

Valéria Andrade Pinto

**EFEITOS DA IDADE E DO FOCO DE ATENÇÃO NO DESEMPENHO E NA
COORDENAÇÃO DA TAREFA DE PASSAR DE SENTADO PARA DE PÉ**

Belo Horizonte

Escola de Educação Física, Fisioterapia e Terapia Ocupacional

Universidade Federal de Minas Gerais

2019

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COORDENAÇÃO DA TAREFA DE PASSAR DE SENTADO PARA DE PÉ**

Dissertação apresentada ao Curso de Mestrado em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais, como requisito à obtenção do título de Mestre em Ciências da Reabilitação.

Orientadoras:

Prof^a. Dr^a. Daniela Virgínia Vaz

Prof^a. Dr^a. Juliana de Melo Ocarino

Belo Horizonte

Escola de Educação Física, Fisioterapia e Terapia Ocupacional

Universidade Federal de Minas Gerais

2019

P659e Pinto, Valéria Andrade Pinto
2019 Efeitos da idade e do foco de atenção no desempenho e na coordenação da tarefa de passar de sentado para de pé. [manuscrito] / Valéria Andrade Pinto – 2019.
69 f., enc.:il.

Orientador: Daniela Virgínia Vaz
Coorientador: Juliana de Melo Ocarino

Dissertação (mestrado) – Universidade Federal de Minas Gerais, Escola de Educação Física, Fisioterapia e Terapia Ocupacional.

Bibliografia: f. 63-65

1. Biomecânica - Teses. 2. Membros inferiores - Teses. 3. Articulações - Teses. 4. Capacidade motora – Teses. 5. Envelhecimento – Teses. I. Vaz, Daniela Virgínia. II. Ocarino, Juliana de Melo. III. Universidade Federal de Minas Gerais. Escola de Educação Física, Fisioterapia e Terapia Ocupacional. IV. Título.

CDU: 796.015

Ficha catalográfica elaborada pelo bibliotecário Danilo Francisco de Souza Lage, CBR 6: nº 3132, da Biblioteca da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG.



UNIVERSIDADE FEDERAL DE MINAS GERAIS

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO

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ATA DA DEFESA DA DISSERTAÇÃO DA ALUNA VALÉRIA ANDRADE PINTO

Realizou-se, no dia 01 de agosto de 2019, às 10:15 horas, Auditório Maria Lúcia Paixão, da Universidade Federal de Minas Gerais, a defesa de dissertação, intitulada *EFEITOS DA IDADE E DO FOCO DE ATENÇÃO NO DESEMPENHO E NA COORDENAÇÃO DA TAREFA DE PASSAR DE SENTADO PARA DE PÉ*, apresentada por VALÉRIA ANDRADE PINTO, número de registro 2017715713, graduada no curso de FISIOTERAPIA, como requisito parcial para a obtenção do grau de Mestre em CIÊNCIAS DA REABILITAÇÃO, à seguinte Comissão Examinadora: Prof(a). Daniela Virginia Vaz - Orientador (UFMG), Prof(a). Andre Gustavo Pereira de Andrade (UFMG), Prof(a). Renan Alves Resende (UFMG).

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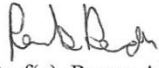
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Finalizados os trabalhos, lavrei a presente ata que, lida e aprovada, vai assinada por mim e pelos membros da Comissão.

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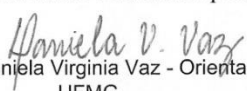
FOLHA DE APROVAÇÃO

EFEITOS DA IDADE E DO FOCO DE ATENÇÃO NO DESEMPENHO E NA COORDENAÇÃO DA TAREFA DE PASSAR DE SENTADO PARA DE PÉ

VALÉRIA ANDRADE PINTO

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em CIÊNCIAS DA REABILITAÇÃO, como requisito para obtenção do grau de Mestre em CIÊNCIAS DA REABILITAÇÃO, área de concentração DESEMPENHO FUNCIONAL HUMANO.

Aprovada em 01 de agosto de 2019, pela banca constituída pelos membros:


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UFMG

Belo Horizonte, 1 de agosto de 2019.

Dedico este trabalho aos meus pais, por me amarem genuinamente e por,
apesar de toda a saudade, me permitirem voar.

AGRADECIMENTOS

Apesar de todos os desafios, a minha trajetória até aqui foi muito prazerosa. Eu termino esta etapa feliz e ansiosa para iniciar a próxima (e que ansiedade!!). Tamanha evolução intelectual e moral não seriam possíveis se Deus não tivesse feito com que o meu caminho cruzasse o de pessoas tão especiais.

Agradeço imensamente à minha orientadora, Prof^a. Dr^a. Daniela Virgínia Vaz. Há dois anos eu não podia imaginar que eu estava escolhendo uma professora tão desafiadora para me orientar. Dani, você me apresentou muitas possibilidades e me fez perceber que eu desconhecia os meus próprios limites. Agradeço-a por ter confiado – e como confiou! – em mim. Levo comigo uma grande admiração por você.

Agradeço à minha co-orientadora, Prof^a. Dr^a. Juliana de Melo Ocarino pelo cuidado em revisar o meu texto. Juliana, ter você como co-orientadora foi uma escolha acertada.

Agradeço ao professor Alysson Fernandes Mazoni por ter contribuído para o meu pensamento crítico e por ter acrescentado muitas dúvidas às minhas poucas certezas. Agradeço-o por ter disponibilizado o seu tempo e por ter tido a humildade de dividir comigo um pouquinho da preciosidade que é a sua sabedoria. Alysson, a minha admiração por você é grande o bastante para eu não conseguir registrá-la em um papel. Como já te disse, se depender de mim, a nossa parceria não terá fim!

Agradeço ao Prof. Dr. Suvobrata Mitra por ter me recebido com tanto cuidado em Nottingham e por ter tornado possível a coleta dos dados do meu Projeto. Suvo, *I learned a lot from the way you work, and my admiration for you goes beyond academic life.*

Agradeço à Daniela Junckes da Silva Mattos por ter se disponibilizado a me ajudar a desvendar os mistérios do MATLAB e da análise do *uncontrolled manifold*. Daniela, sua ajuda foi importante para a qualidade dos resultados.

Agradeço aos professores da pós-graduação em Ciências da Reabilitação e Ciências do Esporte, em especial o Prof. Dr. Renan Alves Resende e o Prof. Dr. André Gustavo Pereira de Andrade. Renan e André, vocês são duas referências positivas que levo comigo na carreira que estou iniciando. A simplicidade e competência de vocês são encantadoras.

Agradeço à Camila Vasconcelos dos Santos por ter compartilhado comigo a experiência de trabalhar com o *uncontrolled manifold*. Camila, você foi uma guerreira e eu te admiro por isso!

Agradeço aos membros do LAM, especialmente o Thiago Teles Santos, Vanessa Lara Araújo, Priscila Albuquerque e Líria Okai-Nóbrega. Vocês são modelos de pesquisadores e professores que um dia quero me tornar.

Eu não posso deixar de agradecer uma figura importante no meu dia-a-dia de mestranda: o Délcio. Délcio, você me ajudou tantas vezes! Ora resolvendo um problema com as chaves do laboratório, ora com um olhar atencioso e uma palavra amiga. Uma lição eu aprendi muito bem com você: se melhorar, melhora!

Agradeço aos amigos da pós-graduação, que dividiram o desafio de se tornarem mestres comigo, em especial Bruna Mara Franco Silveira, Breno Gonçalves Teixeira, Mariana Rodrigues Carvalho de Aquino, Thais Brasil Cardoso, Igor Reis Urbano, Ricardo Rodrigues de Souza Junior, Ludmylla Ferreira Quintino, Ana Carolina Cury, Juliane Franco e Carol Daher. Em vocês encontrei diversão e apoio.

Bruna Silveira, mesmo fazendo parte dos especiais, você ainda merece destaque. É difícil falar sobre você. Eu já te disse, mas preciso repetir: você é essencial para o mundo! Obrigada por ser assim, do jeitinho que você é.

Ricardo, você também ganhará algumas palavras adicionais. Nosso jeito de trabalhar é tão parecido! Que tenhamos mais oportunidades para trabalharmos juntos!

Agradeço às amigas do peito, Bella, Nessa e Fê. Meninas, se for verdade essa história de que amizades que duram mais do que dez anos são para sempre, seremos amigas para o resto de nossas vidas.

Um carinho especial à Luisa Jubilini, uma amiga querida, que levo comigo para onde eu vou. Lu, sua amizade é preciosa e você sempre esteve presente nos momentos fundamentais.

Agradeço à Renata Alves Frederico, por ter sido meu ouvido amigo em tantos momentos. Rê, amizades como a sua são raridade e eu me sinto privilegiada por aprender e evoluir com você a cada conversa.

Agradeço à Alice Brochado Campolina, minha aluna de iniciação científica. Sempre tão atenciosa, até mesmo nas tarefas mais simples. Alice, tenho certeza que seu futuro será brilhante.

Agradeço ao Nazir e à toda equipe da NF pelo apoio e compreensão em todos os momentos que tive que me ausentar.

Agradeço imensamente aos voluntários por terem, gentilmente, aceitado a participar da minha pesquisa.

Agradeço à CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) por custear a minha formação como mestre e por, apesar de todos os desafios, tornar a ciência brasileira possível. Agradeço à British Academy por ter financiado a minha coleta de dados e por ter aproximado duas grandes universidades: Universidade Federal de Minas Gerais e Nottingham Trent University.

Agradeço aos meus pais, Rosane e Nilson. Os sentimentos mais importantes são os mais difíceis de serem expressados. Vocês estiveram ao meu lado, cada um segurando uma das minhas mãos, durante toda esta caminhada. Na vida tenho poucas certezas, mas do amor de vocês eu nunca duvidei! O apoio de vocês foi imprescindível e sentir seus olhares orgulhosos é a maior recompensa de todo este trabalho. Obrigada por tudo!

Agradeço ao meu irmão, Samuel, à Daniela e as meninas do meu coração, Duda e Malu.

Por fim, agradeço à vida! Vida, continue me proporcionando experiências que me permitam ser, estar e transformar.

“O correr da vida embrulha tudo.
A vida é assim: esquentada e esfria,
aperta e daí afrouxa,
sossega e depois desinquieta.
O que ela quer da gente é coragem”

Guimarães Rosa

LISTA DE ILUSTRAÇÕES

- Figure 1 – Schematic of the experimental set-up with active markers (red circles), clusters and virtual markers (blue circles). 53
- Figure 2 – Geometric model linking joint angles to changes in the control variables. The 12 angles used in the Jacobian matrices were (from Θ_1 to Θ_{12}): ankle, knee, hip, lumbar-spine, thoracic-spine, cervical-spine, atlanto-occipital, sternoclavicular, shoulder, elbow, wrist and hand-cup angle. 54
- Figure 3 – Average and standard deviation (SD) over time of the horizontal and vertical positions of the (A) CoM and of the (B) cup position, and (C) cup angle with the horizontal. 55
- Figure 4 – Synergy index (ΔV_z) and standard deviation (SD) over time of the (A) horizontal and vertical positions of the CoM, (B) bidimensional position of the cup and (C) cup angle with the horizontal. 56
- Figure 5 - Average synergy index (ΔV_z) with standard error bars for each movement phase (1: preparatory, 2: lift-off, 3: extension) for the (A) horizontal position of the CoM, for the (B) vertical position of the CoM, for the (C) bidimensional position of the cup, and for the (D) cup angle with the horizontal. Asterisks indicate significant differences between Phases (* $p < 0.05$). 57
- Figure 6 – Average smoothness with standard error bars for the (A) CoM and cup in the horizontal and vertical direction and for the (B) cup angle with the horizontal for young and old adults. Asterisks indicate significant differences between the older and younger groups (* $p < 0.05$). 58
- Figure 7 – Average V_{UCM} and V_{ORT} and standard error (SD) over time of the (A) CoM in the horizontal and (B) vertical direction for older and younger groups. . . .59

LISTA DE ABREVIATURA E SIGLAS

ST-DP –	Sentado para de pé
CM –	Centro de massa
UCM –	Uncontrolled manifold
VE –	Variável elementar
VC –	Variável de controle
ΔV –	Índice de sinergia
ΔV_z –	Índice de sinergia transformado
FE –	Foco externo
FI –	Foco interno
STS –	Sit-to-stand
CoM –	Center of mass
EF –	External focus
IF –	Internal focus

SUMÁRIO

PREFÁCIO	15
RESUMO	16
ABSTRACT	17
INTRODUÇÃO	18
ARTIGO	24
CONSIDERAÇÕES FINAIS	63
REFERÊNCIAS	65
APÊNDICE 1: Termo de consentimento livre e esclarecido	68
MINI-CURRÍCULO	69

PREFÁCIO

Esta dissertação foi elaborada em Formato Opcional, de acordo com a Resolução nº 004/2018 (03 de abril de 2018) do Colegiado de Pós-Graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais.

Após o Resumo e o *Abstract*, o leitor será introduzido ao tema da dissertação. A Introdução revisa a literatura existente sobre a tarefa funcional de passar de sentado para de pé, com descrição de como é feito o seu controle e como o método *uncontrolled manifold* é uma ferramenta útil para a sua investigação. Logo após, é feita uma reflexão sobre a influência da idade no movimento e sobre o potencial do uso de estratégias cognitivas para a melhora do desempenho motor. O texto visa demonstrar como esses temas se relacionam e, portanto, explicitar a motivação para o desenvolvimento deste projeto.

Em seguida, está o artigo proveniente deste estudo. O Artigo está escrito em língua inglesa e segue as normas do periódico *Human Movement Science*, para o qual será submetido. As Considerações Finais concluem como este estudo pode contribuir para a linha de pesquisa Desempenho Motor e Funcional Humano do Programa de Pós-Graduação em Ciências da Reabilitação. Por fim, o leitor encontrará todas as Referências Bibliográficas usadas ao longo desta dissertação.

