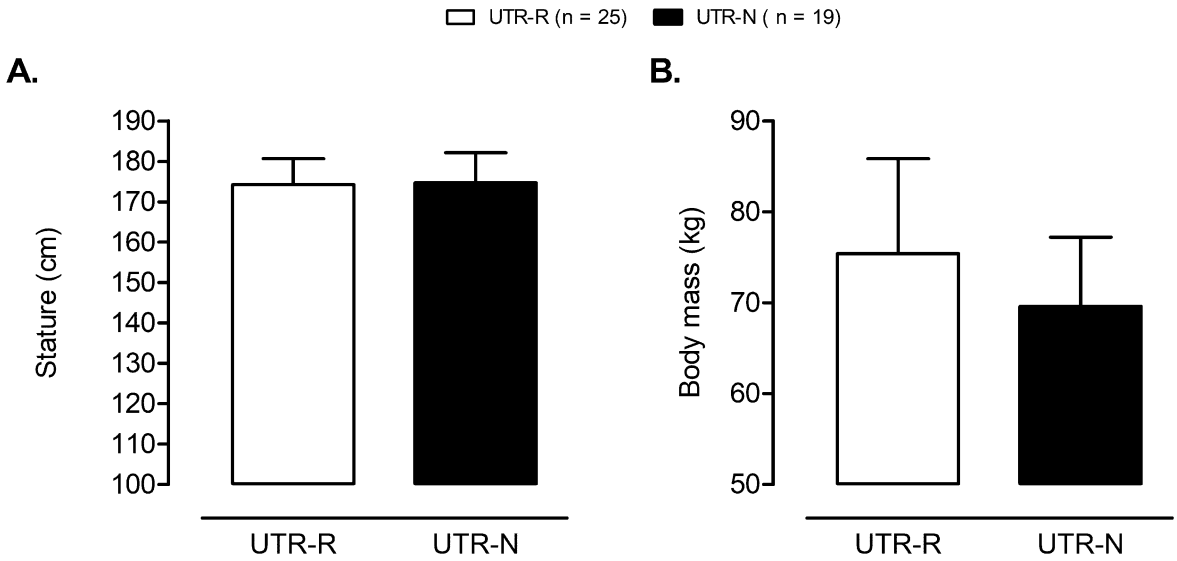

Figure 1. Mean values for body size variables by level of participation. **Legend**: UTR-R (recreational-level runners); UTR-N (national-level runners).

Overall, although there is a consistent trend for UTR-N to attain better absolute values for WAnT outputs (Figure 2), VTs and VO_{2peak} (Figure 3). The two groups only presented moderate mean differences for VT_2 ($t=-2.238$; $p<0.05$). After determination of VT_2 oxygen uptake values per unit of body mass mean differences between groups appeared as large ($t=-4156$; $p<0.01$). Actually, differences were more pronounced when ventilatory oxygen variables were expressed in their relative values: VT_1 (absolute VT_1: not significant; relative VT_1: not significant) and $VO2_{peak}$ (absolute $VO2_{peak}$: not significant; relative $VO2_{peak}$: –$p<0.05$). For maximal HR, RER and blood lactate no significant differences were found, although magnitude of the mean differences was moderate for lactate concentration with lower values noted for national runners.

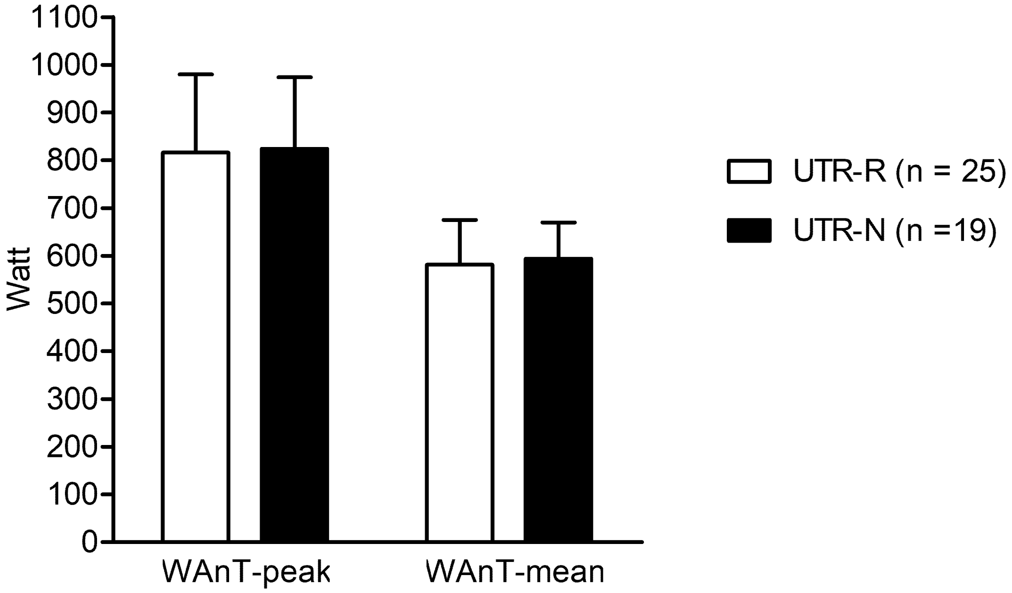

Figure 2. Mean values for anaerobic outputs obtained from the Wingate test by level of participation. **Legend**: UTR-R (recreational-level runners); UTR-N (national-level runners).

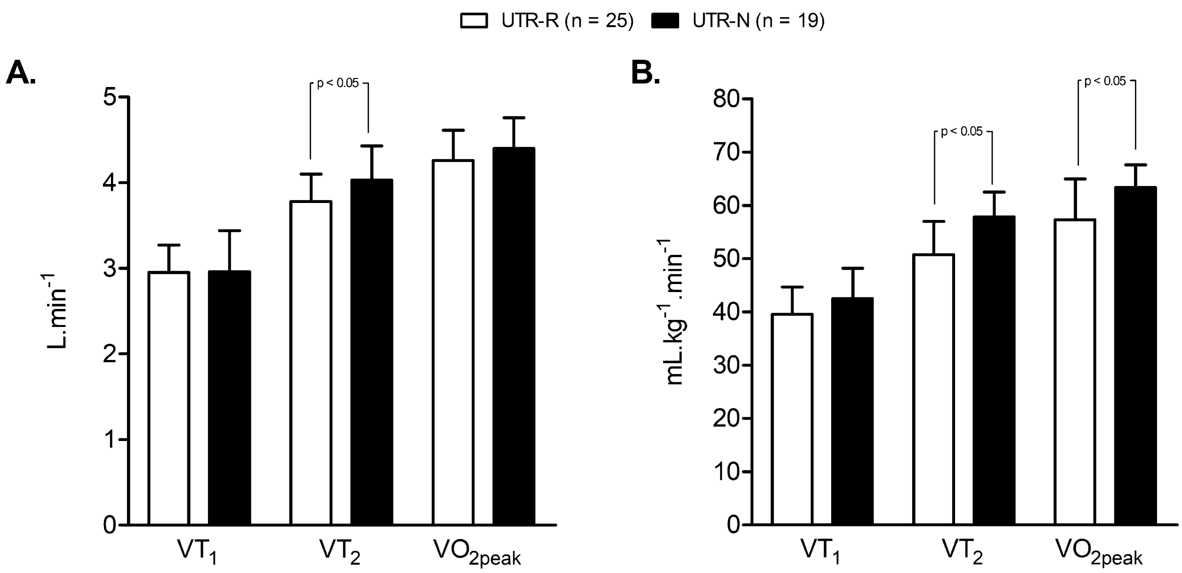

Figure 3. Means for parameters obtained from treadmill test expressed in absolute values and normalized for body mass by level of participation. **Legend**: UTR-R (recreational-level runners); UTR-N (national-level runners).

DISCUSSION

This cross-sectional study profiled male adult UTR athletes and compared them by level of participation (regional versus national) on different tests and parameters related to metabolic pathways. The main findings suggested that UTR-N group was lighter in terms of absolute body mass and, in addition, attained better values for oxygen consumption at intermediate parameters VT_2. Analyses failed to confirm differences in maximal oxygen uptake values. Meantime, relative values (controlling for body mass) for all oxygen uptake parameters tend to present more pronounced differences than absolute values, suggesting the need for adequate weight management in long distance runners.

The differences in VT_2 (absolute values) by level of participation corroborated the available literature. The VT_2 also termed respiratory compensation point is characterized as the second break point in the ventilatory response, as a consequence of acidosis (decreasing pH) caused by lactate production (bicarbonate tamponade becomes insufficient).[17,18] The literature has already reported differences in the absolute oxygen consumption of runners covering different distances: middle or long distance,[19] ant the current study showed that differences between UTR contrasting in participation level can also occur as a mark of adaptability. These results can be in part explained by the fact that UTR-N may be exposed to better training programs including readiness to accelerations and decelerations during the course of the race and are more often tested in morphology and physiological parameters.

Another indicator of performance for endurance activities utilized in this study is the threshold and concentration of the lactate (indicator of anaerobic participation in the effort).[20] Less concentration of lactate during a test suggests the ability of the muscle to prevent or delay the perception of fatigue, since the accumulation of blood lactate leads to premature exhaustion or the appearance of muscle cramping (associated with drooping out or interfering with performance in ultra-marathon).[21] In the present study, the amount of blood lactate concentration from the UTR-N were lower consistently with other findings with middle-and long-distance runners.[22] Long distance runners with less experience tended to adopt a strategy for constant pace[5] to avoid lactate production, while runners attaining better competitive performances tended to fluctuate their pace and demonstrate better recovering after short episodes above their balanced aerobic zone.

In the current study, no significant differences between UTR-N and UTR-R were found for WAnT-P and WAnT-M. The Wingate protocol is commonly used to estimate the anaerobic fitness on several sports.[22,23] It is known that endurance middle- and long-distance runners do not produce high values at anaerobic power parameters, comparatively to sprinters.[12,24] Despite the differences in the training process between runners classified at national and regional level, the profile is similar for Wingate test. It is possible that differences between groups have to be evaluated in specific running protocols such as repeated sprints. In other words, Wingate test in a cycle-ergometer with the participant in a seated position may not be the best option to discriminate UTR.

Although this is a first attempt to compare UTR contrasting in their level of participation (national versus regional) related to metabolic pathway, the study presents limitations that need to be highlighted. First, the sample is not large (due to the recruitment of athletes available to voluntary visit the laboratory). Other protocols for assessing aerobic fitness may need to adopt other initial speed (individually determined) and probably the length of each velocity level is not sufficient to examine the kinetics of oxygen uptake. Future studies may also collect blood samples after completing each velocity level.[17]

CONCLUSION

In summary, ultra-trail running demands well-trained aerobic component. Although maximal oxygen uptake is considered the best single parameter of aerobic fitness, it did not appear as a crucial component of aerobic fitness in the current study. Ultra-trail runners at different levels of participation seemed to be more able for fluctuating their pace and moderate higher values in the second ventilatory threshold seemed to be an advantage in extreme endurance activities. National-level trail runners suggested better second ventilatory threshold /respiratory compensation point, demonstrating readiness to respond for short episodes at a higher intensity level. The versatility seemed specific to running movements and this pattern of effort is essential to assess metabolic fitness of Ultra-trail runners, instead of protocols in a cycle-ergometer. Finally, aerobic fitness in the sport seemed to require an optimal weight management since differences between groups were more pronounced when physiological parameters were expressed per unit of body mass. Future studies should consider intra-individual variation in physiological parameters and performance in competitions.

