LUCAS RODRIGUES NASCIMENTO

EVIDÊNCIAS DE INTERVENÇÕES PARA AUMENTO DA FORÇA MUSCULAR E MELHORA DA MARCHA EM INDIVÍDUOS PÓS-ACIDENTE VASCULAR ENCEFÁLICO

EVIDENCE OF INTERVENTIONS TO INCREASE MUSCLE STRENGTH AND IMPROVE GAIT AFTER STROKE

UNIVERSIDADE FEDERAL DE MINAS GERAIS
THE UNIVERSITY OF SYDNEY

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2015

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Tese apresentada ao Programa de Pós Graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais e a *Faculty of Healthy Sciences*, *Department of Physiotherapy*, *The University of Sydney*, como requisito parcial à obtenção do título de Doutor em Ciências da Reabilitação e *Doctor of Philosophy* (*PhD*).

Área: Desempenho Funcional Humano.

Linha de Pesquisa: Estudos em reabilitação neurológica do adulto.

Orientadoras:
Luci Fuscaldi Teixeira-Salmela – UFMG
Louise Ada – *The University of Sydney*

Belo Horizonte
2015

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Thesis submitted to the Graduate Program in Rehabilitation Sciences of the School of Physical Education, Physiotherapy, and Occupational Therapy of the *Universidade Federal de Minas Gerais*, and to the Faculty of Healthy Sciences, Department of Physiotherapy, The University of Sydney, as a partial requirement for the jointly awarded degree of Doctor of Rehabilitation Sciences and Doctor of Philosophy (PhD).

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ATA DE NÚMERO 44 (QUARENTA E QUATRO) DA SESSÃO DE ARGUIÇÃO E DEFESA DE TESE APRESENTADA PELO CANDIDATO **LUCAS RODRIGUES NASCIMENTO** DO PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO.

Aos 26 (vinte e seis) dias do mês de março do ano de dois mil e quinze, realizou-se na Escola de Educação Física, Fisioterapia e Terapia Ocupacional, a sessão pública para apresentação e defesa da Tese de Doutorado intitulada: **"Evidências de intervenções para aumento da força muscular e melhora da marcha em indivíduos pós-acidente vascular encefálico".** A comissão examinadora foi constituída pelas seguintes Professoras Doutoras: Luci Fuscaldi Teixeira-Salmela, Louise Ada, Aline Alvim Scianni, Leani Souza Máximo Pereira, Renata Cristina Magalhães Lima e Lidiane Andréa Oliveira Lima sob a Presidência da primeira. Os trabalhos iniciaram-se às 13h30min com apresentação oral do candidato, seguida de arguição dos membros da Comissão Examinadora. Após avaliação, os examinadores consideraram o candidato ***aprovado e apto a receber o título de Doutor após a entrega da versão definitiva da Tese***. Nada mais havendo a tratar, eu, Marilane Soares, secretária do Colegiado de Pós-Graduação em Ciências da Reabilitação dos Departamentos de Fisioterapia e de Terapia Ocupacional da Escola de Educação Física, Fisioterapia e Terapia Ocupacional, lavrei a presente Ata, que depois de lida e aprovada será assinada por mim e pelos membros da Comissão Examinadora. Belo Horizonte, 26 de março de 2015.-

Professora Dra. Luci Fuscaldi Teixeira-Salmela ____________________

Professora Dra. Louise Ada ____________________

Professora Dra. Aline Alvim Scianni ____________________

Professora. Dra. Leani Souza Máximo Pereira ____________________

Professora Dra. Renata Cristina Magalhães Lima ____________________

Professora Dra. Lidiane Andréa Oliveira Lima ____________________

Marilane Soares – SIAPE: 084190____________________
Secretária do Colegiado de Pós-Graduação em Ciências da Reabilitação

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PARECER

Considerando que a Tese de Doutorado de **LUCAS RODRIGUES NASCIMENTO** intitulada: **"Evidências de intervenções para aumento da força muscular e melhora da marcha em indivíduos pós-acidente vascular encefálico"** defendida junto ao Programa de Pós-Graduação em Ciências da Reabilitação, nível: Doutorado cumpriu sua função didática, atendendo a todos os critérios científicos, a Comissão Examinadora **APROVOU** a Tese de doutorado, conferindo-lhe as seguintes indicações:

Nome do Professor (a)/Banca	Aprovação	Assinatura
Professora Dra. Luci Fuscaldi Teixeira-Salmela	Aprovado	
Professora Dra. Louise Ada	Aprovado	
Professora Dra. Aline Alvim Scianni	Aprovado	
Professora. Dra. Leani Souza Máximo Pereira	Aprovado	
Professora Dra. Renata Cristina Magalhães Lima	Aprovado	
Professora Dra. Lidiane Andréa Oliveira Lima	Aprovado	

Belo Horizonte, 26 de março de 2015.