RESUMO

Passar de sentado para de pé (ST-DP) é fundamental para uma vida funcional e independente. No entanto, o desempenho nessa tarefa tende a reduzir com o envelhecimento, sendo a sua realização ainda mais desafiadora quando associada a tarefas secundárias, como segurar uma caneca. Uma estratégia cognitiva com potencial para aperfeiçoar o controle do ST-DP é o direcionamento do foco de atenção por meio de instruções verbais. Instruções direcionadas aos objetos com os quais o sujeito interage ou aos efeitos do movimento sobre o ambiente - foco externo - tem se mostrado serem mais eficientes e mais efetivas do que as que direcionam a atenção aos próprios movimentos ou segmentos corporais - foco interno. Portanto, o objetivo deste estudo foi investigar como o passar de ST-DP segurando uma caneca é controlado, como o controle é afetado pela idade e como instruções de foco podem influenciar o controle da tarefa. 21 idosos saudáveis e 26 jovens realizaram a tarefa de passar de ST-DP segurando uma caneca com o membro superior não dominante sob duas condições de foco: externo e interno. Variáveis de desempenho foram quantificadas e a coordenação foi explorada por meio da análise do *uncontrolled manifold* (UCM). Os resultados revelaram que os jovens inclinaram menos a caneca e moveram o centro de massa do corpo na direção horizontal com maior suavidade do que os idosos. No entanto, em relação aos jovens, os idosos moveram a caneca na direção vertical e horizontal e o centro de massa do corpo na direção vertical com maior suavidade. Os idosos também apresentaram médias mais elevadas de V_{UCM} e V_{ORT} para a posição horizontal e vertical do centro de massa do corpo do que os jovens. Porém, os índices de sinergia para as posições horizontal e vertical do centro de massa foram significativamente diferentes entre os grupos, sendo mais fortes para jovens do que para idosos. Portanto, parece que, para estabilizar a posição do centro de massa, os idosos coordenam suas múltiplas articulações de maneira mais flexível, mas também mais instável do que os jovens. Não foram encontradas evidências sobre os efeitos diferenciais do foco externo e interno sobre as variáveis de desempenho e nem sobre as de coordenação. É possível que tarefas bem treinadas e adquiridas espontaneamente com o desenvolvimento, como passar de ST-DP, sejam menos afetadas pelos efeitos negativos do foco interno ou pelos efeitos positivos do foco externo.

Palavras-chave: Envelhecimento. Desempenho. Coordenação. Foco de atenção. *Uncontrolled manifold*. Sentado para de pé.

ABSTRACT

Sit-to-stand (STS) is essential to independence in activities of daily living. However, STS performance tends to decline with aging, becoming even more challenging when it is associated with secondary tasks such as holding a cup. STS control may be improved by cognitive strategies such as directing the focus of attention. For a variety of motor tasks, focusing attention on the environmental effects of movement (i.e. an external focus) leads to more efficient and effective motor performance than focusing attention on the movement itself (i.e. an internal focus). The purpose of this study was to investigate how STS while holding a cup is controlled and how control is affected by age and attention focus. 21 healthy old and 26 young adults performed STS while holding a cup with the non-dominant hand under two attention focus conditions: external and internal. STS performance variables were quantified. STS coordination was investigated with the uncontrolled manifold (UCM) analysis. Young participants tilted the cup less and showed smoother horizontal motion of the body center of mass (CoM) than older adults, but older participants showed smoother vertical motion of the CoM and smoother horizontal and vertical motion of the cup. Older adults also showed significantly higher values of both V_{UCM} and V_{ORT} for the horizontal and vertical dimensions of the CoM. However, younger participants showed higher synergy indices for the horizontal and vertical position of the CoM than older participants. Therefore, it seems that, to stabilize the CoM, older adults coordinate their joint motions in more flexible, but also more unstable patterns. Attention focus instructions did not affect task performance or coordination. It is possible that well-trained tasks learned spontaneously in childhood, like STS, are less prone to the negative effects of an internal focus or to the positive effects of an external focus.

Keywords: Ageing. Performance. Coordination. Attentional focus. *Uncontrolled manifold*. Sit-to-stand.

INTRODUÇÃO

Passar de sentado para de pé (ST-DP) sem auxílio é fundamental para a funcionalidade e independência. Levantar-se é um pré-requisito para a realização de diversas tarefas do cotidiano, como caminhar, usar o banheiro, sair da cama ou andar de ônibus (PATIL *et al.*, 2018; SCHENKMAN *et al.*, 1990). Estima-se que, em um dia, esse movimento seja repetido em torno de sessenta vezes (DALL; KERR, 2010). A habilidade de passar ST-DP é adquirida nos primeiros anos de vida, no entanto, o desempenho nessa tarefa tende, naturalmente, a reduzir com o envelhecimento. Essa transição postural demanda força muscular e equilíbrio, sendo a sua realização ainda mais desafiadora para os idosos, uma vez que essa população apresenta redução da força muscular e do controle postural (GREVE *et al.*, 2013; DANNESKIOLD-SAMSØE *et al.*, 2009; HUGHES; MYERS; SCHENKMAN, 1996).

A dificuldade para alcançar a posição de pé é um importante preditivo de quedas, indicando comprometimento da mobilidade e risco aumentado de hospitalização e admissão em instituições de longa permanência (MAKIZAKO *et al.*, 2017; BUATOIS *et al.*, 2008; LORD *et al.*, 2002; TINETTI; SPEECHLEY; GINTER, 1988). O treinamento do ST-DP é uma demanda frequente na prática clínica e, portanto, é fundamental que os profissionais do movimento compreendam (1) como ocorre o controle do ST-DP, (2) como a idade influencia nesse controle e (3) quais estratégias podem melhorar o desempenho do indivíduo nessa tarefa.

O controle do ST-DP exige coordenação de múltiplos e redundantes graus de liberdade para deslocar o centro de massa (CM) do corpo de uma posição inferior, com base de suporte ampla oferecida pelas coxas e pés, para uma posição mais elevada, com uma base de apoio formada pela limitada área entre os pés (ANAN *et al.*, 2017; DALL; KERR, 2010). Dado que o sistema motor é redundante e possui múltiplas articulações, o deslocamento estável do CM durante o passar de ST-DP pode ser alcançado por meio de diferentes e, ao mesmo tempo, equivalentes combinações de ângulos articulares (LATASH,

2008; LATASH; SCHOLZ; SCHÖNER, 2007a). O uso de configurações articulares diferentes e equivalentes é possível quando o sistema motor opera em sinergia, isso porque sistemas sinérgicos organizam os elementos do seu conjunto para atingir um objetivo comum (LATASH, 2008; LATASH; SCHOLZ; SCHÖNER, 2007b). As diferentes configurações articulares que podem ser adotadas para realizar uma tarefa conferem ao sistema a flexibilidade necessária para se adaptar e garantir um desempenho estável.

A flexibilidade é caracterizada pela capacidade dos elementos do sistema de se reorganizarem de tal modo que, caso algum elemento se comporte de maneira diferente da esperada, os outros alteram sua configuração para garantir estabilidade de desempenho (LATASH, 2008). A flexibilidade de estratégias de movimento também permite adaptação a diferentes restrições do contexto e do indivíduo sem que isso seja notável a nível do resultado final da tarefa (GERA *et al.*, 2010; SCHOLZ; REISMAN; SCHÖNER, 2001). Portanto, por meio da organização sinérgica, é possível manter o desempenho da tarefa de passar de ST-DP constante mesmo quando há redução da força muscular, quando são usados assentos de diferentes alturas ou durante a realização de tarefas secundárias. Em outras palavras, a diversidade de soluções em termos de estratégias de movimento (flexibilidade) garante certa robustez de desempenho (estabilidade) mesmo em situações desfavoráveis.

Informações sobre a estabilidade e flexibilidade do controle do ST-SP podem ser obtidas por meio da análise da variabilidade da cinemática articular. Scholz e Schöner (1999) propuseram uma importante ferramenta para estudar variabilidade: o *uncontrolled manifold* (UCM). O UCM se baseia na ideia de que não existe apenas uma combinação de elementos para solucionar um problema motor, ao contrário, várias soluções equivalentes são capazes de resolver uma tarefa motora e manter o desempenho estável, dentro de uma margem de erro aceitável (LATASH, 2008; LATASH; SCHOLZ; SCHÖNER, 2007b; SCHOLZ; SCHÖNER, 1999).

Dois conceitos são fundamentais para a análise do UCM: o de variáveis elementares (VE) e de controle (VC). As VE são aquelas produzidas pelos

elementos do sistema neuromusculoesquelético e que podem ser alteradas independentemente umas das outras. Os ângulos articulares são exemplos de VE. As VC são aquelas que representam o resultado geral de uma tarefa e cuja estabilização é importante para o sucesso do objetivo final. A posição do CM é um exemplo de VC possivelmente estabilizada em uma tarefa de transferência, como o passar de ST-DP.

A análise do UCM investiga como as VE se organizam para estabilizar uma determinada VC. O método analisa a variabilidade das VE, por meio da separação das variâncias entre tentativas em dois espaços matemáticos: o espaço do *uncontrolled manifold* (V_{UCM}) e o espaço ortogonal a ele (V_{ORT}). V_{UCM} é a variância dentro do espaço de combinações de VE que não afeta a VC, ou seja, as variações que ocorrem dentro desse espaço compensam-se mutuamente de forma a manter o desempenho estável. Por outro lado, o V_{ORT} é o espaço de projeções que contém variância que afeta o desempenho na tarefa, ou seja, não há compensação entre as VE, de modo que o objetivo final da tarefa não é preservado. A razão entre a diferença e a soma dos valores de V_{UCM} e V_{ORT} informa sobre a sinergia do sistema motor ($\Delta V = \frac{V_{UCM} - V_{ORT}}{V_{UCM} + V_{ORT}}$). Quanto maior for esta razão, maior será a família de combinações de VE capaz de manter a VC inalterada.

Estudos tem sugerido que as sinergias de idosos saudáveis e adultos jovens diferem durante a realização de tarefas motoras (OLAFSDOTTIR; ZATSIORSKY; LATASH, 2008; OLAFSDOTTIR *et al.*, 2007; SHINOHARA *et al.*, 2004). No entanto, a direção dessa diferença ainda não está clara. Interessados em entender como a flexibilidade motora se comporta em diferentes idades durante a tarefa de passar de ST-DP, Greve, Hortobágyi e Bongers (2018) investigaram, por meio do UCM, como as articulações de jovens e idosos se organizam para estabilizar o CM. Para tanto, os voluntários foram solicitados a realizar a tarefa repetidas vezes sob diferentes condições de carga e equilíbrio. Ao final do experimento, os autores concluíram que jovens e idosos empregaram flexibilidade semelhante na co-variação das suas articulações. Outro estudo de Greve *et al.* (2013), também comparou a

flexibilidade de jovens e idosos durante a mesma tarefa, porém sem manipulação da carga e equilíbrio. Nesse estudo, os resultados indicaram que os idosos apresentaram maior flexibilidade motora do que os jovens. Segundo os pesquisadores, os idosos, em relação aos jovens, usam mais combinações de variáveis elementares dentro do espaço do UCM (V_{UCM}) como uma estratégia de compensação aos déficits de força comuns no envelhecimento.

Em contrapartida, há evidência de que, em tarefas de recuperação de equilíbrio, o controle das múltiplas articulações para estabilizar o CM dos idosos é menos flexível do que o dos jovens. Hsu, Chou e Woollacott (2013) provocaram instabilidades inesperadas enquanto os voluntários estavam de pé. A análise do UCM revelou que os idosos apresentaram menor índice de sinergia do que os jovens em decorrência do aumento do V_{ORT} . Portanto, eles concluíram que os idosos saudáveis têm menor capacidade de estabilizar o CM durante perturbações posturais. Idosos também apresentaram redução dos índices de sinergia em tarefas de preensão e de pressionar botões utilizando diferentes dedos das mãos (OLAFSDOTTIR; ZATSIORSKY; LATASH, 2008; OLAFSDOTTIR *et al.*, 2007; SHINOHARA *et al.*, 2004).

Uma das possíveis consequências da redução dos índices de sinergia com o avançar da idade é a diminuição na capacidade do indivíduo para lidar com tarefas secundárias, como segurar uma xícara de café enquanto se levanta. Assim, caso seja confirmada essa diminuição na capacidade, as intervenções clínicas deveriam buscar estratégias que otimizem o controle neuromuscular, a fim de aumentar a flexibilidade da combinação de ângulos articulares que mantém o desempenho estável.

Uma estratégia cognitiva que pode ser utilizada no ambiente clínico, e que tem potencial para aperfeiçoar o controle do ST-DP, é o direcionamento do foco de atenção por meio de instruções verbais. Ao realizar uma tarefa motora, a atenção pode ser direcionada a dois tipos de foco: externo ou interno (WULF, 2007). No foco externo (FE), a atenção é dirigida aos objetos com os quais o sujeito interage ou aos efeitos do movimento sobre o ambiente. Já no foco interno (FI), a atenção é convergida aos próprios movimentos ou segmentos

corporais (WULF, 2013; WULF *et al.*, 2009). Instruções para FE levam a desempenho motor mais eficiente (com maior produção de força, menor atividade muscular e melhores respostas cardiovasculares) e mais efetivo (com melhor acurácia, consistência e equilíbrio) do que as que induzem a um FI para uma variedade de tarefas motoras, como equilíbrio, salto, arremesso (WULF *et al.*, 2009; WULF; MCNEVIN; SHEA, 2001).

Diante das evidências, é razoável pensar que os efeitos do foco de atenção podem ser especialmente proveitosos para os idosos, uma vez que essa população está mais propensa a prestar atenção aos seus movimentos (ou seja, a usar um FI) quando realizam tarefas desafiadoras (WOOLLACOTT; SHUMWAY-COOK, 2002). Dirigir a atenção aos próprios movimentos pode prejudicar a coordenação, enquanto manter um foco externo de atenção pode resultar em maior flexibilidade (maiores valores de V_{UCM}) e maior estabilidade (menores valores de V_{ORT}).