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Knee antagonist-agonist ratios considering peak torque and angle-specific peak torque:

Comparison of Portuguese Ultra-trail runners with athletes from other sports

Perfil de força isocinética das ações musculares do joelho de corredores de ultra-trail Portugueses em comparação com atletas de diferentes desportos

Isokinetic strength profile of knee muscle actions of Portuguese ultra-trail runners compared to athletes of different sports

Título em português

Perfil de força isocinética das ações musculares do joelho de corredores de ultra-trail Portugueses em comparação com atletas de diferentes desportos

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Abstract

Background: Isokinetic parameters are commonly used to assess strength and to identify muscle imbalance. To our knowledge no previous study has investigated the isokinetic muscle strength in ultra-trail runners (UTR). **Purpose:** To evaluate the isokinetic profile of the knee extensors (KE) and knee flexors (KF) of male UTR in terms of peak torque (Pτ), torque (τ) of the KF at angle of Pτ of the KE and antagonist-agonist conventional and functional ratios calculated with the preceding parameters; and to compare with athletes of different sports (ADS). **Methods:** A convenience sample (n=70) included two groups of competitive athletes: UTR (n=42) and ADS (n=28). Reciprocal concentric (*con*) and eccentric (*ecc*) muscle actions of the KE and KF were tested at $60^o.s^{-1}$ and $180^o.s^{-1}$ using an isokinetic dynamometer. Pτ-based and angle-specific isokinetic simple and combined parameters were extracted from the isokinetic evaluation. Comparison between groups was performed using the independent samples t-test. **Results:** UTR presented lower τ values in all simple isokinetic parameters, with statistical significance ($p<0.05$) for Pτ_KE*con* and Pτ_KF*con* at $60^o.s^{-1}$ and for Pτ_KE*con*, Pτ_KE*ecc*, Pτ_KF*con*, τ_KF*con* at angle of Pτ_KE*con* and τ_KF*ecc* at angle of Pτ_KE*con* at $180^o.s^{-1}$. UTR presented higher values of functional extension ratio at $60^o.s^{-1}$ (UTR: 0.81±0.16 vs. ADS: 0.72±0.11; p=0.013) and $180^o.s^{-1}$ (UTR: 1.17±0.27 vs. ADS: 1.05±0.19; p=0.040). **Conclusions:** UTR were characterized by average absolute isokinetic knee strength values, although lower than those obtained by ADS. UTR were also characterized by balanced isokinetic knee antagonist-agonist strength relationships. The *ecc* demands of ultra-trail running seem to contribute to reinforce the braking capacity of KF, evidenced by higher functional extension ratios.

Keywords: ultra-trail runners, knee strength; antagonist-agonist ratios; isokinetic conventional ratios; isokinetic functional ratios.

Resumo

Introdução: Os parâmetros isocinéticos são comumente utilizados para avaliar a força e identificar desequilíbrio muscular. Não se conhece nenhum estudo prévio que tenha investigado a força muscular isocinética em corredores ultra-trail (UTR).

Objetivo: Avaliar o perfil isocinético dos extensores de joelho (KE) e flexores de joelho (KF) do UTR masculino em termos de pico de torque (Pτ), torque (τ) do KF em ângulo de Pτ do KE e rácios antagonistas-agonistas convencionais e funcionais calculados com os parâmetros anteriores; e de os comparar com atletas de diferentes desportos (ADS).

Métodos: Uma amostra de conveniência (n=70) incluiu dois grupos de atletas competitivos: UTR (n=42) e ADS (n=28). As ações musculares recíprocas concêntricas (*con*) e excêntricas (*ecc*) da KE e KF foram testadas a $60^{o}.s^{-1}$ e $180^{o}.s^{-1}$ utilizando um dinamômetro isocinético. O Pτ-baseado em e o ângulo-específico dos parâmetros simples e combinados isocinéticos foram extraídos da avaliação isocinética. A comparação entre os grupos foi realizada utilizando o teste-t para amostras independentes.

Resultados: o UTR apresentou valores inferiores de τ em todos os parâmetros simples isocinéticos, com significância estatística ($p<0,05$) em Pτ_KE*con* e Pτ_KF*con* at $60^{o}.s^{-1}$ e para Pτ_KE*con*, Pτ_KE*ecc*, Pτ_KF*con*, τ_KF*con* no ângulo do Pτ_KE*con* and τ_KF*ecc* no ângulo do Pτ_KE*con* at $180^{o}.s^{-1}$. O UTR apresentou valores elevados no rácio funcional de extensão a $60^{o}.s^{-1}$ (UTR: 0.81±0.16 vs. ADS: 0.72±0.11; p=0.013) e a $180^{o}.s^{-1}$ (UTR: 1.17±0.27 vs. ADS: 1.05±0.19; p=0.040).

Conclusões: Os UTR foram caracterizados com valores médios absolutos de força isocinética do joelho, embora inferiores aos obtidos pelos ADS. Os UTR também foram caracterizados com relações equilibradas de força isocinética do joelho antagonista-agonista. A exigência excêntrica da corrida de ultra-trail parece contribuir para reforçar a capacidade de travagem/contenção do KF, evidenciada por maiores rácios funcionais de extensão.

Palavras-chave: corredores ultra-trail, força do joelho, razão/rácio antagonista-agonista, razão isocinética convencional, razão funcional isocinética.

INTRODUCTION

Over the past recent years, participation in ultra-trail running is increasing (1). Ultra-trail runners (UTR) are exposed to cover distances, mainly off-road in various type of surfaces including uphill and downhill sections (2). By inference, a substantial amount of eccentric (*ecc*) muscle actions are required (2) having biomechanical, physiological and neuromuscular implications (3). Regarding the neuromuscular component, in general, lower extremity muscles tend to produce greater mechanical work during positive slope running, whereas during negative slope running energy dissipation is the most predominant occurrence (3). After prolonged graded running the decrease in knee extensors (KE) neuromuscular function seems to be associated with metabolic fatigue in uphill and with mechanical damage in downhill, mainly related with concentric (*con*) and *ecc* muscle actions, respectively (4). Hoffman and Krishnan (5) studied a sample of 1212 long distance runners and concluded that the knee was the most common anatomical musculoskeletal injured region (5). Moreover, imbalance of the KE and knee flexors (KF) was a predictor of musculoskeletal injury in long distance runners (6, 7).

Muscle strength refers to the ability of a muscle to develop tension actively, comprising slow or fast, and *con* (shortening) or *ecc* (lengthening) muscle actions (8). Isokinetic dynamometer is currently recognized as a valid and reliable instrument to assess the dynamic muscle strength (9). In the evaluation of the knee muscle function, among the most relevant parameters and composed variables are the extensors and flexors peak torque (Pτ) and also the flexors-extensors torque (τ) ratio (10). Pτ is a simple parameter that refers to the highest τ produced by a muscle group through a range of motion, therefore it is not angle-specific (11). Flexors-extensors τ ratio is a combined parameter used to diagnosis imbalance between antagonist and agonist muscles (12). In addition, it has been postulated that imbalance between reciprocal muscle groups predisposes the weaker muscle group to injuries (13, 14) and in the case of knee flexors are of particular risk.

The conventional ratio should be computed from Pτ values at the same angular velocity and muscle action type (10, 12). Meantime, the functional ratio considers the combination of Pτ values obtained from *con* and *ecc* muscle actions (15). The potential applications of isokinetic dynamometry remains underexplored if the analysis is limited to Pτ without considering angle-associated variation of simple and composed variables. A new approach has been recently recommended (16). For example Duarte et al. (17) considered conventional and functional ratios derived from Pτ but proposed angle-specific ratios at angle of Pτ of the KE, i.e., τ of the KF at angle of Pτ of the KE.

The literature using isokinetic muscle strength in the context of UTR is still lacking. The present study was aimed to examine the isokinetic profile of the KE and KF of male UTR in terms of Pτ, τ of the KF at angle of Pτ of the KE and antagonist-agonist conventional and functional ratios calculated with the preceding parameters; and to compare them to athletes of different sports (ADS). In addition, considering that ultra-trail runners tend to be more often exposed to *ecc* muscle actions, it was hypothesized that they would be less characterized by imbalanced relationship among knee muscle actions as previously reported for other sports such as soccer.

MATERIALS AND METHODS

Procedures and sample

The procedures of the current study followed the ethical standards established for research in humans by the Declaration of Helsinki (18). The proposal was previously approved by two Ethics Committees (University of Coimbra: CE/FCDEF-UC/00102014;

University of Porto: CEFADE 17.2017). All participants were informed about the objectives of the study, protocols and related potential risks. Their participation was voluntary and they were informed that could dismiss at any time. Participants individually signed an informed consent prior to data collection. The measurements were performed at the Laboratory of Biokinetics located in the Coimbra University Stadium and also in clinical units. Each of the tests was performed by the same experienced observer.

The sample (n=70) included two groups of competitive athletes: UTR and ADS. The UTR (n=42) were recruited by invitation after they completed official competitions in Coimbra area. The ADS (n=28) were recruited at the Coimbra University Stadium and were associated with heterogeneous training experience: combat sports, cycling, roller hockey, rowing, soccer, swimming, tennis, track and field, and volleyball. This group of athletes from different sports was used to discuss the specific profile of UTR in the context of sport participants instead of considering a group of non-athlete adults. Inclusion criteria were: (i) males; (ii) aged ≥ 18 years; (iii) training experience in the respective sports ≥ 2 years. Exclusion criteria were: (i) consumption of supplements or medication known to affect muscle performance; (ii) presence of musculoskeletal injury or history of major musculoskeletal injury in the previous two months. Five UTR did not perform isokinetic *ecc* testing due to personal constraints. Even so, sample size was larger than in previous studies reporting isokinetic evaluation of the knee in long distance runners (6, 7). Chronological age was calculated as observation date minus birth date. Training experience was self-reported.

Anthropometry

Body mass was measured using a SECA portable scale (model 770, Hanover, MD, USA) with a precision of 0.1kg. Stature was measured with a Harpenden stadiometer (model 98.603, Holtain, Crosswell, UK) and sitting height with a Harpenden sitting height table (model 98.607, Holtain, Crosswell, UK) to the nearest 0.1cm. Leg length was estimated as stature minus sitting height. All measurements were performed according to the anthropometric standardization reference manual (19).

Dual energy X-ray absorptiometry (DXA)

Fat tissue and lean soft tissue for whole body and dominant lower limbs were measured by DXA (Lunar DPX-MD+, Software: enCORE version 4.00.145, GE Lunar Corporation, Madison, WI, USA) in the supine position. All participants were assessed during a visit to a certified laboratory.

Isokinetic dynamometry

Reciprocal *con* and *ecc* muscle actions of the KE and KF of the dominant lower limb were tested using a Biodex System 3 isokinetic dynamometer coupled with the Biodex Advantage software package (Biodex Medical Systems, Shirley, NY, USA) and standardized data collection and analysis procedures (20). This isokinetic dynamometer provides mechanically reliable and valid measurements of τ, position and velocity (21). Standard calibration verification was performed according to the manufacturer's guidelines. The participants completed a 5-min warm-up on a stationary cycle ergometer (Ergomedic 814E, Monark, Varberg, Sweden) using a cadence of 50-60 rpm and a braking force corresponding to 2% of the body mass. Thereafter, low-intensity static stretching for the KE and KF muscles were performed. Participants were instructed to hold each position for 20s. Dynamometer orientation was fixed at 90° and tilted at 0°, while the seat orientation was fixed at 90° and the seatback tilted at 85° (hip flexion). Participants were positioned in the seat with standardized chair settings, and stabilized with shoulder, waist and thigh straps. The axis of rotation of the dynamometer was visually aligned with the lateral epicondyle of the knee (anatomical axis of rotation). The length of the dynamometer lever arm was adjusted at the level of the medial malleolus so that the resistance pad was secured to the leg. The correct alignment of the axis of rotation was checked by passively moving the joint through the full range of motion. Complete knee extension was used to determine the anatomical reference angle of 0^o of extension. The effect of gravity on the limb and lever arm was determined from the position of 30^o of knee flexion. Participants were asked to maintain a standardized testing position with arms crossed over the chest and each hand over the contralateral shoulder. The isokinetic testing protocol consisted of one maximal set of five continuous repetitions at each velocity of $60^o.s^{-1}$ and $180^o.s^{-1}$ in the con and in the reactive *ecc* mode, by this order. The testing range of motion was set from 5^o to 90^o of knee flexion. The reduction of 5^o near to full extension was decided to allow the participant to exert at least 10% of the assigned τ limit. At each angular velocity and muscle action type, the maximal set of five continuous repetitions was preceded by a submaximal set of three continuous repetitions for familiarization. Each repetition included a reciprocal movement of knee extension and flexion. A 60-s rest period was given between each set of repetitions. The cushion setting was set to zero (hard) to minimize deceleration at the end of the range of motion. All sets were initiated in the starting position of 90^o of knee flexion. For each *con* repetition the participant was instructed to push and to pull the lever arm up and down. For each *ecc* repetition the participant was instructed to oppose the knee extension by attempting to flex the knee and to oppose the knee flexion by attempting to extend the knee through the whole range of motion. Participants were provided with verbal instructions and visual feedback. The isokinetic data were collected at a sampling rate of 100Hz and were subsequently analyzed with the software AcqKnowledge 4.1 (Biopac Systems Incorporated, Goleta, CA, USA). In order to retain only truly isokinetic data, the curves were visually inspected and windowed at 95% of the preset angular velocities. The best from five repetitions (best curve performed by KE and KF in both the *con* and *ecc* muscle actions) were retained for analysis. The following parameters (at each angular velocity) were considered for statistical analysis:

[1] Pτ of the two muscle groups (KE and KF) in both muscle actions (*con* and *ecc*): Pτ_KE*con*; Pτ_KE*ecc*; Pτ_KF*con*; Pτ_KF*ecc*;

[2] Conventional ratio (Pτ_KF*con* / Pτ_KE*con*);

[3] Functional extension ratio (Pτ_KF*ecc* / Pτ_KE*con*);

[4] Functional flexion ratio (Pτ_KF*con* / Pτ_KE*ecc*);

[5] τ of the KF at angle of Pτ of the KE: τ_KF*con* at angle of Pτ_KE*con*; τ_KF*ecc* at angle of Pτ_KE*con*; τ_KF*con* at angle of Pτ_KE*ecc*;

[6] Angle-specific conventional ratio (τ_KF*con* at angle of Pτ_KE*con* / Pτ_KE*con*)

[7] Angle-specific functional extension ratio (τ_KF*ecc* at angle of Pτ_KE*con* / Pτ_KE*con*);

[8] Angle-specific functional flexion ratio (τ_KF*con* at angle of Pτ_KE*ecc* / Pτ_KE*ecc*).

In a recent study performed in our laboratory, Duarte et al. (17) evidenced that these isokinetic parameters were reasonably reliable to assess muscle strength and function.

Statistical Analysis

Descriptive statistics (minimum, maximum, mean, standard error of the mean, 95% confidence interval and standard deviation) were calculated and normal distribution assessed using the Kolmogorov-Smirnov test. Independent samples t-test was used to compare groups (UTR vs ADS) and, in parallel, effect size was determined adopting Cohen d-values. The magnitude of effect was interpreted as follows (22): <0.20 (trivial); 0.20 to 0.59 (small); 0.60 to 1.19 (moderate); 1.20 to 1.99 (large); 2.00 to 3.99 (very large); ≥4.00 (extremely large) . The significance level was established at 5%. Statistical analysis was performed using the Statistical Package for the Social Sciences - SPSS, version 25 for Windows (SPSS Inc., IBM Company, Armonk, NY, USA).

RESULTS

Descriptive statistics were presented for chronological age, training experience and anthropometry in Table 1. Meantime, corresponding statistics of functional variables derived from isokinetic dynamometry was summarized in Table 2. Chronological age and training experience did not fit the assumptions of normal distribution. In addition, fat tissue values did also fail the test of normality. In both whole body and lower limb fat tissues, standard deviations approached the respective values obtained for lean soft tissue, although dispersion (standard deviation / mean) was consistently about 10% for lean soft tissue and more than 50% for fat tissue.

[Table 1 about here]

[Table 2 about here]

Comparisons between groups of athletes were presented on Tables 3. Ultra-trail runners were 12 years older ($t=+7.835$, $p<0.01$) but accumulated less experience in the sport compared to other athletes ($t=-8.433$, $p<0.01$). For morphology (body size and composition) the two groups did not appear to differ. Meantime, single functional parameters clearly show a trend for lower strength attained by runners except for Pτ of KF*ecc* , independently of angular velocities (trivial effect size: 60º.s^{-1}, $d=-0.01$; 180º. s^{-1}, $d=-0.17$). Mean differences of the two groups under analysis did not differ in conventional ratios that were derived from parameters uniquely extracted from concentric muscle actions and this was consistent for the two angular velocities. Finally, among the composed parameters that were explored as dependent variables significant differences between means were noted for functional knee extension ratio (KF*ecc* divided by KE*con*) in both 60º.s-1 ($t=2.568$, $p<0.05$) and 180º.s-1 ($t=2.097$, $p<0.05$). No differences were found for functional knee flexion ratio.

[Table 3 about here]

DISCUSSION

The current study examined the isokinetic profile of KE and KF of male UTR characterized by normal absolute *con* and *ecc* τ values, although in several parameters lower than those obtained by ADS at 60º.s^{-1} and 180º.s^{-1}. In addition, UTR and ADS differed in functional extension Pτ-based ratios with the first group showing higher values and consequently higher KF*ecc* to KE*con* outcomes at the two angular velocities. Nevertheless, both UTR and ADS exhibited balanced Pτ-based and angle-specific conventional and functional strength ratios.

UTR were older and had less training experience in the sport, comparatively to ADS. This is not surprising since trail running is a relatively recent sport in Portugal, with the Trail Running Association of Portugal being founded in late 2012. Furthermore, Hoffman and Wegelin (1) reported a trend of increasing participation of master runners in this type of competitions, with the mean age of participants around 45 years. Nevertheless, UTR presented a trend to have lower stature with lower leg length, and lower body mass with lower amount of fat tissue and higher amount of soft lean tissue than ADS, although without any significant difference. UTR and ADS were similar for the considered variables of size and body composition.

Assuming that the training experience results in the development of specific muscles related to the sport practiced, the findings of the present study showed that, comparing to ADS, UTR produced lower con Pτ (Pτ_KEcon and Pτ_KFcon) at $60^o.s^{-1}$ and lower values in all simple parameters at $180^o.s^{-1}$, except for two KF parameters (Pτ_KF*ecc* and τ_KFcon at angle of Pτ_KE*ecc*). These outcomes may be explained, at least partly, by the fact that UTR are endurance athletes, not strength athletes. Kong and De Heer (23) showed that elite Kenyan distance runners presented lower absolute isometric τ values than other runners and suggested that lower extremity strength is probably not a determinant success factor in distance running. Other studies also showed that runners obtained lower isokinetic KE and KF strength outcomes compared to jumpers (24) and road cyclists (25) and that sprinters obtained higher isokinetic strength outcomes than endurance runners (26). The fact that UTR were older than ADS cannot be also ignored. Easthope et al. (2) showed that an ultra-trail running event was detrimental to muscular performance, with a decline in KE strength in master UTR, when compared to young UTR, for all maximal isometric tests completed before and after the run. Interestingly, race completion time was not significantly differed between master and young UTR. Even so, the results of the present study are similar to those presented by other isokinetic studies (24-26), including the torque-velocity behavior. Harrison et al. (26) showed that the differences between sprinters and endurance runners were more evident at higher isokinetic velocities.

The isokinetic knee flexors-extensors ratios obtained in this study, both for UTR and ADS, are within the reference values for balanced antagonist-agonist relationships. According to the literature, in healthy individuals, the conventional ratio ranges from 0.50 to 0.80, depending on angular velocity, population group and testing procedures (10-12), the functional extension ratio is around 1.0 (15) and the functional flexion ratio is around 0.30 (15). Angle-specific ratios are also in line with those reported by Duarte et al. (17). Dellagrana et al. (7) described conventional ratios for the dominant lower extremity of 0.61 and 0.66 (at angular velocities of $60^{o}.s^{-1}$ and $240^{o}.s^{-1}$, respectively) in male long distance runners. Sundby et al. (27) presented conventional, functional extension and functional flexion ratios for highly trained (104.6±18.5 $km.wk^{-1}$) and recreational (32.0±15.0 $km.wk^{-1}$) female runners calculated at $60^{o}.s^{-1}$, $120^{o}.s^{-1}$ and $180^{o}.s^{-1}$, respectively. For the highly trained runners the ratios were: 0.56, 0.68 and 0.72 (conventional); 1.10, 1.41 and 1.61 (functional extension); and 0.37, 0.36 and 0.34 (functional flexion). For the recreational runners the ratios were: 0.51, 0.54 and 0.62 (conventional); 0.98, 1.15 and 1.39 (functional extension); and 0.34, 0.31 and 0.29 (functional flexion). In our study, UTR exhibited higher functional extension ratios at both angular velocities, when compared to ADS, indicating a significant ability of the KF to provide dynamic knee stabilization during active extension (15), i.e., that the KF*ecc* have the capacity to brake the action of the KEcon (10). This ratio increases substantially from $60^{o}.s^{-1}$ to $180^{o}.s^{-1}$ which is in line with the torque-velocity relationship, since the con τ of the KE decreases with increases in angular velocity, while the *ecc* τ of the KF remains relatively stable. The higher KF*ecc* to KEcon outcomes obtained by UTR at both angular velocities is probably related with the large amount of *ecc* muscle work which is characteristic of the ultra-trail running (2). The question why Pτ-based functional extension ratios, but not angle-specific functional extension ratios, were significantly different is intriguing. In fact, the optimal angle to obtain the KE Pτ is around 60° to 70° and to obtain the KF Pτ is around 20° to 30° (10, 15, 16). For this reason, the angle-specific functional extension ratio could be expected to be more sensitive to differences. The lower reliability of the Pτ angle parameter (28-30), probably related to the technological source of error (28), may be one of the reasons. Future studies should considerer this interesting question.

Limitations of the present study must be recognized. The sample may not be representative of Portuguese UTR due to convenience sampling. The age difference between the participating groups may have introduced some bias into the results. In the UTR the training experience in other sports previous to ultra-trail running was not collected.

CONCLUSION

In summary, UTR were characterized by average absolute isokinetic knee strength values, comparable to other long distance runners reported in others studies, although lower than those obtained by ADS. UTR were also characterized by balanced isokinetic knee antagonist-agonist strength relationships. The values of the ratios reported in this study, since they were calculated for athletes with no injury, may be useful as reference values in the presence of UTR with muscle imbalance. The values of the ratios should be interpreted taking into account the specific characteristics of the sport. The *ecc* demands of ultra-trail running seem to contribute to reinforce the braking capacity of KF, evidenced by higher functional extension ratios.

CONFLICT OF INTEREST

The authors do not have any conflict of interest.

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Table 1. Descriptive statistics for the total sample on chronological age, training experience and anthropometry (n=70).

	Unit	n	range		mean			standard	normality	
			minimum	maximum	value	SE	(95%CI)	deviation	K-S	p
Chronological age	years	70	18.6	53.2	31.6	1.0	(29.5 to 33.6)	8.6	0.150	<0.01
Training experience	years	70	2	26	8.0	0.8	(6.4 to 9.6)	6.5	0.245	<0.01
Anthropometry										
Stature	cm	70	161.8	193.0	175.8	0.9	(174.1 to 177.6)	7.4	0.105	0.06
Body mass	kg	70	58.6	101.0	73.3	1.1	(71.0 to 75.5)	9.5	0.097	0.17
Leg length	cm	70	72.0	96.8	83.3	0.6	(82.1 to 84.5)	5.1	0.099	0.08
DXA										
Whole body										
Fat tissue	kg	70	4.2	33.6	10.9	0.7	(9.4 to 12.3)	5.9	0.174	<0.01
Lean soft tissue	kg	70	48.3	72.3	58.5	0.7	(57.2 to 59.9)	5.6	0.077	0.20
Lower limb										
Fat tissue	kg	70	1.2	9.5	3.4	0.2	(3.0 to 3.8)	1.8	0.154	<0.01
Lean soft tissue	kg	70	16.5	25.1	20.7	0.3	(20.2 to 21.2)	2.1	0.066	0.20

DXA (dual energy x-ray absorptiometry); SE (standard error); 95%CI (95% confidence interval); K-S (Kolmogorov-Smirnov test); p (significance level).

