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IDOSOS APRESENTAM ALTERAÇÃO DO PADRÃO DE MOVIMENTO DE PELVE E DE TRONCO DURANTE A MARCHA?

Uma revisão sistemática com meta-análise e recomendações grade

Belo Horizonte

Belo Horizonte Escola de Educação Física, Fisioterapia e Terapia Ocupacional/UFMG

2020

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Dissertação apresentada ao programa de pós-graduação em Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais, como requisito a obtenção de título de Mestre em Ciências da Reabilitação.
Área de concentração: Desempenho Funcional
Humano Orientador: Prof. Dr. Renan Alves Resende
Coorientador: Prof. Dr. Rafael Zambelli Pinto

Belo Horizonte

Escola de Educação Física, Fisioterapia e Terapia Ocupacional/UFMG

2020

C982i Cury, Ana Carolina
2020 Idosos apresentam alteração do padrão de movimento de pelve e de tronco durante a marcha? Uma revisão sistemática com meta-análise e recomendações grade. [manuscrito] / Ana Carolina Cury – 2020.
56 f., il.

Orientador: Renan Alves Resende
Coorientador: Rafael Zambelli Pinto

Dissertação (mestrado) – Universidade Federal de Minas Gerais, Escola de Educação Física, Fisioterapia e Terapia Ocupacional.
Bibliografia: f. 53-55

1. Idosos – saúde e higiene – Teses. 2. Aptidão física em idosos – Teses. 3. Marcha – Teses. 4. Envelhecimento – Teses. 5. Biomecânica – Teses. I. Resende, Renan Alves. II. Pinto, Rafael Zambelli. III. Universidade Federal de Minas Gerais. Escola de Educação Física, Fisioterapia e Terapia Ocupacional. IV. Título.

CDU: 612.76

Ficha catalográfica elaborada pelo bibliotecário Danilo Francisco de Souza Lage, CRB 6: n° 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**	UFMG

ATA DA DEFESA DA DISSERTAÇÃO DA ALUNA
ANA CAROLINA CURY

Realizou-se, no dia 03 de setembro de 2020, às 15:00 horas, online, da Universidade Federal de Minas Gerais, a defesa de dissertação, intitulada *IDOSOS APRESENTAM ALTERAÇÃO DO PADRÃO DE MOVIMENTO DE PELVE E DE TRONCO DURANTE A MARCHA? UMA REVISÃO SISTEMÁTICA COM META-ANÁLISE E RECOMENDAÇÕES GRADE.*, apresentada por ANA CAROLINA CURY, número de registro 2017715861, 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). Renan Alves Resende - Orientador (Universidade Federal de Minas Gerais), Prof(a). Juliana de Melo Ocarino (UFMG), Prof(a). Janaine Cunha Polese (Faculdade Ciências Médicas de Minas Gerais (FCMMG)).

A Comissão considerou a dissertação:

(X) Aprovada

(   ) Reprovada

Finalizados os trabalhos, lavrei a presente ata que, lida e aprovada, vai assinada por mim e pelos membros da Comissão.
Belo Horizonte, 03 de setembro de 2020.

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Janaine C. Polese

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AGRADECIMENTOS

A Deus, pela fé que me sustenta, por nos enviar seu filho como nosso modelo maior de conduta.

Ao meu filho, luz da minha vida, que me trouxe até aqui. Sem você a mamãe não teria essa coragem!

Aos meus pais, pelo exemplo de luta e dedicação constante, por me levantarem todas as vezes que meus joelhos fraquejaram. Muito obrigada por sempre acreditar em mim. Amo vocês!

Aos meus irmãos Mariana e Gustavo pelo companheirismo e por me ensinar a ser sempre melhor!

Ao Thiago, por me apoiar.

Às minhas grandes amigas: Isabela, Alice, Stael, Bela, Bibi, Sabrina: Obrigada por serem alegria em minha vida!

Ao meu orientador, Renan Resende, pela paciência, pelo conhecimento e pela dedicação. Aprendi tanto com você, e sou grata por ganhar a sua confiança e sua amizade! Você é um profissional excepcional, mas o que te faz uma pessoa especial é o seu caráter, sua humildade, delicadeza e senso de justiça. Eu jamais poderia ter chegado até aqui sem o seu apoio e sua compreensão. Você é o melhor orientador que eu poderia ter! Muito obrigada!

Ao meu co-orientador Rafael Zambelli pelas conversas, pelo incentivo à autonomia e aprendizado e por me auxiliar nessa trajetória!

Agradeço também aos professores que tanto me incentivaram a encarar esse desafio: Juliana Ocarino, Sérgio Fonseca, Liria Okai e Thales Souza. Sou muito grata por terem me oferecido incentivo e por me fazerem enxergar meu potencial.

Aos funcionários do departamento de Fisioterapia, em especial a Eliane por facilitar, sempre que possível, os andamentos ao longo do mestrado!

Aos colegas de mestrado que me auxiliaram tanto nesse processo: Thais, Fernanda (essa conquista não aconteceria sem a sua ajuda!), Geo, Larissa: obrigada por compartilharem o conhecimento e ajudarem na formação desse trabalho!

Obrigada a todos que de alguma forma contribuíram para esse trabalho!!!

"Diante de diagnósticos e estatísticas,

é preciso sempre lembrar das reticências

que residem nas sutilezas do inexplicável.

E em tudo aquilo que não se pode ver."

Roberta Ferec

RESUMO

Diversos fatores podem influenciar na eficiência da marcha de idosos, como aspectos cognitivos, sensoriais e biomecânicos. Entre os fatores biomecânicos, a redução da amplitude de movimento dos segmentos da pelve e do tronco em idosos tem sido associada à menor velocidade da marcha, menor comprimento do passo e maior suscetibilidade a quedas. O objetivo dessa dissertação foi revisar os estudos que compararam o movimento da pelve e do tronco durante a marcha entre adultos e idosos. A busca eletrônica foi realizada nas bases de dados MEDLINE, EMBASE e Cinahl, sem limite de data de início até maio de 2020. Foram incluídos na revisão estudos que compararam o deslocamento angular do tronco e/ou pelve durante a marcha entre adultos e idosos. Estudos com participantes acometidos por qualquer condição de saúde que pudesse influenciar a marcha foram excluídos. Os seguintes dados foram extraídos: velocidade da marcha, superfície de caminhada e amplitude de movimento (ADM) de tronco e pelve durante a marcha nos três planos de movimento. As metanálises foram calculadas para três faixas diferentes de velocidade da marcha usando o random effects model e resumidas estatisticamente através da diferença média padronizada (DMP) O sistema GRADE foi aplicado para a determinação da força da evidência. A busca identificou 1414 artigos (excluindo duplicatas). Após a triagem, doze estudos foram incluídos para revisão quantitativa. Os resultados demonstraram evidência de qualidade moderada de que idosos apresentam menor ADM de rotação pélvica durante a marcha em velocidade auto-selecionada (DMP=-0,90 [-1,35, -0,45]) e menor ADM de rotação pélvica durante a marcha em velocidade rápida (DMP= -1,55 [-3,43, -0,33]). Além disso, foi encontrada evidência de baixa qualidade de que idosos apresentam redução da ADM de rotação do tronco durante a marcha em velocidade rápida (DMP= -0,63 [-1,23, -0,03]). Idosos e adultos não apresentaram diferença nas ADMs de movimentos pélvico e tronco nos planos sagital e frontal em nenhuma velocidade de marcha. Idosos andam com menor ADM de rotação pélvica em velocidade auto-selecionada e rápida, e menor ADM de rotação do tronco durante a velocidade rápida. A qualidade da evidência variou de baixa a alta.

Palavras-chave: Cinemática. Marcha. Envelhecimento. Pelve. Tronco. Metanálise.

ABSTRACT

Several factors affect the gait efficiency of older adults, such as cognitive, sensory and biomechanical aspects. Among the biomechanical factors, the reduction in the range of motion (ROM) of the pelvis and trunk segments has been associated with lower gait speed, shorter stride length and greater susceptibility to falls. The purpose of this dissertation was to review the studies that compared the movement of the pelvis and trunk during gait between adults and older adults. The electronic search was performed in the MEDLINE, EMBASE and Cinahl databases, from inception until May, 2020. Studies were included in the review if they compared the angular displacement of the trunk and/or pelvis during gait between adults and older adults. Studies with participants with any health condition that could influence gait were excluded. The following data were extracted: gait speed, walking surface and range of motion (ROM) of the trunk and pelvis during gait in the three planes of movement. Meta-analyzes were calculated for three different ranges of gait speed using the random effects model and summarized statistically using the standardized mean difference (SMD). The GRADE system was applied to determine the strength of the evidence. The search identified 1414 articles (excluding duplicates). After screening, twelve studies were included for quantitative review. The results showed evidence of moderate quality that the elderly offer a lower ROM of pelvic rotation during walking at self-transmitted speed (SMD= -0.90 [-1.35, -0.45]) and a lower ROM of pelvic rotation during walking. walking at fast speed (SMD = -1.55 [-3.43, -0.33]). In addition, there was low-quality evidence that the older adults have a smaller ROM of trunk rotation during walking at rapid speed (SMD= -0.63 [-1.23, -0.03]). There was no difference between adults and older adults in ROM of pelvic and trunk movements in the sagittal and frontal regardless of walking speed. Older adults walk with smaller pelvic rotation ROM at self-selected and fast speeds, and lower trunk rotation ROM during fast speed. The quality of the evidence varied from low to high.

Keywords: Kinematics. Walking. Aged. Pelvis. Torso. Data pooling.