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DECLARAÇÃO

Declaramos para os devidos fins que, **LUCAS RODRIGUES NASCIMENTO** defendeu a Tese de Doutorado intitulada: **"Evidências de intervenções para aumento da força muscular e melhora da marcha em indivíduos pós- acidente vascular encefálico"** obtendo em 26/03/2015 a aprovação unânime da Banca Examinadora, junto ao Programa de Pós-Graduação em Ciências da Reabilitação, nível: Doutorado, da Universidade Federal de Minas Gerais; fazendo juz ao título de Doutor em Ciências da Reabilitação a partir da referida data.

Belo Horizonte, 26 de março de 2015.

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"Aos melhores amigos do mundo, por me acompanharem e me incentivarem durante toda essa fase. Obrigado por me proporcionarem os melhores momentos de diversão e descontração na companhia de vocês" (Nascimento LR, 2011): Vocês estão sempre – *Parte 2*: Adam Glória, Alysson Machado, Fernanda Maria, Flávia Cartacho, Inalda Burni e Dr. Renan Resende. Agradecimento especial ao amigo Leôncio Assumpção pela contribuição na formatação da tese.

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PREFÁCIO

O presente trabalho foi elaborado conforme as normas do Colegiado do Programa de Pós-Graduação em Ciências da Reabilitação da Universidade Federal de Minas Gerais e acordadas previamente com *The University of Sydney*. O trabalho foi desenvolvido como requisito parcial à obtenção do título de Doutor em Ciências da Reabilitação pela Universidade Federal de Minas Gerais (UFMG) e de *Doctor of Philosophy* por *The University of Sydney* (USYDNEY) em acordo de cotutela entre as duas instituições e o discente (ANEXO A).

O programa de doutorado do Programa de Pós-Graduação em Ciências da reabilitação da UFMG pressupõe: (1) cumprimento de créditos acadêmicos por meio de produção científica, aulas e *workshops* em programas de pós-graduação; (2) elaboração e desenvolvimento de uma tese, (3) produção de artigos científicos e (4) defesa oral da tese. O programa de doutorado da USYDNEY pressupõe: (1) elaboração e desenvolvimento de uma tese, (2) produção de artigos científicos.

Dessa forma, a fim de atender as exigências de ambas as Instituições de Ensino, o programa de doutorado cotutela compreendeu três fases. A primeira fase foi realizada na UFMG durante o período de 2011-2012 e compreendeu: (i) cumprimento de créditos exigidos pelo programa, (ii) desenvolvimento do projeto de pesquisa, (iii) atualização bibliográfica com produção de artigos científicos para desenvolvimento intelecto-científico do discente em relação ao tema da tese (ANEXOS B, C e D):

1. Nascimento LR, Resende RA, Carvalho AC, Fonseca ST, Teixeira-Salmela LF (2012). Marcha humana: teorias, contribuições musculares e indicações clínicas. Ter Man. 10: 537-543.
2. Nascimento LR, Caetano LCG, Freitas DCMA, Morais TM, Polese JC, Teixeira-Salmela LF (2012). Different instructions during the ten-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. Braz J Phys Ther. 16: 122-127.

3. Polese JC, Ada L, Dean CM, Nascimento LR, Teixeira-Salmela LF (2013). Treadmill training is effective for ambulatory adults with stroke: a systematic review. J Physiother. 59: 73-80.

A segunda fase foi realizada na USYDNEY durante o período de 2012-2013 e compreendeu: (i) aprendizado e desenvolvimento do método para produção das revisões sistemáticas que compõem a tese, (ii) definição do projeto de pesquisa do estudo experimental que compõe a tese.