Embora os benefícios obtidos com um foco de atenção externo sejam amplamente relatados no nível de desempenho, os fenômenos que explicam esses benefícios ainda são desconhecidos. De acordo com a hipótese *constrained action*, o FE permite que o sistema motor utilize mecanismos automáticos e inconscientes de controle que normalmente regulam os movimentos por meio de processos de auto-organização. Por outro lado, o FI prejudica os processos automáticos de coordenação do sistema motor (KAL; VAN DER KAMP; HOUDIJK, 2013; WULF; MCNEVIN; SHEA, 2001).

Lohese, Sherwood e Healy (2010) observaram o efeito do foco de atenção no desempenho da tarefa de lançar dardos em um alvo. Ora os participantes foram orientados a se concentrar no movimento do próprio braço (FI) e ora na trajetória do dardo (FE). Os resultados permitiram concluir que o FE aumentou a variabilidade do movimento das articulações do membro superior entre as repetições da tarefa ao mesmo tempo em que melhorou a acurácia e a consistência do arremesso. Este resultado é indicativo de processos de coordenação com maior flexibilidade nas estratégias de movimento a serviço da estabilidade do desempenho. Um estudo recente que utilizou a análise de

UCM permitiu avançar na compreensão dos mecanismos que estão por trás dos benefícios da adoção do FE (FIETZER; WINSTEIN; KULIG, 2018). Os voluntários deveriam saltar no mesmo lugar com uma perna só sob três diferentes condições: natural (sem instrução de foco), pensando em um alvo que foi colocado no chão (FE) e pensando no próprio pé (FI). Os resultados mostraram que a indução a um FE melhorou, como esperado, o desempenho na tarefa. A melhoria no desempenho foi associada a uma alteração na estrutura da variabilidade do movimento. Confirmando expectativas geradas pelo estudo com dardos (LOHESE *et al.*, 2010), valores de V_{UCM} foram maiores do que do V_{ORT} para o FE em relação às demais condições de foco. Portanto, esse estudo permite pensar que o UCM é uma ferramenta adequada para investigar se o FE pode melhorar o controle do passar de ST-DP.

A tarefa de passar de ST-DS não tem uma referência natural de foco externo (um objeto ou efeito ambiental externo para onde direcionar a atenção). No entanto, em situações de vida diária, passar de ST-DP é frequentemente realizada em associação a tarefas secundárias supra-posturais, como segurar uma caneca com bebida. Nesse tipo de situação, a atenção pode ser direcionada ao objeto, ou seja, à caneca. Portanto, de um ponto de vista experimental, o ST-DP segurando uma caneca constitui uma tarefa útil para testar os efeitos do foco de atenção na coordenação. A caneca é uma referência externa à qual a atenção pode ser ou não direcionada. Esta tarefa pode ser utilizada para testar os efeitos do foco de atenção nos mecanismos de controle motor que dão suporte ao desempenho funcional.

Assim, o objetivo deste trabalho é investigar como o passar de ST-DP é controlado, como o controle do ST-DP é afetado pela idade e como instruções de foco de atenção podem afetar o controle da tarefa. Com base nos achados da literatura, foram projetadas três hipóteses: (1) a variabilidade entre tentativas dos ângulos articulares que preserva a posição do CM e da caneca, isto é, o V_{UCM} , é maior do que a variabilidade que altera essas variáveis de controle (V_{ORT}); (2) os valores do V_{UCM} e V_{ORT} diferem entre jovens e idosos; (3) instruções de foco de atenção afetam o controle do passar de ST-DP e interagem com a idade, sendo especialmente benéficas para os idosos.

ARTIGO**EFFECTS OF AGE AND ATTENTIONAL FOCUS ON PERFORMANCE AND
COORDINATION OF THE SIT-TO-STAND TASK**

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Highlights

- Sit to stand synergies flexibly stabilize postural and supra-postural variables.
- Older adults showed weaker synergistic stabilization of the body CoM.
- Attentional focus did not affect sit-to-stand performance or coordination.

Abstract:

Sit-to-stand (STS) is essential to independence in activities of daily living. However, STS performance tends to decline with aging, becoming even more challenging when it is associated with secondary tasks such as holding a cup. STS control may be improved by cognitive strategies such as directing the focus of attention. For a variety of motor tasks, focusing attention on the environmental effects of movement (i.e. an external focus) leads to more efficient and effective motor performance than focusing attention on the movement itself (i.e. an internal focus). The purpose of this study was to investigate how STS while holding a cup is controlled and how control is affected by age and attention focus. 21 healthy old and 26 young adults performed STS while holding a cup with the non-dominant hand under two attention focus conditions: external and internal. STS performance variables were quantified. STS coordination was investigated with the uncontrolled manifold (UCM) analysis. Young participants tilted the cup less and showed smoother horizontal motion of the body center of mass (CoM) than older adults, but older participants showed smoother vertical motion of the CoM and smoother horizontal and vertical motion of the cup. Older adults also showed significantly higher values of both V_{UCM} and V_{ORT} for the horizontal and vertical dimensions of the CoM. However, younger participants showed higher synergy indices for the horizontal and vertical position of the CoM than older participants. Therefore, it seems that, to stabilize the CoM, older adults coordinate their joint motions in more flexible, but also more unstable patterns. Attention focus instructions did not affect task performance or coordination. It is possible that well-trained tasks learned spontaneously in childhood, like STS, are less prone to the negative effects of an internal focus or to the positive effects of an external focus.

Keywords: ageing, performance, coordination, attentional focus, uncontrolled manifold, sit-to-stand

1. Introduction

The sit-to-stand (STS) is a basic mobility task performed around 60 times a day (Dall & Kerr, 2010). Performance of STS is fundamental for independence and may deteriorate in old age. Decreased STS performance is a key indicator of decreased mobility, increased risk of falls, disability, hospitalization, and nursing home admission (Buatois *et al.*, 2008; Lord *et al.*, 2007; Makizako *et al.*, 2017; Tinetti, Speechley, & Ginter, 1988). There is, therefore, significant interest in understanding how STS is controlled, how control changes with age, and how performance of STS may be improved.

Control of STS requires coordination of multiple and redundant joint motions across the body. The joints of the lower- and upper-extremity, trunk, and neck are coordinated to displace the whole body center of mass (CoM) from a lower position with the base of support formed by the buttocks and the chair to a higher position with a base of support formed by the feet and the floor. Because of redundancy, stable CoM displacement can be achieved through varied equivalent combinations of joint configurations. Specifically, joint angles can fluctuate flexibly from trial to trial while still generating the same CoM trajectory. Such flexibility of movement strategies provides, in addition to stable performance, adaptability to changing constraints, e.g. different seat heights, age-related changes in muscle strength, or secondary tasks such as holding a cup of coffee.

Analysis of the structure of variability of multi-joint kinematics can inform on both stability and flexibility of STS control. The Uncontrolled Manifold (UCM) approach is uniquely suited for such analysis. This method can be used to decompose the trial-to-trial variability of multi-joint motions (elemental variables) into variability that either flexibly preserves (V_{UCM}) or changes (V_{ORT}) values of important control variables, such as the position of the CoM during STS (Scholz & Schöner, 1999). Greater V_{UCM} would indicate more flexibility in multi-joint patterns used to achieve the same position of the CoM, while lower V_{ORT} would

indicate less change in the position of the CoM and thus more stable performance. The relative difference between V_{UCM} and V_{ORT} has been used as an index of synergistic coordination stabilizing performance variables (Latash, Scholz, & Schöner, 2007).

Studies have suggested that healthy older adults may differ from young adults in the synergistic stabilization of movement (H. B. Olafsdottir, Zatsiorsky, & Latash, 2008; H. Olafsdottir, Zhang, Zatsiorsky, & Latash, 2007; Shinohara, Scholz, Zatsiorsky, & Latash, 2004) but the evidence is still contradictory. Two studies showed that old and young adults employed similarly flexible co-variation of joint motions across the body (V_{UCM} relative to V_{ORT}) to stabilize the CoM during STS (Greve, Hortobágyi, & Bongers, 2019; Greve, Zijlstra, Hortobágyi, & Bongers, 2013). In contrast, multi-joint control used by older adults to stabilize the CoM during balance recovery is less flexible (lower synergy index) than young adults (Hsu, Chou, & Woollacott, 2013). Older adults also show a reduction in the synergy index in multi-digit pressing and prehensile tasks (H. B. Olafsdottir *et al.*, 2008; H. Olafsdottir *et al.*, 2007; Shinohara *et al.*, 2004). One possible consequence of reduced synergistic stabilization is decreased adaptability to deal with secondary tasks, such as holding a cup of coffee during STS. In this case, rehabilitative interventions should aim to change complementary aspects of control, i.e. to increase flexibility of multi-joint coordination and decrease instability of performance.

One possible way to modify STS control is through cognitive strategies to focus attention. For a variety of motor skills (e.g., balancing, jumping, throwing), focusing attention on the environmental effects of movement – an external focus (EF) of attention – has been shown to yield better performance than focusing attention on some aspect of the movement itself – an internal focus (IF) of attention. Benefits of an EF have been observed in movement efficiency (e.g., muscular activity, force production, cardiovascular responses) and effectiveness (e.g., accuracy, consistency, balance) (Wulf, 2013). The effects of an EF on performance may be especially relevant for older adults, because they are more prone to pay deliberate attention to their movements (use an IF) in challenging tasks (Woollacott & Shumway-Cook, 2002).

An EF may be beneficial not only at the level of performance, but also at the level of coordination. The "constrained action hypothesis" predicts that an IF impairs automatic coordination processes, while benefits of EF appear to originate from improvement in coordinative variability (Fietzer, Winstein, & Kulig, 2018; Lohse, Jones, Healy, & Sherwood, 2014). In dart throwing, an EF increased trial-to-trial variability of joint motions at the same time it improved accuracy and consistency of dart strike location (Lohse, Sherwood, & Healy, 2010). Thus, an EF may increase coordination flexibility (V_{UCM}) and decrease performance instability (V_{ORT}). A recent study with UCM analysis shows that changing one's focus of attention indeed alters the structure of movement variability (Fietzer *et al.*, 2018).

Nevertheless, one of the challenges for investigating the effects of an EF in STS is that STS does not have a natural external reference for attention. However, STS is often performed in association with manual tasks that require attention to be directed externally to an object, such as a cup of coffee. From an investigative point of view, STS with the added goal of holding a cup constitutes a useful experimental paradigm to test the effects of attention on coordination, because it creates a natural external reference to which attention may or may not be direct during STS.

The goal of this study was to investigate how STS while holding a cup is controlled, how age differences impact STS control and how control of STS may be improved with attention focus instructions. We have 3 hypotheses. 1) We hypothesized that inter-trial variability of joint motions that preserves (V_{UCM}) whole body motion (position of the CoM) and cup motion (bidimensional position and angle) would be greater than variability that changes (V_{ORT}) these control variables. 2) We hypothesized that inter-trial variability of joint coordination of older adults that either preserves (V_{UCM}) or changes (V_{ORT}) the control variables would differ from younger adults. 3) We hypothesized that focus of attention instructions affect STS control and interact with age, being especially beneficial for older people. For older people, conscious attention to body movement (i.e. IF) would impair coordination, while an EF would lead to

more flexible (greater V_{UCM}) and more stable (lower V_{ORT}) control of the CoM and cup during STS.

2. Methods

2.1 *Participants*

Twenty-one healthy old adults (9 males and 16 females; 70.0 ± 4.5 years; 1.69 ± 0.1 m; 72.4 ± 12.5 kg) and twenty-six young adults (7 males and 19 females; 23.2 ± 3.2 years; 1.67 ± 0.1 m; 63.7 ± 12.5 kg) participated in this study. Inclusion criteria were: (1) be over 60 years old or between 18 and 35; (2) be right-handed; (3) have no musculoskeletal or neurological symptoms affecting STS; and (4) have no cognitive disorders affecting the ability to understand and follow focus instructions. The ability to follow instructions was informally assessed throughout the consent process and interview.

The study's protocol was approved by the local Institutional Review Board and all participants provided written informed consent prior to their participation.

2.2 *Equipment and set-up*

Young and old adults performed STS while holding a cup under two conditions of attention focus: EF and IF. Experimental data were collected using four capture units of the Codamotion System (Charnwood Dynamics Ltd., Rothley, UK) at a sampling rate of 100 Hz. Marker placement is illustrated in Figure 1. Active clusters were attached to the left side of the body: shank, thigh, forearm, and arm. Three active markers were placed on the cup and three on the hand (i.e., heads of second and fifth metacarpals, and mid of third metacarpal). Markers were also placed on the temple, mastoid process, and spinous process of C7, T12, and L5 vertebrae. The following landmarks were obtained with a virtual point marker: lateral malleoli, lateral epicondyles of the femur, anterior superior iliac spine, great trochanter, acromion, lateral epicondyle of the humerus, and styloid process of the ulnae. This marker placement was used to define virtual segments corresponding to the foot, shank, thigh, pelvis, lower

trunk, upper trunk, neck, head, arm, forearm, hand and cup, as well as the joints between them.

(Insert Figure 1 around here)

2.3 Experimental procedure

Participants sat on a stool, held a cup with their non-dominant hand and rested the cup on the thigh, in preparation for STS. The non-dominant hand was chosen for the experiment because the effect of attention focus is more pronounced in more difficult tasks (Landers, Wulf, Wallmann, & Guadagnoli, 2005). For the same reason, seat height was set at 80% of shank length. The starting positions of the buttocks, thighs, feet and cup were standardized for each participant.

Participants performed 45 repetitions of the task at a self-selected speed while looking at a target placed 1.3m ahead on the wall, at eye level. Each trial began after a verbal 'go' signal. The first 5 trials had no specific instructions to focus attention. Participants then performed two blocks of 20 trials for each focus condition (EF and IF). The order of blocks was randomized for each participant. EF instructions were *"please mentally focus on keeping the cup level"*. IF instructions were *"please mentally focus on keeping your hand level"*. Participants were reminded of focus instructions every two trials. After each block of 10 trials, participants answered the question *"How well were you able to follow the instructions in the last 10 repetitions?"* on a graded scale of 1 (poorly) to 10 (excellently), printed on a form. Participants took two-minute breaks after each block of 10 trials. None of the participants reported fatigue. The data collection session took approximately 45 minutes.