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LISTA DE ABREVIATURAS

ADM – Amplitude de movimento

ROM – Range of motion

CM – centro de massa

SMD – standardized mean difference

UFMG – Universidade Federal de Minas Gerais

PREFÁCIO

De acordo com as normas para elaboração de dissertações do Programa de Pós-graduação em Ciências da Reabilitação da Universidade Federal de Minas Gerais, este trabalho possui três partes. A primeira é composta por uma introdução, que apresenta a revisão bibliográfica sobre o tema, a justificativa, objetivo e a hipótese do estudo. A segunda parte é composta por um artigo, com descrição dos métodos utilizados, resultados, discussão e conclusão. O artigo foi redigido de acordo com as normas do periódico escolhido para publicação (Brazilian Journal of Physical Therapy – ISSN: 1413 -355). A terceira e última parte deste trabalho possui as considerações finais, referências bibliográficas.

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INTRODUÇÃO

Diversos fatores podem influenciar na eficiência da marcha de idosos, fatores cognitivos, sensoriais e biomecânicos. Estudos prévios demonstraram que idosos apresentam diminuição da velocidade, do comprimento do passo, aumento da largura da base de suporte e perda de estabilidade durante a marcha (BOYER,2017; MENZ,2003; COFRÈ, 2005). O envelhecimento reduz a força muscular, a mobilidade articular, o condicionamento físico e altera o equilíbrio estático e dinâmico (BOYER, 2017; MENZ, 2003; COFRÈ, 2011; JUNG, 2016), o que pode prejudicar o desempenho durante a marcha nesta população. (RANTANEN, 2018). Essas alterações da marcha em idosos parecem ter relação com maior risco de quedas e suas complicações, assim como com restrições de mobilidade e participação de idosos na comunidade (MORELAND, 2004; KASUKAWA,2017). Por exemplo, a perda de força e de extensibilidade dos flexores plantares está associada à redução do comprimento do passo e da velocidade e estabilidade da marcha (MCGIBBON,2003), aumentando o risco de quedas. Além disso, estudos mais recentes demonstraram uma associação entre alterações da postura do tronco durante a marcha e maior dependência para a realização de atividades de vida diária em idosos (KAMITANI,2013). Portanto, faz-se necessário compreender melhor o grande volume de informações existente na literatura sobre as relações entre o envelhecimento e o desempenho da marcha.

Há atualmente um grande número de estudos que demostraram que o envelhecimento influencia aspectos espaço-temporais, cinemáticos e cinéticos durante a marcha (HERSSENS,2018; NEPTUNE, 2001; JUNG, 2016; MCGIBBON 2003). Existem diferentes métodos de avaliação da marcha de idosos, desde a observação visual e testes clínicos padronizados até sistemas de medidas da marcha mais avançados, que usam diferentes recursos tecnológicos, como os sistemas tridimensionais de análise de movimento. Apesar de o uso desses sistemas ter gerado um avanço na compreensão das alterações da marcha de idosos que podem levar a déficits de equilíbrio e perda de mobilidade, não há consenso a respeito das diferenças na cinemática e cinética da marcha em idosos quando comparados com indivíduos adultos jovens, o que poderia ajudar a esclarecer os efeitos do envelhecimento sobre a marcha. (BOYER, 2017)

A maior parte da literatura existente até o momento concentra-se principalmente em pesquisas sobre as alterações observadas nos movimentos dos membros inferiores de idosos durante a marcha. Por exemplo, Herssens *et al.* (HERSSENS, 2018) demonstraram que a marcha de idosos é caracterizada por diminuição da velocidade, cadência e comprimento do passo e da passada. Além disso, uma revisão sistemática realizada por Boyer *et al*. (BOYER, 2017) demonstrou que idosos apresentam menor amplitude de movimento (ADM) do tornozelo e do quadril ao longo de todo o ciclo da marcha, além de menores ângulos de extensão do joelho no contato inicial e na fase de balanço, menor extensão de quadril durante o apoio médio, e menores ângulos de extensão de quadril e de flexão plantar do tornozelo durante a fase de pré-balanço quando comparados com adultos. Além disso, foi demonstrado que idosos produzem menor potência de tornozelo e maior potência de quadril no plano sagital durante a marcha do que adultos jovens, o que pode ajudar a explicar a menor velocidade da marcha em idosos, já que dois terços da energia necessária para realizar a impulsão da marcha é gerada no tornozelo (NEPTUNE,2001) e o aumento de potência no quadril parece não ser capaz de compensar a redução de potência no tornozelo.

Um crescente número de estudos vem demonstrando que é possível que o declínio na eficiência da marcha observado em idosos também pode estar associado a alterações do tronco e da pelve durante a marcha (SHISHOV, 2017; GOLLHOFER, 2012). Alguns estudos exploraram as relações entre as alterações das articulações dos membros inferiores, a pelve e o tronco durante a marcha de idosos. Foi demonstrado que a potência gerada pelos flexores plantares pode auxiliar na progressão do tronco durante a fase de pré-balanço, bem como auxiliar na estabilidade do tronco durante a fase inicial de apoio da marcha. (NEPTUNE, 2011; COFRÈ, 2011). Gimmon *et al.* sugeriram que algumas das mudanças nos padrões de movimento da marcha de idosos, como aumento da cadência e redução de comprimento do passo, podem ser associados com movimentos inadequados da pelve e do tronco, já que a redução da ADM desses segmentos pode reduzir a estabilidade da marcha (GIMMON, 2015). Portanto, alterações cinemáticas encontradas na pelve e no tronco podem refletir respostas compensatórias aos déficits encontrados nas articulações dos membros inferiores.

As regiões da pelve e do tronco também apresentam alterações decorrentes do envelhecimento, como por exemplo, aumento da flexão anterior do tronco e hipercifose torácica, menor mobilidade pélvica e intervertebral, e piora da função muscular de extensores, flexores e flexores laterais do tronco (SURI, 2009; GOLLHOFFER, 2012, SHAHTAHMASSEBI, 2017, KASUKAWA, 2017). Durante a marcha, estudos prévios demonstraram que esses segmentos também apresentam alterações em sua movimentação em idosos, como maior inclinação anterior do tronco e aumento da retroversão pélvica. (VAN

EMMERIK, 2005; AMINIAGHDAM, 2017; LETENEUR, 2015; CRAWFORD, 2018). Além disso, algumas das alterações observadas em idosos nas variáveis espaço-temporais da marcha podem estar relacionadas com alterações de pelve e tórax, pois a mobilidade destes segmentos e a capacidade de modificar a magnitude e padrão de movimentação dos mesmos frente a aumento da velocidade da marcha e ao andar em diferentes superfícies é comprometida pelo envelhecimento (GIMMON, 2015, SHISHOV, 2017, VANEMMERIK, 2005). Essas mudanças na cinemática de pelve e tronco durante a marcha podem estar associadas a um declínio no desempenho da marcha dos idosos, o que pode comprometer, por exemplo, a independência para se movimentar e participar ativamente na comunidade. (BOYER, 2017; RANTANEN, 2018; KANG, 2008; RANTAKOKO, 2013). Um exemplo disso foi a associação encontrada entre hipercifose torácica e a piora da mobilidade de mulheres idosas em comunidade (KATZMAN, 2011).

Dado que a pelve, o tronco, a cabeça e os braços correspondem a aproximadamente 50% da massa corporal total (WINTER, 2009), os padrões alterados de movimento pélvico e do tronco durante a marcha podem explicar parte das mudanças espaço-temporais da marcha em idosos, como o comprimento reduzido da passada e a maior base de suporte (GIMMON, 2015). A hipercifose torácica desloca anteriormente o centro de massa (CM) do tronco e, consequentemente, pode levar a um padrão compensatório do membro inferior com redução da extensão de quadril, aumento da flexão do joelho e da dorsiflexão do tornozelo. A inclinação anterior do tronco no plano sagital foi associada a uma deterioração no desempenho da marcha (TAKASHI, 2005; KAMITANI, 2013) e pode deslocar o centro de gravidade à frente, favorecendo quedas. Além de alterações no plano sagital, estudo prévio demonstrou redução da rotação de tronco no plano transverso durante a marcha em idosos (VANEMMERIK, 2005). As menores amplitudes de rotação do tronco podem ser causadas por diminuição da mobilidade entre os segmentos vertebrais, aumento da rigidez da musculatura do tronco e perda de força muscular dos extensores do quadril (MCGIBBON), dos extensores e flexores do tronco (SURI, 2009, CRAWFORD,2018, KASUKAWA,2017).

Além disso, as alterações no tronco e na pelve também podem contribuir para reduzir a estabilidade em idosos durante a marcha. Por exemplo, Shishov *et al.* (SHISHOV, 2017) demonstraram que idosos caidores apresentam menor amplitude de movimento pélvico e tronco durante a marcha quando comparados aos não-caidores, e essa redução de ADM foi associada a pior desempenho e pior adaptação a velocidades mais rápidas induzidas pela caminhada em esteira.

Apesar do crescente número de estudos que investigam o movimento da pelve e do tronco durante a marcha em idosos (JUNG, 2016; GOLLHOFFER, 2012; SURI, 2009; KERRIGAN, 1998; GIMMON, 2015; VANEMMERIK, 2005), não há consenso se e como o padrão de movimento desses segmentos é alterado em idosos. Uma revisão sistemática com metanálise fornece uma abordagem quantitativa ao combinar os resultados de vários estudos. Sendo assim, oferece mais robustez sobre as pesquisas existentes na literatura e pode ajudar a esclarecer os efeitos do envelhecimento nos padrões de movimento do tronco e da pelve durante a marcha. Esses resultados podem auxiliar no melhor uso e direcionamento de estratégias de avaliação de movimento de pelve e tronco em idosos em ambientes clínicos. A metanálise, por sua vez, é uma abordagem quantitativa para combinar resultados de vários estudos que, ao combinar os resultados de toda a literatura disponível, também fornece um mecanismo para examinar o impacto de possíveis fatores geradores de viés que comprometam a qualidade dos estudos analisados e, por sua vez, comprometam a qualidade da evidência encontrada. Um desses fatores presentes na literatura da marcha do envelhecimento é a velocidade de marcha. Está bem documentado que a velocidade da marcha diminui com a idade e a velocidade explica uma porção significativa da variação nos parâmetros cinemáticos da marcha, entre eles o padrão e ADM de movimento de pelve e tronco. Além disso, a velocidade por si só é um fator que altera a cinemática da marcha, portanto, combinar resultados de estudos com velocidades semelhantes permitiria a investigação de um consenso na literatura independente dos possíveis efeitos da velocidade.