A terceira fase foi realizada na UFMG durante o período de 2013-2015 e compreendeu: (i) submissão e publicação das revisões sistemáticas que compõem a tese, (ii) coleta de dados e produção do artigo relacionado ao estudo experimental que compõe a tese, (iii) redação da tese.

A presente tese é composta por três partes e um resumo substancial redigido em português e em inglês. A primeira parte é constituída pela INTRODUÇÃO – que contém uma revisão bibliográfica sobre o tema proposto, a problematização e a justificativa dos estudos – e pelo MÉTODO utilizado para condução das revisões sistemáticas e do estudo experimental. A segunda parte é constituída por quatro artigos científicos, redigidos na língua inglesa de acordo com as normas das revistas para as quais os manuscritos foram ou serão submetidos para publicação. No início de cada artigo são apresentados dados embasados na literatura que justificam brevemente a realização de cada um dos estudos. Nos artigos apresentados nesta tese estão descritos os resultados e a discussão dos estudos propostos. A terceira e última parte contém as CONSIDERAÇÕES FINAIS acerca dos resultados encontrados nesta tese e as implicações clínicas, apresentadas na língua portuguesa.

PREFACE

This thesis was written according to the guidelines of the Graduate Program in Rehabilitation Sciences of the *Universidade Federal de Minas Gerais* (UFMG), and previously agreed with The University of Sydney (USYDNEY). The thesis is a partial requirement for a jointly awarded degree of Doctor in Rehabilitation Sciences conferred by UFMG, and Doctor of Philosophy conferred by USYDNEY, through a cotutelle arrangement (ANNEXE A).

The requirements of the Graduate Program in Rehabilitation Sciences of the UFMG comprise: (i) the fulfillment of academic credits (scientific production, workshops, and the accomplishment of a coursework offered by graduate programs), (ii) the writing and development of a thesis, (iii) the production of scientific papers, and (iv) an oral defense of the thesis. The requirements of the doctoral program of the USYDNEY comprise: (i) the writing and development of a thesis, and (ii) the production of scientific papers.

In order to meet the requirements of both Institutions, this cotutelle arrangement was conducted in three phases. The first phase was held at UFMG in the period of 2011-2012 and included: (i) the completion of the required coursework and the fulfillment of academic credits, (ii) the writing of the research project, (iii) the writing of basic scientific papers related to the thesis topic, aimed at improving student's scientific and technical abilities (ANNEXES B, C, and D).

1. Nascimento LR, Resende RA, Carvalho AC, Fonseca ST, Teixeira-Salmela LF (2012). Marcha humana: teorias, contribuições musculares e indicações clínicas. Ter Man. 10: 537-543.
2. Nascimento LR, Caetano LCG, Freitas DCMA, Morais TM, Polese JC, Teixeira-Salmela LF (2012). Different instructions during the ten-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. Braz J Phys Ther. 16: 122-127.
3. Polese JC, Ada L, Dean CM, Nascimento LR, Teixeira-Salmela LF (2013). Treadmill training is effective for ambulatory adults with stroke: a systematic review. J Physiother. 59: 73-80.

The second phase was held at USYDNEY in the period of 2012-2013 and included: (i) the learning of the basis of writing systematic reviews, and the development of the method of the systematic reviews included in the thesis, (ii) the refinement of the research project related to the experimental study included in the thesis.

The third phase was held at UFMG in the period of 2013-2015 and included: (i) the submission and publication of the systematic reviews included in the thesis, (ii) the data collection and the writing of the paper related to the experimental study included in the thesis, and (iii) the writing of the thesis.

This thesis contains a substantial abstract written in Portuguese and English, and was structured in three parts. The first part includes the INTRODUCTION – which contains a literature review on the topic, the rationality of the studies, and the research questions – followed by a detailed description of the METHOD used to conduct the systematic reviews, and the experimental study. The second part includes four scientific papers related to the research questions, which were written in English according to the journals' style to which papers have been or will be submitted for publication. At the beginning of each paper, a rationality of each study was provided. The results and discussion of the studies included in the thesis were described in these papers. The third and last part contains the FINAL CONSIDERATIONS and the clinical implications regarding the results of the studies, which were written in Portuguese.