2.4 Data reduction

Marker position data was exported to Matlab™ (Mathworks, MATLAB R2017a) for processing. Time series were filtered with a 4th order Butterworth low pass filter at 6Hz. Cubic spline interpolation was used to estimate marker positions if

data was lost for less than 20 consecutive frames. Trials with data gaps greater than 20 frames were discarded. Marker position was used to calculate segment lengths and joint angles in the sagittal plane. Joint angles from all trials were visually examined for consistency across repetitions and deviant trials were discarded before further analysis. On average there were 37 (± 1) and 38 (± 2) good trials in the old and young group, respectively.

The position of the total body center of mass (CoM) was calculated from position data and anthropometric estimates (Winter, 2009). STS onset and termination were determined automatically by a Matlab™ routine and then checked visually for all trials. Onset was defined at the point that the CoM horizontal velocity exceeded 5% of its baseline value, before its largest upward deviation. Movement termination corresponded to the last downward deviation of the COM vertical velocity, when it crossed the value corresponding to 5% of its baseline. For each trial, the portion from movement onset to termination was normalized to 200 samples in evenly spaced steps with the cubic spline interpolation. STS phases were defined within percentages of the time-normalized trials: preparatory phase (1–30%), lift-off (31–60%) and extension phase (61–100%), according to Greve *et al.* (2013).

2.5 STS performance

Movement smoothness (spectral arc-length metric) (Balasubramanian, Melendez-calderon, Roby-brami, & Burdet, 2015) was calculated for the time series of vertical and horizontal positions of the CoM and cup, for each STS trial, then averaged across trials and participants. The mean cup inclination relative to the horizontal, during each STS, was also used as a performance indicator. Lower movement times, higher smoothness and lower cup inclination indicate better performance.

2.6 STS coordination - UCM analysis

UCM analysis involved four steps (Latash *et al.*, 2007; Latash & Zatsiorsky, 2016). First, twelve angles were defined in the sagittal plane: ankle, knee, hip,

lumbar spine, thoracic spine, cervical spine, atlanto-occipital, sternoclavicular, shoulder, elbow, wrist and hand-cup angles. The hand-cup angle was the angle between the horizontal and the vector from the 2nd metacarpophalangeal to the wrist joint. Second, control variables that are expected to be stabilized by co-variation of joint angles during STS were defined. In line with previous UCM studies, the vertical and horizontal position of the CoM in the sagittal plane are the two main control variables (Latash, Mark L.; Scholz, John F.; Danion, Frederic; Schöner, 2001; Scholz & Schöner, 1999). Cup angle (the angle between the horizontal and the vector from the cup marker and the hand-cup joint) and bidimensional cup position in the sagittal plane were also treated as potentially stabilized control variables, given the added task goal of transferring the cup during STS.

The third step was the definition of geometric models (Figure 2, see also the Appendix 1) linking changes of joint angles to changes in the selected control variables. Jacobian matrices of the models (partial derivatives of the control variable with respect to the joint angles) were defined in each time point and their null-spaces were computed at the reference configuration (mean joint angles across trials). The null space of the Jacobian is the linear approximation of the uncontrolled manifold (UCM) subspace. As the fourth and last step, projections of variance in the space of elemental variables onto the UCM (V_{UCM}) and onto its orthogonal complement (V_{ORT}) were calculated. Magnitudes of V_{UCM} and V_{ORT} were normalized by the number of dimensions in the corresponding subspaces so they could be compared quantitatively. A synergy index (ΔV) given by equation (1) was also computed. V_{UCM} , V_{ORT} and ΔV were calculated at every time frame of STS. The integral of each measure was computed for each of the three STS phases.

$$\Delta V = \frac{V_{UCM} - V_{ORT}}{V_{UCM} + V_{ORT}}$$

(1)

(Insert Figure 2 around here)

2.7 Statistical analysis

The dependent variables of major interest in the analysis of STS performance were the average and standard deviations of total movement time, CoM and cup motion smoothness in the horizontal and vertical dimensions, and mean angle of the cup with the horizontal. Because the variables had normal distribution according to the Shapiro-Wilk test, data were analyzed in mixed ANOVAs with Age (old or young) as a between-subject factor and Focus (external or internal) as a within-subject factor. When there was a significant interaction effect, post-hoc pairwise comparisons with Bonferroni corrections were used.

The dependent variables of major interest in the analysis of STS coordination were the UCM components, i.e. V_{UCM} , V_{ORT} , and ΔV , for horizontal and vertical positions of the CoM, bidimensional cup position and cup angle. To meet statistical requirements, V_{UCM} and V_{ORT} measures were log-transformed before statistical analysis and ΔV values were subjected to Fisher's z-transformation (ΔV_z) to avoid computational boundaries (Solnik *et al.*, 2013). V_{UCM} , V_{ORT} and ΔV_z components were analyzed with a mixed ANOVA with Age (old or young) as between-subject factor while Focus (external or internal) and STS Phase (preparatory, lift-off and extension) were within-subject factors. Post-hoc pairwise comparisons with Bonferroni corrections were used to explore significant effects. Greenhouse-Geisser corrections were used when assumptions of sphericity were violated.

Tests were performed with SPSS version 22.0. Statistical significance was set at $p < 0.05$ for all tests.

3. Results

Results are presented at the level of task performance variables and at the level of multi-joint coordination (UCM indices) for 1) STS control, 2) effects of age and 3) effects of attentional focus.

3.1 STS control

3.1.1 STS performance

Figure 3 shows time series for five performance variables averaged across all trials and participants, regardless of the age or focus condition. The horizontal position of the cup showed the highest value of smoothness (-1.94 ± 0.22), followed by vertical position of the cup (-2.06 ± 0.05), vertical position of the CoM (-2.16 ± 0.04) and horizontal position of the CoM (-2.26 ± 0.56).

(Insert Figure 3 around here)

Movement time did not differ significantly between groups or focus conditions. Participants took on average 3.17 ± 0.24 seconds to complete each STS. The small standard deviation indicates that there was small variability over repetitions.

3.1.2 STS coordination

We investigated whether ΔV_z indicated the presence of synergies stabilizing the horizontal and vertical positions of the CoM, the bidimensional position of the cup and the cup angle with respect to the horizontal. Figure 4 shows the values of ΔV_z during STS averaged over all trials (regardless of age group or focus condition). ΔV_z values greater than zero indicate synergistic coordination stabilizing the control variable, with higher ΔV_z values indicating stronger synergies. In general, the horizontal position of the CoM presented the highest ΔV_z (0.93 ± 0.09), followed by cup angle with the horizontal (0.80 ± 0.03), bidimensional position of the cup (0.61 ± 0.05), and vertical position of the CoM (0.58 ± 0.22).

(Insert Figure 4 around here)

Figure 5 illustrates the average of ΔV_z of each coordination variable for the three movement phases. All four indices were significantly affected by Phase ($p < 0.05$). The average of ΔV_z of the vertical position of the CoM and the cup angle with the horizontal decreased during movement, while the average of ΔV_z of bidimensional position of the cup and of the horizontal position of the CoM decreased between Phase 1 and 2 and then increased between Phases 2 and 3.

(Insert Figure 5 around here)

3.2 Effects of Age on STS

3.2.1 Effects of Age on STS Performance

A significant main effect of Age (see Figure 6) was found for smoothness of the CoM in the horizontal dimension ($F_{1;45}=118.5$, $p=0.001$, *partial* $\eta^2=0.725$), smoothness of the CoM in the vertical dimension ($F_{1;45}=4.58$, $p=0.038$, *partial* $\eta^2=0.092$), smoothness of the cup in the horizontal dimension ($F_{1;45}=4.364$, $p=0.042$, *partial* $\eta^2=0.088$), smoothness of the cup in the vertical dimension ($F_{1;45}=4.364$, $p=0.004$, *partial* $\eta^2=0.171$) and average angle of the cup with the horizontal ($F_{1;45}=478.094$, $p=0.001$, *partial* $\eta^2=0.914$). Young participants showed smoother horizontal motion of the CoM (Young= -1.840 ± 0.058 , Old= -2.786 ± 0.065) and lower inclination of the cup (Young= -0.089 ± 0.017 , Old= 0.460 ± 0.019) than older participants. In contrast, older participants showed smoother vertical motion of the CoM (Young= -2.172 ± 0.008 , Old= 2.146 ± 0.009), smoother horizontal motion of the cup (Young= -2.0 ± 0.041 , Old= -1.873 ± 0.045), and smoother vertical motion of the cup (Young= -2.082 ± 0.009 , Old= -2.041 ± 0.010) when compared to young participants.

(Insert Figure 6 around here)

The Focus*Age interaction was significant for smoothness of the CoM in the vertical dimension ($F_{1;45}=4.902$, $p=0.032$, *partial* $\eta^2=0.098$). Bonferroni post hoc tests revealed that old participants under IF showed smoother vertical motion of

the CoM than young participants under the same focus condition (Young*IF=-2.173±0.008; Old*IF=-2.143±0.009).

Main effects or interaction effects involving Age were not significant for other variables.

3.2.2 Effects of Age on STS Coordination

The mixed ANOVA revealed a significant main effect of Age for V_{UCM} and V_{ORT} of the horizontal and vertical positions of the CoM (V_{UCM} horizontal position of CoM: $F_{1;45}=5.572$, $p=0.023$, *partial* $\eta^2=0.110$; V_{UCM} vertical position of CoM: $F_{1;45}=5.443$, $p=0.024$, *partial* $\eta^2=0.108$; V_{ORT} horizontal position of CoM: $F_{1;45}=15.621$, $p=0.001$, *partial* $\eta^2=0.258$; V_{ORT} vertical position of CoM: $F_{1;45}=15.531$, $p=0.001$, *partial* $\eta^2=0.257$). Compared to young participants, older participants showed significantly higher values of both V_{UCM} and V_{ORT} for the horizontal and vertical positions of the CoM (Figure 7).

(Insert Figure 7 around here)

There was a significant Phase*Focus*Age interaction for V_{ORT} of the cup angle with the horizontal ($F_{1.539;69.264}=4.134$, $p=0.029$, *partial* $\eta^2=0.084$). Bonferroni post hoc revealed that, in Phase 3 and under EF instructions, old participants showed higher V_{ORT} than young participants (Old*EF*Phase 3=-3.317±0.063; Young*EF*Phase 3=-3.519±0.057).

A significant main effect of Age was also found for ΔV_z of the horizontal and vertical positions of the CoM ($F_{1;45}=8.527$, $p=0.005$, *partial* $\eta^2=0.159$ and $F_{1;45}=8.041$, $p=0.007$, *partial* $\eta^2=0.152$, respectively). Young participants showed stronger ΔV_z for the horizontal and vertical position of CoM (0.966±0.017 and 0.651±0.019, respectively) than old participants (0.894±0.018 and 0.571±0.021).

Main effects or interaction effects involving Age were not significant for other variables.

3.3 Effects of Attentional Focus on STS

For the question “How well were you able to follow the instructions in the last 10 repetitions?” the average score for the older adults under EF and IF instructions were respectively, 9.8 ± 0.4 and 9.5 ± 0.7 . The average score for the younger adults under EF and IF instructions were respectively, 8.4 ± 1.4 and 8.1 ± 1.6 . Although a mixed ANOVA revealed that older adults gave a significantly higher score than younger participants ($F_{1,45}=19,965$, $p=0.001$, *partial* $\eta^2=0.307$), the average scores indicated that all participants were able to follow instructions *very well to excellently*.

3.3.1 Effects of Attentional Focus on STS Performance

Main effects involving Focus were not significant for any variable. There was only a significant Focus*Age interaction for smoothness of the CoM in the vertical dimension ($F_{1,45}=4.902$, $p=0.032$, *partial* $\eta^2=0.098$). Bonferroni post hoc tests revealed that older participants under IF showed smoother motion of their CoM in the vertical direction than under EF (Old*IF= -2.143 ± 0.009 ; Old*EF= -2.149 ± 0.009).

3.3.2 Effects of Attentional Focus on STS Coordination

There were no significant main effects of Focus on any UCM indices: V_{UCM} , V_{ORT} nor ΔV_Z . There was a significant Phase*Focus*Age interaction for V_{ORT} of cup angle ($F_{1,539;69.264}=4.134$, $p=0.029$, *partial* $\eta^2=0.084$). Bonferroni post hoc revealed that, in Phase 1, young adults showed significantly higher values of V_{ORT} when they were following the EF instruction (-3.849 ± 0.088) than when they were following the IF instruction (-3.715 ± 0.075).

Main effects or interaction effects involving Focus were not significant for other variables.

4. Discussion

This study employed UCM analysis to investigate how STS while holding a cup is controlled, how age differences impact STS control and how attentional focus instructions may affect the control of STS. We investigated STS performance and coordination. Performance was characterized by motion smoothness, cup inclination and movement time. Coordination was investigated with UCM indices for candidate control variables: vertical and horizontal position of the CoM, bidimensional position of the cup, and cup angle. Hypothesis 1 was confirmed: V_{UCM} was greater than V_{ORT} for all these control variables, leading to positive ΔV values.

Previous UCM studies have shown that the neuromuscular system uses variability in multi-joint coordination with the goal of stabilizing the CoM while rising from a chair (ANAN *et al.*, 2017; Greve *et al.*, 2019; Scholz & Schöner, 1999). Our results showed that the position of the CoM, specifically in the horizontal dimension, showed the stronger synergy index throughout the three phases of movement. These results are consistent with previous studies showing that in usual STS transitions control of the horizontal position of the CoM is directly related to balance control and thus more important than control of the vertical position (Reisman, Scholz, & Schöner, 2002; Scholz, Reisman, & Schöner, 2001).

