UNIVERSIDADE FEDERAL DE SÃO CARLOS
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PROGRAMA DE PÓS-GRADUAÇÃO EM FISIOTERAPIA

BIOMECÂNICA DA CORRIDA EM DIFERENTES FAIXAS ETÁRIAS: CLASSIFICAÇÃO BASEADA NA TÉCNICA ÁRVORE DE DECISÃO E ANÁLISE DE CODIFICAÇÃO VETORIAL MODIFICADA

MARIANA CARVALHO DE SOUZA

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Tese de Doutorado apresentada ao Programa de Pós-Graduação em Fisioterapia (PPG-FT) da Universidade Federal de São Carlos (UFSCar), como parte dos requisitos para a obtenção do título de Doutor em Fisioterapia, Área de Concentração: Fisioterapia e Desempenho Funcional.

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RESUMO

A corrida é uma atividade popular e há um aumento na população idosa praticando esse esporte. Entretanto, está associada ao risco de lesões dos membros inferiores e as mulheres são duas vezes mais propensas a desenvolver essas lesões. A maioria dos estudos que comparou faixas etárias empregou estatística clássica. A técnica árvore de decisão é usada para classificar padrões em conjuntos de dados e se mostrou melhor que a *Support Vector Machine* (SVM) em outros dados. Variáveis dependentes tendem a usar dados discretos de articulações isoladas. A variabilidade da coordenação (VC) quantifica a variedade de padrões de movimento do segmento e está relacionada a um sistema motor saudável. Os objetivos desta tese foram avaliar a capacidade da árvore de decisão em discriminar corredores de diferentes faixas etárias, comparar o desempenho da árvore de decisão com a SVM e comparar a VC entre corredores homens e mulheres de diferentes faixas etárias, separadamente, durante a corrida. Foram avaliadas variáveis cinemáticas e eletromiográficas. A árvore de decisão foi utilizada para discriminar os grupos e uma técnica de codificação vetorial modificada foi utilizada para investigar a VC do segmento. Os resultados mostraram que a árvore de decisão foi capaz de discriminar as diferentes faixas etárias. Além disso, no caso dos homens, os corredores mais jovens apresentaram uma maior VC do que os de meia idade e idosos. E no caso das mulheres, as corredoras mais jovens apresentaram uma menor VC do que as corredoras de meia idade e uma VC similar quando comparadas ao grupo de idosas. Os achados do estudo indicam que a abordagem da árvore de decisão teve um melhor desempenho na discriminação dos grupos do que a SVM. Além disso, mostra que o envelhecimento influencia a função dinâmica para os corredores homens e, por fim, as corredoras mulheres parecem manter sua VC, independentemente da idade.

Palavras-chave: corrida; codificação vetorial; envelhecimento; biomecânica; árvore de decisão.

ABSTRACT

Running is a popular exercise and the elderly population practicing this sport has increased. However, this activity is associated with a risk of lower limb injuries and female runners are twice as likely to develop these injuries. The majority of studies that compared age groups used classical statistics. The decision tree approach is used to classify patterns in data sets and has shown to be better than the support vector machine (SVM) on other sorts of data. Dependent variables have tended to focus on discrete data from isolated joints. Coordination variability (CV) quantifies the variety of segment movement patterns and is linked to a healthy motor system. The aims of this thesis were to evaluate the capacity of the decision tree to discriminate runners of different age groups, to compare the performance of the decision tree to the SVM and to compare CV among male and female runners, separately, during running. Kinematic and electromyography analysis were assessed. The decision tree was used to discriminate the age groups and a modified vector coding technique was used to investigate segment CV. The results show that the decision tree approach was capable of discriminating the different age groups. Also, for the male runners, the younger runners presented a higher CV than the middle-aged and the older. And for the female runners, the younger runners presented a lower CV than the middle-aged runners and a similar coordination variability when compared to the older group. The study findings indicate that decision tree approach had a better performance in discriminating the age groups than the SVM. Also, aging influences dynamic function for male runners and, lastly, female runners appear to maintain their CV during running regardless of age.

Keywords: running; vector coding; aging; biomechanics; decision tree.

LISTA DE TABELAS

LISTA DE FIGURAS

Página

ESTUDO I

ESTUDO II

SUMÁRIO

CONTEXTUALIZAÇÃO

Corridas de longa distância têm se tornado uma prática comum entre participantes de esportes recreacionais e é uma das atividades físicas mais praticadas em todo o mundo (1). Inúmeras cidades do Brasil já possuem seus próprios eventos de corrida, com um crescimento de 2,17% no número de provas no Estado de São Paulo, em 2016 (2). Assim, de acordo com a Federação Paulista de Atletismo, no último ano houve um aumento de 25,24% nas participações em corridas de rua. O crescimento no número de adeptos à corrida recreacional pode ser explicado pela fácil acessibilidade, pelo baixo custo, podendo ser praticada em locais comuns (3) e de forma individualizada (4,5).

A corrida traz muitos benefícios para a saúde, como aumento da vitalidade, melhora da resistência cardiovascular e redução de peso (6,7). Além disso, a corrida de longa distância está associada com redução de incapacidades em idosos e à longevidade (8). Apesar de ser uma das maneiras mais eficientes de se atingir aptidão física, corridas de longa distância podem resultar em lesões, com a incidência variando entre 19% e 79% (3).

Muitos estudos avaliaram a prevalência e incidência de lesões no membro inferior em corredores de longa distância. Num estudo retrospectivo, 143 corredores (de um total de 265) reportaram lesões agudas principalmente em pé, tornozelo e joelho, e lesões por sobreuso em pé e joelho. Assim, a prevalência de todas as lesões foi de 75%, sendo 28,7% lesões agudas e 59,4% lesões por sobreuso (9). Lesões diminuem o prazer na prática do exercício e levam, temporária ou permanentemente, à interrupção da prática da corrida, além de resultarem a gastos aumentados devido à necessidade de tratamento e/ou ausência no trabalho. Ou seja, a corrida é um esporte popular na população adulta, entretanto estratégias são necessárias para prevenir altos índices de lesões relacionadas a ela (10).

Apesar de a corrida estar relacionada à longevidade, estudos mostram que corredores idosos tem um risco aumentado de lesão (11). Além dessa população ter lesões mais frequentes, levam mais tempo para se recuperar quando comparada a corredores jovens (12–14). McKean et al. (14) relataram que entre a população de corredores mais velhos, três diagnósticos foram os mais comuns, sendo eles a fasceíte plantar, a tendinite de quadríceps/isquiotibiais e as lesões no tendão do calcâneo. A maior incidência de lesões e o retorno mais demorado à corrida na população idosa podem ser parcialmente devido à degeneração do sistema musculoesquelético que ocorre com o envelhecimento e parcialmente devido às diferenças na cinemática da corrida observadas entre corredores adultos jovens e mais velhos (14–16).

Em relação às alterações cinemáticas do membro inferior, Bus (15) relatou que corredores mais velhos (55 a 65 anos) apresentaram maior flexão do joelho no contato inicial com o solo e menor amplitude de flexão e extensão do joelho que os corredores adultos jovens (20 a 35 anos). Em 2008, Fukuchi et al. (17) apresentaram resultados similares em ambas variáveis entre corredores idosos (67 a 73 anos) e jovens (22 a 39 anos). Além disso, relataram que os corredores idosos apresentaram aumento na amplitude de rotação medial/lateral da tíbia e maior ângulo de rotação lateral do segmento pé durante a fase de apoio da corrida. Ainda, estudos mais recentes, como o de Nigg et al. (18) também observaram que corredores mais velhos (61 a 75 anos) exibiram uma menor amplitude de flexão/extensão do joelho e maior amplitude de dorsiflexão de tornozelo quando comparados aos jovens (21 a 35 anos). Phinyomark et al. (19), além de concordarem com Bus (15), Nigg et al. (18) e Fukuchi et al. (17) que corredores mais velhos (55 a 72 anos) apresentam uma menor amplitude de flexão/extensão do joelho quando comparados a corredores jovens (18 a 26 anos), relataram não ter encontrado diferenças na cinemática do quadril, nos três planos de movimento, entre corredores jovens e idosos. Por outro lado, Silvernail et al. (20) reportaram uma maior amplitude de movimento na articulação do quadril no plano sagital em corredores idosos (média de 54 anos), quando comparados aos jovens (média de 21 anos). Porém, nenhuma diferença foi encontrada para os movimentos dessa articulação nos planos frontal e transverso. Lilley et al. (21) avaliaram apenas corredoras e relataram que as corredoras mais velhas (40 a 60 anos) apresentam maior pico de eversão do retropé e maior rotação medial de joelho quando comparadas às corredoras jovens (18 a 24 anos). Da mesma forma, Boyer et al. (22) reportaram que as corredoras mais jovens (média de idade de 22 anos) apresentam maior inversão/eversão de tornozelo no contato inicial e maior pico de inversão de tornozelo quando comparadas às mais velhas (média de idade de 52 anos). Além disso, corredoras mais velhas apresentavam maior rotação lateral do quadril quando comparadas às corredoras jovens.

Além das variáveis cinemáticas, pesquisadores têm se interessado em estudar o padrão de ativação muscular e como a idade interfere nessa variável. A ativação muscular é importante para manter a estabilização articular dinâmica durante a corrida. Mudanças na magnitude de ativação podem estar relacionadas a lesões (23). Schmitz et al. (23) compararam, entre indivíduos jovens e idosos, a ativação de vários músculos do membro inferior durante a marcha em velocidade baixa, preferida e alta. Foi reportado que os indivíduos idosos apresentaram maior ativação dos músculos sóleo e tibial anterior durante a fase de apoio médio em todas as velocidades. Além disso, maior ativação nos músculos vasto lateral e isquiotibiais foi reportada em corredores idosos durante a marcha em velocidade alta (23). Sano et al. (24) avaliaram o padrão de ativação dos músculos da perna em corredores jovens e idosos. Os autores relataram maior ativação do músculo gastrocnêmio medial durante as fases de pré-ativação e de retirada do pé com o solo (*push-off*) em corredores idosos.

É importante salientar que a maioria dos estudos prévios empregou estatística clássica para discriminar corredores jovens e idosos. Entretanto, de acordo com Fukuchi et al. (25), técnicas estatísticas são limitadas para a aplicação em tarefas de reconhecimento de padrões, ou seja, nesse caso, na categorização de grupos. Nesse estudo de 2011, Fukuchi et al. (25) aplicaram uma técnica denominada *Support Vector Machine* para discriminar o padrão cinemático entre corredores jovens e idosos. Esse estudo demonstrou que essa técnica foi capaz de discriminar corredores jovens e idosos utilizando dados da cinemática da corrida. Além disso, foi sugerido que nem todas as variáveis cinemáticas têm boas características discriminatórias, visto que a SVM requereu apenas seis variáveis para obter a acurácia máxima, e quando adicionadas mais de 18 variáveis, a performance da SVM diminuía (25). Entretanto, o uso da abordagem baseada na SVM tem algumas desvantagens, como um alto custo computacional (quanto maior a base de dados, maior o tempo de processamento), a dificuldade em se escolher a função Kernel (que afeta significantemente os resultados), bem como ajustar parâmetros para essa função.

Outra abordagem usada para discriminar dados de diferentes grupos é a árvore de decisão. Árvores de decisão são ferramentas baseadas em estratégias decisórias como forma de aprendizado por indução (26). Essa técnica de aprendizado de máquina usa uma estrutura de árvore para classificar padrões em conjuntos de dados, os quais são organizados hierarquicamente em um conjunto de nós interconectados. Assim, os nós, considerados como folhas, classificam as instâncias (dadas como entradas) de acordo com sua saída desejada. Caruana e Niculescu-Mizil (27) demonstraram que as árvores de decisão apresentaram melhores resultados que a SVM para 10 bases de dados distintas. Embora, provavelmente, a árvore de decisão seja uma técnica apropriada na discriminação de corredores de diferentes faixas etárias, de acordo com o nosso conhecimento, não há estudos que tenham utilizado essa técnica, usando variáveis cinemáticas e eletromiográficas, com esse objetivo.

Além disso, tradicionalmente, os pesquisadores na área de biomecânica tendem utilizar dados discretos de articulações isoladas para estudar a cinemática da corrida. Entretanto, essa análise não mostra efetivamente a complexidade dos movimentos coordenados dos componentes do corpo (28). De uma perspectiva de sistemas dinâmicos, onde padrões de movimento são organizados baseados em limitações impostas pela relação complexa entre parâmetros de controle, a coordenação ou o acoplamento entre as articulações do membro inferior é importante (28–30). Variabilidade de coordenação (VC) de movimento quantifica a variedade no padrão de movimento de um segmento utilizado durante uma ação (31). A análise da VC revela informações importantes sobre mudanças em estratégias motoras (32) e, ainda, apresenta uma compreensão adicional sobre a dominância que um segmento tem pelo outro. Isso pode oferecer informações valiosas em um cenário clinico (33) .

Padrões de VC segmentar podem variar dependendo da condição física do indivíduo. Menor VC segmentar pode indicar movimentos pobremente controlados ou muito limitados, podendo levar a lesões ou declínio de performance (34). Por outro lado, VC com valores altos também pode levar a um estado de lesão. Então, aparentemente, existe uma janela ou uma ‘zona segura’ de variabilidade ótima (34). A análise de codificação vetorial modificada (ModCV) é uma técnica comum empregada para quantificar coordenação e variabilidade de coordenação (32).