RESUMO

Dados recentes indicam que mais de 30 milhões de pessoas no mundo sobreviveram a um episódio de Acidente Vascular Encefálico (AVE). Após a ocorrência do AVE, observa-se que mais de 80% dos sobreviventes apresentam fraqueza muscular contralateral à lesão encefálica e consideráveis limitações para deambulação, o que compromete a participação social desses indivíduos. Estudos prévios indicaram que Indivíduos pós-AVE apresentam deficiência em força muscular e limitações em marcha com valores aproximadamente 50% inferiores em comparação a idosos saudáveis. Por isso, esforços contínuos têm sido realizados na tentativa de identificar as mais eficazes formas de intervenção capazes de determinar modificações clínicas nas deficiências relacionadas à força muscular e nas limitações relacionadas à marcha de indivíduos pós-AVE, visando a uma prática clínica baseada em evidências. Entretanto, as principais barreiras para implementação de uma prática baseada em evidências são a falta de tempo dos clínicos para a leitura científica e a falta de habilidades para selecionar e compreender os estudos. O aumento no número de publicações científicas associado à falta de tempo e treinamento adequado para leitura e síntese da evidência desafiam pesquisadores a produzir informações sumarizadas de modo a facilitar o acesso clínico à informação de alta qualidade metodológica.

Embora Guias Clínicos sejam uma alternativa para sumarizar as informações sobre uma determinada condição de saúde, o desenvolvimento de um Guia Clínico é um processo longo, e mesmo seu processo de atualização requer tempo e dedicação de inúmeros profissionais. Dessa forma, por vezes, a informação contida em Guias Clínicos não contempla o estado atual do nível de evidência, e os profissionais devem recorrer a estudos experimentais ou preferencialmente às revisões sistemáticas para atualização da prática clínica. Revisões sistemáticas, por sua vez, são consideradas a melhor forma de sintetizar a informação existente sobre um determinado tópico específico com a vantagem de serem, usualmente, atualizadas com mais frequência do que os Guias Clínicos. Embora revisões sistemáticas sobre efeitos de intervenção sejam a melhor estratégia para fornecer as respostas clínicas necessárias, as mesmas são dependentes da existência de ensaios clínicos de alta

qualidade metodológica. Sabemos, entretanto, que a realização de ensaios clínicos aleatorizados fica limitada por fatores como dificuldades de captação de recursos pecuniários e recrutamento de participantes. Nesse contexto, pesquisadores devem ainda, ser capazes de ajustar as perguntas clínicas, de modo a concluir pesquisas de alta qualidade em tempo hábil e, ainda assim, fornecer repostas imediatas para auxiliar intervenções clínicas destinadas a uma população.

O objetivo geral da presente tese foi fornecer evidências clínicas de alta qualidade sobre efeitos de intervenções destinadas à população de indivíduos pós-AVE e/ou fornecer indicações clínicas que pudessem potencializar o efeito de uma intervenção. Os desfechos clínicos estão relacionados à principal deficiência negativa (i.e., fraqueza muscular) e às limitações em marcha. O processo de definição dos estudos que compuseram a tese teve início pela leitura criteriosa do *Clinical Guidelines for Stroke Management* – um guia clínico desenvolvido com o propósito de fazer recomendações clínicas para prevenção e tratamento de indivíduos pós-AVE, a partir de pesquisa clínica de alta qualidade. Foi realizada a leitura do capítulo referente à reabilitação com propósito de compreender o estado da evidência científica atual, identificar áreas de carência de informação científica e propor estudos capazes de auxiliar a prática clínica do fisioterapeuta em relação à (i) fraqueza muscular e (ii) deambulação. Para tanto, quatro estudos foram realizados, sendo três revisões sistemáticas com meta-análise e um estudo experimental.