Assim, o principal objetivo desta revisão sistemática com metanálise foi revisar os estudos que compararam a cinemática de pelve e tronco durante a marcha em velocidade lenta, auto-selecionada e rápida entre adultos e idosos saudáveis.

ARTIGO

Title

Do older adults present altered pelvic and trunk movement pattern during gait? A systematic review with meta-analysis and GRADE recommendations.

Highlights:

- Older adults have smaller pelvic rotation range of motion than adults during gait.
- This difference occurs during slow, comfortable and fast walking speeds.
- There were no differences in pelvic movement in the sagittal and frontal planes.
- Older adults do not exhibit different trunk range of motion during gait.

Abstract

Several factors may influence on gait efficiency of older adults, such as cognitive, sensory and biomechanical factors. Between the biomechanical factors, reduced range of movement of pelvis and trunk segments have been associated with slower gait speed, shorter step length and increased susceptibility to fall in older adults. This meta-analysis compared trunk and pelvic movement during gait among adults and older adults. Electronic search was conducted on MEDLINE, EMBASE and Cinahl from inception until May 2020. Studies that compared trunk and/or pelvis angular displacement during gait between adults and older adults were included. Studies with participants affected by any healthy condition that could influence gait were excluded. The following data were extracted from studies: gait speed, walking surface and pelvis and trunk range of motion (ROM) during gait in the three planes of motion. Meta-analyses were calculated for three different ranges of gait speed using random effects models. GRADE determined the strength of evidence. The search strategy identified 1414 papers (excluding duplicates). After screening, twelve studies were included for quantitative review. There was moderate-quality evidence that older adults have reduced pelvic rotation ROM in comfortable speed range (SMD=-0.90 [-1.35, -0.45]) and moderate-quality evidence that older adults also have reduced pelvic rotation ROM during fast walking speed (SMD=-1.55 [-3.43, 0.33]). In addition, there was low-quality evidence that older adults have reduced trunk rotation during fast walking speed (SMD=-0.63[-1.23, -0.03]). There were no differences for pelvic and trunk movement in the sagittal and frontal planes.

Keywords: kinematics; walking; aged; pelvis; torso; data pooling.

61. **Introduction**

The impact of aging on gait is frequently discussed in literature. Aging reduces muscle strength, joint mobility, physical conditioning and static and dynamic balance[1,2,3,4] which influences the performance of walking in older adults.5 Previous systematic reviews showed that aging affects spatiotemporal, kinematic and kinetics during gait. For example, Herssens *et al.* demonstrated that gait of older adults is characterized by decreased walking speed, cadence, and step and stride length.[6] In addition, Boyer *et al.*

(2017) demonstrated that older adults have smaller knee and hip extension angles during mid-stance, and smaller hip extension and ankle plantarflexion angles during toe-off than adults.[1] These changes in gait kinematics may be associated to a decline in older people's walking performance that can compromise, for instance, their independence to move about and interact within their neighborhood.[1,5,7,8]

Existing research focuses mainly in lower limb alterations during gait. Nevertheless, it has been hypothesized that the decline in gait efficiency seen in older adults might also be due to compensatory pelvic and trunk kinematics during gait.[9,10] Given that pelvis, trunk, head and arms (i.e. the upper body) correspond to approximately 50% of the total body mass,[11] altered pelvic and trunk movement patterns during gait may explain part of the gait spatiotemporal changes in older adults, such as the reduced stride length and larger support base.[12] These altered movement patterns may result from deficits in trunk functions often seen in older people, including reduced intervertebral mobility[13] and trunk muscles weakness.[10,14] Hyperkyphosis is one common postural alteration found in this population.[15] Increased thoracic and lumbar kyphosis anteriorly displaces the trunk center of mass (COM) and may consequently lead to a compensatory lower limb pattern of reduced hip extension, increased knee flexion and ankle dorsiflexion. In addition, trunk and pelvic changes may also contribute to reduced stability in older adults during gait. For example, Shishov *et al.* demonstrated that older adults fallers show smaller range of pelvic and trunk movement during gait when compared to non-fallers, and this reduced range of movement (ROM) was associated with poorer performance and adaptation to faster speeds induced by treadmill walking.[9]

Despite the growing number of studies investigating the pelvic and trunk movement during gait in older adults,[4,10,14,16,17] there is no consensus on how the pelvic and trunk movement changes as we age. A systematic review with meta-analysis provides a quantitative approach to combine results from multiple studies. Findings from a systematic review are more robust and may help to clarify the effects of aging on the movement patterns of the trunk and pelvis, and, therefore, provide better guidance to clinical gait assessment of older adults during different speeds. Thus, the objective of this systematic review with meta-analysis was to compare the patterns of trunk and pelvic movement between adults and older adults during walking at different speeds.

2. Methods

This review was prospectively registered at PROSPERO (CRD42018107005) and followed the recommended methods from the Cochrane Collaboration[18] and MOOSE reporting guidelines[19].

2.1. Search strategy

Electronic search was conducted by two reviewers on MEDLINE, EMBASE and CINAHL (via Ovid), from inception to May, 2020, without language or publication date restriction. Hand search was done through the reference lists of the relevant papers. The search strategy used the following key words: 'aged', 'elder', 'old', 'adult', 'gait', 'walk', 'locomotor', 'ambulation', 'torso', 'trunk', 'pelvis', 'kinematics', 'kinetics', 'biomechanics'. The detailed search strategy is provided in supplementary material (Supplementary Material Online 1). The two reviewers were physiotherapists enrolled in a master's degree graduate program in rehabilitation sciences. Both reviewers were blinded to the results of the retrieved studies. In case of disagreement, a third reviewer, a PhD assistant professor at a physiotherapy department, was consulted.

2.2. Inclusion criteria

Included papers were limited to those published in peer-reviewed journals without language or publication date restrictions. Original research studies comparing trunk and/or pelvis angular displacement during gait between adults and older adults were included. We considered adults as being over 18 years of age and lower than 60 years of age and older adults as being over 60 years of age. Research studies investigating trajectories of markers placed on the trunk segment in order to convey coordination and stability measures were not included in this review.

2.3. Assessment of studies quality

All included studies were assessed for risk of bias using an adapted version of a Quality Assessment Checklist used in previous reviews analyzing kinematics studies. As no standardized or validated quality checklists exist for this type of review, a quality assessment checklist was adapted based on tools used in similar studies to establish

sources of bias in the selected articles.[20, 21] The quality assessment checklist is divided into three domains: study population bias, measurement and outcome bias, and data presentation bias (Table 2). The categorization suggested by Ratcliffe *et al.*, was chosen for this review: studies scored as high quality of it achieved a score > 66.8%, medium quality 33.4–66.7%, and low quality < 33.3%.[22] Assessment checklist questions and the correspondent decision rules on each question are available in Supplementary Material (Supplementary Material Online 2). Each included study was initially assessed by two independent reviewers and scored using the modified checklist. Subsequently, if required, a consensus score was reached after discussion.

2.4. Data extraction and synthesis

Data extraction was carried out by the first reviewer (ACC) and checked by the second reviewer (FOM), using standardized forms. The following data was extracted from each included study: author, date of publication, study design, instrumentation, marker set protocol, sample size, age of participants, pelvis and trunk angular displacement variables in degrees, gait speed and type of surface of walking (ground or treadmill).

2.5. Data analysis

Means and standard deviations for pelvic and trunk ROM were extracted for each group (i.e. adults and older adults). When numerical data was not available in tables or text, we contacted the authors to retrieve the data of interest. If there were no response, we followed the Cochrane recommendations[18] and extracted data from graphs, using GetData Graph Digitizer.[24] Due to the low number of studies included, studies with different settings were grouped in the same analysis. The main criterion used to categorize studies was gait speed. To investigate the influence of different gait speeds on the trunk and pelvic movement patterns, data extracted from studies testing different gait speeds were grouped into three categories:

slow speed (0.49 – 0.90 m/s); near comfortable/community ambulation speed (0.91 – 1.50m/s); fast speed (1.51 – 1.90 m/s). The choice of comfortable velocity was based on studies that determined reference values for the older adults population[24,25] and studies investigating the speed required for community walking and ability to increase speed during functional activities.[26,27] The slow and fast speed ranges were determined based on the speeds investigated in the included studies. Pooled estimates of overall differences were calculated by metanalysis of studies that measured kinematic characteristics of trunk and pelvis motion using comparable methods. Studies were included if they used the same unit of measurement and if they described similar gait situations, for example, no use of dual tasks, perturbations or assistive devices.

The differences in pelvic and trunk ROM between groups were calculated using standardized mean difference (SMD) and 95% confidence interval (CI). SMDs were interpreted as small (SMD<0.2), moderate (0.2 ≤SMD<0.5), or large (0.5<SMD<0.8)19. The level of heterogeneity across studies was estimated with I2 statistics. Meta-analyses were calculated using random effects models in RevMan version 5.328.

2.6 Assessment of quality of evidence

To summarize the overall quality of the evidence, the GRADE system (Grading of Recommendations Assessment, Development and Evaluation)[23] was used for each meta-analysis. Scoring of evidence started at high-quality evidence, which was downgraded one level if one of the following pre-specified criteria was present: (i) poor methodological quality (downgraded if ≥ 25% of the studies included in the meta-analysis used groups that were not comparable or lacked information on point estimates and variability in key outcomes (i.e., items 3 and 21 of the quality assessment scale); (ii) imprecision (downgraded if ≥ 25% of the included studies did not have sufficient power to detect a clinically important effect [i.e., item 22 of the quality assessment scale]); (iii) indirectness (downgraded if ≥ 25% of the included studies did not use valid and reliable methods for data collection or did not specify if the subjects that participated in the study were representative of the population; and (iv) inconsistency (downgraded if there as wide variance of point estimates across studies and minimal or no overlap of confidence intervals of different studies).