Dois estudos prévios investigaram a influência da idade na biomecânica da corrida estimando a VC. Silvernail et al. (20) não encontraram diferenças entre corredores jovens e idosos para sete acoplamentos analisados (coxa/perna no plano sagital, coxa/perna no plano transversal, coxa no plano sagital/perna no plano transversal, perna/pé no plano transverso, perna/pé no plano frontal, pelve/coxa no plano sagital e pelve/coxa no plano transverso), porém esse estudo analisou grupos mistos (homens e mulheres) de corredores. Por outro lado, Boyer et al. (22) dividiram o grupo de corredores considerando o sexo e a faixa etária, e analisaram apenas três acoplamentos (perna no plano transverso/pé no plano frontal, coxa/perna no plano transverso e coxa no plano sagital/perna no plano transverso). Os autores encontraram apenas diferenças no acoplamento entre coxa e perna no plano transverso, sendo que, as corredoras jovens apresentaram maior VC quando comparadas às corredoras idosas. Não foram encontradas diferenças entre os corredores jovens e idosos (22).

Como descrito acima, o envelhecimento pode produzir alterações cinemáticas e no padrão de ativação dos músculos do membro inferior de corredores que podem, por sua vez, predisporem a lesões. No entanto, embora vários estudos tenham demonstrado diferenças na cinemática articular e no padrão de ativação muscular do membro inferior entre corredores jovens e idosos, a maioria usou estatística clássica para a análise dos resultados, o que pode não ser o mais adequado para discriminar corredores de diferentes faixas etárias. Além disso, a maioria dos estudos não incluiu um grupo de corredores de meia-idade, o que permitiria identificar se e quando as mudanças decorrentes da idade começam a ocorrer. O presente estudo apresenta uma ferramenta (árvore de decisão) que potencialmente pode apresentar melhores resultados do que as técnicas empregadas em estudos prévios para discriminar corredores jovens, de meia-idade e idosos. Além disso, a VC segmentar tem sido utilizada para compreender melhor a biomecânica da corrida. Essa variável tem sido relacionada com a probabilidade de lesão na corrida. No entanto, os estudos que compararam a VC segmentar entre corredores de diferentes faixas etárias incluíram homens e mulheres em um único grupo (20) ou, ainda, não incluíram na amostra um grupo de corredores de meia idade (22). O presente estudo traz uma análise mais ampla dos acoplamentos segmentares do membro inferior, analisando oito acoplamentos diferentes, com uma amostra composta por homens e mulheres separadamente, bem como incluiu um grupo de corredores de meia idade.

TEMA DE INTERESSE

Diante do exposto, os temas de interesse desta Tese foram: verificar se a técnica árvore de decisão é eficiente para discriminar corredores jovens, de meia idade e idosos, usando variáveis cinemáticas e eletromiográficas e comparar a performance da arvore de decisão com a SVM na discriminação dos três grupos de corredores. Além disso, quantificar a VC segmentar, separadamente, em corredores homens e mulheres, nas três faixas etárias (jovens, meia idade e idosos) durante a fase de apoio da corrida.

HISTÓRICO DE COMPOSIÇÃO DA TESE

A presente Tese de Doutorado é composta por três artigos originais. O estudo I foi desenvolvido no Núcleo Multidisciplinar de Análise do Movimento (NAM), pertencente ao Departamento de Fisioterapia da Universidade Federal de São Carlos (UFSCar). Teve como objetivo verificar se a técnica árvore de decisão é eficiente para discriminar corredores jovens, de meia idade e idosos, usando variáveis cinemáticas e eletromiográficas, e comparar a performance da árvore de decisão com a SVM na discriminação dos três grupos de corredores.

Os resultados obtidos no estudo I, conduziram ao aprofundamento de outros fatores cinemáticos que também poderiam estar relacionados a lesões em corredores idosos. Dessa forma, realizou-se o estudo II e o estudo III no *Biomechanics Laboratory* da *University of Massachusetts*, durante um período de estágio de pesquisa no exterior. O objetivo do estudo II foi quantificar e comparar a VC segmentar em corredores jovens, de meia idade e idosos, durante a fase de apoio da corrida. Da mesma forma, o estudo III teve como objetivo avaliar a mesma variável (VC segmentar), porém em corredoras, jovens, de meia idade e idosas.

CLASSIFICATION OF YOUNG, MIDDLE-AGED AND OLDER RUNNERS BASED ON DECISION TREES USING KINEMATIC AND ELECTROMYOGRAPHY VARIABLES

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ABSTRACT

Running is a popular exercise and the elderly population practicing this sport has increased. This activity is associated with a risk of lower limb injuries in older runners. Although lower limb kinematics and electromyography activity have been investigated in this population, the majority of studies analyzed the data using classical statistics. A decision tree uses a tree structure to classify patterns in data sets and has shown to be better than the support vector machine (SVM) on other sorts of data. Thus, the aim of this study was to evaluate the capacity of the decision tree to discriminate young, middle-aged, and elderly runners and to compare the performance of the decision tree to the SVM. Fifteen young, 14 middle-aged, and 13 elderly runners' kinematic and electromyography data were analyzed. The results revealed that using kinematic data (6 variables selected), the mean precision rate for the decision tree was 92.6% and for the SVM was 87.8%. For the electromyography data (5 variables selected), the mean rate was 93% for the decision tree and 84.1% for the SVM. Combining both data, the mean data was 95.2% for the decision tree and 78.6% for the SVM. So, the decision tree approach was capable of discriminating young, middle-aged, and older runners using kinematic and electromyography variables and presented a higher precision rate to distinguish young, middle-aged, and elderly runners than the SVM approach.

INTRODUCTION

Nearly 42 million Americans are considered runners/joggers, and approximately 24 million are over 35 years old (35). It is well known that running in middle-age and older can improve bone mineral density and cardiovascular health, among other age-related problems (36,37).

Despite the health benefits associated with running in middle-aged and older individuals, the number of running-related injuries has increased in this population (38). The high rate of lower limb injuries may be partly due to reduced muscle strength, flexibility, and altered running mechanics (39). Also, musculoskeletal injuries may affect the older population’s health status since it limits their participation in the majority of physical activities (40).

The identification of running patterns in older ages is important to the development of lower limb injury prevention programs. Several studies have compared young runners to older runners in order to find a different pattern between those groups. Fukuchi et al. (39) showed that older runners exhibited reduced hip, ankle, and trunk kinematic excursions in comparison to young runners. Another study comparing ages found an increased range of motion for knee flexion and ankle dorsiflexion in the younger runners compared to the older (18) . However, Silvernail et al. (20) reported very few differences in running mechanics between older and younger runners, concluding that runners appear to maintain joint mechanics during running with increasing age. Thus, there are disagreements between studies that compare kinematics in older and younger ages.

Muscular activation is important to maintain articular dynamic stabilization during running and changes in the activation magnitude might be related to injuries (23). Schmitz et al. (23) compared the activation of several lower limb muscles during low, preferred, and high-speed gaits between young and elderly individuals. The authors showed that the older runners presented higher activation of the soleus and tibialis anterior muscles during the mid-stance in all the velocities. Also, higher activation was reported in the vastus lateralis and hamstring muscles in older individuals during high-speed gaits (23). Sano et al. (24) examined the pattern of activation of the lower leg muscles during running in young and elderly runners. This study found greater activation of the medial gastrocnemius muscle during the pre-activation and push-off phases in older runners.

It is important to highlight that the majority of previous studies employed statistics to discriminate young and older runners. However, in accordance with Fukuchi et al. (25) statistical techniques are limited for application to pattern-recognition tasks, that is, in this case, to categorize groups of runners. To the best of the author's knowledge, only Fukuchi et al. (25) applied a machine learning technique to analyze differences between young and older runners. The authors employed SVM to discriminate the kinematic patterns between groups. However, the use of an SVM-based approach has some disadvantages, such as a high computational cost (the larger the database, the greater the processing time). It is also very difficult to choose the kernel function (this function greatly affects the results) and the adjustment of the regularization parameter is difficult. Furthermore, Fukuchi et al. (25) employed only kinematic variables to discriminate the two groups. Another approach used to discriminate data from different groups is the decision tree. Decision trees are tools based on divide-and-conquer strategies as a form of learning by induction (26). This machine learning technique uses a tree structure to classify patterns in data sets, which are hierarchically organized in a set of interconnected nodes. Thus, the nodes considered as leaves classify the instances (inputs) in accordance with their associated label (output). Caruana and Niculescu-Mizil (27) demonstrated that the decision trees presented better results than the SVM for 10 distinct databases. So, for this study, the decision tree is the more appropriate technique to discriminate runners from different age ranges. Thus, studies were not found that aimed to discriminate different running groups by using kinematic and electromyography variables as inputs for decision trees.

The aim of this study was to evaluate if the decision tree is efficient to discriminate young, middle-aged, and older runners using kinematic and electromyography variables. The second purpose was to compare the performance of the decision tree to the SVM to discriminate the 3 groups of runners. It was hypothesized that the decision tree should be able to classify different age groups of runners and will be a better approach for these data.

Subjects

Forty-two male runners volunteered for this study. Fifteen young adults (between 21 and 34 years old), 14 middle-aged (between 38 and 50 years old), and 13 older runners (between 61 and 70 years old) were evaluated. Participants were recruited through advertisements on the Internet, local races, and posted flyers. Prior to their participation, each subject signed a consent form **(Appendix 1)** approved by the University Ethics Committee for Human Investigations **(Attachment 1)**. The demographic data and sports practice information about the 3 groups can be found in Table 1. The inclusion criteria were being injury-free over the previous 3 months, having a minimum weekly running distance of 10 km, and being rearfoot strikers (RFS). Participants were excluded if they presented any lower limb injury or surgery, chronic diseases, or orthopedic conditions that could influence running biomechanics (such as arthritis, coronary disease, vestibular disorders, etc.).

Table 1. Demographic data and sports practice information (mean ± standard deviation).

	Young (n = 15)	**Middle-Aged** (n = 14)	**Older** (n = 13)
Participant Characteristics			
Age (years)	28 ± 4[a,b]	41 ± 5[c]	64 ± 2
Height (cm)	179 ± 0[b]	179 ± 0[c]	167 ± 0
Body Mass (kg)	80 ± 12[b]	80 ± 12[c]	64 ± 9
BMI (kg/m^2)	24 ± 3	25 ± 6	23 ± 2
Running Experience (years)	5 ± 3[a,c]	12 ± 3	10 ± 5
Running Distance (km/week)	39 ± 20	29 ± 16	34 ± 26

[a]Significant differences between young and middle-aged runners.
[b]Significant differences between young and older runners.
[c]Significant differences between middle-aged and older runners.

Protocol

During a single visit to the laboratory, the participants' anthropometric and sports practice information data were collected **(Appendix 2)** and a running analysis was performed. All of the evaluations were conducted on the dominant lower limb, which was defined by asking the subjects which leg they would use to kick a ball as far as possible (12). A neutral running shoe (Asics Gel-Equation 5, ASICS, Kobe, Japan) was provided for all of the runners.

The dominant lower limb (7 left, 35 right) kinematic was recorded at 240 Hz using a passive 7-camera motion capture system (Qualisys, Qualisys Inc., Gothenburg, Sweden). Sixteen reflective markers located on anatomical landmarks (15 mm in diameter) and 3 cluster tracking markers were placed on each participant (Figure 1). A static trial in a neutral standing position was used to align the subject with the laboratory coordinate system and to serve as a reference point for subsequent kinematic analysis.

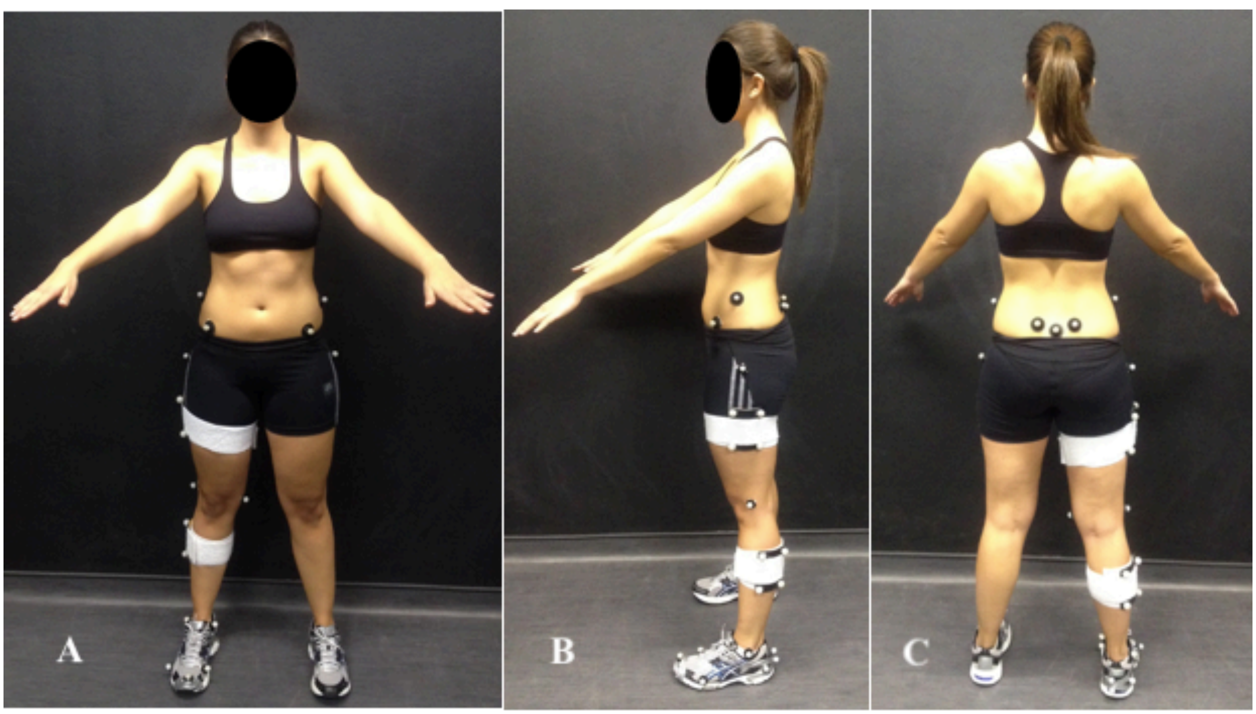

Figure 1. Marker set protocol used in this study. (A) Anterior view. (B) Lateral view. (C) Posterior view.