Artigo 1: *Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review.*

Este estudo avaliou o efeito de elestroestimulação cíclica em medidas de força muscular e atividades de indivíduos com AVE. As perguntas clínicas foram: (i) Eletroestimulação é efetiva para aumentar força muscular pós-AVE? (ii) Esses benefícios são mantidos após o período de intervenção e/ou são transferidos para atividade? Uma revisão sistemática com meta-análise de ensaios clínicos aleatorizados ou controlados foi realizada. Os participantes eram adultos com diagnóstico de AVE e a intervenção considerada foi eletroestimulação cíclica com objetivo de promover aumento de força muscular. As medidas de desfecho deveriam ser relacionadas à força muscular e/ou atividade. As medidas de força deveriam ser

representativas de contração voluntária máxima e foram obtidas como medidas contínuas de força ou torque, ou medidas ordinais (e.g., teste manual de força muscular). Atividade, por sua vez, foi mensurada utilizando medidas diretas de desempenho que produziram dados contínuos ou ordinais, ou por meio de escalas que produziram dados ordinais. Dezesseis estudos, representando 17 comparações, foram incluídos. Os tamanhos de efeito foram calculados por meio de diferença de *Cohen* (SMD), pelo fato de diferentes músculos com variados instrumentos de medida terem sido utilizados. De modo geral, eletroestimulação aumentou a força muscular em 0.47 SMD (95% CI 0.26 a 0.68) e este efeito foi mantido além do período de intervenção (SMD 0.33, 95% CI 0.07 a 0.60). Eletroestimulação também melhorou os parâmetros de atividade (SMD 0.30, 95% CI 0.05 a 0.56) com manutenção dos resultados além do período de intervenção (SMD 0.38, 95% CI 0.09 a 0.66). Em conclusão, eletroestimulação cíclica aumentou força muscular e melhorou atividade de indivíduos pós-AVE. Esses benefícios foram mantidos além do período de intervenção com tamanhos de efeito variando entre pequeno e moderado. Os efeitos mantidos em atividade sugerem que os benefícios tenham sido incorporados nas atividades de vida diária.

Artigo 2: *Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review.*

Este estudo avaliou o efeito da adição de pistas auditivas rítmicas ao treino de marcha para melhora de velocidade de marcha, comprimento de passada, cadência e simetria em indivíduos com AVE. A pergunta clínica foi: Após AVE, o treino de marcha com pistas auditivas rítmicas é superior ao treino de marcha isolado para melhorar velocidade de marcha, comprimento de passada, cadência e simetria? Uma revisão sistemática com meta-análise de ensaios clínicos aleatorizados ou controlados foi realizada. Os participantes eram adultos com diagnóstico de AVE e a intervenção considerada foi treino de marcha associado a pistas auditivas rítmicas guiando cadência durante o treino de marcha. Foram quatro as medidas de desfecho de interesse: velocidade de marcha, comprimento da passada, cadência e simetria. A revisão incluiu sete estudos envolvendo 211 participantes. Um dos estudos incluídos causou substancial heterogeneidade estatística e, portanto, as

análises foram conduzidas com e sem este estudo. Treino de marcha associado a pistas auditivas rítmicas aumentou velocidade de marcha em 0.23 m/s (95% CI 0.18 a 0.27, I^2 = 0%), comprimento da passada em 0.21 m (95% CI 0.14 a 0.28, I^2 = 18%), cadência em 19 passos/minuto (95% CI 14 a 23, I^2 = 40%), e simetria em 15% (95% CI 3 a 26, *random effects*) quando comparado ao treino de marcha isolado. Em conclusão, esta revisão indicou que o treino de marcha associado a pistas auditivas rítmicas melhora velocidade de marcha e comprimento de passada mais que o treino de marcha isolado. A intervenção também aparenta produzir benefícios em cadência e simetria. A evidência encontrada é suficiente para recomendar a adição de pistas auditivas rítmicas ao treino de marcha por 30 minutos, quatro vezes por semana, durante quatro semanas visando melhorar habilidade de marcha em indivíduos pós-AVE com comprometimento moderado.