We also found that the strength of synergy stabilizing the vertical displacement of the CoM decreased over time, while the synergy index of the horizontal position of the CoM decreased in the lift-off phase and then recovered in the extension phase. Synergies stabilize performance, therefore they must be attenuated in preparation for change (Friedman, SKM, Zatsiorsky, & Latash, 2009; Goodman, Kun, Zatsiorsky, & Latash, 2005; Latash, Scholz, & Danion, 2002; Shim, Latash, & Zatsiorsky, 2005). Stabilization of the horizontal dimension needs to be decreased around lift-off, when the individual is rotating the trunk toward the thigh to displace the CoM horizontally toward the feet (Janssen, Bussmann, & Stam, 2002; Hirschfeld, Thorsteinsdottir, & Olsson, 1999). After lift-off, the horizontal position of the CoM must be kept stable to maintain balance. Stabilization of the vertical dimension needs to be decreased

towards the end of STS when lower extremities are extended to displace the CoM vertically towards standing (Janssen, Bussmann, & Stam, 2002; Hirschfeld, Thorsteinsdottir, & Olsson, 1999). Thus, the patterns seen in ΔV_z values are compatible with the functional requirements of STS. Data suggestive of a similar CoM stabilization patterns during STS has been reported in previous UCM studies (Greve *et al.*, 2013; Scholz *et al.*, 2001).

Our STS task was associated to a suprapostural goal of holding a cup. Suprapostural tasks affect postural adjustments in such a way that the suprapostural goal can be achieved (Mcnevin & Wulf, 2002; Mitra, 2003; Mitra & Fraizer, 2004; Riley, 1999). Thus, the added demand of holding the cup impels a synergistic organization of multi-joint motions to stabilize the cup position and angle, in addition to the CoM. In this study, the stabilization of the CoM is a basic postural requirement and the stabilization of the cup is a basic suprapostural requirement. Our findings showed that the cup angle and bidimensional cup position exhibited the second and third strongest synergy indices, respectively. These results demonstrate that the addition of a suprapostural goal to the STS is accommodated by synergistic coordination.

We had also hypothesized that V_{UCM} and V_{ORT} of older adults would differ from young adults (hypothesis 2). Coordination indices were able to capture differences between young and older adults in control of the CoM, but not cup motion, so hypothesis 2 was only partially confirmed. Our findings indicated that, compared to young adults, older participants showed significantly increased flexibility (V_{UCM}) but also instability (V_{ORT}) for the horizontal and vertical positions of the CoM. As a result, the synergy indices for the same two variables were significantly lower for older than for young adults. At the performance level, age-related differences were inconsistent. Contrary to previous literature (Greve *et al.*, 2019), movement time did not differ between age groups. While old adults showed smoother displacement of the CoM in the vertical dimension, young adults showed smoother displacement of the CoM in the horizontal dimension. While young participants showed less inclination of the cup, old participants showed smoother horizontal and vertical displacement of the cup. These results suggest that aging may affect coordination and

weaken synergies irrespective of changes in performance, or before performance is significantly affected. The weaker synergy indices suggest that older age may decrease the ability to exploit motor abundance for the benefit of performance, in line with previous studies (H. B. Olafsdottir *et al.*, 2008; H. Olafsdottir *et al.*, 2007; Shinohara *et al.*, 2004; Wu, Pazin, Zatsiorsky, & Latash, 2013).

From the clinical point of view, interventions for older individuals should address coordination patterns that give rise to performance, preferably before any functional repercussions. We investigated whether a cognitive intervention with focus instructions would have any effect on coordination and performance. We expected that attention instructions would affect STS control and interact with age, being especially beneficial for older people. Our hypothesis 3 was that, for older participants, an EF would lead to more flexible (greater V_{UCM}) and more stable (lower V_{ORT}) control of the CoM and cup during STS, compared to IF. This hypothesis was not confirmed. Overall, no significant focus effects were found. Interaction effects suggested effects that were opposite to expected: old participants showed smoother vertical displacement of the cup under IF compared to EF, and young adults showed greater instability the cup angle (V_{ORT}) under EF compared to IF during the STS preparatory phase.

Our results are surprising given that the enhancements in motor performance with EF compared to IF instructions are well established in the literature. These results cannot be explained by low adherence to instructions, because young and old adults reported following instructions *very well* or *excellently*. Thus, our results are probably related to other factors. It is possible that the EF is beneficial only for specialized complex skills learned later in life (ontogenetic skills such as sports gestures), usually acquired with great amounts of explicit instruction in early practice. For these tasks, an IF may revert the individual back to an earlier declarative stage of learning and interfere with the automaticity of control, while an EF might prioritize relevant, goal-related information for fluent coordination (de Melker Worms, Stins, van Wegen, Verschueren, *et al.*, 2017; Young & Williams, 2014). In contrast, EF instructions may produce no benefit for easy or for well-trained tasks learned early in life.

Possibly, general postural and mobility skills, that are learned spontaneously in childhood with little declarative instruction (phylogenetic skills such as the STS) are less vulnerable to inferences of attentional focus (de Melker Worms, Stins, van Wegen, Loram, & Beek, 2017; Young & Williams, 2014). We speculate that because the STS is a phylogenetic mobility skill, it would be less prone to the negative effects of an IF or the positive effects of EF. Cognitive attention strategies may not be sufficient to change coordination patterns in tasks of this nature. Specific exercise protocols to improve coordination flexibility and decrease instability may be needed (H. B. Olafsdottir *et al.*, 2008; Wu *et al.*, 2013).

However, limitations of our study may have interfered in the results. Focus effects could have been present in more difficult versions of the task, for example with different levels of liquid in the cup and higher speed demands, because the beneficial effects of an EF are especially evident in difficult tasks. Further studies should test this possibility.

In conclusion, this study indicates that synergies are organized to stabilize the CoM as well as suprapostural goal-related variables during STS, that older adults show weaker CoM-stabilizing synergies even without apparent performance decline, and that attention focus instructions are not effective to improve their STS performance or coordination. Given the importance of this task for functional independence, future studies should test the effects of other kinds of interventions to prevent coordination and performance age-related decline.

Acknowledgements

This study was supported in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001; and by a Newton Advanced Fellowship (Award number 140050) granted by the British Academy.

Appendix 1: geometric models

Angles computed: θ_1 = ankle, θ_2 = knee, θ_3 = hip, θ_4 = lumbar spine, θ_5 = thoracic spine, θ_6 = cervical spine, θ_7 = atlanto-occipital, θ_8 = sternoclavicular, θ_9 = shoulder, θ_{10} = elbow, θ_{11} = wrist, and θ_{12} = hand-cup.

A. The geometric model relating cup orientation (*Cang*) to joint configuration space is:

$$Cang = \theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10} + \theta_{11} + \theta_{12}$$

B. The geometric model relating horizontal Cup position (*Cup hor*) to joint configuration space is:

$$\begin{aligned} Cup\ hor = & l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\theta_1 + \theta_2 + \theta_3) \\ & + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5) \\ & + l_8 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8) \\ & + l_9 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9) \\ & + l_{10} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10}) \\ & + l_{11} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10} + \theta_{11}) \\ & + l_{12} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10} + \theta_{11} + \theta_{12}) \end{aligned}$$

C. The geometric model relating vertical Cup position (*Cup vrt*) to joint configuration space is:

$$\begin{aligned} Cup\ vrt = & l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\theta_1 + \theta_2 + \theta_3) \\ & + l_4 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5) \\ & + l_8 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8) \\ & + l_9 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9) \\ & + l_{10} \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10}) \\ & + l_{11} \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10} + \theta_{11}) \\ & + l_{12} \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_8 + \theta_9 + \theta_{10} + \theta_{11} + \theta_{12}) \end{aligned}$$

D. The geometric model relating horizontal COM position (COM_{hor}) to joint configuration space is:

$$\begin{aligned}
 COM_{hor} = & origin_{pos_{hor}} + m_1(l_1 \cos(\theta_1) r_1) \\
 & + m_2(l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) r_2) \\
 & + m_3(l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\theta_1 + \theta_2 + \theta_3) r_3) \\
 & + m_4(l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\theta_1 + \theta_2 + \theta_3) \\
 & + l_4(\theta_1 + \theta_2 + \theta_3 + \theta_4) r_4) \\
 & + m_5(l_1 \cos(\theta_1) \\
 & + l_2 \cos(\theta_1 + \theta_2) \\
 & + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
 & + \theta_2 + \theta_3 + \theta_4 + \theta_5) r_5) \\
 & + m_6(l_1 \cos(\theta_1) \\
 & + l_2 \cos(\theta_1 + \theta_2) \\
 & + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
 & + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_6 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6) r_6) \\
 & + m_7(l_1 \cos(\theta_1) \\
 & + l_2 \cos(\theta_1 + \theta_2) \\
 & + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
 & + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_6 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6) \\
 & + l_7 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7) r_7) \\
 & + m_8(l_1 \cos(\theta_1) \\
 & + l_2 \cos(\theta_1 + \theta_2) \\
 & + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
 & + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_8 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 \\
 & + \theta_8) r_8) \\
 & + m_9(l_1 \cos(\theta_1) \\
 & + l_2 \cos(\theta_1 + \theta_2) \\
 & + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
 & + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_8 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 \\
 & + \theta_8) + l_9 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9) r_9)
 \end{aligned}$$

$$\begin{aligned}
& +m_{10}(l_1 \cos(\theta_1) \\
& \quad + l_2 \cos(\theta_1 + \theta_2) \\
& \quad + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
& \quad + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_8 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 \\
& \quad + \theta_8) + l_9 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9) \\
& \quad + l_{10} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9 + \theta_{10})r_{10}) \\
& + m_{11}(l_1 \cos(\theta_1) \\
& \quad + l_2 \cos(\theta_1 + \theta_2) \\
& \quad + l_3 \cos(\theta_1 + \theta_2 + \theta_3) + l_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \cos(\theta_1 \\
& \quad + \theta_2 + \theta_3 + \theta_4 + \theta_5) + l_8 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 \\
& \quad + \theta_8) + l_9 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9) \\
& \quad + l_{10} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9 + \theta_{10}) \\
& \quad + l_{11} \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 + \theta_7 + \theta_8 + \theta_9 + \theta_{10} \\
& \quad + \theta_{11})r_{11})
\end{aligned}$$

E. The geometric model relating vertical COM position (COM_{vrt}) to joint configuration space is:

$$\begin{aligned}
COM_{vrt} = & \text{origin pos } vrt + m_1(l_1 \sin(\theta_1) r_1) \\
& + m_2(l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) r_2) \\
& + m_3(l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\theta_1 + \theta_2 + \theta_3) r_3) \\
& + m_4(l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\theta_1 + \theta_2 + \theta_3) \\
& + l_4 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4) r_4) \\
& + m_5(l_1 \sin(\theta_1) \\
& + l_2 \sin(\theta_1 + \theta_2) \\
& + l_3 \sin(\theta_1 + \theta_2 + \theta_3) + l_4 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4) + l_5 \sin(\theta_1 \\
& + \theta_2 + \theta_3 + \theta_4 + \theta_5) r_5)
\end{aligned}$$

[illegible]

$origin\ pos\ hor$ is the horizontal position of the origin, i.e. the ankle, $origin\ pos\ vrt$ is the vertical position of the origin, i.e. the ankle, li is the segment length where $i=\{\text{shank, thigh, pelvis, lower trunk, upper trunk, neck, head, clavicle, upper arm, forearm, hand, hand-cup, great trochanter to acromion}\}$, mi is the mass proportion of the segment, ri is the length proportion of the segment CoM to distal reference point, and θ_i is the angle between segments.

References

- Anan, M., Hattori, H., Tanimoto, K., Wakimoto, Y., Ibara, T., Kito, N., & Shinkoda, K. (2017). The coordination of joint movements during sit-to-stand motion in old adults: the uncontrolled manifold analysis. *Physical Therapy Research*. <https://doi.org/10.1298/ptr.E9923>
- Balasubramanian, S., Melendez-calderon, A., Roby-brami, A., & Burdet, E. (2015). On the analysis of movement smoothness. *Journal of NeuroEngineering and Rehabilitation*, (December). <https://doi.org/10.1186/s12984-015-0090-9>
- Buatois, S., Miljkovic, D., Manckoundia, P., Gueguen, R., Miget, P., Vançon, G., Benetos, A. (2008). Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. *Journal of the American Geriatrics Society*, 56(8), 1575–1577. <https://doi.org/10.1111/j.1532-5415.2008.01777.x>
- Dall, P. M., & Kerr, A. (2010). Frequency of the sit to stand task: An observational study of free-living adults. *Applied Ergonomics*. <https://doi.org/10.1016/j.apergo.2009.04.005>
- de Melker Worms, J. L. A., Stins, J. F., van Wegen, E. E. H., Loram, I. D., & Beek, P. J. (2017). Influence of focus of attention, reinvestment and fall history on elderly gait stability. *Physiological Reports*, 5(1), 1–9. <https://doi.org/10.14814/phy2.13061>

de Melker Worms, J. L. A., Stins, J. F., van Wegen, E. E. H., Verschueren, S. M. P., Beek, P. J., & Loram, I. D. (2017). Effects of attentional focus on walking stability in elderly. *Gait and Posture*, 55, 94–99.

<https://doi.org/10.1016/j.gaitpost.2017.03.031>

Fietzer, A. L., Winstein, C. J., & Kulig, K. (2018). Changing one's focus of attention alters the structure of movement variability. *Human Movement Science*, 62(September), 14–24. <https://doi.org/10.1016/j.humov.2018.09.004>

Friedman, J., SKM, V., Zatsiorsky, V. M., & Latash, M. L. (2009). The sources of two components of variance: an example of multifinger cyclic force production tasks at different frequencies. *Exp Brain Res*.

Goodman, S. R., Kun, Æ. J., Zatsiorsky, V. M., & Latash, Æ. M. L. (2005). Motor variability within a multi-effector system : experimental and analytical studies of multi-finger production of quick force pulses, 75–85.

<https://doi.org/10.1007/s00221-004-2147-z>

Greve, C., Hortobágyi, T., & Bongers, R. M. (2019). Flexibility in joint coordination remains unaffected by force and balance demands in young and old adults during simple sit-to-stand tasks. *European Journal of Applied Physiology*, 119(2), 419–428. <https://doi.org/10.1007/s00421-018-4035-4>

Greve, C., Zijlstra, W., Hortobágyi, T., & Bongers, R. M. (2013). Not all is lost: old adults retain flexibility in motor behaviour during sit-to-stand. *PloS One*, 8(10), e77760. <https://doi.org/10.1371/journal.pone.0077760>

Hirschfeld, H., Thorsteinsdottir, M., Olsson, E., Thorsteinsdottir, M., & Olsson, E. (2018). Coordinated Ground Forces Exerted by Buttocks and Feet are Adequately Programmed for Weight Transfer During Sit-to-Stand, 3021–3029.