3. Results

3.1. Flow of studies through the review

The electronic search strategy identified 1414 records from the selected databases (excluding duplicates). It was not necessary to ask authors for full text studies to be included, nor did we have to include any studies published in languages other than English. After screening titles, abstracts and reference lists, 55 potentially relevant records underwent full-text review. Two additional studies were found by hand searching, 26 studies failed to meet the inclusion criteria, and 12 articles were included after full text review. Therefore, 12 studies were included in the metanalysis. Figure 1 shows the flow of studies through the review.

3.2. Characteristics of included studies

Table 1 presents the studies characteristics. The included studies were observational cross-sectional studies investigating gait parameters with motion capture systems. Ten studies used 3D systems,[12,29,30,31,32,33,34,35,36,37] one used interrupted light photography[38] and one used inertial measurement units[39]. Nine studies asked the participants to walk at self-selected speed on floor level,[29,30,31,34,35,36,37,38,39] and other three studies asked the participants to walk at pre-determined speeds on the treadmill.[12,32,33] Only one study[29] asked the participants to walk on both, floor level and treadmill, at self-selected and pre-determined speeds. The data from this study were divided in data from subjects who walked on floor level and treadmill for comparison purposes.

3.3. Quality Assessment of Studies

Overall studies were of moderate quality, scoring 33%- 66%.[12,29,30,31,32,33,38] Two studies[34,37] score high (69% and 74%) and one scored low (26%).[38] The major sources of low score were lack of sample size calculation, sample selection and description of functional status, lack of information on blinding and training of the assessors. Potential sources of bias are summarized in table 2.

3.4. Participants

A total of 521 participants (242 adults and 299 older adults) were investigated in the 12 studies included in the metanalysis. The mean age ranged from 21 to 45 years for the adults and from 60 to 87 years for the older adults.

3.5. Outcomes

None of the included studies reported data on pelvis and trunk kinetics. Therefore, data analyses were conducted for kinematic data only. Data on trunk planar angles from Crawford *et al.* (2018) is reported only descriptively[32]. This study showed that older adults have increased trunk forward inclination, regardless of the gait speed, along with a smaller lumbar region ROM in the sagittal plane. Table 3 summarizes data extracted from the included studies.

3.6. Pelvic Kinematics

Meta-analysis (n= 207).[29,31,32,34,35,36] provided low-quality evidence that there are no differences between older adults and adult in pelvic sagittal plane ROM during walking, regardless of the speed (Slow: SMD: 1.33, [-5.66 to 3.00], p= 0.55; Comfortable: SMD: SMD= -0.28 [-0.17, 0.73], p=0.22; Faster: SMD: -0.41, [-0.94 to 0.12], p=0.13). In addition, meta-analysis of pelvic obliquity in slow speed walking (n=110)[12,29,32] provided moderate quality evidence that there are no differences in pelvic obliquity ROM between the groups. The meta-analysis for comfortable speed walking(n=79)[12,29,31,32,34] and for fast speed (n=136)[29,30,32,34] walking provided low quality evidence that there is no difference between adults and older adults. (Slow: SMD: -1.08, [-2.27 to 0.11], p=0.08; Comfortable: SMD: -0.72, [-1.56 to 0.12], p= 0.95); Faster: SMD: -0.85 [-2.01 to 0.32], p=0.15). Finally, six studies (n=259) reported pelvic rotation data. Meta-analysis showed low-quality evidence that older adults have smaller pelvic rotation ROM during slow walking speed (SMD= -0.04 [-1.07, 0.99], p=0.95), moderate quality evidence that older adults have smaller pelvic rotation during comfortable speeds (SMD = -0.90 [-1.35 to -0.45], p= 0.0001) and high-quality evidence that older adults have smaller pelvic rotation during fast walking speed (SMD: -1.55 [-3.43 to -0.33], p=0.0001).

3.7. Trunk Kinematics

Two studies reported trunk rotation data for slow (n= 68),[12,32] comfortable (n=82),[32,39] and fast (n= 82)[32,39] walking speeds. There is low quality evidence that there are no differences for trunk rotation ROM in slow (SMD: -0.47, [-1.95 to 1.01], p=0.53) and comfortable (SMD: -0.41 [-1.17, 0.35], p=0.29) walking speeds. On the other hand, there is low quality of evidence that older adults have smaller trunk rotation ROM during fast walking speed (SMD: -0.63[-1.23 to -0.03], p=0.04). Five studies[31,32,34,36,37] (n=151) reported data on trunk flexion during comfortable speeds (SMD=-0.16 [-0.69 to 0.37], p=0.55). Three studies[30,31,32] (n=74) reported data on trunk lateral flexion for comfortable walking speed (SMD: -0.08 [-.0.54 to 0.38], p=0.73) and two studies[30,32] (n=46) for fast walking speed (SMD:-0.17 [-0.74 to 0.41], p=0.58). There is low to moderate quality evidence that there are no differences in trunk ROM in the sagittal and frontal planes during comfortable and fast walking speeds. There were an insufficient number of studies to compare trunk ROM in the sagittal and frontal planes during slow speed, and trunk ROM in the sagittal plane during fast speed.

4. Discussion

Older adults have a smaller pelvic rotation ROM in comfortable and fast speed ranges and a smaller trunk rotation in fast speed ranges. There were no differences between groups in pelvic tilt and pelvic obliquity ROM in any speed. The overall quality of the evidence was low, although for the pooled data for pelvic rotation that showed significant effects, it was moderate-quality evidence.

Considering the small number of studies and the high heterogeneity in most of the meta-analyses, further research is likely to change these results. These high heterogeneity levels may be due to the differences in settings of the studies and variations in the functional status of participants in the older adults group. Older adults had smaller pelvic ROM in the transverse plane than adults. As shown in figure 2, the mean ROM of pelvic rotation during slow walking speed was 6.8o for older adults and 9.2o for adults; during comfortable walking speed it was 12.2o and 8.8o for older adults. This difference was greater at fast walking speeds, with the adults showing increased pelvic rotation ROM (14.4°) in comparison to older adults (8.8o). We observed a moderate to large effect size of age on pelvic ROM in the transverse plane (slow: -0.75 [-1.23 to -.027]; comfortable: -0.86 [-1.49 to -0.22]; fast: -1.45 [-2.33 to -0.56]). The reason for smaller pelvic ROM might be multifactorial, since the pelvic segment is the connection between the lower limbs and the upper body. Older adults present important loss of body muscle mass and strength40 and trunk muscle weakness.[14,10,41] Spine, hip and knee extensor weakness is related to poor thoracic and lumbar mobility, especially after the 70th decade of life[15]. The muscle weakness may help to explain the smaller pelvic rotation during gait. Pelvic rotation loss might be associated with some features of gait typically observed in older adults, like decreased stride length and speed. Pelvic movement in the transverse plane influences on step length, especially during faster gait speeds.[12,42] Therefore, the smaller pelvic rotation demonstrated by older adults help to explain why older adults have smaller step length and consequently gait speed.[34]

A previous study demonstrated that older adults have smaller hip extension during late stance phase.[1] During late stance, pelvic posterior rotation is coupled with hip extension.[42] Moreover, pelvic anterior rotation is dependent of proper ankle push-off, which is also compromised in older adults.[1,43] Younger participants increase the pelvic rotation ROM in order to keep up with imposed speed increments (either by walking on a treadmill or being asked to walk faster), while the older subjects are not able to use this movement strategy, despite of being able to achieve the same speed levels. They might have to develop different strategies or compensations to be able to achieve faster gait speeds. Future studies could investigate muscle activation patterns along with kinematics research in order to verify this rationale.

In this review, the lack of differences in trunk movement in slow and comfortable speeds may be related to the reduced overall trunk ROM. Therefore, statistical comparisons might not have been able to identify between-group differences adequately. In addition, adults and older adults' trunk movement may respond to increases in gait speed differently. According to VanEmmerik et al (2005)[32], adults respond to increases in speed with larger changes of the trunk movement in the sagittal plane, while older adults increase transverse plane movement.[32] Therefore, the differences between the two groups might only be expected with an imposed increase in speed. In addition, faster speeds increase coordinated rotation of the pelvic and trunk segments during walking.[44] Older adults are less adaptable to changes in walking speed, and might exhibit smaller oscillations of the trunk in order to maintain stability during more challenging gait speeds.[12,32]

Heterogeneity for trunk data was low to moderate. The small number of studies with small sample size included in each comparison might have compromised the power of the meta-analysis. Another source of heterogeneity is how the trunk segment was defined as the use of different trunk models result in different magnitudes of trunk motion[43,45,46,47]. The older adults group had a small number of participants older than seventy years, with an overall mean age of approximately 72 years of age, which may have contributed to the lack of difference in trunk movement between groups. Previous studies have demonstrated that age,[17,48] with increased trunk inclination and kyphosis in older older adults[15,49,50,48,52,53] affect overall trunk alignment. Moreover, trunk inclination and kyphosis are associated with slower speed and reduced gait function[54] therefore, trunk kinematic alterations could have been found if more advanced age ranges were included. Trunk ROM is also influenced by gait speed variations.[55] The range of faster speeds (1.51 – 1.90 m/s) implemented by the included studies was probably not sufficiently challenging to increase trunk motion and consequently elucidate differences between groups. Future studies should include more challenging gait speeds to investigate trunk movement differences in older adults properly.