Artigo 3: ***Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis.***

Este estudo avaliou o efeito da adição de elementos de realidade virtual ao treino de marcha para melhora de velocidade de marcha de indivíduos pós-AVE. As perguntas clínicas foram: (i) O treino direcionado à marcha associado à realidade virtual é eficaz para promover aumento em velocidade de marcha de indivíduos com hemiparesia? (ii) Essa modalidade de intervenção promove maior aumento em velocidade de marcha comparada a outras intervenções sem uso de realidade virtual? Foi realizada uma revisão sistemática com meta-análise de ensaios clínicos aleatorizados. Os participantes eram adultos pós-AVE e a intervenção experimental considerada foi o treino direcionado à marcha associado ao uso de realidade virtual com o objetivo de melhorar a velocidade de marcha. Os dados referentes à velocidade de marcha foram extraídos para combinação por meta-análise. Sete estudos, representando oito comparações, foram incluídos nesta revisão sistemática. O treino de marcha associado à realidade virtual aumentou a velocidade de marcha dos participantes, em média, 0.17 m/s (IC 95% 0.08 a 0.26) comparado à intervenção placebo, não-intervenção ou intervenção não específica para os membros inferiores. Adicionalmente, o treino associado à realidade virtual aumentou a velocidade de marcha dos participantes, em média, 0.15 m/s (IC 95% 0.05 a 0.24)

comparado a diferentes intervenções destinadas aos membros inferiores sem uso de realidade virtual associada. Em conclusão, esta revisão sistemática apresentou evidência clínica de que a adição da realidade virtual ao treino de marcha demonstrou ser eficaz para aumentar a velocidade de marcha de indivíduos com hemiparesia e apresentou melhores resultados, quando comparada outras intervenções sem uso de realidade virtual.

Artigo 4: ***The provision of a cane provided greater benefit to the group of community-dwelling people with chronic stroke with speed between 0.4 and 0.8 m/s.***

Este estudo avaliou o efeito da provisão de uma bengala em variáveis relacionadas à marcha (i.e., velocidade de marcha, comprimento do passo e simetria) de indivíduos pós-AVE. As perguntas clínicas foram: (i) Qual o efeito da provisão de uma bengala em variáveis relacionadas à marcha (i.e., velocidade de marcha, comprimento do passo e simetria) de indivíduos em fase crônica do AVE, capazes de deambular independentemente? (ii) O efeito é diferente quando os indivíduos são agrupados de acordo com a velocidade de marcha confortável? (< 0.4 m/s versus 0.4-0.8 m/s versus > 0.8 m/s)? Vinte e quatro indivíduos com AVE crônico, que não faziam uso regular de dispositivos de auxílio à marcha, foram avaliados em duas diferentes condições experimentais: (i) deambulação sem auxílio de bengala; (ii) deambulação com auxílio de uma bengala ajustável. As variáveis de desfecho foram reportadas como velocidade (m/s), comprimento do passo (m) e cadência (passos/minuto). Os participantes foram divididos em três grupos e categorizados como indivíduos lentos (<0.4 m/s), indivíduos intermediários (0.4-0.8 m/s) e indivíduos rápidos (>0.8 m/s), baseados em sua velocidade de marcha confortável. A provisão da bengala aos indivíduos intermediários produziu um aumento em velocidade de marcha de 0.27 m/s (95% CI 0.18 a 0.36) em comparação aos indivíduos rápidos e um aumento de 0.12 m/s (95% CI 0.03 a 0.21) em comparação aos indivíduos lentos. Também produziu um aumento de 0.05 m (95% CI 0.02 a 0.08) no comprimento do passo e de 20 passos/min (95% CI 12 a 28) em comparação aos indivíduos rápidos. Em síntese, a provisão da bengala determinou maiores benefícios aos indivíduos categorizados como intermediários e foi prejudicial à marcha de indivíduos rápidos. Os resultados indicaram que bengalas

podem ser prescritas a indivíduos pós-AVE com limitações graves ou moderadas da marcha, mas não devem ser prescritas a indivíduos com alta velocidade de deambulação.

Palavras-chave: Acidente vascular encefálico; Prática baseada em evidências; Revisões sistemáticas; Marcha; Fisioterapia.

ABSTRACT

Recent data indicated that more than 30 million people in the world have experienced and survived a stroke. As a consequence of stroke, more than 80% of the survivors experience muscle weakness contralateral to the brain lesion and walking limitations, which contribute to participation restrictions. Previous studies have demonstrated that strength and walking parameters in ambulatory people after stroke are approximately half of the values expected for older, able-bodied adults. Thus, there is a constant move in order to examine the most efficient interventions capable of improving weakness and walking limitations after stroke, and several clinical trials to support an evidence-based practice have been conducted. However, the main barriers to the implementation of an evidenced-based practice are the lack of time for reading all the published evidence, and the lack of skills in finding and understanding the randomised clinical trials. The increase in the number of published papers associated with the lack of time for reading and synthesizing the available evidence challenge researchers to produce summarized information, in order to enhance clinical access to the most updated evidence.