The surface electromyography (EMG) activity of the rectus femoris, vastus medialis, vastus lateralis, biceps femoris, tibialis anterior, medial gastrocnemius, gluteus medius, and gluteus maximus were recorded during the running. The surface electrodes were applied to the skin according to SENIAM recommendations (42). EMG was simultaneously recorded with the kinematics at a 2400 Hz sampling rate using wireless surface EMG electrodes (Trigno Wireless System, Delsys, Inc., Boston, MA, USA). Each electrode pre-amplified the signal and was interfaced to an amplifier unit (Delsys, Inc., Boston, MA, USA) with an operating range of 40 m, a transmission frequency of 2.4 GHz, a common mode rejection ratio (CMRR) > 80 dB, and a bandwidth of 450 Hz at > 80 dB/s. The EMG signals were digitized using a 16-bit analog-to-digital board that was synchronized with the motion analysis data.

Initially, all the participants warmed up on a treadmill at a constant speed of 4.5 km/h for 5 minutes. Then the participants preferred running speed and kinematic data were collected. After the volunteer had been running for 5 minutes, at least 5 consecutive steps of the dominant lower limb were recorded (17).

Data processing and feature extraction

Visual 3D software (Version 3.9; C-Motion Inc., Rockville, MD, USA) was used to calculate kinematic data. The Cardan angles were calculated using the joint coordinate system definitions that were recommended by the International Society of Biomechanics (43) relative to the static standing trial. Lower limb joint kinematics were calculated as the motion of the distal segment relative to the proximal reference, and lower limb segment kinematics were calculated considering the lab coordinate system. All the kinematic data were analyzed at initial contact and during the stance phase. Initial contact was identified as the point in time when the calcaneus marker moved from positive to negative velocity in the anteroposterior direction (44). The toe-off was determined by the second knee extension peak (41). The kinematic data were filtered using a fourth-order, zero-lag, low-pass Butterworth filter at 12 Hz. Matlab software (Version 2008; MathWorks Inc., Natick, MA, USA) was used to identify the kinematic variables of interest. The segment angles (relative to the laboratory) of the rearfoot, tibia, femur, and pelvis at initial contact, peak angle at stance phase, and excursion angle at stance phase at the 3 planes of motion were compiled. The articular angles (relative to the proximal reference) of the ankle, knee, and hip at initial contact, peak angle at stance phase, and excursion angle at stance phase for all planes of motion were also collected.

The EMG signals were processed using custom Matlab software. Raw EMG data were band-pass filtered (20-450 Hz, fourth-order Butterworth), full-wave rectified, and smoothed using a 50-Hz low-pass filter (bidirectional, sixth-order Butterworth). An average of 5 stance phases of each condition from the dominant lower limb was analyzed. The mean EMG activity was normalized by the average of the total gait cycle.

Seventy-two running kinematics and eight electromyography features were extracted from the collected data.

Classification based on decision tree

This study used decision trees of the type J48, where the Weka open-source software was employed. In this sense, the previously generated database (with electromyography and kinematic features) was presented as input to the software. Consequently, this database was normalized (for values between 0 and 1) with the aim of obtaining better condition data and facilitating the classifier's convergence process. Thus, the decision tree had its confidence factor parameter adjusted to 0.9. Finally, the J48 was running considering 10 folds. Bellow, Figure 2 shows a flowchart of the computational tool used in this study.

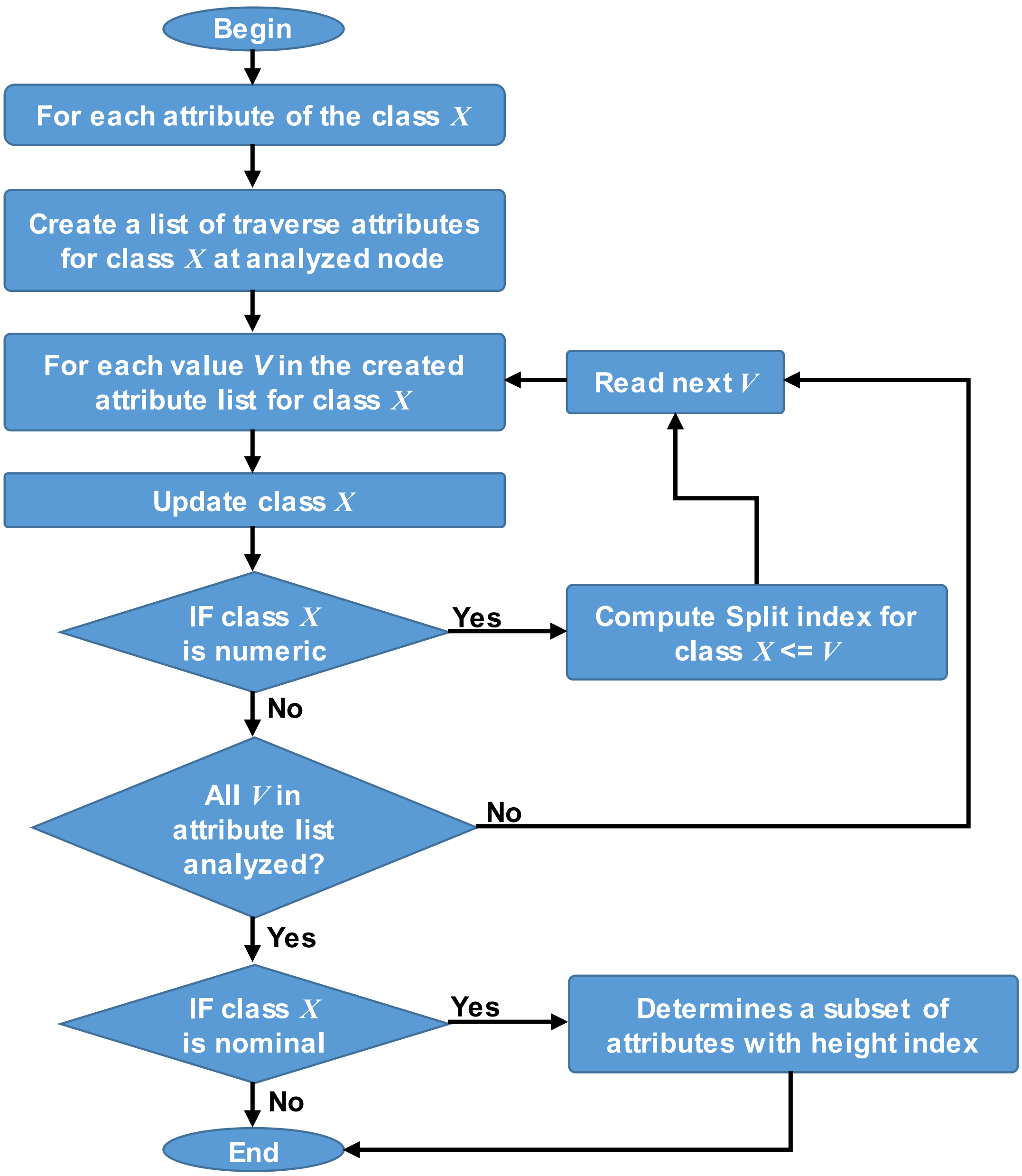

Figure 2. Flowchart of the J48 decision tree

The potential of decision trees for pattern recognition problems was demonstrated by comparative tests performed between the proposed decision tree (J48) and the SVM-based classifier proposed by Fukuchi et al. (25). The data analysis followed 5 steps:

(1) First, the performance of the SVM and the decision tree were compared using the features given as relevant by Fukuchi et al. (25) (the knee excursion angle, the knee abduction angle at initial contact, the ankle peak dorsiflexion angle, the peak knee abduction angle, the tibial rotation excursion, and the toe-out at initial contact) with the SVM classifier with linear function (with the parameter C=1). However, 3 classes of runners were considered, defined as young, middle-aged, and older.

(2) Starting from the results obtained by both the SVM and the decision tree, in sequence, all kinematic and electromyography data were given as input to a correlation-based feature selector, which correlates the variables with the classes. This correlation returns the weight of each analyzed variable. Thus, these weights can assume values between 0 (less relevant variables) and 1 (most relevant variables). In this sense, only the variables with weights greater than 0 were selected to compose the data set.

(3) It was applied the SVM and the decision tree using the kinematic features selected.

(4) It was applied the SVM and the decision tree using the electromyography features selected.

(5) Finally, it was applied both SVM and the decision tree using the kinematics and electromyography features combined.

It is important to note that both classification algorithms (SVM and J48) were trained and validated through a cross-validation process. Thus, the error rate of the algorithms was a tenfold cross-validation that is commonly employed for machine learning classifiers. In this process, the data is divided into ten parts, where the class is as well represented as for the complete database. It is also emphasized that, because ten folds are adopted, the learning process is executed ten times, where the error rate is measured for each execution. Thus, the percentage error rate demonstrated in this paper for both algorithms is represented by the average of all errors obtained in the 10 runs.

RESULTS

The potential of using decision trees for pattern recognition problems was demonstrated by comparative tests performed between the decision tree (J48) and the SVM-based classifier proposed by Fukuchi et al. (25). Moreover, it assessed the relevance of kinematic and electromyography variables, where decision trees had their performances evaluated.

The results obtained by the SVM classifier and by the decision tree using features used by Fukuchi et al. (25) can be viewed in the confusion matrix (Table 2).

Table 2. Confusion matrix representing the results obtained by the SVM classifier and the J48 decision tree classifier, respectively, using the features selected by Fukuchi et al. (25).

	SVM				J48			
	Young	**Middle-Aged**	**Older**	**Precision Rate**	**Young**	**Middle-Aged**	**Older**	**Precision Rate**
Young	**12**	1	2	80%	**14**	1	0	93.3%
Middle-Aged	1	**12**	1	85.7%	2	**11**	1	78.6%
Older	6	2	**5**	38.5%	2	0	**11**	84.6%

Note, for instance, that of 15 young runners, 12 were classified as young, 1 as middle-aged, and 2 as older, with a precision rate of 80%. Thus, the mean precision rate obtained by the SVM classifier is around 69%. Thus, a decision tree-based classifier would be most suitable when increasing the nonlinearity inherent in the problem. In this sense, the features defined by Fukuchi et al. (25) were maintained, where the results showed a significant improvement (a mean precision rate around 85.7%) for a J48 decision tree with a confidence factor set to 0.9.

Table 3 shows the correlation-based feature selector and the most relevant variables. The higher value features are the most discriminative ones.

Table 3. Relevant features selected between kinematic and electromyography variables.

Kinematic	Weight	Electromyography	Weight
KerIC	1	Gluteus Medius	0.8
KflIC	0.7	Vastus Lateralis	0.7
HirIC	0.6	Tibialis Anterior	0.1
TerPK	0.1	Gluteus Maximus	0.1
KflEX	0.1	Rectus Femoris	0.1
HaddIC	0.1		

KerIC, knee external rotation angle at initial contact; KflIC, knee flexion angle at initial contact; HirIC, hip internal rotation angle at initial contact; TerPK, tibial external rotation peak angle; KflEX, knee flexion excursion angle; HaddIC, hip adduction angle at initial contact.

Analyzing the variables in Table 3, only KflEX is from the set of variables selected by Fukuchi et al. (25). Aside from KflEX, there are five other variables selected, such as knee flexion angle at initial contact (KflIC), hip internal rotation angle at initial contact (HirIC), tibial external rotation peak angle (TerPK), hip adduction angle at initial contact (HaddIC), and knee external rotation angle at initial contact (KerIC) containing the most discriminative information. The electromyography features selected were the average amplitude from the gluteus medius, vastus lateralis, tibialis anterior, gluteus maximus, and rectus femoris, with the gluteus medius and vastus lateralis the most discriminative ones.

Table 4 shows the results from the SVM and decision tree using the selected kinematic features. When the SVM was applied, the mean precision rate was 87.8%, while when the decision tree was applied, the mean rate was 92.6%.

Table 4. Confusion matrix representing the results obtained by the SVM classifier and the J48 decision tree classifier using the kinematic data selected by the method based on the correlation.

	SVM				J48					
	Young	**Middle-Aged**	**Older**	**Precision Rate**		**Young**	**Middle-Aged**	**Older**	**Precision Rate**
Young	**14**	0	1	93.3%	**Young**	**14**	0	1	93.3%
Middle-Aged	0	**12**	2	85.7%	**Middle-Aged**	0	**14**	0	100%
Older	1	1	**11**	84.6%	**Older**	1	1	**11**	84.6%

Table 5 shows the result from the application of SVM and the decision tree using the electromyography features selected. When the SVM was applied, the mean precision rate was 84.1%, while when the decision tree was applied, the mean rate was 93%.

Table 5. Confusion matrix representing the results obtained by the SVM classifier and the J48 decision tree classifier using the EMG data selected by the method based on the correlation.

	SVM					J48				
	Young	**Middle-Aged**	**Older**	**Precision Rate**		**Young**	**Middle-Aged**	**Older**	**Precision Rate**
Young	**9**	6	0	60%	**Young**	**13**	2	0	86.7%
Middle-Aged	0	**14**	0	100%	**Middle-Aged**	0	**14**	0	100%
Older	0	12	**1**	92.3%	**Older**	1	0	**12**	92.3%

Table 6 shows the results of the comparison of the two techniques using both kinematics and EMG features. The decision tree was able to classify correctly 95.2% of the data, while the SVM achieved a mean precision rate of only 78.4% (Table 6).