Table 2. Descriptive statistics for the total sample in relation to the torques exerted by the knee muscles and to the antagonist-agonist conventional and functional ratios extracted from the isokinetic strength dynamometry at different angular velocities.

Velocity	parameter	muscle group	muscle action	unit	n	range		mean			standard deviation	normality	
						min	max	value	SE	(95%CI)		K-S	p
60º.s-1	Pτ	KE	*con*	N.m	70	127.6	308.5	204.6	4.6	(195.5 to 213.6)	38.1	0.055	0.20
	Pτ	KE	*ecc*	N.m	65	114.7	397.9	257.5	8.2	(241.1 to 273.9)	66.2	0.054	0.20
	Pτ	KF	*con*	N.m	70	70.1	191.6	117.3	3.0	(111.4 to 123.2)	24.8	0.085	0.20
	Pτ	KF	*ecc*	N.m	65	93.4	272.0	156.8	4.1	(148.6 to 165.0)	33.2	0.081	0.20
	τ at angle of Pτ_KE*con*	KF	*con*	N.m	70	60.7	142.5	97.7	2.5	(92.8 to 102.6)	20.6	0.094	0.20
	τ at angle of Pτ_KE*con*	KF	*ecc*	N.m	65	69.7	180.5	113.9	3.1	(107.7 to 120.1)	25.0	0.080	0.20
	τ at angle of Pτ_KE*ecc*	KF	*con*	N.m	65	53.4	142.2	95.7	2.8	(90.0 to 101.3)	22.9	0.065	0.20
180º.s-1	Pτ	KE	*con*	N.m	70	86.8	226.7	145.6	3.2	(139.3 to 151.9)	26.5	0.079	0.20
	Pτ	KE	*ecc*	N.m	65	132.3	410.7	259.7	8.7	(242.3 to 277.1)	70.0	0.099	0.19
	Pτ	KF	*con*	N.m	70	49.1	156.2	100.0	2.5	(94.9 to 105.0)	21.1	0.049	0.20
	Pτ	KF	*ecc*	N.m	65	107.3	242.6	161.5	4.2	(153.1 to 170.0)	34.1	0.102	0.09
	τ at angle of Pτ_KE*con*	KF	*con*	N.m	70	47.8	119.6	82.5	2.1	(78.3 to 86.8)	17.9	0.070	0.20
	τ at angle of Pτ_KE*con*	KF	*ecc*	N.m	65	70.2	201.3	124.3	3.6	(117.2 to 131.5)	28.8	0.099	0.18
	τ at angle of Pτ_KE*ecc*	KF	*con*	N.m	65	46.3	121.2	79.0	2.2	(74.6 to 83.3)	17.7	0.080	0.20
60º.s-1	Conventional ratio (X/Y)				70	0.34	0.79	0.58	0.01	(0.56 to 0.60)	0.08	0.073	0.20
	Functional extension ratio (Z/Y)				65	0.54	1.25	0.77	0.02	(0.73 to 0.81)	0.15	0.102	0.09
	Functional flexion ratio (X/Z)				65	0.25	0.87	0.48	0.02	(0.45 to 0.52)	0.13	0.126	0.01
	Angle-specific conventional ratio (X'/Y)				70	0.27	0.75	0.48	0.01	(0.46 to 0.50)	0.08	0.120	0.01
	Angle-specific functional extension ratio (Z'/Y)				65	0.35	0.91	0.56	0.01	(0.53 to 0.59)	0.12	0.099	0.19
	Angle-specific functional flexion ratio (X'/Z)				65	0.14	0.73	0.39	0.02	(0.36 to 0.42)	0.12	0.117	0.03
180º.s-1	Conventional ratio (X/Y)				70	0.38	1.12	0.69	0.01	(0.66 to 0.72)	0.12	0.093	0.20
	Functional extension ratio (Z/Y)				65	0.75	1.85	1.12	0.03	(1.06 to 1.18)	0.24	0.104	0.08
	Functional flexion ratio (X/Z)				65	0.17	0.67	0.40	0.01	(0.38 to 0.43)	0.10	0.113	0.04
	Angle-specific conventional ratio (X'/Y)				70	0.33	0.93	0.57	0.01	(0.55 to 0.60)	0.11	0.067	0.20
	Angle-specific functional extension ratio (Z'/Y)				65	0.42	1.61	0.86	0.03	(0.81 to 0.92)	0.22	0.107	0.06
	Angle-specific functional flexion ratio (X'/Z)				65	0.15	0.61	0.32	0.01	(0.30 to 0.35)	0.09	0.067	0.20

Pτ (peak torque); τ (torque); KE (knee extensors); KF (knee flexors); *con* (concentric); *ecc* (eccentric); X (Pτ_KF*con*); Y (Pτ_KE*con*); Z (Pτ_KF*ecc*); X' (τ_KF*con* at angle of Y); Z' (τ_KF*ecc* at angle of Y); SE (standard error); 95%CI (95% confidence interval); K-S (Kolmogorov-Smirnov test); p (significance level). NOTE: Valid information of eccentric muscle action was not obtained for 5 participants.

Table 3. Descriptive statistics (mean ± standard deviation) by group (ultra-trail runners and athletes of different sports) and comparisons for torques exerted by the knee muscles and to the antagonist-agonist conventional and functional ratios extracted from the isokinetic strength dynamometry at different angular velocities.

Yi: dependent variable (velocity, parameter, muscle group, action)	unit	X: Independent variable				Comparison				
		UTR		ADS		mean difference	t-student		Magnitude of effects	
		n	mean±sd	n	mean±sd	(95%CI)	t-value	p	d	(qualitative)
60º.s-1: Pτ of KE (*con*)	N.m	42	194±32	28	221±41	-27 (-45 to -10)	-3.093	<0.01	-0.76	(moderate)
60º.s-1: Pτ of KE (*ecc*)	N.m	37	252±68	28	265±645	-13 (-46 to 20)	-0.786	0.44	-0.20	(small)
60º.s-1: Pτ of KF (*con*)	N.m	42	110±21	28	129±26	-19 (-31 to -8)	-3.467	<0.01	-0.86	(moderate)
60º.s-1: Pτ of KF (*ecc*)	N.m	37	157±36	28	157±29	0 (-17 to 16)	-0.035	0.97	-0.01	(trivial)
60º.s-1: τ at angle of Pτ_KE*con* of KF (*con*)	N.m	42	934±18	28	103±23	-9 (-19 to 0)	-1.912	0.06	-0.47	(small)
60º.s-1: τ at angle of Pτ_KE*con* of KF (*ecc*)	N.m	37	109±26	28	120±22	-11 (-23 to 2)	-1.709	0.09	-0.44	(small)
60º.s-1: τ at angle of Pτ_KE*ecc* of KF (*con*)	N.m	37	91±18	28	102±27	-26 (-24 to 0)	-1.981	0.05	-0.53	(small)
180º.s-1: Pτ of KE (*con*)	N.m	42	137±21	28	159±29	-22 (-34 to -10)	-3.604	<0.01	-0.89	(moderate)
180º.s-1: Pτ of KE (*ecc*)	N.m	37	245±68	28	280±69	-35 (-70 to -1)	-2.069	0.04	-0.53	(small)
180º.s-1: Pτ of KF (*con*)	N.m	42	96±20	28	106±22	-11 (-21 to -1)	-2.113	0.04	-0.52	(small)
180º.s-1: Pτ of KF (*ecc*)	N.m	37	159±32	28	165±38	-6 (-23 to 11)	-0.686	0.50	-0.17	(trivial)
180º.s-1: τ at angle of Pτ_KE*con* of KF (*con*)	N.m	42	78±16	28	89±20	-11 (-19 to -3)	-2.601	0.01	-0.64	(moderate)
180º.s-1: τ at angle of Pτ_KE*con* of KF (*ecc*)	N.m	37	117±28	28	135±27	-18 (-32 to -5)	-2.660	0.01	-0.67	(moderate)
180º.s-1: τ at angle of Pτ_KE*ecc* of KF (*con*)	N.m	37	77±16	28	81±20	-4 (-13 to 5)	-0.828	0.41	-0.22	(small)
60º.s-1: conventional ratio (X/Y)		42	0.57 ±0.08	28	0.59±0.08	-0.02 (-0.06 to 0.02)	-1.033	0.31	-0.25	(small)
60º.s-1: functional extension ratio (Z/Y)		37	0.81±0.16	28	0.72±0.11	0.09 (0.02 to 0.16)	2.568	0.01	+0.65	(moderate)
60º.s-1: functional flexion ratio (X/Z)		37	0.46±0.11	28	0.51±0.14	-0.05 (-0.11 to 0.01)	-1.645	0.11	-0.41	(small)
60º.s-1: angle-specific conventional ratio (X'/Y)		42	0.49±0.08	28	0.47±0.10	0.01 (-0.03 to 0.06)	0.715	0.48	+0.23	(small)
60º.s-1: angle-specific functional extension ratio (Z'/Y)		37	0.57±0.14	28	0.55±0.09	0.02 (-0.04 to 0.08)	0.706	0.48	+0.17	(trivial)
60º.s-1: angle-specific functional flexion ratio (X'/Z)		37	0.38±0.11	28	0.41±0.13	-0.03 (-0.09 to 0.03)	-0.886	0.38	-0.26	(small)
180º.s-1: conventional ratio (X/Y)		42	0.70±0.13	28	0.68±0.11	0.02 (-0.03 to 0.08)	0.848	0.40	+0.17	(trivial)
180º.s-1: functional extension ratio (Z/Y)		37	1.17±0.27	28	1.05±0.19	0.12 (0.01 to 0.24)	2.097	0.04	+0.51	(small)
180º.s-1: functional flexion ratio (X/Z)		37	0.41±0.11	28	0.39±0.08	0.02 (-0.03 to 0.07)	0.841	0.40	+0.21	(small)
180º.s-1: angle-specific conventional ratio (X'/Y)		42	0.57±0.10	28	0.57±0.12	0.01 (-0.05 to 0.06)	0.218	0.83	+0.00	(trivial)
180º.s-1: angle-specific functional extension ratio (Z'/Y)		37	0.87±0.26	28	0.86±0.17	0.00 (-0.11 to 0.11)	0.034	0.97	+0.04	(trivial)
180º.s-1: angle-specific functional flexion ratio (X'/Z)		37	0.34±0.10	28	0.30±0.08	0.04 (0.01 to 0.09)	1.635	0.11	+0.44	(small)

Pτ (peak torque); τ (torque); KE (knee extensors); KF (knee flexors); *con* (concentric); *ecc* (eccentric); X (Pτ_KF*con*); Y (Pτ_KE*con*); Z (Pτ_KF*ecc*); X' (τ_KF*con* at angle of Y); Z' (τ_KF*ecc* at angle of Y); sd (standard deviation); 95%CI (95% confidence interval; p (significance level) ; d (d-Cohen value). NOTE: Valid information of eccentric muscle action was not obtained for 5 participants.

Capítulo 4

Discussão

Este capítulo tem como intuito reunir e integrar as principais contribuições dos cinco artigos, resumindo os principais resultados e refletindo genericamente sobre as implicações para pesquisas futuras e aplicações práticas na área da fisioterapia.

Esta tese pretende promover com o conhecimento de aspetos epidemiológicos das lesões decorrentes do TR de atletas Portugueses e, identificar potenciais fatores determinantes de lesões significativas, nas extremidades inferiores. Adicionalmente, reunindo um conjunto de informação morfológica, fisiológica e neurofuncional, caracterizar os atletas de UTR. Havendo uma pretensão em alguns dos estudos, de explorar a associação entre o nível participativo e alguns parâmetros de caracterização quer da lesão quer dos próprios atletas.

O que distingue esta pesquisa relativamente a estudos já disponíveis na literatura, é o recurso a dois estudos com metodologias descritivas distintas que serviram de base para a elaboração desta tese. Como objeto de estudo tivemos então o grupo de atletas de TR portugueses. Os instrumentos de recolha de dados foram selecionados de acordo com os objetivos de cada estudo.