Hsu, W. L., Chou, L. S., & Woollacott, M. (2013). Age-related changes in joint coordination during balance recovery. *Age*, 35(4), 1299–1309.

<https://doi.org/10.1007/s11357-012-9422-x>

Janssen, W., Bussmann, H., & Stam, H. (2002). Determinants of the sit-to-stand movement: a review. *Physical Therapy*.

Landers, M., Wulf, G., Wallmann, H., & Guadagnoli, M. (2005). An external focus of attention attenuates balance impairment in patients with Parkinson's disease who have a fall history. *Physiotherapy*.

<https://doi.org/10.1016/j.physio.2004.11.010>

Latash, Mark L.; Scholz, John F.; Danion, Frederic; Schöner, G. (2001). Structure of motor variability in marginally redundant multifinger force production tasks. *Exp Brain Res*, 141(2), 153–165.

<https://doi.org/10.1007/s002210100861>

Latash, M. L., Scholz, J. F., & Danion, F. (2002). Finger coordination during discrete and oscillatory force production tasks, 419–432.

<https://doi.org/10.1007/s00221-002-1196-4>

Latash, M. L., Scholz, J. P., & Schöner, G. (2007). Toward a New Theory of Motor Synergies. *Motor Control*, 11(3), 276–308.

<https://doi.org/10.1123/mcj.11.3.276>

Latash, M. L., & Zatsiorsky, V. M. (2016). *Biomechanics and Motor Control* (First). Elsevier.

Lohse, K. R., Jones, M., Healy, A. F., & Sherwood, D. E. (2014). The role of attention in motor control. *Journal of Experimental Psychology: General*, 143(2), 930–948. <https://doi.org/10.1037/a0032817>

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2010). How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. *Human Movement Science*.

<https://doi.org/10.1016/j.humov.2010.05.001>

Lord, S. R., Murray, S. M., Chapman, K., Munro, B., Tiedemann, A., D'Souza, G., Jacobson, L. P. (714). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people
Incidence and epidemiology of anal cancer in the multicenter AIDS cohort study. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 57(8), M543.

Makizako, H., Shimada, H., Doi, T., Tsutsumimoto, K., Nakakudo, S., Hotta, R., & Suzuki, T. (2017). Predictive cutoff values of the Five-Times Sit-to-Stand and the Timed "Up & Go" Test for disability incidence in older people dwelling in the community. *Physical Therapy*, 4(97), 417–124.

Mcnevin, N. H., & Wulf, G. (2002). Attentional focus on supra-postural tasks affects postural control, 21, 187–202.

Mitra, S. (2003). Postural costs of suprapostural task load, 22, 253–270.
[https://doi.org/10.1016/S0167-9457\(03\)00052-6](https://doi.org/10.1016/S0167-9457(03)00052-6)

Mitra, S., & Fraizer, E. V. (2004). Effects of explicit sway-minimization on postural – suprapostural dual-task performance, 23, 1–20.
<https://doi.org/10.1016/j.humov.2004.03.003>

Olafsdottir, H. B., Zatsiorsky, V. M., & Latash, M. L. (2008). The effects of strength training on finger strength and hand dexterity in healthy elderly individuals. *Journal of Applied Physiology*, 105(4), 1166–1178.
<https://doi.org/10.1152/jappphysiol.00054.2008>

Olafsdottir, H., Zhang, W., Zatsiorsky, V. M., & Latash, M. L. (2007). Age-related changes in multifinger synergies in accurate moment of force production tasks. *Journal of Applied Physiology*, 102(4), 1490–1501.
<https://doi.org/10.1152/jappphysiol.00966.2006>

Reisman, D. S., Scholz, J. P., & Scho, G. (2002). Differential joint coordination

in the tasks of standing up and sitting down, *12*, 493–505.

Riley, M. A. (1999). Postural stabilization for the control of touching, *18*, 795–817.

Scholz, J. P., Reisman, D., & Schöner, G. (2001). Effects of varying task constraints on solutions to joint coordination in a sit-to-stand task. *Experimental Brain Research*, *141*(4), 485–500. <https://doi.org/10.1007/s002210100878>

Scholz, J. P., & Schöner, G. (1999a). The uncontrolled manifold concept: Identifying control variables for a functional task. *Experimental Brain Research*, *126*(3), 289–306. <https://doi.org/10.1007/s002210050738>

Scholz, J. P., & Schöner, G. (1999b). The uncontrolled manifold concept: Identifying control variables for a functional task. *Experimental Brain Research*. <https://doi.org/10.1007/s002210050738>

Shim, J. K., Latash, M. L., & Zatsiorsky, V. M. (2005). Prehension Synergies: Trial-to-Trial Variability and Principle of Superposition During Static Prehension in Three Dimensions. *J Neurophysiol*.

Shinohara, M., Scholz, J. P., Zatsiorsky, V. M., & Latash, M. L. (2004). Finger interaction during accurate multi-finger force production tasks in young and elderly persons. *Experimental Brain Research*, *156*(3), 282–292. <https://doi.org/10.1007/s00221-003-1786-9>

Solnik, S., Pazin, N., Coelho, C. J., Rosenbaum, D. A., Scholz, J. P., Zatsiorsky, V. M., & Latash, M. L. (2013). End-state comfort and joint configuration variance during reaching. *Experimental Brain Research*, *225*(3), 431–442. <https://doi.org/10.1007/s00221-012-3383-2>

Tinetti, M. E., Speechley, M., & Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. *The New England Journal of Medicine*, *319*, 1701–1707.

Winter, D. A. (2009). *Biomechanics and Motor Control of Human Movement: Fourth Edition*. *Biomechanics and Motor Control of Human Movement: Fourth Edition*. <https://doi.org/10.1002/9780470549148>

Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: A review of an emerging area of research. *Gait and Posture*, 16(1), 1–14. [https://doi.org/10.1016/S0966-6362\(01\)00156-4](https://doi.org/10.1016/S0966-6362(01)00156-4)

Wu, Y. H., Pazin, N., Zatsiorsky, V. M., & Latash, M. L. (2013). Improving finger coordination in young and elderly persons. *Experimental Brain Research*, 226(2), 273–283. <https://doi.org/10.1007/s00221-013-3433-4>

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology*. <https://doi.org/10.1080/1750984X.2012.723728>

Young, W. R., & Williams, A. M. (2014). Gait & Posture How fear of falling can increase fall-risk in older adults : Applying psychological theory to practical observations. *Gait & Posture*. <https://doi.org/10.1016/j.gaitpost.2014.09.006>

Figures' captions

Figure 1. Schematic of the experimental set-up with clusters, active markers (red circles) and virtual markers (blue circles).

Figure 2. Geometric model linking joint angles to changes in the control variables. The 12 angles used in the Jacobian matrices were (from Θ_1 to Θ_{12}): ankle, knee, hip, lumbar-spine, thoracic-spine, cervical-spine, atlanto-occipital, sternoclavicular, shoulder, elbow, wrist and hand-cup angle.

Figure 3. Average and standard deviation (SD) over time for the horizontal and vertical positions of the (A) CoM and of the (B) cup position, and (C) cup angle with the horizontal, across all participants.

Figure 4. Synergy index (ΔV_z) and standard deviation (SD) over time of the (A) horizontal and vertical positions of the CoM, (B) bidimensional position of the cup and (C) angle of the cup with the horizontal.

Figure 5. Average synergy index (ΔV_z) with standard error bars for each movement phase (1: preparatory, 2: lift-off, 3: extension) for the (A) horizontal position of the CoM, for the (B) vertical position of the CoM, for the (C) bidimensional position of the cup, and for the (D) cup angle with the horizontal. Asterisks indicate significant differences between Phases (* $p < 0.05$).

Figure 6. Average smoothness with standard error bars for the (A) CoM and cup in the horizontal and vertical direction and for the (B) cup angle with the horizontal for young and old adults. Asterisks indicate significant differences between the older and younger groups (* $p < 0.05$).

Figure 7. Average V_{UCM} and V_{ORT} and standard error (SD) over time of the (A) CoM in the horizontal and (B) vertical direction for older and younger groups.

Figure 1.

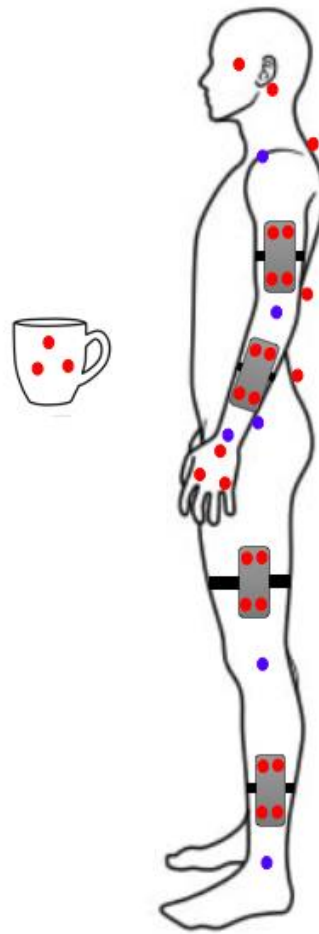


Figure 2.

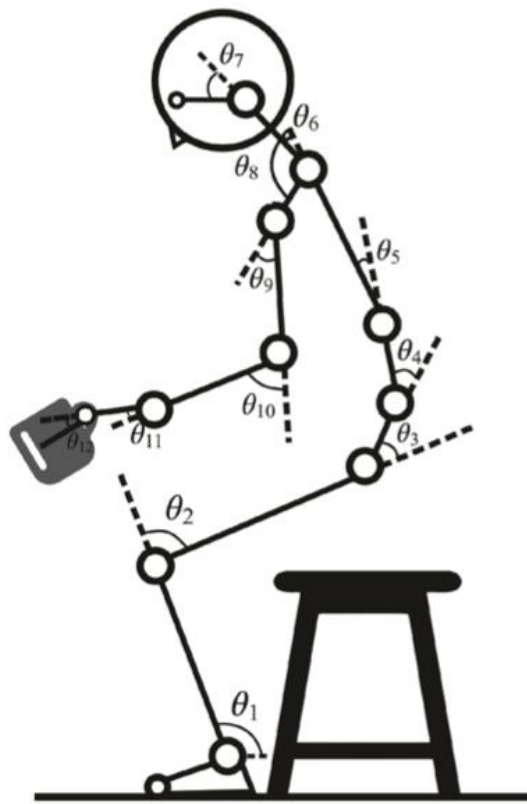


Figure 3.

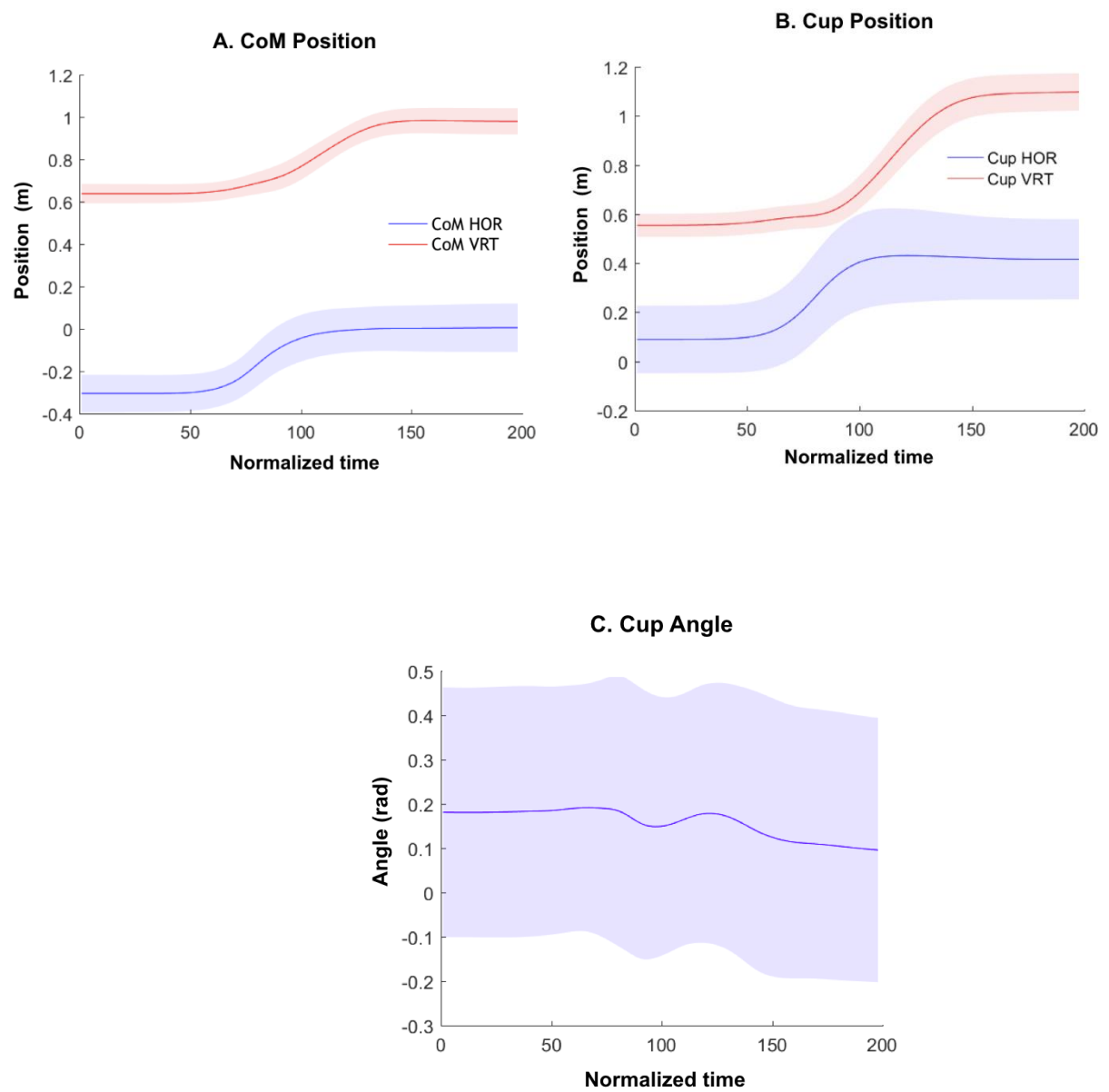


Figure 4.