Table 6. Confusion matrix representing the results obtained by the SVM classifier and the J48 decision tree classifier using the kinematic and EMG data selected by the method based on the correlation.

	SVM					J48			
	Young	**Middle-Aged**	**Older**	**Precision Rate**		**Young**	**Middle-Aged**	**Older**	**Precision Rate**
Young	**11**	3	1	73.3%	**Young**	**14**	0	1	93.3%
Middle-Aged	0	**13**	1	92.9%	**Middle-Aged**	0	**14**	0	100%
Older	1	3	**9**	69.2%	**Older**	0	1	**12**	92.3%

Figure 3 shows an example of the resulting decision tree to classify 3 distinct categories of runners: (A) is the young class, (B) is the middle-aged class, and (C) is the older class. It is important to note that KerIC is the knee external rotation angle at initial contact, KflIC is the knee flexion angle at initial contact, HirIC is the hip internal rotation angle at initial contact, and TerPK is the tibial external rotation peak angle.

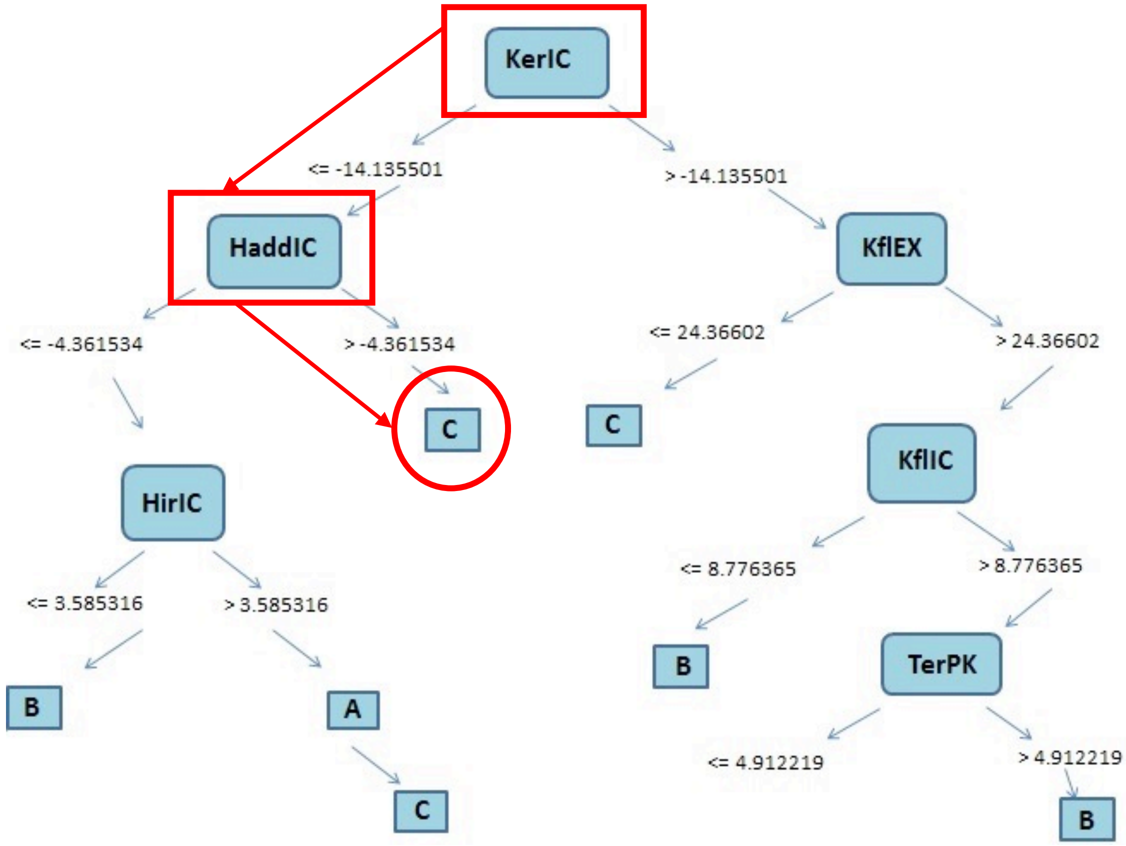

Figure 3. A resulting decision tree to classify categories of runners: (A) young, (B) middle-aged, (C) and older.

For a better understanding of the resulting decision tree, the following example can be given: a runner will be considered as Class C (older) if his or her KerIC is less than or equal to -14.135501 and if his or her HaddIC is greater than -4.361534. This example is shown by the path highlighted in red in Figure 3.

DISCUSSION

This study aimed to evaluate if the decision tree approach was capable of discriminating young, middle-aged, and older runners using kinematic and electromyography variables and to compare the performances of the decision tree to the SVM to discriminate the 3 groups of runners. The hypothesis was confirmed that the decision tree would be able to classify different age groups of runners and would be a better approach.

Although Fukuchi et al. (25) revealed that the classifier based on the SVM with linear function has shown excellent performance, its precision rate (91%) was obtained due to the separation of only 2 classes (young and older runners). Therefore, with the increase in classes, as proposed in this paper, the SVM with linear function did not have the same performance (the precision rate was around 69% with Fukuchi's features). Still, when the decision tree was applied using the same variables, the precision rate was around 85.7%. This shows a better performance of the decision tree to discriminate the 3 groups of runners.

When the correlation-based feature selector was applied to the kinematic data, six variables were found for discriminating the three groups (KerIC, KflIC, HirIC, TerPK, KflEX, and HaddIC), with KerIC, KflIC, and HirIC the most discriminative features. It is important to emphasize that the decision tree is an approach that takes into account only numbers and yet it selected movements that are clinically relevant. For instance, the hip internal rotation and the knee external rotation are components of the dynamic knee valgus (45), which in turn can be related to lower limb injuries (46), such as patellofemoral pain and iliotibial band syndrome, among others. Further, it is important to note that differences in KflIC and tibial rotation excursion were already reported in previous studies that applied inferential statistics (15,17). After the identification of the relevant kinematic variables, the performance of the SVM and the decision tree were again compared, which showed a higher mean precision rate of the decision tree (92.6%) compared to the SVM (87.8%). Thus, the decision tree approach is more capable of discriminating three groups of runners using the selected kinematic variables.

One of the differentials from this study was to verify if the decision tree was capable of discriminating the three groups using electromyography features. Thus, first the correlation-based feature selector was applied to identify the electromyography features. The mean activation of the gluteus medius, vastus lateralis, tibialis anterior, gluteus maximus, and rectus femoris were identified as relevant features, and the gluteus medius and vastus lateralis were the most discriminative. These results have a high clinical relevance. Considering that the gluteus medius muscle controls hip adduction (47), and hence the dynamic knee valgus, a deficit in the activation of these muscles can also predispose runners to injuries (46). Similarly, the vastus lateralis muscle is important to control knee flexion. Therefore, as was done with the kinematic variables, after the identification of the relevant electromyography variables, the SVM and the decision tree were again performed. The performance of the decision tree was higher (a mean precision rate of 93%) than the SVM (a mean precision rate of 84.1%) to discriminate the three groups of runners. Thus, the application of the decision tree approach using electromyography variables is an alternative to discriminate runners of different age ranges. In addition, the confirmation that it is possible to separate runners of different age ranges using electromyography variables has financial significance, since usually the equipment and software used in data collection and data processing has a lower cost than the systems used in kinematic analysis.

Finally, it was verified that the association between the kinematic and electromyography variables selected by the correlation-based feature select increased the performance of the SVM and the decision tree in discriminating the three groups of runners. The results shown that the decision tree was able to correctly classify 95.2% of the data, while the SVM achieved a mean precision rate of only 78.6%. Therefore, the performance of the decision tree was even higher than the SVM. However, when the results of the decision tree using kinematic variables and electromyography were compared individually, the precision rate increased only 2-3%. Thus, there is probably no need to associate kinematic and electromyography data when the aim is distinguishing young, middle-aged, and older runners using the decision tree approach.

CONCLUSION

The decision tree approach was capable of discriminating young, middle-aged, and older runners using kinematic and electromyography variables and gave a better performance for distinguishing these groups than the SVM approach.

ESTUDO II

DOES THE COORDINATION VARIABILITY DURING RUNNING CHANGE ACROSS DIFFERENT AGE RANGES?

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Artigo submetido para publicação no periódico Gait & Posture.

ABSTRACT

Running is a popular form of exercise and the health benefits of regular running are well known. The elderly population now running has increased and, despite of health benefits, running is associated with a risk of injuries in older runners. Dependent variables have tended to focus on discrete data from isolated joints. Coordination variability quantifies the variety of segment movement patterns available to an individual during running. The aim of this study was to compare coordination variability among runners during the stance phase of the gait cycle. Forty-two healthy male runners were separated equally into three age groups (younger, middle-aged and older runners). Three-dimensional kinematic data were recorded using a motion capture system operating at 240 Hz. A modified vector coding technique was used to investigate segment coordination variability. Eight different lower limb segment couplings were selected for analysis. To assess differences in coordination variability between the three groups, one-way analyses of variance (ANOVA) were conducted with a Bonferroni adjustment applied. In general, younger runners presented a higher coordination variability than the middle-aged and the older group while the older runners had a lower coordination variability compared to middle-aged group. The study findings indicate that aging influences dynamic function for male runners. Also, the results may help to explain the process causing the altered injury pattern for runners in different age ranges and can help physical therapists to draw strategies for prevention or rehabilitation for running-related injuries.

INTRODUCTION

Distance running has become a common form of physical activity (48). It is estimated that nearly 42 million Americans are runners/joggers today and approximately half of those are over 35 years-old (35). The health benefits of regular running are well known with, for example, improvements of bone mineral density and cardiovascular health particularly in older runners (36,37).

Despite of these benefits for healthy aging, it has been shown that older runners have an increased risk for injuries (11). Thus, Wen et al. (49) showed that younger runners were significantly protected against overall overuse injury in runners. Still, some studies obtained contrary results and reported that younger male runners were positively associated with the risk of sustaining a running related injury (50). This finding was supported by other studies that concluded that increasing age was significantly related with a lower incidence of running related injuries (13,51). However, Nielsen et al. (52) did not find differences in injury risk between young and older runners. It is noted that studies diverge whether injuries are related to age or not.

Researchers have been interested in investigating if there are any biomechanical differences that could explain the changes in injury patterns between young and older runners. Fukuchi et al. (39) reported alterations in running biomechanics between young and older runners. Specifically, in this study, older runners exhibited reduced hip, ankle and trunk kinematic excursions. Agreeing with these findings, Nigg et al. (18) detected less movement in the sagittal plane including decreased range of motion for knee flexion and ankle dorsiflexion for the older groups compared to the young group. Still, Silvernail et al. (20) found that runners appear to maintain joint mechanics during running in older age. There is a clear disagreement on the literature concerning biomechanical patterns between young and older runners.

Traditionally, dependent variables in studies of running biomechanics have tended to focus on discrete data from isolated joints. However, this analysis does not effectively capture the complexity of the coordinated motions of components of the body (28). From a dynamical systems perspective, where a movement patterns are arranged based on constraints imposed from the complex relationships between control parameters, coordination or coupling between joints of the lower extremity is important (28–30). Segment coordination variability (CV) quantifies the variety of segment movement patterns an individual uses during a motion (31). A CV analysis reveals important information regarding changes in motor strategies (32) and also provides an additional insight to the dominance of one segment over another. This can offer valuable information in a clinical setting (33).

Differences in segment CV patterns may vary with health status. Lower segment CV may indicate a poorly controlled motion or motion that is overly-constrained , that could lead to injury or decreased performance (34). On the other hand, CV that is extremely high could also results in an injury. It would appear that a ‘safe-zone’ or window of optimal variability exists (34). A modified vector coding analysis (ModVC) is a common technique employed to quantify coordination and variability (32).

Two previous studies have investigated the age influences on running biomechanics assessing CV. Both Silvernail et al. (20) and Boyer et al. (22) found subtle CV differences between young and older runners indicating that these runners maintain the running pattern in older ages. As opposed to the previous studies, the current study presents a broader analysis of lower limb segment couplings evaluating eight different couplings. Also, a sample composed only of men was selected creating a homogeneous sample. Lastly, adding a middle-aged group may verify if and when the age changes start to occur.

The purpose of this study was to quantify the CV in younger, middle-aged and older runners during the stance phase. To assess CV, a ModVC approach was used. We hypothesized that there would be systematic differences between runners, with the young runners having greater CV than middle-aged and older runners and middle-aged runners having greater CV than older runners.

METHODS

Participants

Forty-two heathy male runners volunteered for this study. Fourteen young adults (between 21 and 34 years old), 14 middle-aged (between 38 and 50 years old) and 14 older runners (between 61 and 70 years old) were evaluated. The inclusion criteria were: have a minimum weekly running distance of 10 km, be rearfoot striker and injury free in the last 3 months. Participants were excluded if presented chronic diseases or orthopedic conditions, that could influence running biomechanics (i.e., arthritis, coronary disease, vestibular disorders, etc.), and any lower limb injury or surgery. Prior to their participation, each subject signed a consent form **(Appendix 1)** approved by the University Ethics Committee for Human Investigations **(Attachment 1)**. The demographic data and sports practice information about the three groups can be found in Table 1.

Table 1. Demographic data and sports practice information (mean ± standard deviation).

	Young (n=14)	**Middle-aged** (n=14)	**Older** (n=14)
Participants Characteristics			
Age (years)	28±4[a,b]	43±4[c]	64±2
BMI (kg/m^2)	24±3[b]	25±6[c]	23±2
Running Experience (years)	6±5[b]	12±3[c]	10±5
Running Distance (km/week)	41±19	29±16	34±26

[a] Significant differences between young and middle-aged runners.
[b] Significant differences between young and older runners.
[c] Significant differences between middle-aged and older runners.