Para o **primeiro estudo** recorreu-se à aplicação de um questionário autoadministrado. Apesar da utilização deste tipo de questionário ter "fragilidades" intrínsecas não deixa de ser recomendado e considerado fundamental para avaliação clínica e para a investigação. A acessibilidade e o uso constante de questionários validados em diferentes idiomas facilita a compilação de dados confiáveis em estudos multicêntricos internacionais (1,2). A construção do questionário foi baseada na revisão de literatura. Para recolher informação relacionada com as lesões optou-se por utilizar uma adaptação do Questionário Nórdico Músculo-esquelético, na versão portuguesa, validada por Mesquita, Ribeiro e Moreira (1) para a população portuguesa. Este questionário permitiu uma rápida identificação dos sintomas, em dez regiões anatómicas e recolher outros aspetos importantes de caracterização da lesão (1). Para este estudo, selecionou-se apenas participantes do sexo masculino, com base na informação recolhida resultaram dois artigos (artigo 1 e 2) que caraterizam o atleta e as lesões associadas ao trail-running. O primeiro oferece uma visão ampla da sintomatologia em áreas anatómicas, mais suscetíveis de lesão, apresentando a extremidade inferior uma maior prevalência de lesão.

O **segundo estudo**, do qual resultaram três artigos (artigo 3, 4 e 5), carateriza particularidades inerentes ao corredor de trail de ultra- distâncias. Para a concretização deste estudo, utilizaram-se metodologias precisas de avaliação direta obtidas no Laboratório Integrado da Faculdade de Ciências do Desporto e Educação Física da Universidade de Coimbra, para que os seus resultados permitam alcançar conclusões comparáveis, credíveis e aceites pela comunidade científica. Foi decidido convidar atletas masculinos com níveis de participação diferentes. Deveriam participar em competições com distâncias superiores a 42 km e tinham mais de dois anos de experiência na modalidade. Estes aspetos permitiriam que o tempo de exposição à prática da modalidade desenvolvesse nos atletas caraterísticas (físicas, fisiológicas e neurofuncionais) que se esperavam ser diferenciadoras, nos grupos estudados.

Do que se conhece, o TR é uma modalidade que atrai atletas de todas as categorias, incluindo atletas de elite mesmo de outros desportos, no entanto, é uma modalidade onde poucos são corredores profissionais. Embora a sua popularidade esteja associada a uma vertente de saúde e bem-estar e ao desafio físico inerente à corrida num ambiente natural existe, contudo, um risco de lesão associado, que não deve ser negligenciado. Este tipo de corrida exige mais do atleta do que as tradicionais provas de estrada. Considerando o **nível de participação**, com base nos objetivos de cada corredor e tipo de competições com exigência distinta (ex. altimetria, distância e tipo de superfície/piso), esta Tese permitiu caracterizar os atletas e identificar a prevalência de lesões relacionadas com o TR, com o intuído de reunir informação que ajude a implementar adequadamente ações de educação e intervenções de saúde eficazes. Além disso a aplicação de uma definição mais abrangente de lesão, destacou os efeitos das lesões usualmente excluídas dos estudos epidemiológicos por não traduzirem o seu impacto em ausência de dias de corrida (treino ou competição).

O ATLETA DE TRAIL RUNNING

Os atletas masculinos (403 participantes) que participaram no primeiro estudo desta Tese, respondendo ao questionário online, apresentaram uma média da idade de 40.01±8.18 anos, apontada por outros autores como sendo a ideal para correr longas distâncias. (3,4) Igualmente a estatura e a quantidade de massa corporal dos corredores de TR foram similares aos apresentados nesses estudos. A maioria dos corredores masculinos de TR é casado (67,0%), licenciado ou com estudos superiores (53,8%), e trabalham por conta de outrem/própria (95,0%) cerca de 30 a 40 horas por semana (68,0%). Estes resultados acabam por ser muito similares aos apresentados no estudo de Hoffmann M. e Fogard K. (5) onde se utilizou uma grande amostra de ultramaratonistas, maioritariamente da América do Norte.

Os anos de experiência na modalidade (em média 5.63±3.43 anos) e o volume de treino de corrida (frequência: 4.45± 1.43 dias/semana; tempo: 6.33±2.45 horas/semana e distância: 56.81±21.08 km/semana) foram ao encontro de outros resultados encontrados em estudos que utilizaram atletas de longas distâncias como as maratonas e as ultramaratonas. Nestes últimos, os resultados são mais variados dependendo do tipo estudo e da modalidade apresentada. (6,7)

Os atletas de TR são conhecidos por terem caraterísticas morfológicas que os distingue de atletas de outras modalidades (6). As caraterísticas relacionadas com aspetos antropométricos parecem estar dependentes do número de anos de experiência e das distâncias percorridas (5,7–9). Se considerarmos a análise realizada nos atletas portugueses de TR por nível de participação, os que correspondem ao grupo UTR-N e, portanto, a um nível competitivo mais exigente, revelaram serem mais novos, mais leves e apresentaram um IMC menor comparativamente aos UTR-R. Com caraterísticas semelhantes a outros corredores de longas distâncias, tais como dimensões apendiculares e pregas cutâneas reduzidas e baixo valor de massa corporal, em particular nas extremidades inferiores (4,10). Tal como noutros estudos, verificou-se que o valor médio de percentagem de gordura corporal dos corredores de ultra-trail é substancialmente inferior aos valores obtidos nos atletas ultramaratonistas que percorram 161-km ou que realizam 65-km em montanha (11). A importância atribuída à composição corporal do atleta foi analisada no **terceiro artigo**. Neste estudo, apurou-se a inter-variabilidade dos participantes por nível participativo. Aqueles, que se inserem no grupo mais competitivo mostraram diferenças nos resultados de volume corporal e consequentemente na densidade corporal com implicações nos valores médios da massa gorda estimada.

EPIDEMIOLOGIA DA LESÃO DECORRENTE DA CORRIDA DE TRAIL

Numa primeira leitura podemos verificar através dos resultados obtidos **no primeiro estudo** que existe um número elevado de atletas portugueses de TR suscetíveis de se lesionarem como resultado da corrida. As lesões podem localizar-se em diferentes áreas anatómicas e não se encontrou associações entre a localização e o tipo de nível participativo. A maior prevalência tende a ocorrer nas extremidades inferiores, tal como encontrado por outros autores (9,12,13). De acordo com o nível de participação, os atletas nacionais apresentam proporção de lesão (0.75) superior aos regionais, contudo, as lesões são mais significativas nos atletas regionais (0.27). De acordo com Tonoli et al (14) a identificação de rácios de incidência de lesões em corredores de níveis diferentes de corrida, leva a uma ampla distribuição, onde os atletas considerados novatos ou recreativos apresentam rácios de lesão superiores aos atletas competitivos e profissionais de modalidades como maratona e corta-mato.

Esta Tese concluiu que as lesões podem ser lesões ligeiras e/ou significativas, tendo em consideração o seu impacto a nível pessoal e/ou desportivo. Verificou-se também que existe uma quantidade de lesões ligeiras (0,30) face ao número total de atletas praticantes de TR que devem ser tidas em consideração. De acordo com o nível de participação, os atletas nacionais apresentaram uma proporção de lesões ligeiras superior (0.27) às dos atletas regionais (0.21). Este resultado, realça mais uma vez a importância de ter em conta lesões que mesmo não levando o atleta a deixar de correr (treino ou competição) podem, de alguma maneira, ter impacto na sua vida. Esta decisão surge, em parte, pela forte evidência de que muitas das lesões decorrentes da corrida estão associadas a condições de sobre uso das estruturas por repetição e/ou por agravamento de uma lesão pré-existente (sub- diagnosticada ou latente) (7,15,16), outras, não originando alterações na prática de corrida, podem ter interferência no quotidiano do atleta e por isso não devem ser negligenciadas. Estas são as que não levam o atleta a procurar uma correta avaliação da condição deste problema e que a longo prazo as pode transformar em lesões significativas.

O impacto individual das lesões (ligeiras ou significativas) depende de alguns fatores (local, tipo, gravidade). Parece consensual de que nem todas as lesões levam à necessidade de avaliação e/ou tratamento por um profissional de saúde. De acordo com os nossos resultados cerca de 59,9% ou 61,4% dos atletas necessitaram da assistência por um profissional de saúde, seja qual for a região anatómica onde tenha ocorrido. Estes resultados estão de acordo dos obtidos por Hoffman and Krishnan (9) onde cerca de 60% dos ultramaratonistas lesionados necessitaram de cuidados médicos ou por de Van Mechelen (17), que na sua revisão de literatura, afirma que entre 20% a 70% dos atletas lesionados procuram cuidados médicos, sem no entanto os particularizar. Contudo, é Besomi et al. (7) que consegue ser mais específico ao referir que dos 30,4% atletas lesionados avaliados por um profissional de saúde 26,3% necessitaram de acompanhamento por parte de um fisioterapeuta para recuperar da lesão.

Esta necessidade de avaliação da lesão deve ser transmitida ao atleta como forma de promoção de saúde e de prevenção de reincidência do problema. Em particular se consideramos a informação facultada por alguns autores, onde 56% dos atletas avaliados por um profissional de saúde tiveram de reduzir o tempo de corrida sendo que este número diminuiu comparativamente aos que não foram avaliados e 40% dos atletas lesionados tiveram de parar de correr após uma avaliação por um profissional de saúde (18,19). Mais uma vez aqui se realça a importância da inclusão no estudo das lesões ligeiras.

Vários estudos epidemiológicos têm estimado que cerca de 70% dos corredores sofrem uma lesão em corrida por excesso de uso, a cada ano (20). O atleta tem maior predisposição à lesão quando tem um historial de lesão prévia (21). Nestas situações a reincidência pode originar lesões ou danos tecidulares mais graves, isto porque a causa original não foi identificada e/ou corrigida. Também pode ocorrer que a reparação do tecido pode não ter tido o tempo suficiente para se refazer ou então, deixou o tecido com alterações fisiológicas diferentes do tecido original tornando-o mais suscetível à lesão (22). Nestas situações deve haver necessidade de avaliar os tecidos sempre que ocorra uma lesão e implementar programas de prevenção e/ou de recuperação adequados antes do atleta começar a correr novamente (7,16).

Estipulou-se que, para as 10 regiões anatómicas identificadas, a análise de uma possível associação entre o nível de participação com o tipo de lesão e com a gravidade da lesão, seriam observadas apenas as lesões significativas por serem as que se traduzem com maior impacto pessoal e desportivo para o indivíduo. Por outro lado, são também as que podem levar a que o indivíduo fique privado de correr um dia ou mais. Dos resultados 71,3% teve necessidade de o fazer na sequência da lesão, resultante da corrida, sendo estes resultados consistentes com os apresentados por outros autores (9) que referiam que cerca de 64,6% dos atletas perderam pelo menos um dia de corrida/treino devido a lesão. Se se considerar que os atletas de TR correm no seu tempo livre, a impossibilidade de o fazer pode ter um impacto psicossocial elevado (19,23,24) especialmente se isso ocorrer num período prolongado. O tempo de impedimento desportivo, do que foi estudado, irá depender do local e da severidade da lesão. Segundo com alguns autores (19) a classificação da gravidade de lesão foi estipulada de acordo com períodos de tempo de ausência desportiva em: *insignificante, moderadamente grave, grave*. Nesta Tese, a maioria das lesões significativas, independentemente do nível de participação, foram associadas a sobrecarga e originaram um afastamento da corrida por mais de 21 dias (37,0% - lesão significativa grave). Os estudos encontrados na literatura não permitiram avaliar se a amostra de corredores portugueses com lesão tem um tempo de paragem de corrida superior a outros corredores de longas distâncias.

Com base nos resultados do primeiro artigo, percebeu-se que a localização das lesões, independentemente do tipo de participação, se localizava nas extremidades inferiores. Também a literatura apresenta esta região como tendo maior predisposição a lesão, mas a variabilidade dos valores de incidência reportados pelos autores (17,25,26), desde 19,4% até 92,4%; ou 24,0% até 77,0% ou de 21,6% realça, mais uma vez, a importância da definição das metodologias, do tipo de atletas e das distâncias percorridas.