According to the GRADE system, pooling of studies that compared the pelvic movement during walking between adults and older adults provided varied from low to moderate quality evidence. The major sources of bias that may compromise the generalizability of the findings[51] were related to lack of report of sample characteristics that could assert their comparability, i.e. gait functional status for the older adults group[30,31,32,33,34,35,38] and use of non-representative samples.[12,29,30,31,32,33,34,35, 36,37,38,39] Other concerns derive from poor experimental protocol consistency (e.g. not using standardized instruction to participants and assessor's training,) and omission of sample size calculations. In addition, all of the included studies only reported average ROM data for the entire gait cycle. Therefore, it is not possible to affirm if there are differences in pelvic motion during specific gait phases, such as single limb support or toe-off, for instance. Future studies could feature specific phases during the gait cycle[54] and should follow recommendations from the international society of biomechanics to reduce variability in the implemented methods and in the reporting of the results.[57]

The relatively low mean age of the older adults participants is a limitation of the included studies. Therefore, differences in pelvic and trunk ROM of older adults might have been washed out by the inclusion of adults younger than 60 years of age. Alterations in gait are more pronounced in individuals older than 70 years of age.[17,54,58,59,60] While an older age cut-off would be desirable, it is also interesting to investigate kinematic changes that occur in middle-aged subjects. Another limitation is that the analysis included both men and women in the same group. Whitcome *et al.* (2017) showed that mean pelvic rotation was greater in females at slow and faster speeds.[59] Since the studies included men and women in the same groups, it was not possible to make a gender analysis. Finally, the inclusion of studies using treadmill and overground walking in the meta-analysis is another possible limitation, since pelvic movement is affected by treadmill walking.[60] Walking on the treadmill significantly decreases pelvic ROM in the transverse plane and, to a lesser extent, the anterior tilt.61 This could mask the effects of age on pelvic motion reported in this review.

5. Conclusions

Our findings showed that older adults walk with less pelvic rotation ROM in comfortable and fast walking speeds, and less trunk rotation ROM during fast walking speed. The quality of evidence varied from low to high. Future research would benefit from consensus on experimental setup and trunk segment definition to provide comparisons that are more homogeneous. It is also advised to calculate sample sizes and try to make samples as representative as possible. Other suggestions might be to include older age groups (>75) based on justified age limits and to assess participants' functional status with validated tools, to help comparison and generalization of the findings.

Table 1 Characteristics of the included studies (total number = 12)

Study, Year	Design	Instrumentation/ marker placement	Sample size	Average age of participants	Segment/ Definition	Outcomes	Speed/Setting
Fukuchi *et al.*, 2018	Cross sectional exploratory study	Motion capture system (Raptor-4; Motion Analysis Corporation, Santa Rosa, CA, USA), force platforms (Optima models AMTI; Watertown, MA, USA and 9281EA models; Kistler, Winterthur, Switzerland) and dual-belt treadmill (FIT; Bertec, Columbus, OH, USA) / markers on: ASIS, PSIS, sacrum(Leardini, 2009)	Young adults = 24 Older adults = 18	Young adults = 27.6 ± 4.4 years Older adults = 62.7 ± 8.0 years	Pelvis	ROM Pelvic tilt (sagittal plane) Pelvic obliquity (frontal plane) Pelvic rotation (transverse plane)	Speed: self-selected speed and controlled speeds. Setting: level floor and treadmill.
Gimmon *et al.*, 2015	Cross sectional exploratory study	Ariel Performance Analysis System 3D (APAS, Ariel Dynamics Inc.CA, USA)./ markers on: ASIS, acromion process, radial styloid process.	Young adults = 14 Older adults = 34	Young adults = 26.0 ± 0.9 years Older adults = 80.0 ± 5.3 years	Pelvis Trunk	ROM Pelvic rotation (transverse plane) Pelvic obliquity (frontal plane) Trunk rotation (transverse plane)	Speed: 5 different walking speeds. Setting: treadmill
Kulmala *et al.*, 2010	Cross sectional exploratory study	Motion analysis system (Vicon T40, Oxford, UK) and force platforms (AMTI, Watertown, Massachusetts, USA) / markers on: ASIS, PSIS, clavicula, sternum, T7 and T10. (Romkes, 2007)	Young adults= 13 Older adults = 13	Young group = 26 ± 6 years Early old group = 61 ± 5 years Older group = 78 ± 4 years	Pelvis Trunk	Pelvic ROM (frontal plane) Trunk ROM (frontal plane)	Speed: self-selected Setting: level floor.

Schmid *et al.*, 2017	Cross sectional exploratory study	12-camera motion analysis system (type MXT20, Vicon, Oxford, UK; sampling frequency: 200 Hz / type MXV612, Vicon, Oxford, UK; sampling frequency: 100 Hz). / markers on: C7, shoulders, T3-T11, costal arch, sternum, ASIS, MSIS, PSIS, sacrum (List, 2013; Romkes,2007)	Young aduts=13 Older adults=15	27.0 ±2.5 69.7 ±1.8	Cervical segment Thoracic segment Lumbar segment Pelvis segment	Pelvic ROM (sagittal, frontal and transverse plane) Trunk ROM Sagittal, frontal and transverse	Speech: self-selected Setting: level floor
Van Emmerick et al., 2005	Cross sectional exploratory study	7-camera motion analysis sytem (Qualysis Inc.) / markers on: C7, bottom of rib cage, midpoint between iliac crest and PSIS, sacrum.	Young adults = 10 Older adults=10	23.3±4.0 72.6±3.8	Head Trunk Pelvis	ROM Pelvic tilt (sagittal plane) Pelvic obliquity (frontal plane) Trunk lateral flexion (frontal plane), flexion-extension (sagittal plane) and axial rotation (transverse plane)	Speed: systematically increased and decreased between minimum (0.2m/s) and maximum (1.8m/s) in intervals of 0.2m/s. Setting: treadmill
Crawford *et al.*, 2018	Cross sectional exploratory study	8-camera stereo-photogrametry system (Oqus 300+, Qualysis Gothenburg, Sweeden) / markers on: C7, T11, L3, S2, ASIS, PSIS, sacrum, trochanters.	Young adults = 10 Older adults = 9	26.3±2.5 67.1±4.2	Trunk Pelvis	ROM Pelvic Rotation (transverse plane) ROM Trunk inclination (biplanar)	Speed: 0.55m/s and 1.1 m/s Setting: treadmill
Judge *et al.*, 1996	Cross sectional exploratory	3-camera motion analysis system (Vicon, Oxford	Young adults = 32 Older adults: 26	26±6 79±6	Trunk Pelvis	ROM Pelvic tilt Pelvic obliquity	Speed: self- selected Setting: level floor

	study	Metrics, Oxford, England) / markers on: midpoint shoulder and neck, C7, ASIS, PSIS (wand), sacrum.				Pelvic rotation Pelvic posture (AP tilt) Trunk tilt	
Murray *et al.*, 1969	Cross sectional exploratory study	Interrupted light photography / marker set placement was not described	Young Adults = 32 Older adults = 32	37.4± 73.7±	Trunk Pelvis	ROM Pelvic Rotation Trunk Rotation	Speed: self-selected "normal paced" and "faster paced" speeds Setting: level floor
Mirelman *et al.*, 2015	Cross sectional exploratory study	Inertial sensors (three 3-axis accelerometer/ gyroscope/ magnetometer (Opal, APDM, USA) placed on L4 and L5.	Young Adults = 46 Older Adults = 16	45±3.5 64±4.4	Trunk	Trunk Rotation	Speed: Self selected preferred speed and fast speed. Setting: level floor
Lim *et al.*, 2013	Cross sectional exploratory study	9-camera motion analysis system (Vicon, Oxford Metrics, Oxford, England) / does not inform marker positioning set up	Young Adults = 10 Older Adults = 10	24±2.5 71.5±6.3	Trunk Pelvis	Trunk extension (sagittal plane) Pelvic tilt (sagittal plane)	Speed: prescribed 1.4 m/s Setting: level floor
Lee *et al.*, 2005	Cross Sectional exploratory study	6-camera motion analysis system (Vicon 512 system, Oxford Metrics, Oxford, England) / markers on: ASIS, latetal femoral	Young Adults = 25 Older Adults = 25	26±5 71±5	Pelvis	Pelvic tilt (sagittal plane)	Speed: self-selected "comfortable pace", "faster pace", "slower pace" Setting: level floor

Krupenevich *et al.*, 2020		condyles, lateral malleoli, forefeet, heels, sacrum. 13-camera motion analysis system (Vicon 512 system, Oxford Metrics, Oxford, England) / does not inform marker positioning set up	Young Adults = 13 Older Adults = 12	21±3 67±4	Trunk	Trunk extension (sagittal plane)	Speed: prescribed 1.3 ± 3% m/s Setting: level floor

N,sample size; AP, anteroposterior; ROM, range of motion; COM, center of mass, ±, standard deviation.

Table 2 Quality Assessment Summary

Quality assessment domains	**% of studies scoring yes**
Study population bias	
1 Was the study population adequately described?	100%
2 Were both groups drawn from the same population?	33%
3 Were both groups comparable for gender, BMI/weight?	58%
4 Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	0%
5 Was gait or functional level adequately described for the older adult group?	41%
6 Was an attempt made to define the age limit or categories for the older adult group?	0%
7 Were the eligibility criteria specified?	75%
Measurement and outcome bias	
8 Did the method description enable accurate replication of the measurement procedures?	83%
9 Was the measurement equipment adequately described?	66%
10 Was a system for standardizing movement instructions reported?	66%
11 Were assessors trained in standardized measurement procedure?	0%
12 Did the same assessors test both groups?	0%
13 Were assessors blinded as to which group subjects were in?	0%
14 Was assessment procedure applied to both groups the same?	91%
15 Were the main outcomes to be measured and the related calculations (if applicable) clearly described?	91%
16 Were the main outcome measures used accurate (valid and reliable)?	75%
Data presentation bias	
17 Are the main findings of the study clearly described?	91%
18 Were the statistical tests appropriate?*	91%
19 The results of between-group statistical comparisons were reported for at least one key outcome.*	90%
20 Have actual probability values been reported (e.g. 0.035 rather than<0.05) for the main outcomes except where the probability value is<0.001?*	54%
21 Point estimates and measures of variability were provided for at least one key outcome for both groups.*	66%
22 Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is<5%?*	0%
23 Was the reliability and/or validity of the outcomes commented upon?*	0%

*Questions 18-23 were not applicable to *Fukuchi et al., 2018*, due to specific study design. In these questions, this study was suppressed and eight studies were considered in total for the percentage calculations.