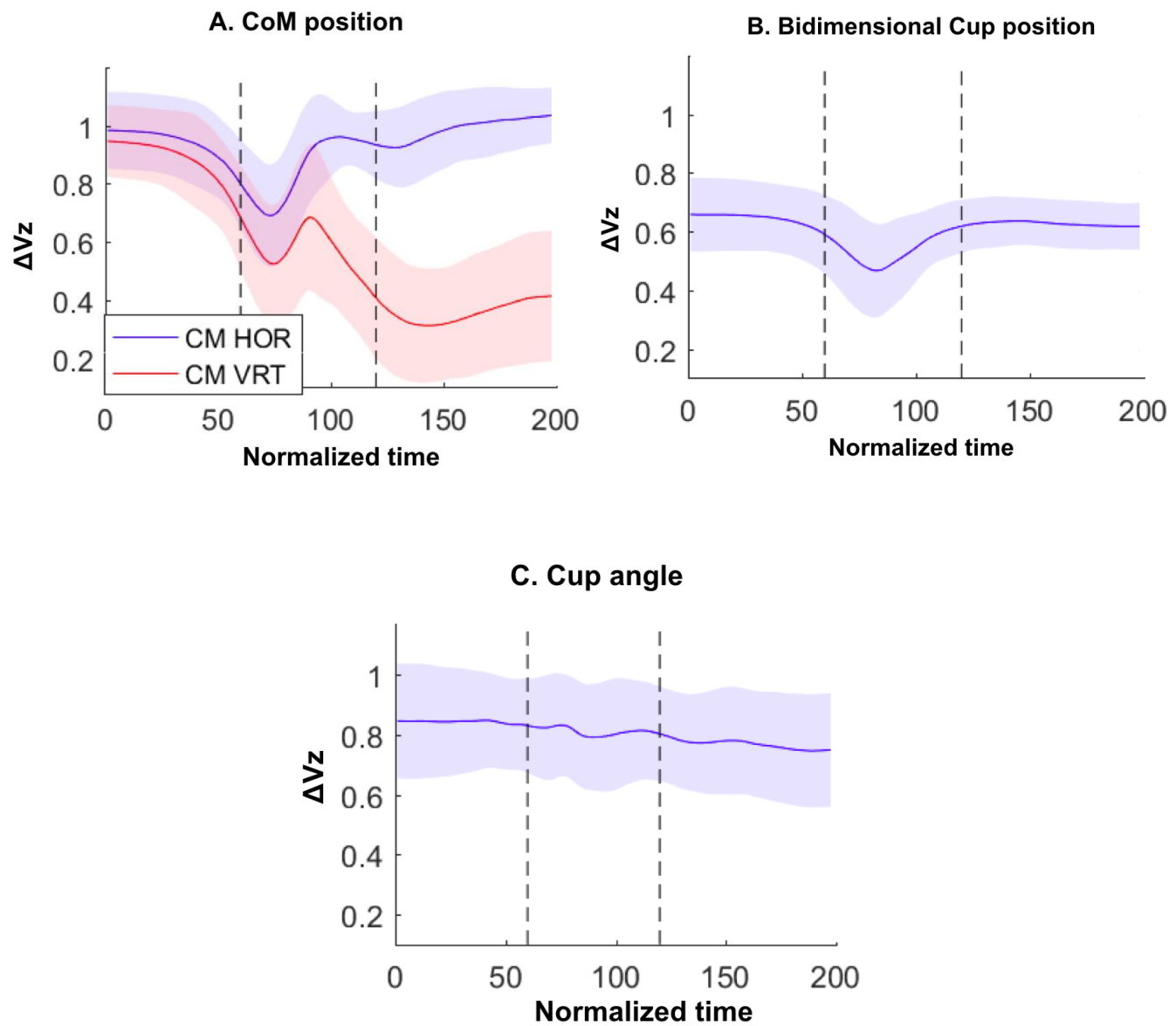


Figure 5.

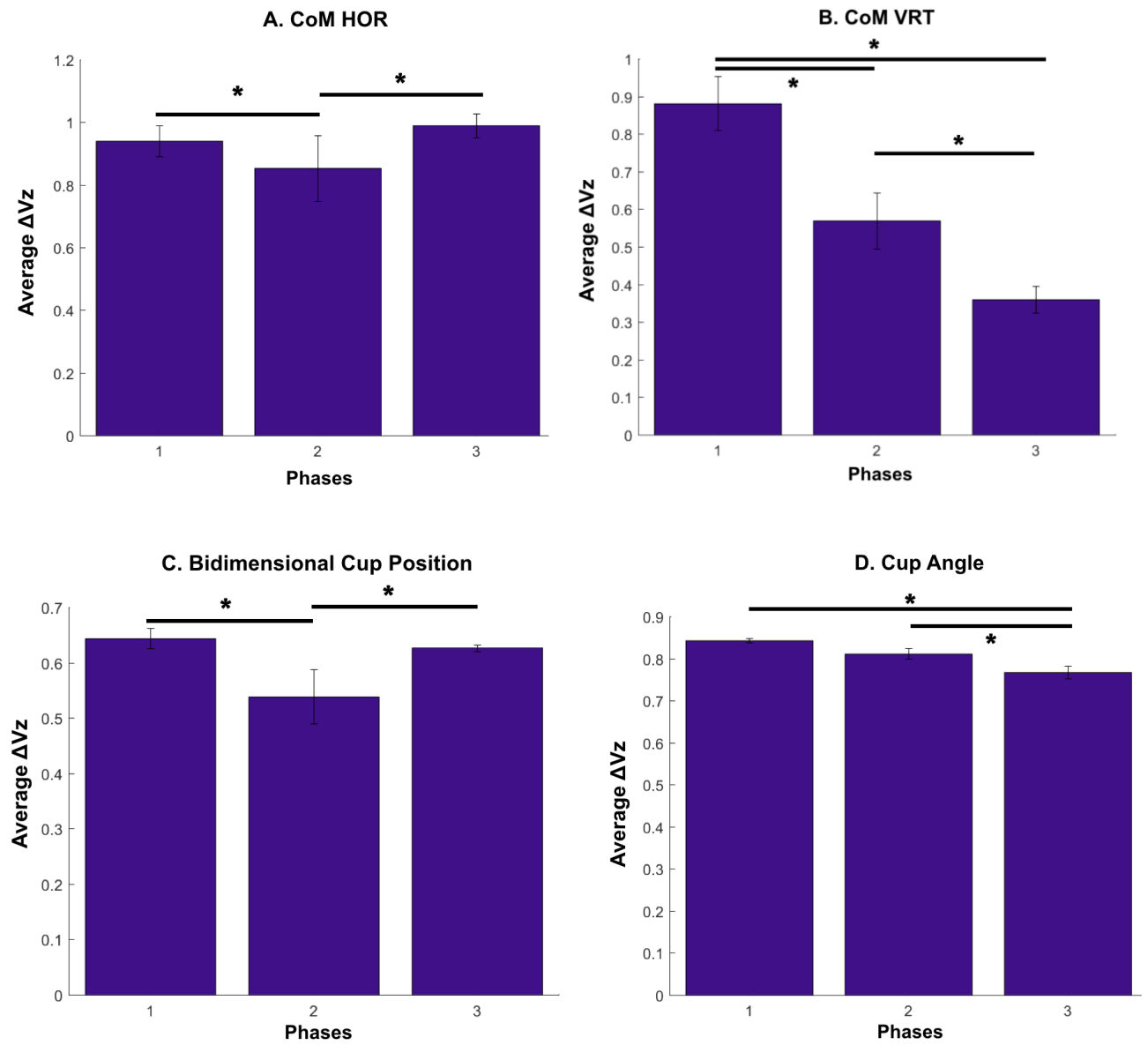


Figure 6.

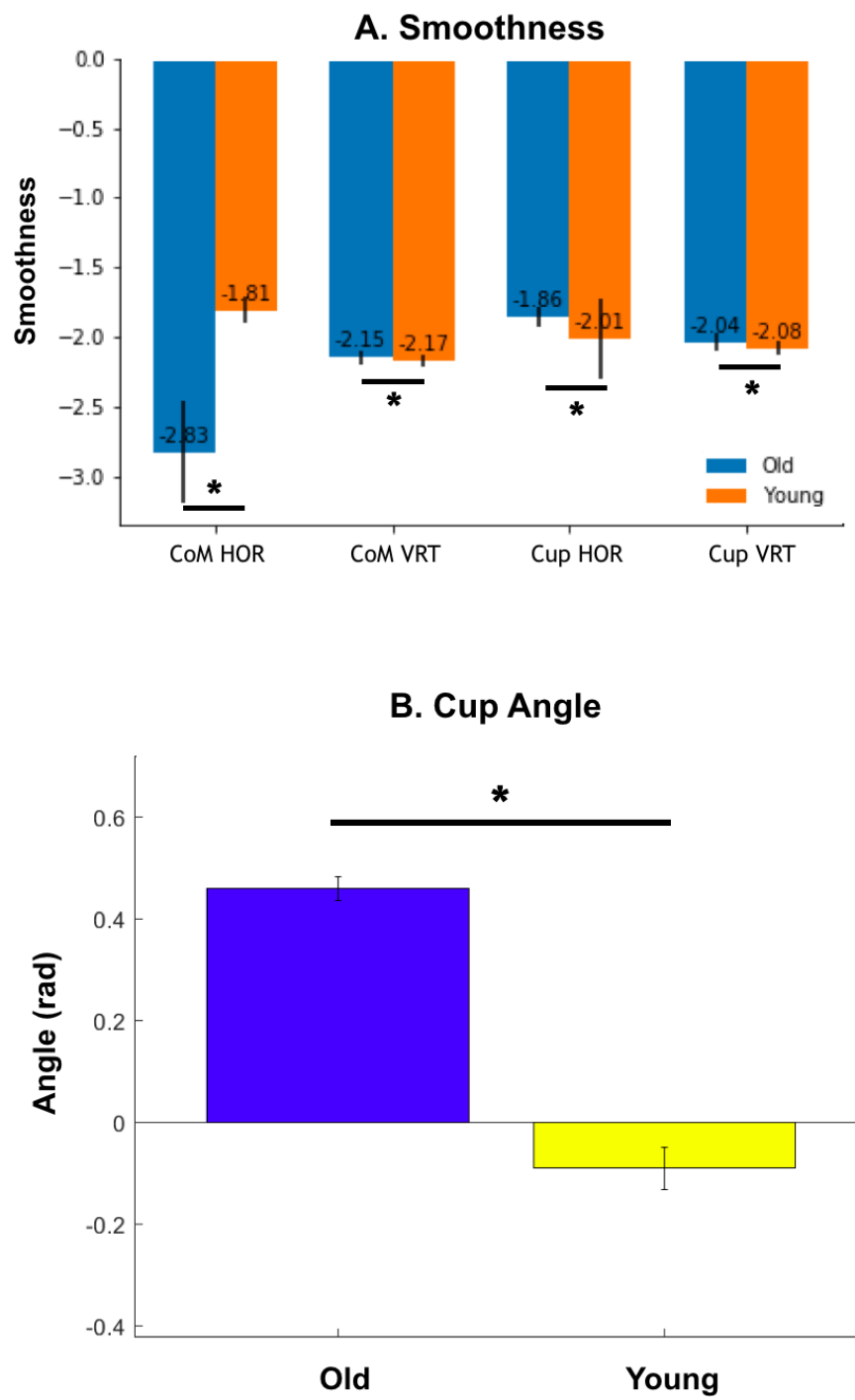
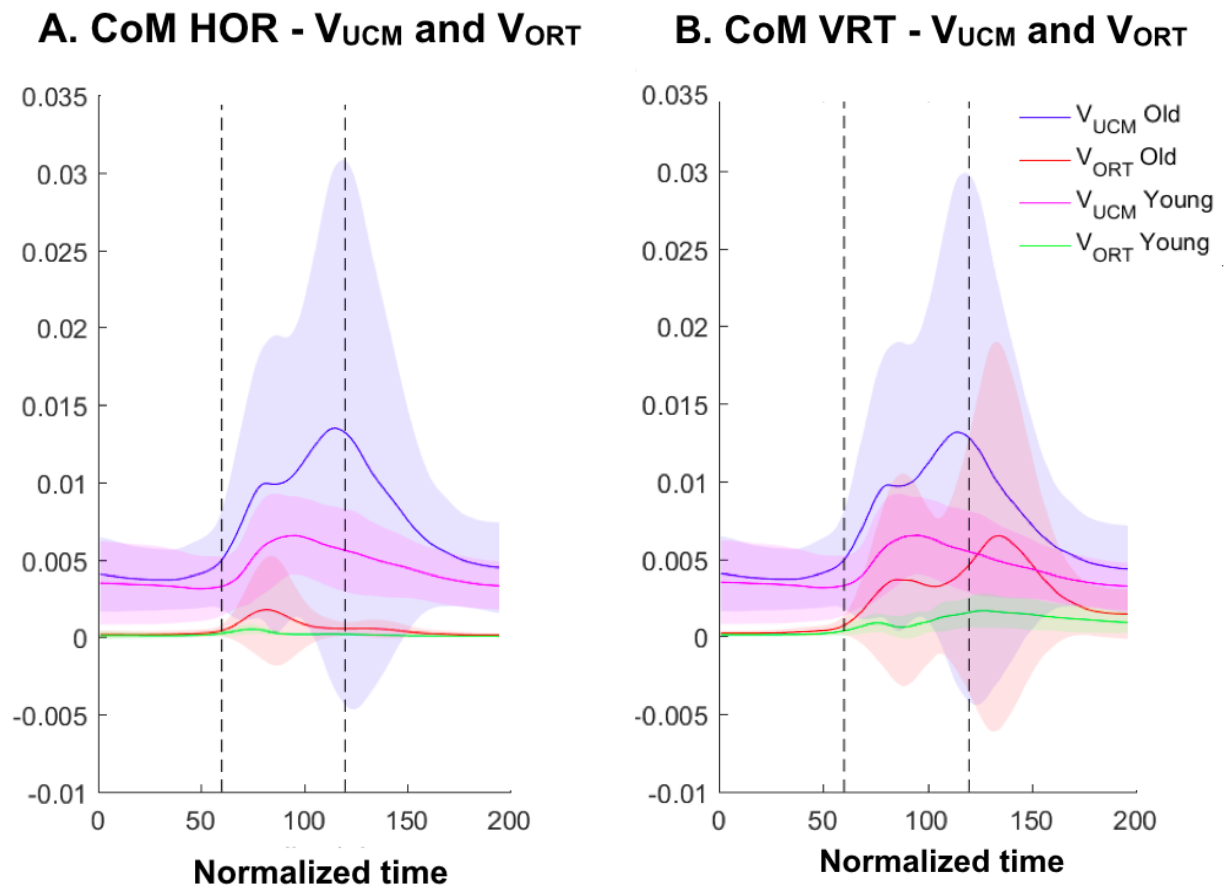


Figure 7.