No **segundo artigo**, deu-se enfase à caracterização detalhada de aspetos demográficos e de treino, nomeadamente se tinham acompanhamento de um treinador e que tipo de superfície de treino utilizava regularmente. Estes aspetos foram posteriormente considerados para serem identificados como possíveis preditores de lesão significativas. Por outro lado, pretendeu-se caraterizar a severidade das lesões nas diferentes regiões anatómicas das extremidades inferiores (ancas/coxas, joelhos, tornozelos/pés), o tipo de gravidade que originaram, bem como o grau de dificuldade sentido pelo atleta e que tipo de tecido seria mais afetado, de acordo com o tipo de lesão.

Nos atletas portugueses de TR a prevalência de lesão localizadas nas extremidades inferiores foi bastante elevada (62,5%). Com uma distribuição similar quer nos joelhos (31,3%) quer nos tornozelos/pés, sendo esta última a região reportada como tendo maior número de lesões (31,5%). Apesar de não haver uma diferença significativa, estes resultados são um pouco diferentes dos apresentados na revisão sistemática de Van Gent et al (26) onde os joelhos foram descritos como sendo a região anatómica mais comum de lesão relacionada com a corrida de longas distâncias (7,2% to 50,0%), seguido da região anatómica dos pés com 5,7% até 39,3%, sendo consensual que a menor ocorrência de lesões encontra-se a nível da ancas/coxas (3,3% até 11,5%). Esta elevada disparidade de resultados, mais uma vez prende-se com o facto de os estudos utilizados na revisão da literatura utilizarem diferentes tipo de atletas relacionado à diversidade de distâncias percorridas. O aspeto comum nas modalidades estudadas no artigo de revisão foi o tipo de superfície em que estes atletas correm, já que se referem a maratonista e ultramaratonistas e, como se sabe, estes correm em superfícies mais duras e/ou pavimentadas durante o percurso (ou em grande parte).

O tipo de superfície utilizada para correr, também foi alvo de estudo e identificado como possível determinante de lesão. (27) Os resultados indicam que o atleta de TR utiliza mais a montanha para correr/treinar (75,4%). Portugal, pelas suas caraterísticas geográficas, permite facilmente o acesso a trilhos irregulares e com desnível (positivo) de diferente graduação, que diversificam o treino/corrida e, que também preparam e adaptam as estruturas músculo esqueléticas para os desequilíbrios e estímulos propriocetivos constantes inerentes da corrida em trilhos naturais. Estes trilhos podem ser constituídos de superfícies macias (ex. areia, lama, terra), mas também irregulares (irregularidade do piso, rochas, pedras soltas, percurso com água). São estas as caraterísticas que segundo alguns autores, aumentam o risco de lesões na região dos tornozelos e dos joelhos (17,28) e que expõem os tecidos moles à lesão. Por exemplo superfícies duras sobrecarregam os ligamentos, tendões e cartilagens, porque a sua adaptação à carga mecânica é lenta (29) enquanto as superfícies moles afetam particularmente o músculo. (30). As lesões de natureza muscular e articular são as mais frequentes nas regiões anatómicas identificadas com maior número de lesões. Na região anatómica dos tornozelos/pés a distribuição das lesões foi equitativa no que respeita ao tipo de lesão (aguda ou de sobrecarga); e aos tecidos afetados (pele, músculo e articulação). Apesar dos tornozelos/pés terem maior ocorrência de lesões, foram as localizadas nos joelhos que tiveram como consequência, um maior número de dias de interrupção de corrida (84,3±60,5 dias, amplitude: 30-300 dias), logo consideradas mais graves e que se caraterizaram por terem surgido devido a sobrecarga. Constatou-se na literatura que, como consequência das lesões, pode ocorrer uma média de 13,8 dias (amplitude: 0-240 dias) de paragem de treino na sequência da lesão relacionada com corrida (9). Embora este estudo não considera apenas na extremidade inferior, como nesta Tese.

Outra caraterística dos percursos corrida de trail é o gradiente de inclinação do terreno, associado habitualmente a grandes subidas (desnível positivo). Este aspeto é considerado pelo atleta como desafiante, contudo é nas descidas que acresce o risco de lesão. A corrida descendente com declive é conhecida por induzir danos graves nas estruturas músculo esqueléticas das extremidades inferiores devido essencialmente à fadiga que é tipicamente associada ao trabalho excêntrico dos músculos da articulação do joelho (31). Durante a corrida um contacto incorreto dos pés no solo pode originar uma lesão nas regiões anatómicas que estão a ser mais solicitadas (joelhos e tornozelos/pés). Por outro lado, a preparação inerente a uma corrida de longa distância, leva a que sejam necessárias algumas horas ou quilómetros, por semana, a correr. Esta exposição prepara o atleta para a corrida de maior duração, mas por outro lado, também pode expô-lo a cargas excessivas que podem originar lesão. Hreljac A. (32) sugeriu que a lesão deve ser evitada não através da minimização do stress aplicado a uma estrutura biológica, mas pela sua otimização através da quantidade e frequência de carga/stress, esse limite ótimo de tensão de qualquer tecido, que é conseguido durante o treino. Existe um equilíbrio de natureza dinâmica entre a quantidade de stress aplicado e a aparecimento de lesão (32). A caracterização do volume de treino também foi estudada por outros autores, porque foi identificada como sendo um fator importante associado às lesões de corrida (13,17,27,33).

Dos potenciais **determinantes** das lesões significativas dos membros inferiores, houve alguns que, ao contrário das revisões sistemáticas estudadas, não obtiveram associações. O tipo de atletas e distâncias percorridas pelas amostras utilizadas nesses estudos podem explicar o porquê dessa situação. Destacam-se nesta Tese apenas os que resultaram em associações considerados com significância estatística (índice de massa corporal, média de distância percorrida semanalmente e treino regular em montanha).

Índice de massa corporal

Da análise da literatura e da relevância atribuída aos fatores intrínsecos como possíveis determinantes de lesão, apenas o índice de massa corporal revelou associações significativas que pudessem determinar a presença de lesões significativas da extremidade inferior no atleta português de TR.

O índice de massa corporal (IMC) é um dos indicadores antropométricos mais utilizados em estudos epidemiológicos, por ser o rácio entre a massa corporal de um individuo pelo quadrado da sua estatura. É um indicador de saúde pública muitas vezes associado à definição de excesso de peso e obesidade. (34,35) Uma massa corporal elevada nem sempre é sinónimo de excesso de peso. Por isso mesmo esta medição simples e direta tem limitações, especialmente por não fornecer informações relativa à composição corporal, existindo outras metodologias que conseguem com maior exatidão obter essa informação.

A maioria dos atletas portugueses de TR apresenta um IMC considerado normal (25kg/m^2) para a idade de um adulto. Dos resultados alcançados no estudo, encontrou-se associação entre o potencial determinante dos atletas de TR com IMC inferior a 25 kg/m^2 do que aqueles atletas que apresentam IMC superior a 25 kg/m^2. Esta associação foi significativa para as lesões da extremidade inferior em geral e das que se localizaram na região dos tornozelos/pés.

Estes resultados traduzem uma "razão de chances" (*odds ratio*). A literatura reporta alguns resultados de risco pelo que os resultados devem ser interpretados tendo isso em consideração, por exemplo na revisão sistemática de van der Worp (27) onde aparentemente um IMC baixo pode ser considerado como fator de risco para lesões localizadas nos pés em corredores masculinos. Já que outros autores referiram que um IMC menor que 19.5kg/cm^2 e maior que 27kg/cm^2 teria um risco maior associado e, apresentou que um IMC superior a 26 kg/m^2 foi descrito como protetor em corredores masculinos mas que corriam distâncias de 10km (36). Contrariamente Buist et al. (37) refere que "indivíduos mais pesados" parecem ter maior suscetibilidade de ocorrência de lesão relacionada com a corrida. A revisão sistemática de van der Worp et al. (27) conclui que na maioria dos estudos analisados o IMC não teve efeito significativo como risco de lesão nos corredores em geral.

Esta disparidade de conclusões aliada à fragilidade interpretação dos resultados do IMC, realça a importância de uma recolha de informação exata de caraterísticas do atleta de TR com recurso a metodologias que determinem a composição corporal e que diferenciem a massa gorda da massa isenta de gordura, e talvez assim se perceba se o IMC possa ser um fator protetivo ou não do risco de lesão. A estimativa da composição corporal pode ser obtida utilizando equipamento como a pletismografia, BIA e DXA, igualmente usada em estudos com outros desportos (combate, futebol, ténis) (35,38–41) e que foi aplicada no **terceiro artigo.**

Neste artigo utilizou-se uma amostra com atletas que correm ultras distâncias e analisou-se a sua composição corporal de acordo com o nível de participação. Aqui reuniu-se um conjunto de informação que de certa forma carateriza o atleta português de TR e pode trazer uma explicação ao que anteriormente foi dito. Os resultados de estatura e massa corporal também são comparáveis e consistentes com os obtidos por atletas de longa distância (maratonistas e ultramaratonistas de 24 horas) (6). Da comparação da composição corporal, ambos os grupos apresentam a mesma quantidade de tecido isento de gordura. Os atletas que participam na modalidade com objetivos competitivos têm significativamente maior valor de densidade corporal que resulta em menores valores de massa gorda e volume corporal. Independente do método utilizado (pletismografia ou DXA), a quantidade de massa gorda de todo o corpo e dos membros inferiores foi superior nos atletas recreativos. A importância da quantidade de massa gorda destes atletas é assumida por alguns autores como estando relacionada com os resultados esperados durante uma corrida (42).

A composição corporal tem tendência a mudar em consequência da quantidade e tipo de atividade física. Os resultados revelaram caraterísticas diferenciadoras de composição corporal dos diferentes tipos de atletas de TR reforçando a necessidade de se recorrer a metodologias mais seguras e acessíveis quando se realizam estudos epidemiológicos ou de determinantes de lesão, e assim se perceber porque é um IMC elevado possa estar associado a menor probabilidade de lesão ou ter um efeito protetivo.

Distância média percorrida de corrida semanal

A distância média percorrida durante uma semana foi identificada como sendo um aspeto extrínseco ao individuo possível de risco associado ao aparecimento de lesões de corrida. (22,43,44) Os resultados do segundo estudo evidenciam que os atletas de TR que correm uma distância média semanal entre 40km e 70km parecem ter uma associação com o aparecimento de lesão da extremidade inferior com os que correm menos 40km, igual associação se verifica quando analisada a região dos tornozelos/pés.

Quando se analisa as lesões na região das ancas/coxas verifica-se que a possibilidade de ocorrer uma lesão em atletas que correm distâncias superiores a 70km é superior do que aqueles que correm distâncias inferiores a 40 km. Esta região (ancas/coxas) não é dos locais indicados como sendo de maior prevalência de lesão. Mas foi apontada como sendo a região que na presença de uma lesão significativa grave o atleta teve a maior perceção de dificuldade na realização da tarefa. Este aspeto é importante e deve ser considerado especialmente pelos profissionais de saúde que o acompanhem.

A revisão sistemática de Van Middelkoop et al.(45) refere que a distância de corrida semanal de 40 km, parece ser um forte preditor de lesão relacionada com a corrida nos membros inferiores mas a sua associação foi considerada protetora. Para outros, a distância de corrida semanal superior a 64km parece aumentar a probabilidade de o atleta ter uma lesão. (44,46,47) A maioria dos estudos mostrou que a distância de corrida semanal é o preditor mais forte para surgirem lesões. Apesar dos resultados apresentados na literatura não serem muito conclusivos, parece que uma exposição de corrida (em quilómetros) não muito elevada parece proteger os atletas das lesões. Por outro lado, parece também não haver associação para o aumento do risco de lesões se ocorrer um aumento da distância de corrida semanal. O que pode elucidar este fato é que o treino semanal e a distância percorrida só por si não explicam o risco.