Clinical Guidelines represent good alternatives for clinicians to obtain summarized information regarding a specific health condition. However, the development of a clinical guideline is a long process, and even its update process requires time and dedication of many professionals. Thus, sometimes, the information provided by Clinical Guidelines does not represent the most updated evidence, and clinicians may have to read numerous clinical trials or, preferably, systematic reviews in order to update the knowledge that will help with clinical practice. Systematic reviews of randomised clinical trials are the most robust source of information to answer questions regarding the efficacy of an intervention, with the advantage of being updated more frequently in comparison with Clinical Guidelines. Although systematic reviews are the best design to provide evidence of effect of interventions, they are dependent on the publication of clinical trials with good methodological quality. The development of clinical trials, however, is not an easy procedure, and it is constantly limited due to difficulties in funding and participants' recruitment. In this case,

researches should also be able to produce trials with the potential of immediately answering clinical questions that may improve clinical practice.

The overall purpose of this thesis was to provide clinical evidence, based on high quality research, regarding effects of interventions delivered to people after stroke, and to provide clinical implications with the potential to enhance the effect of an intervention. Clinical interests are related to a major impairment after stroke (i.e., muscle weakness) and to walking limitations. The definition of each study which comprised the thesis and its research design began by carefully reading the *Clinical Guidelines for Stroke Management* – a clinical guideline developed with the purpose of making clinical recommendations for prevention and treatment of patients after stroke. The rehabilitation chapter of the guideline was analyzed in order to understand the current level of evidence, to identify areas with lack of evidence, and to develop studies capable of providing evidence that could help clinical practice regarding muscle weakness and walking limitations after stroke. Four studies were planned: three systematic reviews and one experimental trial.

Study 1: Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review.

This study examined the effect of cyclical electrical stimulation on muscle strength and activities after stroke. The research questions were: Does electrical stimulation increase strength after stroke? Are any benefits maintained beyond the intervention period or carried over to activity? A systematic review with meta-analysis of randomised or controlled trials was conducted. Participants were adults who have had a stroke, and the intervention was cyclical electrical stimulation applied in order to increase muscle strength. The outcome measures were related to muscle strength and to activity. Strength measures had to be representative of maximum voluntary contraction and were obtained as continuous measures of force or torque, or as ordinal measures such as manual muscle tests. Activity was measured using direct measures of performance that produced continuous or ordinal data, or with scales that produced ordinal data. Sixteen trials, representing 17 relevant comparisons, were included in this systematic review. Effect sizes were calculated as standardised mean differences because various muscles were studied and different outcome

measures were used. Overall, electrical stimulation increased strength by a standardised mean difference (SMD) of 0.47 (95% CI 0.26 to 0.68) and this effect was maintained beyond the intervention period (SMD 0.33, 95% CI 0.07 to 0.60). Electrical stimulation also improved activity (SMD 0.30, 95% CI 0.05 to 0.56) and this effect was also maintained beyond the intervention period (SMD 0.38, 95% CI 0.09 to 0.66). In conclusion, cyclical electrical stimulation increased strength and improved activity after stroke. These benefits were maintained beyond the intervention period with a small-to-moderate effect size. The sustained effect on activity suggests that the benefits were incorporated into daily life.

Study 2: Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review.

This study examined the effect of the addition of cueing of cadence to walking training for improving walking speed, stride length, cadence and symmetry after stroke. The research question was: After stroke, is walking training with cueing of cadence superior to walking training alone in improving walking speed, stride length, cadence and symmetry? A systematic review with meta-analysis of randomised or controlled trials was conducted. Participants were ambulatory adults who have had a stroke. The intervention was walking training with cueing of cadence, and four walking outcomes were of interest: walking speed, stride length, cadence and symmetry. This review included seven trials involving 211 participants. Because one trial caused substantial statistical heterogeneity, meta-analyses were conducted with and without this trial. Walking training with cueing of cadence improved walking speed by 0.23 m/s (95% CI 0.18 to 0.27, I^2 = 0%), stride length by 0.21 m (95% CI 0.14 to 0.28, I^2 = 18%), cadence by 19 steps/minute (95% CI 14 to 23, I^2 = 40%), and symmetry by 15% (95% CI 3 to 26, *random effects*) more than walking training alone. In conclusion, this review provided evidence that walking training with cueing of cadence improves walking speed and stride length more than walking training alone. It may also produce benefits in terms of cadence and symmetry of walking. The evidence appears strong enough to recommend the addition of 30 minutes of cueing of cadence to walking training, four times a week for 4 weeks, in order to improve walking in moderately disabled individuals with stroke.