We, Valéria A Pinto, Alysson F Mazoni, Daniela J S Mattos, Camila V dos Santos, Juliana M Ocarino, Subobrata Mitra and Daniela V Vaz, authors of the paper “Effects of age and attentional focus on performance and coordination of the sit-to-stand task” declare that we have no conflicts of interest to disclose.

CONSIDERAÇÕES FINAIS

Este estudo visou contribuir para o avanço do conhecimento no campo da reabilitação, que é a proposta da linha de pesquisa em que ele foi desenvolvido: Desempenho Motor e Funcional Humano, do Programa de Pós-Graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais. O movimento de passar de sentado para de pé é realizado repetidas vezes ao longo do dia e é associado, com frequência, a tarefas supra-posturais. O desempenho e a coordenação nessa tarefa podem deteriorar com o envelhecimento ou em decorrência de alguma lesão musculoesquelética, o que faz com que o seu treinamento seja uma demanda comum no ambiente clínico. Entender como ocorre o movimento de passar de sentado para de pé, não só no nível do desempenho, mas também da coordenação, é essencial para elaborar propostas de intervenção bem fundamentadas.

Os resultados deste estudo indicaram que o desempenho na tarefa de passar de sentado para de pé segurando uma caneca não foi consistentemente diferente entre jovens e idosos. Apesar disso, a análise da coordenação com o método UCM mostrou que os idosos apresentaram valores de V_{UCM} e V_{ORT} maiores do que os jovens para as posições do CM na horizontal e vertical. No entanto, os jovens apresentaram maior índice de sinergia do que os idosos para a posição horizontal e vertical do CM. Não houve evidência de diferença significativa para os demais índices de sinergia analisados entre os dois grupos de idade. Dessa forma, o estudo sugere que alterações da coordenação são evidentes antes mesmo do declínio de desempenho, que é comum com o envelhecimento. Para ambos os grupos, a posição horizontal do CM do corpo é a variável de controle de maior relevância, ou seja, com maior índice de sinergia.

Além disso, instruções de foco de atenção não foram capazes de alterar o desempenho ou a coordenação de jovens e idosos. Embora a literatura que indica os benefícios do foco externo em relação ao interno seja extensa, é possível que esses benefícios sejam limitados a tarefas complexas, como os

gestos esportivos, que, geralmente, são adquiridas após práticas guiadas por instruções explícitas. A tarefa de passar de sentado para de pé é aprendida naturalmente nos primeiros anos de vida e, tanto os idosos quanto os jovens que se voluntariaram a participar deste estudo não apresentavam queixa ou dificuldade para realizá-la. É possível que tarefas bem treinadas e adquiridas espontaneamente com o desenvolvimento, como passar de ST-DP, sejam menos afetadas pelos efeitos negativos do foco interno ou pelos efeitos positivos do foco externo.

Este estudo investigou aspectos de desempenho e coordenação da tarefa de passar de sentado para de pé, diferenças entre idosos e jovens em relação a estes dois aspectos, e os efeitos de uma estratégia cognitiva com potencial para modificar ambos positivamente. Os achados podem subsidiar propostas futuras para prevenir o declínio funcional de idosos nesta importante tarefa da vida diária.

REFERÊNCIAS

- ANAN, M. *et al.* The coordination of joint movements during sit-to-stand motion in old adults: the uncontrolled manifold analysis. **Physical Therapy Research**, 2017.
- BUATOIS, S. *et al.* Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. **Journal of the American Geriatrics Society**, v. 56, n. 8, p. 1575–1577, 2008.
- DALL, P. M.; KERR, A. Frequency of the sit to stand task: An observational study of free-living adults. **Applied Ergonomics**, 2010.
- DANNESKIOLD-SAMSØE, B. *et al.* Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. **Acta Physiologica**, v. 197, n. Suppl. 673, p. 1–68, 2009.
- FIETZER, A. L.; WINSTEIN, C. J.; KULIG, K. Changing one's focus of attention alters the structure of movement variability. **Human Movement Science**, v. 62, n. September, p. 14–24, 2018.
- GERA, G. *et al.* Motor abundance contributes to resolving multiple kinematic task constraints. **Motor Control**, v. 14, p. 83–115, 2010.
- GREVE, C. *et al.* Not All Is Lost: Old Adults Retain Flexibility in Motor Behaviour during Sit-to-Stand. **PLoS ONE**, 2013.
- GREVE, C.; HORTOBÁGYI, T.; BONGERS, R. M. Flexibility in joint coordination remains unaffected by force and balance demands in young and old adults during simple sit-to-stand tasks. **European Journal of Applied Physiology**, v. 119, n. 2, p. 419–428, 2019.
- HSU, W. L.; CHOU, L. S.; WOOLLACOTT, M. Age-related changes in joint coordination during balance recovery. **Age**, v. 35, n. 4, p. 1299–1309, 2013.
- HUGHES, M. A.; MYERS, B. S.; SCHENKMAN, M. L. The role of strength in rising from a chair in the functionally impaired elderly. **Journal of Biomechanics**, 1996.

KAL, E. C.; VAN DER KAMP, J.; HOUDIJK, H. External attentional focus enhances movement automatization: A comprehensive test of the constrained action hypothesis. **Human Movement Science**, 2013.

LATASH, M. L. **Synergy**. 1 ed. New York: Oxford University Press, 2008.

LATASH, M. L.; SCHOLZ, J. P.; SCHÖNER, G. Toward a New Theory of Motor Synergies. **Motor Control**, 2007a.

LATASH, M. L.; SCHOLZ, J. P.; SCHÖNER, G. Toward a New Theory of Motor Synergies. **Motor Control**, v. 11, n. 3, p. 276–308, 2007b.

LOHSE, K. R.; SHERWOOD, D. E.; HEALY, A. F. How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. **Human Movement Science**, 2010.

LORD, S. R. *et al.* Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. Incidence and epidemiology of anal cancer in the multicenter AIDS cohort study. **The journals of gerontology. Series A, Biological sciences and medical sciences**, v. 57, n. 8, p. M543, 714.

MAKIZAKO, H. *et al.* Predictive cutoff values of the Five-Times Sit-to-Stand and the Timed “Up & Go” Test for disability incidence in older people dwelling in the community. **Physical Therapy**, v. 4, n. 97, p. 417–124, 2017.

OLAFSDOTTIR, H. *et al.* Age-related changes in multifinger synergies in accurate moment of force production tasks. **Journal of Applied Physiology**, v. 102, n. 4, p. 1490–1501, 2007.

OLAFSDOTTIR, H. B.; ZATSIORSKY, V. M.; LATASH, M. L. The effects of strength training on finger strength and hand dexterity in healthy elderly individuals. **Journal of Applied Physiology**, v. 105, n. 4, p. 1166–1178, 2008.

PATIL, G. *et al.* Momentum-based trajectory planning for lower-limb exoskeletons supporting sit-to-stand transitions. **International Journal of Intelligent Robotics and Applications**, v. 2, n. 2, p. 180–192, 2018.

SCHENKMAN, M. *et al.* Whole-body movements during rising to standing from sitting. **Physical therapy**, v. 70, n. 10, p. 638–48; discussion 648-51, 1990.

SCHOLZ, J. P.; REISMAN, D.; SCHÖNER, G. Effects of varying task constraints on solutions to joint coordination in a sit-to-stand task. **Experimental Brain Research**, v. 141, n. 4, p. 485–500, 2001.

SCHOLZ, J. P.; SCHÖNER, G. The uncontrolled manifold concept: Identifying control variables for a functional task. **Experimental Brain Research**, v. 126, n. 3, p. 289–306, 1999.

SHINOHARA, M. *et al.* Finger interaction during accurate multi-finger force production tasks in young and elderly persons. **Experimental Brain Research**, v. 156, n. 3, p. 282–292, 2004.

TINETTI, M. E.; SPEECHLEY, M.; GINTER, S. F. Risk factors for falls among elderly persons living in the community. **The New England Journal of Medicine**, v. 319, p. 1701–1707, 1988.

WOOLLACOTT, M.; SHUMWAY-COOK, A. Attention and the control of posture and gait: A review of an emerging area of research. **Gait and Posture**, v. 16, n. 1, p. 1–14, 2002.

WULF, G. **Attention and moto skill learning**. 1 ed. Human Kinetics, 2007.

WULF, G. *et al.* External Focus Instructions Reduce Postural Instability in Individuals With Parkinson Disease. **Physical Therapy**, 2009.

WULF, G. Attentional focus and motor learning: A review of 15 years. **International Review of Sport and Exercise Psychology**, 2013.

WULF, G.; MCNEVIN, N.; SHEA, C. H. The automaticity of complex motor skill learning as a function of attentional focus. **Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology**, v. 54, n. 4, p. 1143–1154, 2001.

APÊNDICE 1: Termo de consentimento livre e esclarecido**SIT-TO-STAND STUDY****Informed consent**

I have read the SIT-TO-STAND STUDY Information for Participants document.

The experimenters have shown me the motion activity sensors and explained how and where they would be placed. I understand the experimental task I will be asked to perform during data collection.

I have been told that my sex, height, and weight, and the length of my arm, leg, torso and neck segments will be measured and recorded for the purpose of biomechanical calculations.

I understand that all my data will be stored under an anonymised, pre-generated participant ID, and that it will not remain possible for the researchers or anyone else to identify me from the records kept for the purpose of this study.

I understand that, at the end of the session, I will receive a debrief explaining the purpose and significance of the experiment in more detail.

Based on this information, I agree to be a participant in this study.

----- (Signature)

----- (Date)

MINI-CURRÍCULO

Valéria Andrade Pinto

FISIOTERAPEUTA

CREFITO-4/ 231.098-F

<http://lattes.cnpq.br/6939530145711530>

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**Estágio em docência*

2.1.2 Disciplina FIT003: Cinesiologia Aplicada a Fisioterapia* (agosto a dezembro/2018)

**Estágio em docência*

3. Experiência clínica:

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4.1 IV CIM - Congresso de Inovação e Metodologias no Ensino Superior (2019)

- 4.2 8th World Congress of Biomechanics (2018)
- 4.3 VIII Seminário Mineiro do Comportamento Motor (2017)
- 4.4 22nd Congress of the European Society of Biomechanics (2016)
- 4.5 XXV Semana de Iniciação Científica/PRPQ (2016)
- 4.6 I Congresso da Associação Brasileira de Fisioterapia Traumatológica Ortopédica (2015)
- 4.7 XXIV Semana de Iniciação Científica /PRPQ (2015)
- 4.8 II Jornada Acadêmica de Fisioterapia (2015)
- 4.9 1st PanAmerican Congress of Physiological Science (2014)
- 4.10 5th International Meeting on the Physiology and Pharmacology of Temperature Regulation (2014)
- 4.11 5th International Symposium on the Physiology and Pharmacology of Temperature Regulation (2014)
- 4.12 XXV Congreso Internacional Sociedade Galega de Xerontología e Xeriatria (2013)
- 4.13 I Congreso Nacional de Estudiantes de Fisioterapia de A Coruña (2012)
- 4.14 VII Congreso Internacional de la Asociación Española de Ciencias del Deporte (2012)

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- 5.1 Vaz D., **Pinto V.**, Junior R., Mattos D., Mitra S. (2018), Coordination in adults with neurological dysfunction - a systematic review of Uncontrolled Manifold studies. *Gait and Posture*. Accepted with revision.
- 5.2 Souza T., Pires C., Carvalho D., Fonseca S., Teixeira B. Barsante L., **Pinto V.**, Almeida R. (2018), Pelvic sagittal torsion caused by induced leg length discrepancy: geometrical illusion may influence measures based on superior-iliac spines positions. *Journal of Manipulative and Physiological Therapeutics*. Accepted with revision.

5.3 Moraes M., Rabelo P., **Pinto V.**, Pires W., Wanner S., Szawka R., Soares D. (2018), Auditory stimulation by exposure to melodic music increases dopamine and serotonin activities in rat forebrain areas linked to reward and motor control. *Neuroscience Letters*, 73:78. doi: 10.1016/j.neulet.2018.02.058

5.4 Kunstetter A., Barbosa N., Moraes M., **Pinto V.**, Soares D., Pires W., Wanner S., (2017), Pre-exercise exposure to the treadmill setup changes the cardiovascular and thermoregulatory responses induced by subsequent treadmill running in rats. *Temperature*. doi:10.1080/23328940.2017.1388343

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7.2 Fisioterapia Manual em Cirurgia Plástica e Tecidos Cicatriciais (2018) – *carga horária: 30 horas*

7.3 Atendimento Cardiovascular de Emergência (2016) – *carga horária: 8 horas*