Experimental Set-up

Three-dimensional kinematic data of the lower extremity were recorded at 240 Hz using 7-camera motion capture system (Qualisys Inc., Gothenburg, Sweden). The running was performed in a treadmill (model LX 160 GIII, Movement) surrounded by the passive cameras. Before the protocol, a neutral running shoe (Asics Gel-Equation 5, ASICS, Kobe, Japan) was provided for all runners.

Protocol

During a single visit to the laboratory, the participants' anthropometric and demographic data were collected **(Appendix 2)** and a running analysis was performed.

Sixteen 15 mm reflective markers were placed on anatomical landmarks in addition to three tracking clusters each with four markers were attached on each participant (Figure 1). A static trial in neutral standing position was used to align the subject with the laboratory coordinate system and to serve as a reference point for subsequent kinematic analysis.

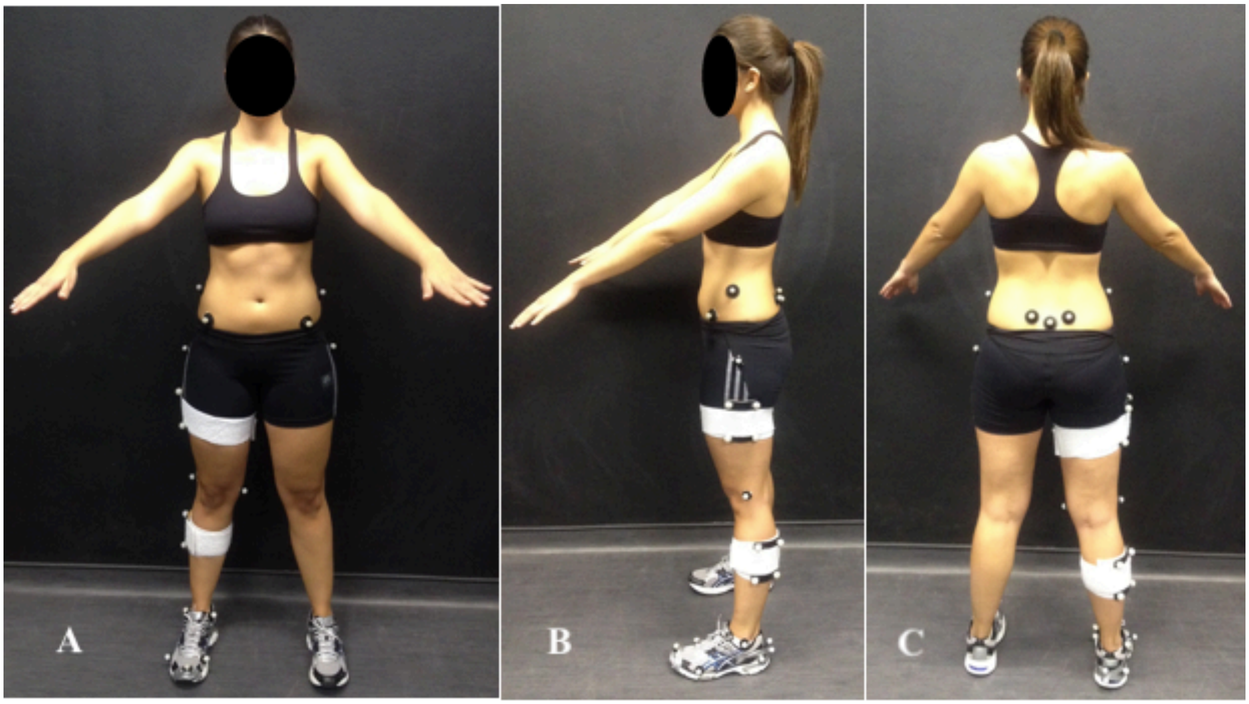

Figure 1. Marker set protocol used in this study. (A) Anterior view. (B) Lateral view. (C) Posterior view.

Initially, all the participants of each group (young, middle-aged and older) warmed up on a treadmill at a constant speed of 4.5 km/h for five minutes. Next, the preferred running speed of each participant was determined. Lastly, kinematic data were collected. After the participant had run for five minutes, at least five consecutive steps of the dominant lower limb were recorded (17).

Data Processing and Feature Extraction

Visual 3D software (version 3.9; C-motion Inc., Rockville, Maryland, MD) was used to calculate kinematic data. The data were filtered using a 4th-order, zero-lag, low-pass Butterworth filter at 12 Hz. The Cardan angles were calculated using the joint coordinate system definitions that were recommended by the International Society of Biomechanics (43) relative to the static standing trial. The lower limb segment kinematics were calculated in the laboratory coordinate system. Segment angles (relative to the laboratory) of foot, shank, thigh and pelvis at stance phase at the three planes of motion were calculated. All the kinematic data were analyzed during the stance phase and normalized to the standing calibration trial. Initial contact was identified as the point in time when the calcaneus marker moved from positive to negative velocity in the anteroposterior direction (44) and verified by a qualitative camera (Figure 2). The toe-off was determined by the second knee extension peak (41). Each trial was normalized with respect to time to make all trials equal to 100% of the stance. Matlab software (version 2008; MathWorks Inc., Natick, USA) was used to identify the kinematic variables of interest.

Figure 2. Landing pattern verification by qualitative camera (240 Hz).

A modified vector coding technique (32,53) was used to investigate segment coordination variability. To begin this analysis, contiguous segment angles are plotted with one on the horizontal axis and one on the vertical (Figure 3A). This technique calculates the angle, with respect to the right horizontal, of the vector formed between two consecutive time points on an angle–angle plot created using time normalized global segment angles from the stance phase (Figure 3A). Contiguous segments form a coupling represented by the vector coding angle. Because vector coding angles are directional, circular statistics must be used (54). Mean and standard deviations of each participant for all trials were calculated using circular statistics. The standard deviation (SD) of the vector created between each consecutive two-time points throughout stance represents the variability of the coordination of the of the analyzed segment (Figure 3B).

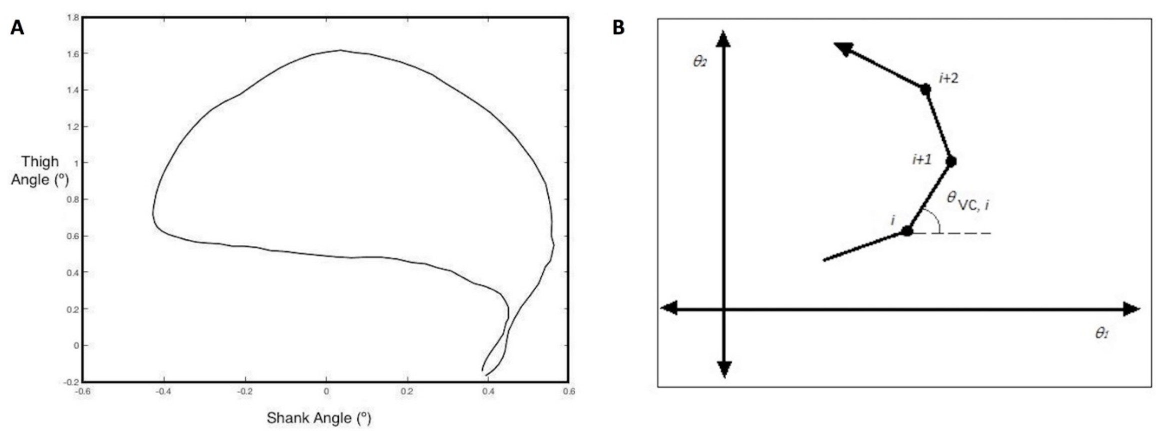

Figure 3. A modified vector coding technique. (A) An exemplar plot of contiguous segment angles to conduct a modified vector coding analysis. (B) The modified vector coding method to calculate the phase angle (*i* indicates the point within the time series and θ_{vc} indicates vector coding coupling).

CV was calculated for the following couplings between thigh and shank (thigh flexion/shank internal rotation, thigh/shank flexion, and thigh/shank internal rotation), shank and foot (shank internal rotation/foot eversion, shank/foot internal rotation, and shank adduction/foot eversion) and pelvis and thigh (pelvis tilt/thigh flexion, and pelvis rotation/ thigh internal rotation). Mean CV for each coupling was established for three phases of the gait cycle (early, mid and late stance) and the overall average across the stance phase.

Statistical analysis

In order to assess differences in CV between the three groups at the different portions of the stance phase and across the stance phase, one-way analyses of variance (ANOVA) were conducted. Bonferroni *post hoc* tests were applied to confirm where the differences occurred between groups. The effect size of the group differences was examined using the Cohen's d effect size. An effect size of d=0.5 was considered moderate and greater than d=0.8 was considered large. The criterion alpha level was set at α=0.05.

RESULTS

CV differed between young, middle-aged and older runners during the complete stance phase. For the thigh/shank flexion coupling, the young group had a higher CV when compared to the middle-aged group (p=0.001, d=0.48), and when compared to the older group (p=0.000, d=0.91). The middle-aged group presented a higher CV than older runners (p=0.016, d=0.42) (Figure 4A). For the thigh flexion/shank internal rotation coupling, differences between the young group and the older group were found (p=0.021, d=0.38) in which young runners had a higher CV than the older runners (Figure 4B). For the shank adduction/foot eversion coupling, the young group had a higher CV when compared to the middle-aged group (p=0.001, d=0.53) and when compared to older runners (p=0.000, d=1.00). The middle-aged runners presented higher CV than older runners (p=0.001, d=0.58) (Figure 5A). For the shank internal rotation/foot eversion coupling, differences were found between the young group and the older group (p=0.002, d=0.45) and between the middle-aged group and the older group (p=0.034, d=0.36), in which young runners and middle-aged runners presented a higher CV than older runners (Figure 5B). And for the pelvis rotation/thigh internal rotation coupling, young runners presented higher CV than middle-aged runners (p=0.004, d=0.45) (Figure 6).

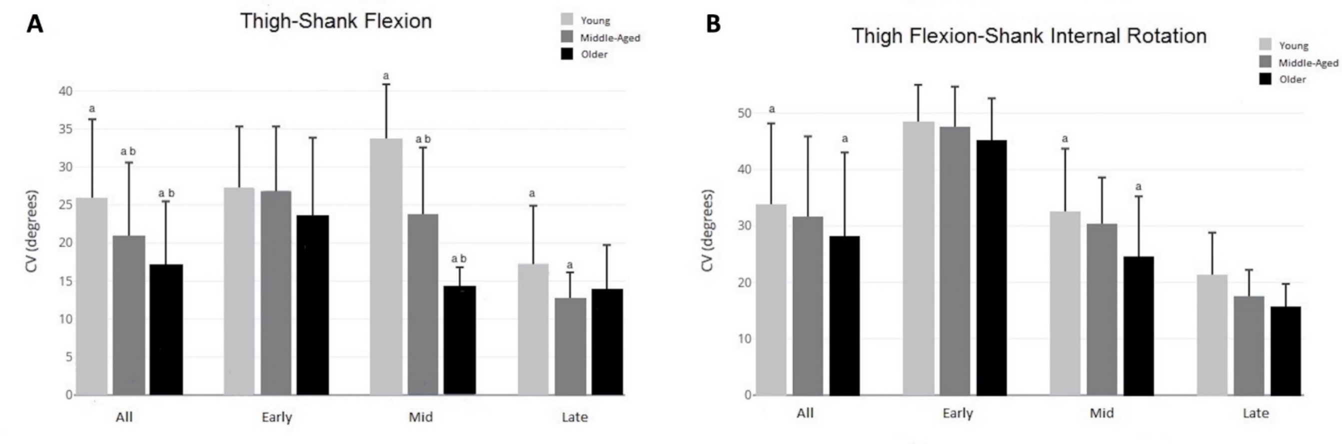

Figure 4. Mean CV for all, early, mid and late stance phase during running (A) for the thigh/shank flexion coupling and (B) for the thigh flexion/shank internal rotation coupling. The same letters indicate stastically significant differences ($p<0.05$).

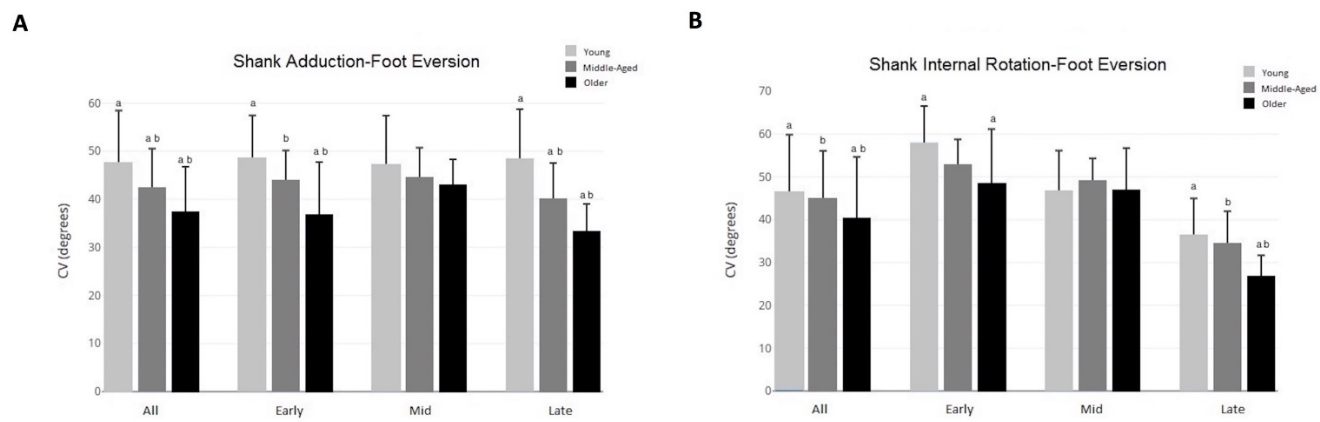

Figure 5. Mean CV for all, early, mid and late stance phase during running (A) for the shank adduction/foot eversion coupling and (B) for the shank internal rotation/foot eversion coupling. The same letters indicate stastically significant differences ($p<0.05$).