Table 3 Speed, pelvic and trunk mean (standard deviation) range of motion during gait for each age group in the three planes of movement. Pelvic and trunk range of motion are reported in degrees.

Studies	**Speed (m/s)**	**Pelvic tilt (SAG)**		**Pelvic Obliquity (FRONT)**		**Pelvic Rotation (TRANS)**		**Trunk Flexion (SAG)**		**Trunk Lateral Flexion (FRONT)**		**Trunk Rotation (TRANS)**	
		Adult	Older	Adult	Older	Adult	Older	Adult	Older	Adult	Older	Adult	Older
Fukuchi et al., 2018	Self-selected Adult: 1.2(0.1) Older: 1.2(0.2)	3.3(1)	3.0(0.8)	10.7 (3.4)	9.7(4.2)	14(4.2)	11.5(4)						
Kulmala et al., 2016	Self-selected Adult 1.6(0.1) Older 1.6(0.2)			4.0(1.3)	4.7(1.4)					2.7(1.7)	2.3(2.3)		
Schmid et al., 2017	Self-selected Adult 1.5(0.2) Older 1.6 (0.1)	3.8(1.6)	4.2(2.3)	7.1(2.8)	6.2(2.6)	12.0(4.3)	11.8(4.5)	3.4(0.8)	3.3(0.9)	3.7(1.5)	4.0(1.8)	6.7(1.7)	5.8(2.3)
Fukuchi et al., 2018**	Adult												
	v01(0.49±0.06)	3.1(0.9)		5.7(1.9)		10.6(3.9)							
	v02(0.68±0.08)	3.21(1.2)		5.6(2.7)		8.9(2.8)							
	v03 (0.87±0.10)	3.05(0.78)		6.6(3.1)		8.8(2.4)							
	v04(1.05±0.12)	3.14(0.8)		7.5(3.6)		8.9(2.2)							
	v05(1.24±0.15)	3.23(0.9)		8.1(4.5)		10.3(2.9)							
	v06(1.43±0.17)	3.6(1.0)		10.4(4.9)		12.3(4.5)							
	v07(1.61±0.20)	3.7(1.2)		10.2(5.8)		13(5.3)							
	v08 (1.8±0.22)	5.0(3.8)		8.8(7.8)		16.5(5.2)							
	Older:												
	v01(0.49+0.06)		2.6(0.5)		5.7(1.9)		9.0(4.1)						
	v02(0.67+0.10)		2.5(0.8)		5.6(2.7)		7.1(3.8)						
	v03(0.87+0.12)		2.6(0.5)		6.6(3.1)		6.5(3.1)						
	v04(1.06+0.16)		2.7(0.6)		7.5(3.6)		6.9(3.2)						
	v05(1.25+0.19)		4.1(3.5)		8.1(4.5)		7.5(4.0)						
	v06(1.44+0.22)		3.3(0.7)		10.4(4.9)		10.1(4.3)						
	v07(1.61+0.22)		3.2(1.4)		10.2(5.8)		10.2(5.1)						
	v08(1.76+0.24)		2.5(2.1)		8.8(7.8)		8.8(7.2)						
Gimmon et al., 2015**	0.5			5.1(1.8)	3.1(1.3)	10.4(3.3)	5.7(2.2)					7.3(2.4)	4.5(1.9)
	0.6			5.5(2.0)	3.2(1.3)	9.9 (4.3)	6.0(2.2)					8.2(2.6)	5.3(2.3)
	0.65			5.6(1.8)	3.2(1.3)	9.5(3.5)	5.7(1.8)					9.2(2.8)	6.0(2.2)
	0.75			6.1(1.7)	3.1(1.4)	9.1(2.9)	5.6(1.8)					10.7(3.4)	6.9(2.5)
	0.85			6.3(1.7)	3.2(1.4)	9.2(3.2)	5.9(2.0)					11.9(4.3)	7.5(2.6)

Van	0.2	8.7(4.4)	6.5 (4.4)	6.1(2.2)	4.2(1.1)	9.5(4.4)	8.1(4.4)	4.9(3.3)	4.0(4.4)	3.4(4.4)	3.5(4.4)	9.3(6.7)	9.3(4.4)
Emmerik* et	0.6	10.2(4.4)	6.5 (4.4)	9.0(2.2)	5.8(1.1)	8.8(5.6)	7.2(4.4)	4.9(3.3)	3.7(3.3)	3.7(2.2)	3.8 (2.2)	9.3(6.7)	11.4(6.7)
al., 2005**	1.0	8.2(3.3)	6.7 (4.4)	10.0(2.2)	7.5(1.1)	7.1(3.3)	6.3(3.3)	4.3(3.3)	3.7(1.1)	5.1(2.2)	4.6(2.2)	9.5(4.4)	9.8(5.6)
	1.4	9.0(3.3)	6.9 (4.4)	11.5(2.2)	8.4(1.1)	11.2(4.4)	6.6(3.3)	3.5(2.2)	3.5(2.2)	5.3(3.3)	5.0(3.3)	8.7(5.6)	8.5(5.6)
	1.8	10.1(4.4)	7.8 (3.3)	12.8(2.2)	7.8(1.1)	15.8(4.0)	9.7(4.4)	3.6(0.4)	4.5(2.2)	5.1(2.2)	5.1(2.2)	8.1(5.6)	6.8(5.6)
Crawford et	0.5					7.6(1.8)	5.3(3.0)						
al., 2018**	1.1					14.2(3.4)	7.2(4.1)						
Mirelman et al., 2015	Self Selected Adult: 1.34 Older: 1.24											5.8(2.0)	4.4(1.5)
	Adult fast: 1.69 Older fast: 1.61											7.5(2.9)	5.2 (1.6)
Murray et al., 1969	Self Selected Adult: 1.5 Older: 1.26					10.0(1.5)	8.5(0.2)						
	Adult fast: 2.1 Older Fast: 1.7					16.7(1.2)	10.7(2.9)						
Judge et al., 1996	Self Selected Adult: 1.16 Older: 1.03	3.0(1.0)	3.0(1.0)	9.0(3.0)	6.0(2.0)	9.0(4.0)	7.0(2.0)	1.0(4.0)	0.0(4.0)				
Lee et al., 2005	Self Selected												
	Adult: 1.3(0.14)	11.0(5.0)											
	Older: 1.2(0.18)	15.0(5.0)											
	Adult slow: 0.9 (0.15)	12.0(5.0)											
	Older slow: 0.9 (0.14)	15.0(4.0)											
	Adult fast: 1.7 (0.24)	13.0(5.0)											
	Older fast: 1.6 (2.3)	17.0(5.0)											
Lim et al., 2013	Self-selected Adult: 1.2(2.9) Older: 1.6(3.7)	3.5(2.9)	9.0(3.7)					7.7(2.8)	4.0(3.6)				

Krupenevich et al., 2020***	Self-selected Adult: 1.43(0.1) Older: 1.42(0.1)	6.8(2.24)	8.3(1.7)

SAG, sagital plane; FRONT, frontal plane; TRANS, transverse plane.

*Data provided by author. Standard Deviation (SD) estimated from graphs and calculated from SE according to the Cochrane Handbook.

** Gait speed on treadmill was calculated based on the participant's average self-selected comfortable speed and leg length, and was selected as: V01:40% of comfortable speed; V02: 55%; V03: 70%; V04: 85%; V05: 100%; V06; 115%; V07: 130%; V08: 130%.

*** Data extracted from graphs with GetData Software. SD estimated from graphs and calculated from SE according to the Cochrane Handbook.