Face aos resultados obtidos, o praticante de TR português pode correr entre 20km a 140km por semana. Portanto, o atleta precisa de estar fisicamente preparado e que haja uma resposta fisiologia seja adaptada à distância percorrida, especialmente se forem distâncias elevadas (ultradistância). A capacidade funcional dos corredores de longa distância é altamente influenciada por exigências fisiológicas sendo o principal indicador de resposta central é a capacidade aeróbia (48–50). No **quarto estudo,** avaliou-se as capacidades anaeróbia e aeróbia corredor adulto masculino de provas de ultra-trail e posteriormente, comparou-se com o seu nível de participação. Este estudo evidenciou o perfil fisiológico de corredores de longa distância revelando que este é potencialmente modificável com o exercício e treino apropriado. Os UTR-N, apesentaram melhor resposta central ao exercício prolongado, uma vez que a sua aptidão aeróbia se traduziu em resultados superiores aos UTR-R. Estes resultados foram similares aos reportados por outros autores que avaliaram a quantidade absoluta do consumo de oxigénio em atletas que correm diferentes distâncias e verificaram que os valores obtidos são igualmente diferentes de acordo com as exigências da corrida (média ou longa distância) (51–53).

Por outro lado, a capacidade anaeróbia do atleta não apresenta diferenças quando se compara o nível competitivo do atleta. Os resultados da potência máxima e média foram consistentes, tal como previamente relatado na literatura com os corredores masculinos de sprint, os corredores de média distância e os corredores de longas distâncias.(54) A resposta do metabolismo anaeróbio parece ser menor em corridas de longa distância comparativamente a corridas curtas e/ou rápidas (55) ou a modalidades desportivas com gestos explosivos. (56) Na corrida de trail o atleta tem que por vezes fazer movimentos explosivos e rápidos (escalada, saltos, sprints) que podem durar de apenas alguns segundos ou poucos minutos. (57) A performance destes movimentos está relacionada com capacidade de contração muscular, com o tipo de fibras envolvidas na atividade, mas também com a capacidade de oxigenação aos tecidos musculares. (55,58–60)

A interação entre os sistemas muscular e cardiovascular garante eficientemente a transferência de energia dos metabolismos aeróbio e anaeróbio, e é por isso que o UTR apresenta a mesma capacidade anaeróbia para responder a uma explosão como uma maratona ou corrida de sprint. Por outro, lado apresenta, com diferenças estatisticamente significativas, melhor aptidão aeróbia o atleta UTR-N e quando a aptidão física aeróbia é expressa por unidade de massa corporal.

Treino em montanha

Na literatura também é identificado como podendo estar associado ao aparecimento da lesão é o tipo de terreno/superfície (duro, macio, relva, cascalho, montanhoso e plano) utilizado para treinar a corrida (61,62). Aliada à distância percorrida, o tipo de superfície e caraterísticas do terreno que o atleta escolhe para treinar, expõe as estruturas músculo esqueléticas a diferentes tipos de cargas. Esta exposição não pode ser necessariamente prejudicial desde que haja uma preparação gradual (treino) para essa exposição, ou desde que, a capacidade de resposta das diferentes estruturas músculo esqueléticas à irregularidade de um terreno esteja otimizada. Há autores que referem que a maior utilização de pistas de corrida ou de superfícies mais suaves (trilhos) em detrimento de outras (asfalto/betão) pode proteger algumas estruturas, nomeadamente se estas estiverem expostas durante várias horas no mesmo terreno (17,28).

Os resultados mostraram que o atleta que regularmente treina em montanha tem maior probabilidade de ter lesão do que aquele que não o faz. Para se correr em montanha é necessário que as estruturas músculo esqueléticas estejam preparadas. A região dos joelhos e dos tornozelos/pés apresentam uma maior prevalência de lesão. Alguns autores referem que o risco de ocorrerem lesões agudas quando se corre em superfícies instáveis é maior nestas duas regiões anatómicas (17,28). Esta condição também foi identificada por Malliaropoulos et al. (13) como tendo um efeito mais protetor em algumas estruturas anatómicas do que a corrida em estrada devido à maior absorção do impacto e pela variação do gradiente de inclinação. As estruturas anatómicas que conferem maior estabilidade à extremidade inferior são aquelas que também ficam mais expostas a cargas excessivas. Os atletas de TR também apresentaram maior prevalência lesões significativas articulares agudas nas articulações referidas.

É esperada uma resposta neuromuscular dentro dos limites de tensão de qualquer estrutura biológica e que haja equilíbrio de forças (32) para correr longas distâncias, em trilhos com vários tipos de superfícies, incluindo subidas e descidas (63). Um dos aspetos estudados por ser associado ao risco de aparecimento de lesão da extremidade inferior são os desequilíbrios entre a ação muscular agonista/antagonista na articulação do joelho (64). No **quinto artigo**, pretendeu-se analisar se nos atletas de ultra-trail running existia essa condição comparativamente a atletas de outras modalidades. Os parâmetros isocinéticos são comumente utilizados para avaliar a força e identificar desequilíbrio muscular. Neste estudo os corredores de ultra-trail apresentaram relações de força isocinética antagonista-agonista equilibradas do joelho. Os resultados apresentados referem que a exigência excêntrica da corrida de ultra-trail parece contribuir para reforçar a capacidade de travagem obtida pelos flexores do joelho, e que foi evidenciada por maiores rácios funcionais de extensão. Outros autores referiram que os eventos ocorridos em trilhos com variações de gradiente de inclinação iam gerar uma quantidade substancial de ações musculares excêntricas (excêntricas) (63) com implicações biomecânicas, fisiológicas e neuromusculares (65).

Em relação ao componente neuromuscular, em geral, os músculos das extremidades inferiores tendem a produzir maior trabalho mecânico durante a corrida em declive positivo (subidas), enquanto que durante a corrida em declive negativo a dissipação de energia acaba por ser a ocorrência mais predominante (65). Se este trabalho muscular for prolongado e repetitivo, pode ocorrer uma diminuição da função neuromuscular dos extensores do joelho devido à fadiga metabólica que ocorre quando o atleta realiza subidas e a danos mecânicos quando realiza descidas, principalmente relacionados com ações musculares concêntricas e ações musculares excêntricas, respetivamente. (9) A associação do tipo de trabalho muscular e o tipo de declive também pode explicar em parte, a ocorrência elevada de lesões significativas agudas articulares no joelho e a maior prevalência de lesões de sobrecarga nos tecidos musculares e articulações.

Limitações

Há limitações a apontar nos estudos deste trabalho. A limitação transversal aos estudos desta Tese foi a recolha de informações de corredores Portugueses de trail running masculinos e, portanto, não permitindo generalizar os resultados.

Depois existem limitações inerentes a cada um dos estudos e artigos realizados.

ESTUDO 1 - As condicionantes inerentes ao fato da recolha de informação ter sido feita através de um questionário auto reportado.

Artigo 1- Alguns parâmetros, como o índice de massa corporal (IMC), foram definidos com base na informação do respondente e não de uma medição com direta. Esta análise com base no que o outro refere, pode resultar em enviesamentos, conduzindo a errada uma classificação de composição corporal (ou seja, sem a identificação concreta de quantidade de massa isenta de gordura e de massa gorda).

As lesões musculoesqueléticas foram igualmente identificadas pelo respondente e não avaliadas por um profissional de saúde. O questionário não explora o diagnóstico exato dos problemas, levando a uma redutora classificação das lesões.

Outras limitações estão relacionadas com a dificuldade em encontrar na literatura suporte para alguns dos resultados obtidos, nomeadamente devido às diferenças encontradas na definição de lesão, e, consequentemente na taxa e proporção de lesão, bem como ausência de estudos que diferenciem os atletas pelo nível de participação.

Artigo 2- Os determinantes selecionados para este estudo foram suportados pela literatura que engloba diferentes atletas e distâncias percorridas. A variedade nas amostras e distâncias podem explicar porque é que nem todos são bons preditores de lesões das extremidades inferiores e que estejam relacionadas com a corrida.

A identificação e caracterização da lesão foi realizada pelo próprio atleta e, portanto, podem não ser completamente confiáveis. Considerando-se esta associação uma limitação metodológica que pode comprometer a comparação.

Os fatores extrínsecos que podem interferir no desempenho (tipo de terreno: montanhas, neve, dunas/areia fina, travessias de rios, hora do dia, temperatura de inclinação e humidade) deveriam ser considerados quando se pretende ser minucioso na caracterização de lesões decorrentes da corrida (treino ou competição), mas são de difícil recolha.

ESTUDO 2 - Este estudo apresenta limitações, nomeadamente dado que foi utilizada uma amostra de conveniência. Para cada artigo identificaram-se as seguintes limitações:

Artigo 3- Não podemos transpor os resultados para a otimização do desempenho porque não recolhemos as informações necessárias para tal. Além disso, não encontramos investigações que avaliem os corredores de acordo com o nível de prática e são escassos os estudos que utilizam os corredores UTR da população para contrariar o nosso trabalho, porém utilizamos como referência aqueles em que as amostras se referem aos corredores de longa distância e corredores de maratona.

Artigo 4- A precisão do nível de determinação do $VO^2_{máx}$ foi pobre porque o teste incremental ocorreu numa maior velocidade do que uma corrida real, mas os resultados podem explicar a capacidade de VO^2 desses atletas. Encontramos poucos estudos com este tipo de população para contradizer nossos achados, mas foram utilizados como referência, nomeadamente aqueles em que foram utilizadas amostras de corredores de longa distância (> 40 km) e corredores de maratona. Os procedimentos e caracterização de treino deviam ter sido recolhidos porque seriam úteis para a compreensão de alguns dos resultados.

Artigo 5- Houve dificuldade em se obterem dados com qualidade, na velocidade superior isocinética ($180^o.seg^{-1}$) reduzindo o número de atletas válidos para o teste. A avaliação isocinética é realizada num movimento não natural com uma articulação isolada e por estas razões a precisão destes resultados é limitada. Devia-se registar que outras modalidades desportivas estes atletas realizaram e por quanto tempo antes de serem apenas corredores UTR.

Recomendações para futuras investigações

Tendo em consideração que a corrida é uma modalidade que está acessível a qualquer um, independente da idade e estrato social, e que as campanhas de promoção para a saúde incentivam a realização de exercício físico, e sendo a corrida identificada, como uma forma de se obter um estilo de vida ativo, as investigações futuras devem considerar alguns dos seguintes critérios:

ESTUDO 1

Classificar e categorizar as lesões de acordo com as estruturas anatómicas (músculo, tendão, ligamentos, articulações), com recurso a um profissional de saúde na identificação da localização, severidade e gravidade da lesão e no diagnóstico da lesão, para se ter a certeza do tipo de tecido afetado. Realizar um estudo longitudinal para caraterizar as lesões associadas ao trail running. Incluir informações mais detalhadas sobre o treino e/ou competição (fatores extrínsecos e intrínsecos).

ESTUDO 2

Artigo 3- Parece pertinente obter informações sobre outras modalidades praticadas antes do trail-running; A inclusão de caraterística relacionadas com o número de horas de treino e competições realizadas, para ver se isso poderia levar a diferenças entre os grupos em relação aos parâmetros de saúde óssea e composição corporal. São poucos os estudos que avaliam a ingestão de suplementos no contexto da competição UTR. A correta avaliação da frequência alimentar antes, durante e em período de recuperação de uma competição, pode permitir compreender como prevenir desistências, minimizar o dano tecidual e/ou o risco de lesões ósseas em atletas de UTR.

Artigo 4- Considera-se importante que um programa de treino de eventos de ultra-trail deva considerar protocolos aeróbios e anaeróbios para melhorar a economia do exercício que combinado com o limiar de lactato pode oferecer informações para ajudar o atleta a otimizar a função e resulte num melhor desempenho. O treino desportivo e as intervenções de fisioterapia neste tipo de atletas, e com diferentes níveis de prática, devem ter em consideração que existe variação intra-individual dos parâmetros fisiológicos e do desempenho, que podem ser potencialmente modificáveis, por meio de uma prescrição apropriada de exercícios.