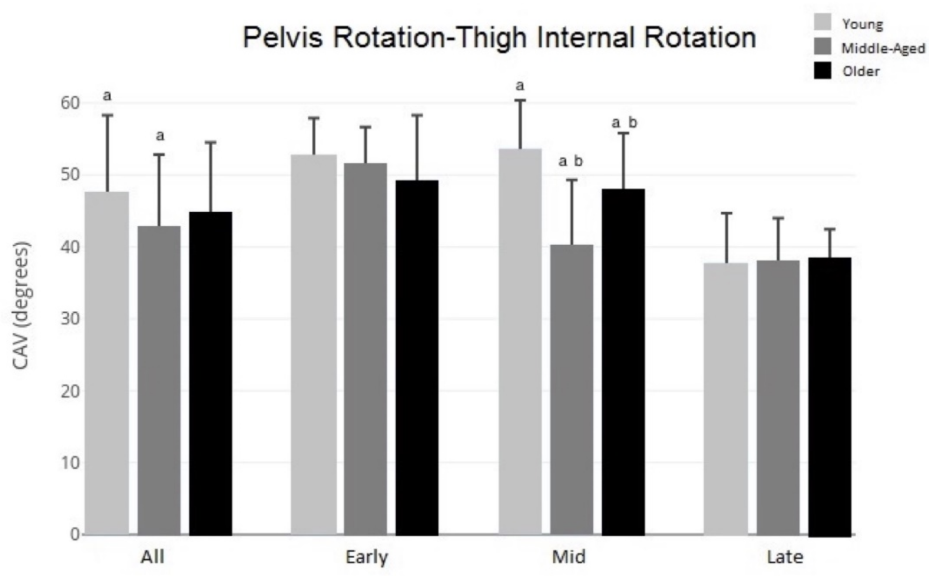

Figure 6. Mean CV for all, early, mid and late stance phase during running for the pelvis rotation/thigh internal rotation coupling. The same letters indicate stastically significant differences (p<0.05).

In early stance, for the shank/foot internal rotation coupling, older runners presented a higher CV than the young runners (p=0.015, d=0.71) (Figure 7). For the shank adduction/foot eversion coupling, young group presented a higher CV than older group (p=0.000, d=1.18), and the middle-aged group had a higher CV than the older group (p=0.005, d=0.80) (Figure 5A). For the shank internal rotation/foot eversion coupling, young runners had a higher CV than older runners (p=0.000, d=0.87) (Figure 5B).

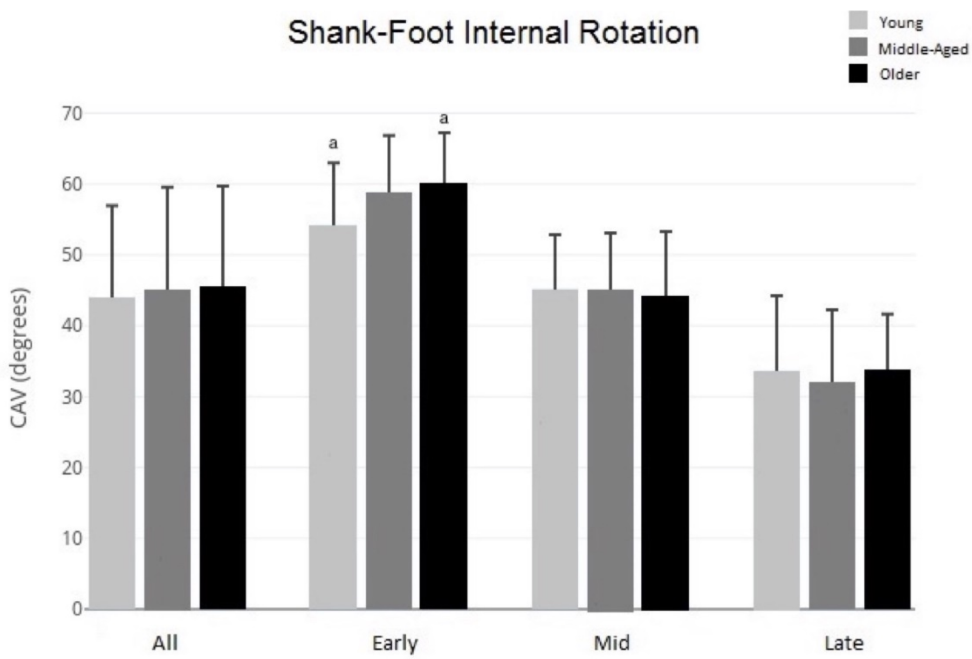

Figure 7. Mean CV for all, early, mid and late stance phase during running for the shank/foot internal rotation coupling. The same letters indicate stastically significant differences (p<0.05).

During mid stance, for the thigh/shank flexion coupling, the young group had a higher CV than the middle-aged group (p=0.000, d=1.23), and a higher CV than older runners (p=0.000, d=3.58). Also, middle-aged runners presented a higher CV when compared to older runners (p=0.000, d=1.43) (Figure 4A). For the thigh flexion/shank internal rotation coupling, young runners presented a higher CV when compared to older runners (0.007, d=0.71) (Figure 4B). And for the pelvis rotation/thigh internal rotation coupling, younger runners presented a higher CV when compared to middle-aged runners (p=0.000, d=1.67), and a higher CV when compared to the older group (p=0.015, d=0.78). Also, older runners had a higher CV when compared to middle-aged runners (p=0.001, d=0.90) (Figure 6).

Lastly, during the late stance, for the thigh/shank flexion coupling, young runners presented higher CV than middle-aged runners (p=0.009, d=0.75) (Figure 4A). For the shank adduction/foot eversion coupling, young runners presented higher CV than middle-aged runners (p=0.000, d=0.92), and a higher CV than older runners (p=0.000, d=1.80). Also, the middle-aged group presented a higher CV when compared to the older group (p=0.003, d=0.1.02) (Figure 5A). And for the shank internal rotation/foot eversion coupling, young runners presented a higher CV than middle-aged runners (p=0.031, d=0.23) and a higher CV when compared to older runners (p=0.000, d=1.36) (Figure 5B).

There were no statistically significant differences for the thigh/shank internal rotation coupling and for the pelvis tilt/thigh flexion between the three groups at any of the different portions of the stance phase and across the stance phase.

DISCUSSION

The purpose of this study was to investigate differences in CV between younger, middle-aged and older runners during the stance phase. In order to assess CV, a ModVC approach was used. It was hypothesized that there would be systematic differences between the runners, with the young group having greater CV than the middle-aged and the older group and the middle-aged group having greater CV than the older group for all couplings. Our findings were in partial agreement with the study hypothesis. In general, the younger runners presented a higher CV than the middle-aged and the older group. The older runners had a lower CV compared to middle-aged group.

The couplings were selected to assess the joints as they move to absorb the foot/ground impact associated with running. For the knee joint, the non-pathological motion contains the combination of thigh flexion and shank internal rotation and thigh and shank flexion. These motions are associated with the attenuation of impact forces at the knee. For these couplings, younger runners presented higher CV than older runners. Our results disagree with previous studies. Silvernail et al. (20) investigated the CV between young and older runners and found no differences between these groups for all of the selected couplings, including thigh flexion and shank internal rotation and thigh and shank flexion. However, in this study, the older group consisted of life-long recreational runners. Although these results are contrary to our findings, the Silvernail et al. (20) study investigated runners of both sexes mixed in the different groups. Knowing that sex can influence the running mechanics, it can make comparisons difficult and could explain the divergence in the findings.

In another recent study investigating differences in the CV in young and older male runners reported no differences between those groups in the thigh flexion and shank internal rotation coupling (22). However, in that study, the age average of the older group is lower than the average age from the current study. In fact, the Boyer et al. (22) older group was equivalent to the middle-aged group in the current study. Therefore, for this specific coupling, no differences were found between young and middle-aged runners in the current study that is in agreement with the Boyer et al. (22) findings.

The shank internal rotation/foot eversion coupling has an important role in controlling impact forces (55). Coordination between the segments of this coupling might create torsional stresses on the tibia and atypical loads on the knee joint (56–58) and is a proposed mechanism linking foot eversion to knee injury risk (20). The current results show differences between the three groups with young runners presenting a higher CV than middle-aged and older runners. In turn, the older runners presented a lower CV than middle-aged runners. Again, Boyer et al. (22) did not report differences in this coupling between young and older runners.

The current study also found significant differences for three additional couplings: pelvis/thigh rotation, shank adduction/foot eversion and shank/foot rotation. Previously, one study evaluated these couplings (20). The results in that study showed no differences between young and older runners, again, in disagreement with our results. Another coupling only evaluated by Silvernail et al. (20) was the pelvis tilt/thigh flexion. As in current study, the authors did not find any differences between the groups for this coupling. Lastly, for the thigh/shank internal rotation coupling, Boyer et al. (22) found significant differences between their two groups. In contrast, the current study did not find any differences for this coupling. Thus, there are both similar and contrary results in the literature. Differences in these studies versus the current study may result from differences in the samples used. In previous studies life-long runners were used whereas in the current study we used recreational runners, who were not necessarily life-long runners.

It is suggested that CV in movement might provide a better distribution of stresses among the tissues, potentially reducing the excessive load on internal structures of the body (60–62). It has been suggested that a decreased variability can be associated with an injury state or a decline in performance. Studies report that older runners present a higher risk for overuse injuries than young runners (14,49). With the CV results from the current study, it could partly explain why older runners have an increased risk for injuries.

There are limitations in the current study that could influence the study findings. The participants on this study were recreational runners who were more familiar with overground running than with treadmill running. Even though they were familiarized with treadmill running prior to participation in the study, overground running is a different task. The difference in the running tasks may have influenced our results. Secondly, the relationship between coordination variability and injury is hypothetical and, although the literature shows that too low or too high variability is dangerous, there is no yet to be determined threshold.

CONCLUSIONS

The study findings indicate that aging influences dynamic function for male runners. Interaction between segments is important for understanding movement. The analysis of an isolated joint may omit valuable information about the quality of the movement produced. Segment interaction may provide better understanding of the etiology of an injury and provide a measure to evaluate progression of a potential risk of injury. This concept may also help clinicians to track the progression of an injured state before and after injury occurs and assess differences in rehabilitative methods. Thus, the results of this study may help to explain the process causing altered injury pattern for runners in different age ranges and can help physical therapists to draw strategies for prevention or rehabilitation for running-related injuries.

ESTUDO III

DIFFERENCES IN COORDINATION VARIABILITY ACROSS AGE RANGES IN FEMALE RUNNERS

Mariana C. de Souza, Ana F. dos Santos, Bruna C. Luz, Joseph Hamill, Fábio V. Serrão.

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ABSTRACT

The participation in distance running has increased in master's age groups. Female runners now compose the largest group in 5k and 10k races. However, older runners are more frequently injured and female runners are twice as likely to develop certain injuries. Coordination variability is understood to be important, providing flexibility for the individual to adapt to a task. Also, coordination variability is linked to a healthy motor system. The aim of this study was to examine the impact of age on coordination variability in female runners. Ten young, ten middle-aged and seven older runners were recruited. Three-dimensional kinematic data were recorded using a motion capture system at 240 Hz. A modified vector coding technique was used to investigate segment coordination variability of eight lower limb couplings. To assess the differences between the three groups, one-way analyses of variance (ANOVA) with a Bonferroni correction were conducted. In general, younger runners presented a lower coordination variability than the middle-aged runners and a similar when compared to the older group. The findings of the current study indicate that female runners appear to maintain their coordination variability during running regardless of age. Thus, running activity can play a role in preserving health in older women.

INTRODUCTION

Long-distance running has become a very popular form of physical activity (48) and the participation has increased in the past 30 years, with the greatest increases seen in Master's age groups (≥ 50 years old) (63–66). Females account for 9.7 million finishers and represent 57% from event fields. Also, the 5k and 10k races continue to have greatest composition of female participants (67). Reasons for participation in recreational running are most likely the positive health effects (68,69), including improved cardiovascular health, muscle strength, psychological health, and decreased risk of death (8,70,71).

However, older runners are more frequently injured and may require more time to recover from injury when compared to younger runners (12–14). Due to physiological and mechanical changes with aging, biomechanical contributors to the increased injury rate in older runners may differ from those in the younger population (72). Also, it has been suggested that female runners are twice as likely to experience certain running-related injuries such as iliotibial band syndrome, patellofemoral pain syndrome, and tibial stress fractures when compared to male runners (11).

Several biomechanical studies have compared young and older runners (20,40). These studies reported differences such as greater hip range of motion but lesser peak angles and/or excursions at the knee and ankle in the stance phase of running compared with younger runners (17,18,20,39,40,72). However, all of these studies had non-homogeneous or mixed sex groups or used a sample of just men.

Knowing that there are biomechanical differences between sexes (18,73), combining males and females in a study with age as a factor on running mechanics may not be adequate since these sex changes can interfere in the results. It is important, therefore, to study changes in running biomechanics due to aging separately in men and women. Thus, the effects of aging in female runners has not been investigated as yet.