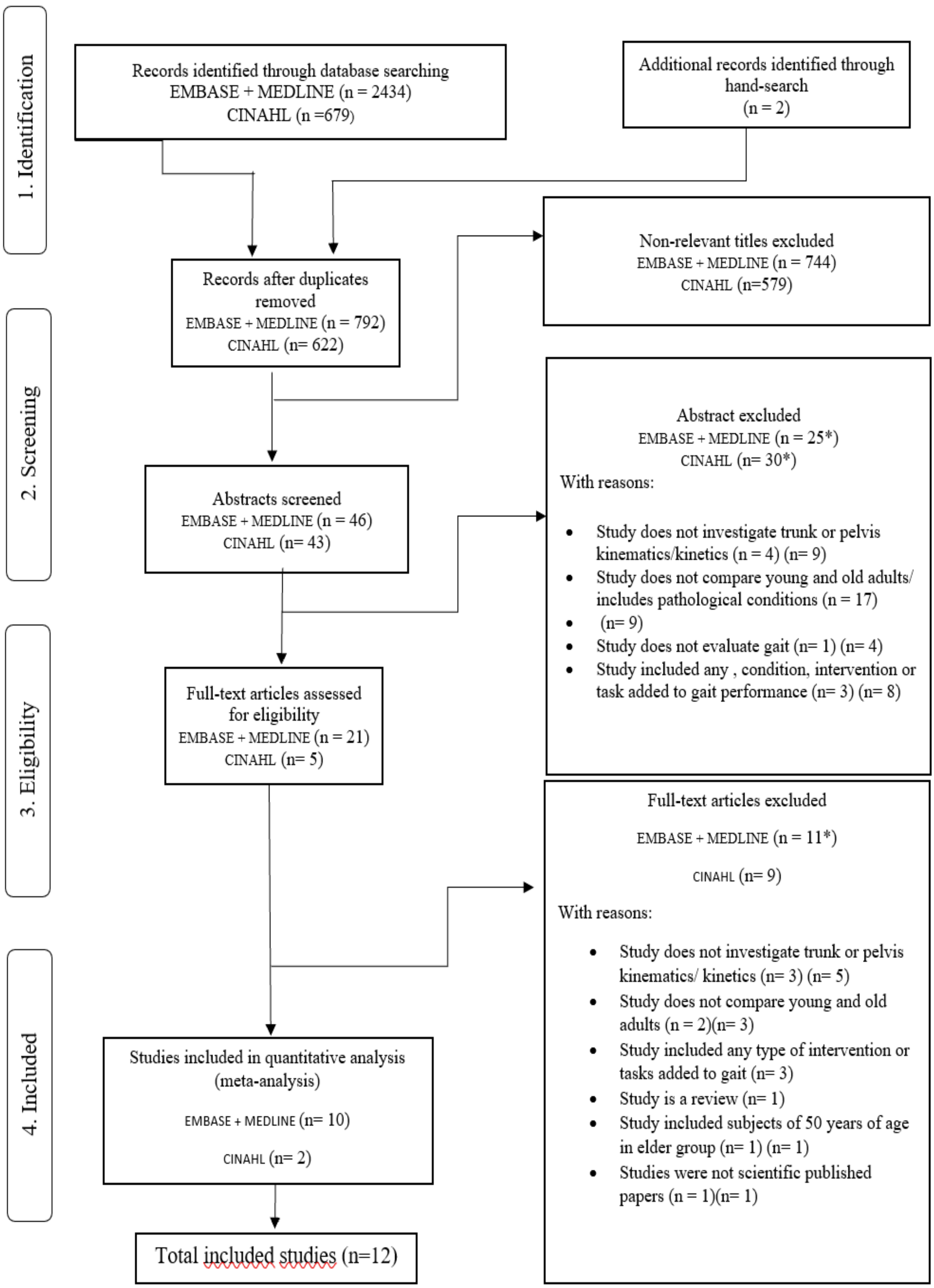
Conflict of interest

None.

Funding sources

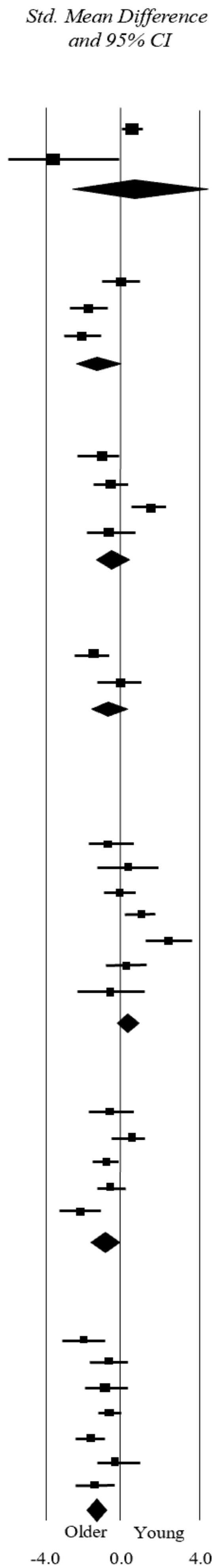
This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001; the State of Minas Gerais Funding Agency FAPEMIG [Grant number APQ-01139-15] and the Brazilian Funding Agency CNPQ.

Figure 1 Flow-chart of studies through the review.



*Studies could be excluded due to more than one reason.

	Older			Young			
	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*Weight*
Slower Speed Range (0.49 - 0.90 m/s)							
Pelvic Tilt (Sagital Plane)							
Fukuchi et al., 2018(T)	18	3.1	0.9	24	2.6	0.5	39.8%
VanEmmerik et al., 2005(T)	10	6.5	4.4	10	10.2	4.4	27.6%
Total	28			34			100.0%
I² = 86.0%; random-effects, SMD=-1.33 [-5.66, 3.00]							
Pelvic Obliquity (Frontal Plane)							
Fukuchi et al., 2018 (T)	18	5.7	1.9	24	5.7	1.9	35.7%
Gimmon et al., 2015(T)	34	3.2	1.3	14	5.5	2.0	34.8%
VanEmmerik et al., 2005	10	5.5	1.1	10	9.0	2.2	29.5%
Total	62			48			100.0%
I² = 86.0%; random-effects, SMD=-1.08 [-2.27, 0.11]							
Pelvic Rotation (Transverse Plane)							
Crawford et al., 2018(T)	9	5.3	3.0	10	7.6	1.8	23.4%
Fukuchi et al., 2018 (T)	18	9.0	4.1	18	10.6	3.9	26.3%
Gimmon et al., 2015(T)	34	6.0	2.2	14	9.9	4.3	26.1%
VanEmmerik et al., 2005(T)	10	6.3	3.3	10	7.1	3.3	24.2%
Total	71			52			100.0%
I² = 86.0%; random-effects, SMD=-0.04 [-1.07, 0.99]							
Trunk Rotation							
Gimmon et al., 2015(T)	34	5.3	2.3	14	8.2	2.6	52.9%
VanEmmerik et al., 2005(T)	10	9.3	4.4	10	9.3	6.7	47.1%
Total	44			24			100.0%
I² = 78.0%; random-effects, SMD=-0.47 [-1.95, 1.01]							
Comfortable Speed Range (0.91 - 1.50m/s)							
Pelvic Tilt (Sagital Plane)							
Fukuchi et al., 2018	9	3.0	0.8	12	3.3	1.0	13.7%
Fukuchi et al., 2018 (T)	9	4.1	3.5	12	3.2	0.9	13.4%
Judge et al., 1996	26	3.0	1.0	32	3.0	1.0	17.7%
Lee et al., 2005	25	15.0	5.0	25	11.0	5.0	17.0%
Lim et al., 2013	10	9.0	3.7	10	3.5	2.9	10.3%
Schmid et al., 2017	15	4.2	2.3	13	3.8	1.6	14.9%
VanEmmerik et al., 2005(T)	10	6.7	4.4	10	8.2	3.3	13.2%
Total	104			114			100.0%
I² = 0.0%; random-effects, SMD=-0.28 [-0.17, 0.73]							
Pelvic Obliquity (Frontal Plane)							
Fukuchi et al., 2018	9	9.7	4.2	12	10.7	3.4	20.0%
Fukuchi et al., 2018 (T)	9	10.4	4.9	12	8.1	4.5	19.9%
Judge et al., 1996	26	6.0	2.0	32	9.0	3.0	22.9%
Schmid et al., 2017	15	6.2	2.6	13	7.1	2.8	21.2%
VanEmmerik et al., 2005(T)	10	8.0	1.1	10	13.0	2.2	15.9%
Total							
I² = 81.0%; random-effects, SMD= -0.72 [-1.56, 0.12]							
Pelvic Rotation (Transverse Plane) *							
Crawford et al., 2018(T)	9	7.2	4.1	9	14.2	1.8	9.1%
Fukuchi et al., 2018	9	11.5	4.0	12	14.0	4.2	13.0%
Fukuchi et al., 2018 (T)	9	7.5	4.0	12	10.3	2.9	12.7%
Judge et al., 1996	26	7.0	2.0	32	9.0	4.0	19.2%
Murray et al., 1969	32	8.5	0.2	32	10.0	1.5	18.9%
Schmid et al., 2017	15	11.8	4.5	13	12.0	4.3	15.3%
VanEmmerik et al., 2005(T)	10	6.0	3.3	10	11.0	4.4	11.8%
Total	110			120			100.0%
I² = 57.0%; random-effects, SMD=-0.69 [-1.26, -0.12]							



	Older			Young			
	n	Mean	SD	n	Mean	SD	Weight
Trunk Flexion (Sagital Plane)							
Judge et al., 1996	26	0.0	4.0	10	1.0	4.0	26.2%
Krupenevich et al.,2020	12	8.3	1.7	13	6.8	2.2	19.2%
Lim et al., 2013	10	4.0	2.8	10	7.7	2.8	16.0%
Schmid et al., 2017	15	3.3	0.9	13	3.4	0.8	20.8%
VanEmmerik et al., 2005(T)	10	5.1	2.2	10	3.7	1.1	17.9%
Total	73			78			100.0%
I² = 59.0%; random-effects, SMD= -0.16[-0.69, 0.37]							
Trunk Lateral Flexion (Frontal Plane)							
Kulmala et al., 2010	13	2.3	2.3	13	2.7	1.7	35.2%
Schmid et al., 2017	15	4.0	1.8	13	3.7	1.5	37.7%
VanEmmerik et al., 2005(T)	10	4.6	2.2	10	5.1	2.2	27.1%
Total	38			36			100.0%
I² = 0.0%; random-effects, SMD=-0.08 [-0.54, 0.38]							
Trunk Rotation (Transverse Plane)							
Mirelman et al., 2015	16	4.4	1.5	46	5.8	2.0	58.8%
VanEmmerik et al., 2005(T)	10	9.8	5.6	10	9.5	4.4	41.2%
Total	26			56			100.0%
I² = 54.0%; random-effects, SMD= -0.41 [-1.17, 0.35]							
Faster Speed Range (1.51 - 1.90 m/s)							
Pelvic Tilt (Sagital Plane)							
Fukuchi et al., 2018 (T)	18	2.5	2.1	24	5.0	3.8	25.4%
Judge et al.,1996	26	3.0	1.0	32	3.0	1.0	27.3%
Lee et al., 2005	25	17.0	5.0	25	13.0	5.0	26.3%
VanEmmerik et al.,2005(T)	10	7.8	3.3	10	10.1	4.4	21.0%
Total	54			66			100.0%
I² = 80.0%; random-effects, SMD= -0.41 [-0.94, 0.12]							
Pelvic Obliquity (Frontal Plane)							
Fukuchi et al., 2018 (T)	18	8.8	7.8	24	8.8	7.8	26.9%
Judge et al., 1996	26	6.0	2.0	32	9.0	3.0	27.3%
Kulmala et al., 2016	13	4.7	1.4	13	4.0	1.3	25.7%
VanEmmerik et al., 2005(T)	10	7.8	1.1	10	12.8	2.2	20.1%
Total	67			79			100.0%
I² = 89.0%; random-effects, SMD=-0.85 [-2.01, 0.32]							
Pelvic Rotation (Transverse Plane)*							
Fukuchi et al., 2018(T)	18	8.8	7.2	24	16.5	5.2	25.6%
Judge et al., 1996	26	7.0	2.0	32	9.0	4.0	27.1%
Murray et al., 1969	32	10.7	3.2	32	16.7	1.2	25.6%
VanEmmerik et al., 2005(T)	10	9.7	4.4	10	9.0	4.0	21.7%
Total	86			98			100.0%
I² = 85.0%; random-effects, SMD=-1.55 [-3.43, 0.33]							
Trunk Lateral Flexion (Frontal Plane)							
Kulmala et al., 2016	13	2.3	2.3	13	2.7	1.7	56.4%
VanEmmerik et al., 2005(T)	10	5.1	2.2	10	5.1	2.2	43.6%
Total	23			23			100.0%
I² = 0.0%; random-effects, SMD= -0.17 [-0.74, 0.41]							
Trunk Rotation (Transverse Plane)*							
Mirelman et al., 2015	16	5.2	1.6	46	7.5	2.9	63.6%
VanEmmerik et al., 2005(T)	10	6.8	5.6	10	8.1	5.6	36.4%
Total	26			56			100.0%
I² = 29.0%; random-effects, SMD=-0.63[-1.23, -0.03]							