Artigo 5- Deve ponderar-se a utilização de grupos na amostra com idade similar para minimizar ou evitar vieses nos resultados comparativos. A recolha de informação relacionada com o tipo de desporto praticado antes de serem corredores de ultra-trail, durante quanto tempo o fizeram e se incluem outro tipo de modalidade desportiva no treino (além da corrida), uma vez que as ações funcionais do joelho durante a atividade desportiva e/ou treino podem ser potencialmente modificáveis.

Implicações práticas

Considerando que o TR em Portugal, assim como em outros países, é uma modalidade que teve um crescimento elevado é esperado que uma vez na vida o atleta possa necessitar de cuidados de fisioterapia (7). Os fatores de risco e caracterização das lesões relacionadas com a corrida estão bem fundamentados (13,17,27,33). Contudo, parece importante reunir informação científica em diversas áreas, para que, os diferentes profissionais (treinadores ou profissionais de saúde) que trabalham com estes atletas, possam intervir com base em evidência científica e ajustada à população à qual intervêm. Percebe-se que nem todos os corredores têm o seu treino orientado por alguém especializado apesar de este aspeto não ter mostrado associação de probabilidade de lesão. Identificaram-se outros aspetos (IMC, distância semanal e correr em montanha) devem ser considerados quando se delinear um plano de treino por forma a reduzir a "chance" do corredor se lesionar. Entende-se por isso, que o fisioterapeuta, é um dos profissionais de saúde que, num determinado momento da vida do atleta, pode ser chamando a intervir junto destes atletas. As situações podem ocorrer de duas formas, ou porque o atleta apresenta lesão ou porque necessita de se preparar para um evento e a prevenção de lesão deve ser o seu objetivo principal.

Para que a intervenção do fisioterapeuta seja fundamentada com conhecimento académico e não apenas na experiência clínica, parece relevante que o fisioterapeuta aceda a informações que ajudem a caraterizar o tipo de atleta (66). A vasta base de conhecimentos e competências da fisioterapia levou ao desenvolvimento de áreas especializadas, como, por exemplo a fisioterapia desportiva (67–69). Apesar do atleta poder recorrer a este profissional mesmo que não seja especialista na área do desporto, a formação académica do fisioterapeuta confere-lhe competências para poder intervir não só para reabilitar, mas também prevenir condições incapacitantes ao atleta.

O fisioterapeuta do desporto é um "profissional reconhecido que demonstra competências avançadas na promoção da participação segura na atividade física, prestação de aconselhamento e adaptação de intervenções de reabilitação e treino, com o objetivo de prevenir lesões, restaurar a função ótima e contribuir para a melhoria do desempenho desportivo, em atletas de todas as idades e capacidades, garantindo um elevado padrão de prática profissional e ética". (68,69)

Algumas intervenções incluem terapia pelo movimento com recurso aos exercícios terapêuticos, reaprendizagem motora e sensório motora, reabilitação motora e de força, reabilitação combinada com maximização funcional, mobilização e manipulação articular, hidroterapia e uso de agentes físicos (70) como a terapia por calor e a terapia por gelo, terapia com energia mecânica (ex. ultra som e ondas de choque) e correntes elétricas contínuas, alternadas, baixa, média e alta frequência; radiofrequência (tecarterapia, onda curta e micro ondas); magnetoterapia de alta frequência e outros. Algumas destas intervenções são opções frequentes no tratamento de lesões músculo-esqueléticas (71) e devem ser utilizadas de acordo com o objetivo terapêutico, resposta fisiológica a alcançar e o tipo de tecido a tratar.

Considerando os resultados obtidos nesta pesquisa os fisioterapeutas, treinadores, atletas e outros profissionais envolvidos na modalidade, devem levar em consideração alguma da informação aqui reunida, a fim de poderem alcançar melhores resultados desportivos e/ou performance, de definirem planos de treino, e elaborarem programas que os ajudem na prevenção (novas lesões e recidivas) e/ou se for o caso, na recuperação da lesão.

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Capítulo 5

Conclusão

Apesar de cada artigo, apresentado no capítulo 3, possuir as suas próprias conclusões, neste capítulo pretende-se proceder a uma integração capaz de levar à obtenção de conclusões mais abrangentes sobre o presente trabalho.

1.- *(Lesões músculo-esqueléticas em corredores de trail-running masculinos nacionais e regionais portugueses)* O nível de participação dos atletas de TR determinou diferentes resultados referentes ao tipo, localização e severidade da lesão músculo-esquelética resultante do trail-running, bem como, no tempo de ausência de treino/corrida e necessidade de ser visto/tratado por um profissional de saúde. Apesar dos atletas do grupo nacional (NTR) terem apresentado uma maior incidência de lesões, os atletas do grupo regional (RTR) registaram uma maior proporção na quantidade de lesões por número de corredores lesionados. Observou-se uma associação significativa entre o nível de participação e a necessidade de interrupção do treino/competição aquando da presença de uma lesão significativa. Estes resultados permitirão que os profissionais de desporto e de saúde, que trabalhem com este tipo de atletas, devam estar familiarizados com o fato de que, o nível de participação, determina diferentes caraterísticas nas lesões, nomeadamente: na localização, na severidade e no tipo.

2.- (*Prevalência e Determinantes das Lesões Musculoesqueléticas na Extremidade Inferior em Corredores de Trail Masculinos Portugueses*) As lesões músculos esqueléticas das extremidades inferiores localizaram-se maioritariamente nos tornozelos/pés e nos joelhos. As lesões classificadas pelo participante como significativas resultaram de uso excessivo (*overuse*), sendo o músculo o tecido mais lesionado. As lesões localizadas na anca/coxa foram as que, apesar de não serem as mais prevalentes, tiveram uma atribuição de grau de dificuldade percecionado elevado. As lesões significativas localizadas nos joelhos, foram aquelas que levam a um maior número de dias sem correr (treino/competição). As que se situaram nos tornozelos/pés, refletiram uma maior interferência, quer na atividade do quotidiano quer na corrida e originaram a necessidade de ser visto/tratado pelo profissional de saúde e as que causaram menos dias de paragem de corrida.

Os determinantes (ajustados à idade) das lesões significativas da extremidade inferior foram associados ao IMC, à distância média semanal realizada (Km) e ao treino habitual realizado em montanha. Assim, atletas que apresentaram um **IMC** inferior a 25 kg/m^2 tiveram mais chance de lesão do que aqueles que apresentaram IMC superior a 25kg/m^2 quer na análise geral das lesões da extremidade inferior quer quando se analisou o *odds ratio* para a região dos tornozelos/pés. Os atletas que realizaram um **treino semanal médio** entre 40km e 70km/semana apresentaram mais chance de lesão do que os que treinam menos de 40km/semana, relativamente à análise geral das lesões na extremidade inferior, mas também quando se examinou o potencial determinante de lesão localizado nos tornozelos/pés. Aquando da avaliação da região anatómica das ancas/coxas estas apresentaram *maior chance* de lesão nos atletas que correm uma distância média de treino semanal superior a 70km do que nos que treinam menos de 40km/semana. Por último, os atletas que têm um treino regular em montanha apresentaram mais chances de lesão do que aqueles que não treinam regularmente na montanha, quer no geral (lesão da extremidade inferior) quer naqueles que apresentaram lesões nos joelhos e nos tornozelos/pés.

3.- *(Composição corporal em corredores de longa distância)* De uma maneira geral, os corredores de longas distâncias, como o ultra-trail, independentemente do nível participativo, caracterizaram-se por terem baixos níveis de gordura corporal, elevada densidade corporal, carecendo de uma regulação precisa do peso corporal, incluindo uma manutenção adequada da quantidade de massa isenta de gordura. Para isso, o atleta deve ter uma dieta adequada em relação à ingestão da quantidade de calorias totais e também de nutrientes que contribuam para manter a integridade dos tecidos musculares e ósseos. As metodologias combinadas, utilizadas neste trabalho permitiram avaliar a composição corporal e determinar um perfil dos UTR. A bioimpedância é mais popularizada do que a absorciometria de Raio-X de Dupla Energia e a pletismografia de ar deslocado surge, no presente estudo, como uma opção razoável para avaliar a composição corporal.

4.- *(Perfil Fisiológico de corredores adultos masculinos de trail de longa distância (nacional versus regional))* O atleta de UTR exige um componente aeróbico bem treinado. Embora o consumo máximo de oxigénio seja considerado o melhor parâmetro da aptidão aeróbica ele não apareceu, neste estudo, como um componente crucial da aptidão. Os atletas de UTR de acordo com o nível de participação, evidenciaram ser mais capazes de oscilar o seu ritmo e moderar valores mais altos, no segundo limiar ventilatório, que se podem traduzir numa vantagem, quando falamos em atividades extremas de endurance. Os UTR Nacionais suscitaram melhores valores no segundo ponto de compensação respiratória, demonstrando prontidão para responder por episódios curtos num nível de intensidade superior. A versatilidade pareceu específica aos movimentos de corrida e esse padrão de esforço é essencial para avaliar a aptidão metabólica dos UTR, em vez de protocolos em ciclo-ergómetro. O presente estudo destacou a importância de considerar parâmetros fisiológicos, derivados de protocolos de corrida, preferencialmente expressos por unidade de massa corporal. Além disso, em relação aos parâmetros de aptidão aeróbia, o segundo limiar ventilatório apresentou-se como a melhor variável para distinguir os atletas de UTR com diferentes níveis de participação. Por fim, a aptidão aeróbica na modalidade desportiva mostra requerer uma ótima gestão do peso, uma vez que as diferenças entre os grupos foram mais pronunciadas quando os parâmetros fisiológicos foram expressos por unidade de massa corporal.

5.- *(Perfil de força isocinética das ações musculares do joelho de corredores de ultra-trail Portugueses em comparação com atletas de diferentes desportos)* Os UTR foram caracterizados por valores médios de força isocinética absoluta do joelho, comparáveis aos de outros corredores de longa distância relatados noutros estudos, embora inferiores aos valores obtidos pelos ADS. Os UTR também foram caracterizados por relações equilibradas de força isocinética do joelho antagonista-agonista. Os valores dos rácios relatados neste estudo, por terem sido calculados para atletas sem lesão, podem ser úteis como valores de referência na presença de UTR com desequilíbrio muscular. Os valores das proporções devem ser interpretados tendo em consideração as características específicas da modalidade. A exigência excêntrica da corrida de ultra-trail parece contribuir para reforçar a capacidade de travagem/contenção do KF, evidenciada por maiores rácios funcionais de extensão.

Apesar de terem sido conduzidos estudos independentes, em períodos de tempo diferentes, a constatação do que a literatura consultada já deixava antever, no que diz respeito à prevalência de lesões e determinantes das lesões subsequentes do trail running, foi de algum modo confirmado. Do **primeiro estudo** destacam-se os determinantes de lesões significativas como a chance de um IMC inferior a 25Kg, a distância do treino ser superior a 40km por semana e o treino habitual ocorrer em montanha. Com estes resultados realça-se a importância de uma boa gestão do peso/massa corporal tendo em consideração que um IMC elevado pode significar um quantidade superior de massa isenta de gordura; a importância de se gerirem as distâncias durante o treino; o treinar com regularidade em superfícies que exigem produção de força e de estabilidade das extremidades inferiores como é o caso do treino em montanha. Assim sendo, o atleta tem que estar apto para tal. Compreende-se que, da informação recolhida, aspetos relacionados com a composição corporal do atleta de TR, nomeadamente a massa corporal, o contributo das vias metabólicas e a força das extremidades inferiores, devem ser avaliados com metodologias rigorosas.

Do **segundo estudo**, pelo tempo de exposição à prática e pela particularidade das distâncias corridas (acima de 42,195 km), os atletas apresentariam caraterísticas morfológicas e respostas das vias metabólicas diferenciadoras de acordo com o nível de participação e, o resultado obtido da força isocinética das ações musculares do joelho seria distinta de atletas expostos a outras modalidades.

Os resultados apresentados nos diferentes artigos conseguem, de alguma forma, mostrar que aspetos se devem reforçar quando se delinearem os planos de treinos e/ou os programas de reabilitação. Ainda assim, é necessária investigação adicional com recurso a amostras maiores e desenhos longitudinais para consolidar estas conclusões e aumentar o escopo do conhecimento.