Movements require coordination (i.e., muscles, joints) to execute a specific task (74). Quantifying differences in running mechanics provides information about the motor system but gives little insight on how the achievement of the movement differs. The human neuro-musculoskeletal system is complex; thus, there are a number of different possible combinations of segment and joint positions to execute a movement resulting in variability in these movements (75).

Variability in movement is important and provides flexibility for the individual to adapt to a specific task (76,77). Also, variability is believed to be a property of a healthy motor system (60). Therefore, segment coordination variability (CV) quantifies the variety of segment movement patterns an individual uses during a motion (31) and may vary with health status (34).

While differences in running mechanics with age are documented in the literature (15,17,18), differences in the coordination variability with age was not found in a previous study 20). However, a recent study, Boyer et al. (22) found a significant effect of age in females for two of the three coupling assessed and suggested how these movements are executed may be altered with age. The current study reports a broader analysis of lower limb segment couplings, evaluating eight different couplings. Also, adding a middle-aged group may verify if and when the age changes start to occur.

Therefore, aim of this study was to examine the impact of age on coordination variability in female runners. We hypothesized that there would be systematic differences between the runners, with the young runners having greater CV than middle-aged and older runners and middle-aged runners having greater CV than older runners.

Participants

Twenty-seven female runners volunteered for this study. Ten young adults (between 21 and 34 years old), 10 mature runners (between 36 and 55 years old) and seven older runners (between 61 and 65 years old) were evaluated. To be included in the experiment the runners had to have a minimum weekly running distance of 10 km, be rearfoot strikers and lower limb injury free in the last 3 months. If participants presented chronic diseases or orthopedic conditions, that could influence running biomechanics (i.e., arthritis, coronary disease, vestibular disorders, etc.), and any lower limb injury or surgery, they were excluded. Each subject signed a consent form **(Appendix 1)** approved by the University Ethics Committee for Human Investigations **(Attachment 1)**. The demographic data and sports practice information regarding the three groups is shown in Table 1.

Table 1. Demographic data and sports practice information (mean ± standard deviation).

	Young (n=10)	**Middle-aged** (n=10)	**Older** (n=7)
Participants Characteristics			
Age (years)	25.2±4.7 [a, b]	44.0±6.2 [c]	62.8±1.2
BMI (kg/m^2)	23.0±5.9	24.7±6.1	24.1±4.8
Running Experience (years)	3.2±2.7	7.9±0.6	6.7±3.5
Running Distance (km/week)	26.8±7.1	16.4±17.9	19.4±8.9

[a] Significant difference between young and mature runners.
[b] Significant difference between young and older runners.
[c] Significant difference between middle-aged and older runners.

Experimental Set-up

Lower extremity three-dimensional kinematic data were recorded at 240 Hz using a 7-camera motion capture system (Qualisys Inc., Gothenburg, Sweden). A neutral running shoe (Asics Gel-Equation 5, ASICS, Kobe, Japan) was provided for all the runners before the protocol. Running was performed in a treadmill (model LXz 160 GIII, Movement), that was surrounded by the camera system.

Protocol

The data collection was done during one visit to the laboratory, where the anthropometric and demographic data of the participants were collected **(Appendix 2)** and a running analysis was performed. Sixteen 15 mm reflective markers were placed on anatomical landmarks and three tracking clusters were attached on each participant. To align the subject with the laboratory coordinate system and to serve as a reference point for subsequent kinematic analysis, a static trial in neutral standing position was used.

All the participants of each group (young, middle-aged and older), initially, warmed up on a treadmill at a constant speed of 4.5 km/h for five minutes. Then, the preferred running speed of each participant was determined. Lastly, kinematic data were collected. After the participant had run for five minutes, at least five consecutive steps of the dominant lower limb were recorded (17).

Data Processing and Feature Extraction

Kinematic data was calculated using Visual 3D software (version 3.9; C-motion Inc., Rockville, Maryland, MD). The data were filtered using a 4th-order, zero-lag, low-pass Butterworth filter at 12 Hz. Joint coordinate system definitions, recommended by the International Society of Biomechanics (43), was used to calculate the Cardan angles, relative to the static standing trial. Lower limb segment kinematics were calculated in the laboratory coordinate system. Segment angles (relative to the laboratory) of foot, shank, thigh and pelvis at stance phase at the three planes of motion were calculated. All the kinematic data were analyzed during the stance phase and normalized to the standing calibration trial. Initial contact was identified as the point in time when the calcaneus marker moved from positive to negative velocity in the anteroposterior direction (44) and verified by a 240Hz qualitative camera (Figure 1). Each trial was normalized with respect to time to make all trials equal to 100% of the stance. Matlab software (version 2008; MathWorks Inc., Natick, USA) was used to identify the kinematic variables of interest.

Figure 1. Landing pattern verification by qualitative camera (240Hz).

To investigate segment coordination variability a modified vector coding technique was used (32,53). At first, contiguous segment angles are plotted with one on the horizontal axis and one on the vertical. This technique calculates the angle, with respect to the right horizontal, of the vector formed between two consecutive time points on an angle–angle plot created using time normalized global segment angles from the stance phase (Figure 2). Contiguous segments form a coupling represented by the vector coding angle. Because vector coding angles are directional, circular statistics must be used (54). Mean and standard deviations of each participant for all trials were calculated using circular statistics. The standard deviation (SD) of the vector created between each consecutive two-time points throughout stance represents the variability of the coordination of the of the analyzed segment.

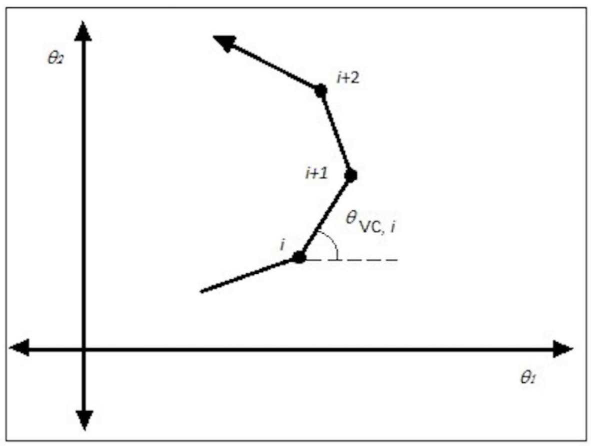

Figure 2. The modified vector coding method to calculate the phase angle (*i* indicates the point within the time series and θ_{vc} indicates vector coding coupling).

CV was calculated for the following couplings between thigh and shank (thigh flexion/shank internal rotation, thigh/shank flexion, and thigh/shank internal rotation), shank and foot (shank internal rotation/foot eversion, shank/foot internal rotation, and shank adduction/foot eversion) and pelvis and thigh (pelvis tilt/thigh flexion, and pelvis rotation/ thigh internal rotation). Mean CV for each coupling was established for the entire stance.

Statistical analysis

One-way analyses of variance (ANOVA) were conducted in order to assess differences in CV between the three groups during the stance phase. Bonferroni *post hoc* tests were applied to confirm where the differences occurred between groups. The effect size of the group differences was examined using the Cohen's d effect size. An effect size of d=0.5 was considered moderate and greater than d=0.8 was considered large. The criterion alpha level was set at $\alpha=0.05$.

RESULTS

CV differed between young, middle-aged and older runners during the complete stance phase. For the thigh/shank flexion coupling, the middle-aged group had a higher CV when compared to the young group (p=0.000, d=1.45), and when compared to the older group (p=0.000, d=1.40) (Figure 3). For the shank adduction/foot eversion coupling, the middle-aged group had a higher CV when compared to the young group (p=0.000, d=0.62) and when compared to older runners (p=0.000, d=0.92). The young runners presented higher CV than older runners (p=0.018, d=0.38) (Figure 4). For the thigh flexion/shank internal rotation coupling, the middle-aged group had a higher CV when compared to the young group (p=0.000, d=0.74) and when compared to older runners (p=0.001, d=0.54) (Figure 3). For the shank internal rotation/foot eversion coupling, differences were found between the middle-aged group and the young group (p=0.000, d=1.07) and between the middle-aged group and the older group (p=0.000, d=1.20), in which middle-aged runners presented a higher CV than young and older runners (Figure 4). For the thigh/shank internal rotation coupling, differences were found between the middle-aged group and the young group (p=0.005, d=0.43) and between the middle-aged group and the older group (p=0.003, d=0.49), in which middle-aged runners presented a higher CV than young and older runners (Figure 3). For the shank/foot internal rotation coupling, the middle-aged group had a higher CV when compared to the young group (p=0.000, d=0.55), and when compared to the older group (p=0.000, d=0.71) (Figure 4). For the pelvis tilt/thigh flexion coupling, middle-aged runners presented a higher CV when compared to young runners (p=0.000, d=0.99) and when compared to older runners (p=0.000, d=0.57) (Figure 5). And for the pelvis rotation/thigh internal rotation coupling, middle-aged runners presented higher CV than older runners (p=0.018, d=0.40) (Figure 5).

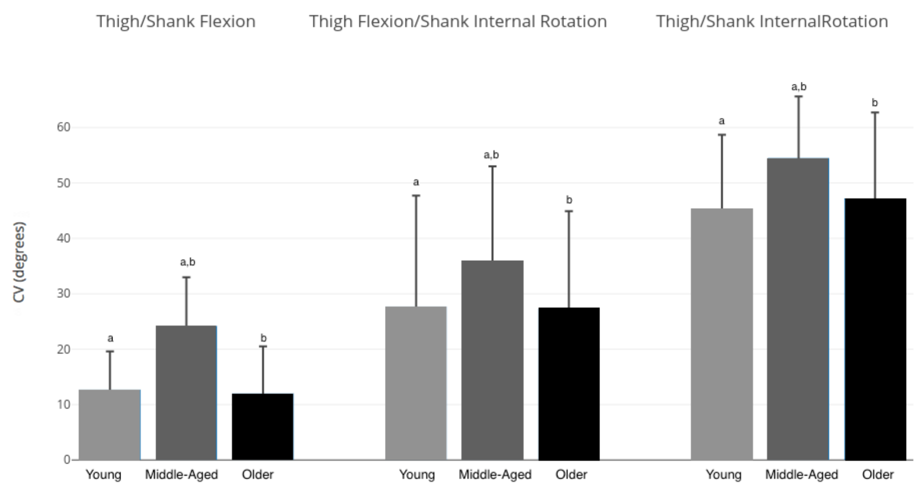

Figure 3. Mean CV for young, middle-aged and older runners for the thigh/shank flexion coupling, the flexion/shank internal rotation coupling and the thigh/shank internal rotation coupling, respectively. The same letters indicate stastically significant differences ($p<0.05$).

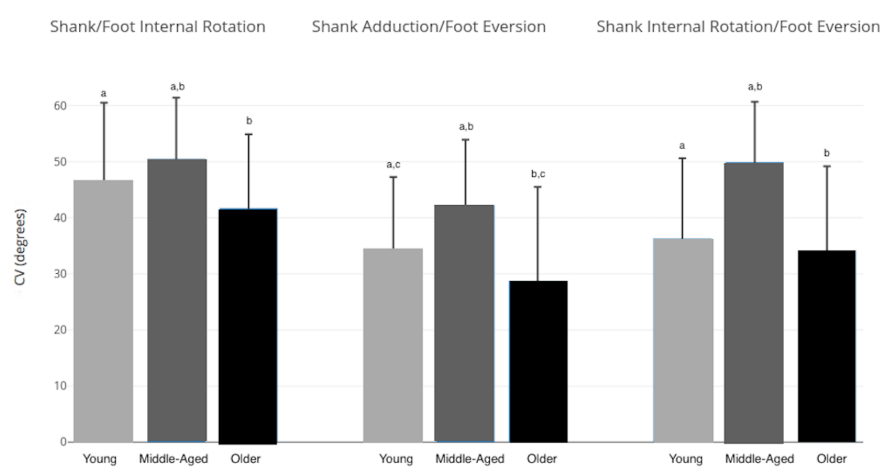

Figure 4. Mean CV for young, middle-aged and older runners for the shank/foot internal rotation coupling, the shank adduction/foot eversion coupling, and for the shank internal rotation/foot eversion coupling, respectively. The same letters indicate stastically significant differences ($p<0.05$).

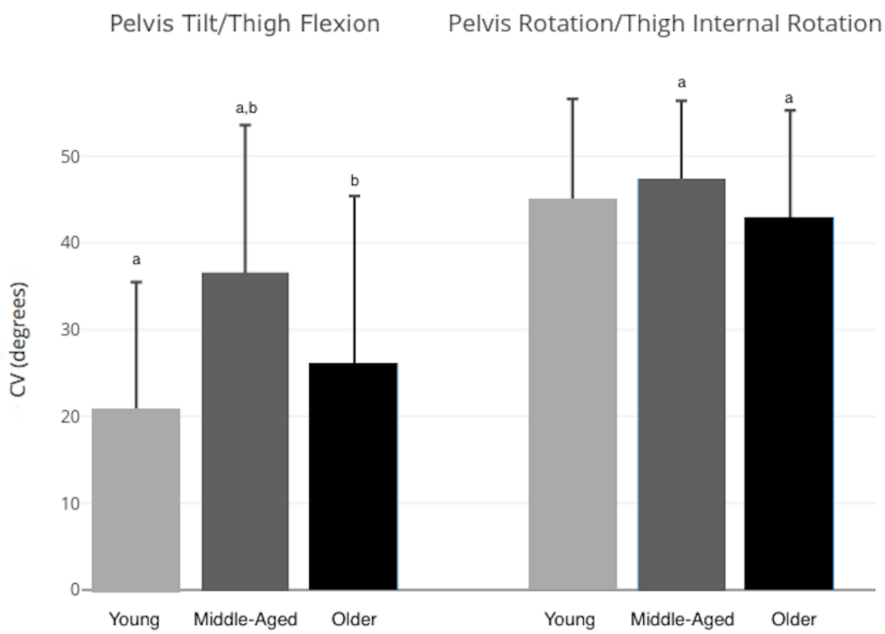

Figure 5. Mean CV for young, middle-aged and older runners for the pelvis tilt/thigh flexion coupling and for the pelvis rotation/thigh internal rotation coupling, respectively. The same letters indicate stastically significant differences ($p<0.05$).