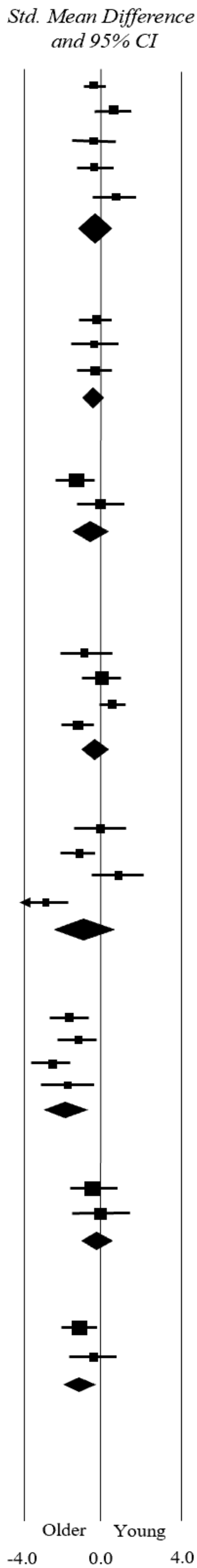


Figure 3. Forest plot displaying the pooled effects of aging on the variables included in the meta-analysis: ROM of the pelvis and trunk segments in three planes of motion. (*)Statistically significant results. (T): data from treadmill walking. (n): number of participants. (SD): standard deviation. (CI): confidence interval.

CONSIDERAÇÕES FINAIS

Os resultados do presente estudo demostraram que idosos saudáveis andam com menor ADM de rotação pélvica em velocidade auto-selecionada e rápida, e menor ADM de rotação do tronco em velocidade rápida. A qualidade da evidência demonstrada nas metanálises realizadas variou de baixa a alta.

A estratégia de busca inicial desta revisão incluiu termos que se relacionam a parâmetros cinéticos e cinemáticos da marcha, no entanto, não foram encontrados estudos relativos à cinética da marcha que comparassem grupos de adultos e idosos e observamos que alguns parâmetros cinemáticos da marcha não foram consistentemente abordados nos estudos que incluem esta comparação.

Por exemplo, o estudo dos picos de movimento da pelve e do tronco, bem como os valores angulares desses segmentos em diferentes subfases do ciclo da marcha poderia gerar informações mais completas sobre as alterações do padrão de movimento de pelve e tronco durante a marcha decorrentes do envelhecimento. No plano transverso, as rotações que ocorrem entre a pelve e o tronco contribuem para maior estabilidade da marcha e para uma progressão mais suave do centro de massa corporal. É sabido que, imediatamente após o contato inicial, o tronco gira em direção ao membro inferior de apoio, causando acelerações deste segmento que precisam ser estabilizadas. Com a perda de mobilidade intervertebral nos idosos, esta rotação pode estar diminuída ou descoordenada, prejudicando a capacidade de lidar com diferentes demandas, como manter a estabilidade da marcha. A rotação da pelve também é importante na fase de pré-balanço da marcha, pois aumenta o comprimento do passo e auxilia na progressão do centro de massa a frente. Dessa forma, a perda de ADM desta rotação pode ser uma das causas de diminuição do comprimento do passo em idosos.

Além disso, alguns estudos mais recentes mostram que a postura do tronco pode influenciar as articulações distais. A maior inclinação do tronco para frente pode alterar a posição da pelve levando-a para maior retroversão, bem como levar as articulações do quadril, joelho e tornozelo a uma maior flexão, em uma estratégia para controlar a oscilação do centro de massa e alcançar maior estabilidade. Estudos que avaliem a postura do tronco de idosos durante a marcha e sua influência sobre os membros inferiores poderiam ajudar a elucidar como como as alterações que comumente ocorrem neste segmento afetam o desempenho da marcha nesta população.

Um dos parâmetros mais relevantes para a avaliação de desempenho durante a marcha de idosos é a velocidade. Existe uma relação entre as alterações de movimento da pelve e do tronco em resposta às alterações de velocidade, na qual se observa uma resposta de diminuição de ADM nos extremos (velocidades muito lentas ou muito rápidas). Os resultados encontrados nesta revisão mostraram que não houve diferença para a maior parte das análises realizadas, no entanto, as velocidades avaliadas talvez não tenham sido suficientes para que diferenças significativas pudessem aparecer na comparação entre os dois grupos.

Por fim, alguns aspectos metodológicos dos estudos incluídos podem ser destacados para melhoria de estudos futuros. A precisão e a qualidade da informação poderiam ser aprimoradas se a coleta dos dados cinemáticos seguisse um consenso sobre a configuração experimental e a definição do segmento de tronco para fornecer comparações mais homogêneas. Também é aconselhável que estudos futuros utilizem cálculos adequados de tamanhos amostrais e, além disso, sejam mais rigorosos ao reportar alguns aspectos relacionados aos critérios de inclusão e exclusão de participantes, como por exemplo, a avaliação padronizada da presença ou não de alterações posturais prévias, déficits de força ou limitações de ADM em qualquer articulação, para que as amostras possam ser o mais representativas possível. A caracterização da população também poderia ser mais informativa, considerando que o impacto dos déficits fisiológicos associados ao envelhecimento varia de acordo com fatores como nível de atividade diária, prática de atividade física e acesso a prevenção ou tratamento de doenças crônicas. Outras sugestões podem ser incluir grupos de idade mais avançada (> 75 anos) com base em limites de idade justificados e avaliar o estado funcional dos participantes com ferramentas validadas, para ajudar na comparação e generalização dos resultados.

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APÊNDICE 1:

1. **Search Strategy**

Population	Exposure	Comparison	Outcome
Aged.mp	Gait.mp	Torso.mp	Kinematics.mp
OR	OR	OR	OR
Elder*.mp	Walk*.mp	Trunk.mp	Kinetics.mp
OR	OR	OR	OR
Old*.mp	Locomot*.mp	(upper ADJ	Biomechanics.mp
OR	OR	body).mp	
Adult.mp	Ambulation.mp	OR	
		Pelvis.mp	

APÊNDICE 2:

Quality Assessment checklist

	Criteria	Decision rule
Study population bias		
1.	Was the study population adequately described?	Gender (proportion male vs female subjects), and anthropometric information (the following: body mass, height, BMI). All three variables must be included to score yes.
2.	Were both groups drawn from the same population?	People were from the same setting, eg people from a single setting such as an institution or community, OR were they matched gender/BMI. If so score yes, if no or no data, score no.
3.	Were both groups comparable for gender, BMI/weight?	Was a comparison made between groups on these parameters? Yes if comparison made AND groups were comparable. No if not comparable or no comparison made.
4.	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample.
5.	Was gait or functional level adequately described for the older adult group?	Score yes if measured using a validated scale, questionnaire or test to assess the level of independence, function, or walking ability of the older group or of both groups.
6.	Was an attempt made to define the age limit or categories for the older adult group?	Score yes, if information provided a referenced age limit or categorisation of physical status for the older adult group.
7.	Were the eligibility criteria specified?	Yes if inclusion and exclusion criteria were clearly stated.
Measurement and outcome bias		
8.	Did the method description enable accurate replication of the measurement procedures?	Description enables accurate replication of the measurement procedures (score yes).
9.	Was the measurement equipment adequately described?	Instrument used to measure described (score yes).
10.	Was a system for standardizing movement instructions reported?	A system for standardizing movement instructions is reported (score yes).
11.	Were assessors trained in standardized measurement procedure?	Yes if report of training, or no, if no mention of training process.
12.	Did the same assessors test both groups?	If yes then score yes. If no detail score no.
13.	Were assessors blinded as to which group subjects were in?	If blinding attempted, was it evaluated and found to be successful (e.g. attempting to guess group assignment resulted in answers that could occur by chance alone).
14.	Was assessment procedure applied to both groups?	If there was any difference to procedure or measurement then score no.
15.	Were the main outcomes to be measured and the related calculations (if applicable) clearly described?	Score yes if details of outcomes and how they were obtained from the collected data are reported.
16.	Were the main outcome measures used accurate (valid and reliable)?	For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.
Data presentation bias		
17.	Are the main findings of the study clearly described?	Simple outcome data should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).

18.	Were the statistical tests appropriate?	Yes or no.
19.	The results of between-group statistical comparisons were reported for at least one key outcome	Yes or no.
20.	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	Yes or no.
21.	Point estimates and measures of variability were provided for at least one key outcome for both groups.	Yes or no.
22.	Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?	Sample sizes have been calculated (score yes).
23.	Was the reliability and/or validity of the outcomes commented upon?	Yes or no.