DISCUSSION

The purpose of this study was to examine the impact of age on coordination variability in female runners. We hypothesized that there would be systematic differences between the runners, with the young runners having greater CV than middle-aged and older runners and middle-aged runners having greater CV than older runners. Our findings do not support the study hypothesis. In general, the younger runners presented a lower CV than the middle-aged runners and a similar CV when compared to the older group.

Several previous studies have assessed the influence of aging on running biomechanics. The majority of these studies have found differences between young and older runners, indicating that the older runners could be more susceptible to running-related injuries (15,17,18,21). Research studying female runners and the changes that occur with age has been less prevalent. Most studies have either used only males or a mixed group of males and females. More recently, however, Lilley et al. (21) compared young and mature women kinematics during running. Their study indicated that the variables found higher in the mature group have previously been associated with development of overuse injuries and debilitating conditions. Still, Boyer et al. (22) found that the impact of aging on the mechanics of running is more subtle for female runners.

The analysis of dependent variables has tended to focus on discrete data from isolated joints. However, coordination or coupling between joints of the lower extremity is important (28–30) since movement patterns are arranged based on constraints imposed from the complex relationships between control parameters. Analyzing an isolated joint does not actually indicate the complexity of the coordinated motions of components of the body (28).

A recent study evaluated coordination variability during running in young and older females. Boyer et al (22) assessed three different couplings (i.e. segment relationships) and found differences in two of them. Similar to the current study, they found differences for the shank internal rotation/foot eversion coupling, with the mature group presenting a higher CV than the younger runners. For all of the eight couplings assessed in the current study, the middle-aged group presented a higher CV when compared to the young and older runners. Since it is known that movement pattern variability is believed to be functional because it may provide flexibility to adapt to certain tasks to satisfy performance constraints (76), these results could have occurred possibly because the middle-aged group ran longer than the young group, and so, they increased their flexibility and adapted to the running task.

With the exception of the shank adduction/foot eversion coupling, the younger group had a similar CV compared to the younger runners. This suggests, in agreement with Silvernail et al. (20), that running may be a protective activity, contributing to the maintenance of health in older female runners. Even though older runners run as long as middle-aged runners, they present a similar CV to younger runners. This similarity can be a movement strategy that the older group developed to compensate for the biological changes that occur with aging. It is important to highlight that all of the runners selected for the current study were longtime runners. Because no CV threshold has as yet been determined, the differences found between the age groups may not mean necessarily that all groups are not in the 'CV safe zone'.

The current study has limitations that could influence the study findings. First, overground and treadmill running are different tasks. The participants in this study were recreational runners who were more familiar with overground running than treadmill running even though they had a previous experience with treadmill running. So, the difference in the running tasks may have influenced our results. Also, this is a cross-sectional study, so it cannot be stablished a cause-effect relationship.

CONCLUSION

The findings of the current study indicate that female runners seem to maintain coordination variability during running regardless of age. These findings support previous research by Silvernail et al. (20). Therefore, the current results may suggest that the running activity can play a role in preserving the health in older women. Future work should conduct a prospective study to clarify if aging produces biomechanical changes that can lead to a running-related injury in females and thus alter coordination variability with aging.

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ATTACHMENT 1

UNIVERSIDADE FEDERAL DE SÃO CARLOS/UFSCAR

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: A influência do envelhecimento e do sexo na cinemática articular e na ativação muscular do membro inferior de corredores
Pesquisador: Fábio Viadanna Serrão
Área Temática:
Versão: 2
CAAE: 25124214.4.0000.5504
Instituição Proponente: Universidade Federal de São Carlos/UFSCar
Patrocinador Principal: MINISTERIO DA EDUCACAO

DADOS DO PARECER

Número do Parecer: 664.672
Data da Relatoria: 08/04/2014

Apresentação do Projeto:
O presente projeto está apresentado de forma bem clara e atende as normas de um projeto de pesquisa; inclusive com o desenvolvimento do mesmo na forma de um projeto de Doutorado Direto.

Objetivo da Pesquisa:
Os objetivos também estão elaborados de forma bem clara e pertinentes com a área de execução do projeto.

Avaliação dos Riscos e Benefícios:
Foi descrito tanto nas informações básicas do projeto como no TCLE os riscos envolvidos para o objeto da pesquisa. Dessa forma, a pendência indicada no parecer anterior do Coordenado desse Comitê foi sanada.

Comentários e Considerações sobre a Pesquisa:
O projeto está bem fundamentado e a pesquisa é relevante no sentido que o aumento da expectativa de vida da população e os benefícios que a atividade física traz à saúde, tem resultado num aumento de indivíduos de meia idade e idosos que praticam esporte; em especial a corrida. Dentro deste contexto, estudos iniciais apontam que a incidência de lesões em idosos é maior que em jovens. Essa maior incidência pode ser parcialmente devido às alterações na cinemática da

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corrida; objetivo de investigação da presente pesquisa. Outro aspecto que está sendo considerado dentro das hipóteses investigadas no presente trabalho é a diferença encontrada entre os sexos. Estudos demonstram que as mulheres que correm são duas vezes mais susceptíveis a algumas lesões quando comparadas aos homens. Com esse cenário a pesquisa pretende contribuir com dados na avaliação da cinemática e o padrão de ativação muscular entre corredores jovens, de meia idade e idosos, bem como comparando os sexos nessas faixas etárias.

Considerações sobre os Termos de apresentação obrigatória:

A pendência indicada no parecer anterior foi sanada, pois o proponente do projeto discorreu no TCLE sobre os riscos que podem surgir ao objeto da pesquisa.

Recomendações:

Conclusões ou Pendências e Lista de Inadequações:

As pendências indicadas no parecer anterior pelo Coordenador desse Comitê foram sanadas.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

SAO CARLOS, 28 de Maio de 2014

Henrique Affonso de André Sobrinho
Secretário Executivo
ProPq/UFSCar

Assinado por:
Ricardo Carneiro Borra
(Coordenador)

Endereço: WASHINGTON LUIZ KM 235
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APPENDIX 1

d.fisio. Departamento de **Fisioterapia** • Centro de Ciências Biológicas e da Saúde • **UFSCar**
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TERMO DE CONSETIMENTO LIVRE E ESCLARECIDO

Título do Projeto: A influência do envelhecimento e do sexo na cinemática articular e na ativação muscular do membro inferior de corredores

Responsáveis:
Prof. Dr. Fábio Viadanna Serrão – Departamento de Fisioterapia – UFSCar
Ft. Mariana Carvalho de Souza – Aluna de Pós-Graduação em Fisioterapia – PPGFt USFCar

Eu,____, RG n.º______________,
residente à____, n.º______, bairro
_____________, na cidade de___________________, estado de__________________,
declaro ser conhecedor das condições sob as quais me submeterei no experimento acima citado, detalhado a seguir:

Os objetivos desse estudo são: comparar a cinemática articular e a magnitude de ativação de músculos do membro inferior entre corredores, homens e mulheres, jovens, de meia idade e idosos.

a) Inicialmente, você será submetido(a) a uma avaliação física, segundo a ficha de avaliação específica desse trabalho, para sua inclusão (ou não) no presente estudo.

b) Caso selecionado(a) para participar do estudo, você realizará seis testes de força muscular máxima para a normalização dos dados de ativação muscular durante a corrida. Depois desta fase, será realizada a avaliação cinemática (avaliação dos movimentos) durante a atividade. Você permanecerá caminhando na esteira ergométrica durante 5 minutos na velocidade de 4,5km/h e depois será solicitado que você corra em sua velocidade confortável em uma esteira durante 1 minuto. A sessão será realizada no Departamento de Fisioterapia da Universidade Federal de São Carlos. Sendo que sua participação não é obrigatória.

c) Essas avaliações fornecerão maiores informações sobre o padrão de movimento e de ativação muscular de corredores jovens, de meia idade e idosos. Essas novas informações ajudarão na elaboração de outros novos estudos sobre o tema e poderão beneficiar diretamente a atenção fisioterapêutica, em relação à prevenção de lesões em corredores de meia idade e idosos.

d) Os resultados das avaliações cinemática e eletromiográfica serão disponibilizados e esclarecidos para você, ao final de sua participação neste estudo.

e) Sua identidade será preservada em todas as situações que envolvam discussão, apresentação ou publicação dos resultados da pesquisa, a menos que haja uma manifestação de sua parte por escrito, autorizando tal procedimento.

f) Sua participação no presente estudo é estritamente voluntária. Sendo que você não receberá qualquer forma de remuneração pela participação no experimento, e os resultados obtidos serão propriedades exclusivas dos pesquisadores, podendo ser divulgados de qualquer forma, a critério dos mesmos.

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g) Os riscos de ordem física aos quais você estará exposto serão mínimos. Entretanto, as avaliações do presente experimento poderão ou não provocar uma possível dor muscular devido ao esforço físico realizado (de intensidade variável para cada voluntário). Embora exista a possibilidade de ocorrência de pequena dor muscular (imediata ou tardia) devido alguma etapa da avaliação, essa dor terá condições de ser bem suportada, pois se assemelha àquela decorrente de qualquer prática inicial de exercícios de força e resistência muscular. Você participará das avaliações de acordo com os seus limites físicos, sempre respeitados pelos pesquisadores. Outro risco existente durante a realização da corrida na avaliação cinemática consiste na possibilidade de perda de equilíbrio, com posterior queda da própria altura. Entretanto, a velocidade da esteira será aumentada gradativamente para atenuar essa situação de desequilíbrio. Além disso, a esteira ergométrica possui braços de apoio para que você possa se apoiar, caso se sinta inseguro.

h) Sua participação no presente estudo envolve riscos mínimos de lesões. Mesmo assim, no caso de ocorrerem riscos não previstos e, caso seja necessário, os próprios pesquisadores se responsabilizam pelas condutas de primeiros socorros ou qualquer tipo de avaliação fisioterapêutica como resultado de dano físico. Se constatados danos de maior gravidade, os pesquisadores se responsabilizam em acompanhá-lo a um médico, para a realização do tratamento adequado.

i) Não haverá qualquer tipo de comparação direta ou indireta, na sua presença, de seu desempenho com o de outros voluntários do estudo. Além disso, as avaliações serão realizadas em locais reservados, sem observadores externos ao Projeto, para garantir maior privacidade a você. Por fim, sua participação neste estudo obedecerá rigorosamente a sua disponibilidade de horários livres para tanto. Em nenhuma hipótese será solicitado que você abra mão de algum compromisso ou atividade social para a sua participação no mesmo.

j) Sua participação nesse estudo é estritamente voluntária. Sua recusa em participar de qualquer etapa do estudo não trará qualquer prejuízo a você, estando livre para abandonar o experimento a qualquer momento em que achar necessário. Se houver qualquer questionamento neste momento ou futuramente, por favor, pergunte-nos.

Eu li e entendi todas as informações contidas neste documento, assim como as da Resolução 196/96 do Conselho Nacional de Saúde.
São Carlos,________de____________________de 2014.

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Assinatura do Voluntário

Responsáveis:

____
Prof. Dr. Fábio Viadanna Serrão
Orientador e Coordenador do Projeto
UFScar

____
Ft. Mariana Carvalho de Souza
Aluna de Pós-Graduação em Fisioterapia - PPGFt

APPENDIX 2

UNIVERSIDADE FEDERAL DE SÃO CARLOS

DEPARTAMENTO DE FISIOTERAPIA

PROGRAMA DE PÓS-GRADUAÇÃO EM FISIOTERAPIA

Via Washington Luiz, Km 235 - C.P.676 - 13565-905

APÊNDICE 1- FICHA DE AVALIAÇÃO FÍSICA

Voluntário Número: __________

Data da avaliação: ____/ ____/ ____ Examinador: ____________________________

Nome:____

Data de nascimento: ____/ ____/ ____ Telefone:____________________________

Idade: _______ anos Tamanho calçado: _________

Peso: _________ kg Altura: _________ m IMC: _______ Kg/m^2

Corrida: _________ km/semana Frequência/Tempo:____________________________-_______

Padrão de aterrissagem durante a corrida: _____________________

Outra atividade física: (   ) Não (   ) Sim Modalidade: ____________________________

Freqüência/Tempo: _____________________

Dominância: (   ) D (   ) E

H.P./H.A: Questionar ao voluntário sobre possíveis lesões e/ou traumas envolvendo o sistema ósteo-mio-articular, recentes e/ou pregressas:

____

____

____

Faz uso de algum medicamento? (   ) Não (   )Sim Qual? _____________________

Realizou alguma cirurgia prévia nos membros inferiores? (   )Não (   )Sim

Onde:____

História de lesão ou trauma na articulação do joelho? (   ) Não   (   ) Sim

Qual? ____

Presença de dor na articulação do joelho ou em alguma parte do corpo? (   ) Não   (   ) Sim

Local? _______________________________________

Presença de doença cardiovascular, respiratória, vestibular ou neurológica?

(   ) Não   (   ) Sim   Qual? ____

Presença de dor no joelho e/ou quadril em atividades funcionais:

(   ) Agachamento por tempo prolongado

(   ) Subir ou descer escadas

(   ) Ajoelhar-se

(   ) Praticar esporte

(   ) Permanecer muito tempo sentado

(   ) Contração isométrica do quadríceps

(   ) Correr