Study 3: Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis.

This study examined the effect of the addition of virtual reality-based training to walking training for improving walking speed after stroke. The research questions were: (i) Is walking training associated with virtual reality-based training effective in increasing walking speed after stroke? (ii) Is this type of intervention more effective in increasing walking speed, than non-virtual reality-based walking interventions? A systematic review with meta-analysis of randomised clinical trials was conducted. Participants were adults with chronic stroke and the experimental intervention was walking training associated with virtual reality-based training to increase walking speed. The outcome data regarding walking speed were extracted from the eligible trials and were combined using a meta-analysis approach. Seven trials, representing eight comparisons, were included in this systematic review. Overall, the virtual reality-based training increased walking speed by 0.17 m/s (IC 95% 0.08 to 0.26), compared with placebo/nothing or non-walking interventions. In addition, the virtual reality-based training increased walking speed by 0.15 m/s (IC 95% 0.05 to 0.24), compared with non-virtual reality walking interventions. In conclusion, this review provided evidence that walking training associated with virtual reality-based training was effective in increasing walking speed after stroke, and resulted in better results than non-virtual reality interventions.

Study 4: The provision of a cane provided greater benefit to the group of community-dwelling people with chronic stroke with speed between 0.4 and 0.8 m/s.

This study examined the effect of the provision of a cane to ambulatory people after stroke on walking speed, step length, and cadence. The research questions were: (i) What is the effect of the provision of a cane on speed, step length, and cadence in people with chronic stroke who are independently ambulatory? (ii) Is there a differential effect according to comfortable walking speed (<0.4 versus 0.4-0.8 versus >0.8 m/s)? Twenty-four people with chronic stroke, who were not regular users of

walking sticks, were evaluated under two different experimental conditions: walking with and without a cane. Walking was reported as speed (m/s), step length (m), and cadence (steps/min). Participants were categorized as slow (<0.4 m/s), intermediate (0.4-0.8 m/s), and fast walkers (>0.8 m/s). The provision of a cane to the intermediate walkers produced a 0.27 m/s (95% CI 0.18 to 0.36) increase in speed compared with the fast walkers, and a 0.12 m/s (95% CI 0.03 to 0.21) increase compared with the slow walkers. It also produced 0.05 m (95% CI 0.02 to 0.08) increase in step length and 20 steps/min (95% CI 12 to 28) increase in cadence compared with the fast walkers. The provision of a cane produced the most benefit in intermediate walkers, and was detrimental to the fast walkers. Canes can be prescribed to stroke survivors with moderate and severe walking limitations, but caution should be taken regarding their prescription for fast walkers.

Key-words: Stroke; Evidence-based practice; Systematic review; Gait; Physiotherapy.

SUMÁRIO

1 INTRODUÇÃO

INTRODUCTION

1 INTRODUÇÃO

Considerado um problema de saúde mundial e representando a principal causa de morte no Brasil e a terceira causa de morte nos Estados Unidos (LESSA, 1999; KAISER, 2004), o Acidente Vascular Encefálico (AVE) é conceituado como uma síndrome clínica decorrente de uma redução do suprimento sanguíneo para estruturas encefálicas, caracterizado por rápido desenvolvimento de sinais focais ou globais de perturbação das funções encefálicas (ROYAL COLLEGE OF PHYSICIANS, 2004). Descreve-se, entretanto, a partir da década de 70, uma tendência ao declínio da mortalidade por doenças cerebrovasculares e, consequentemente, um maior número de indivíduos enfrenta as incapacidades decorrentes do AVE (UEMURA; PISA, 1988). Dados recentes indicam que mais de 30 milhões de pessoas no mundo sobreviveram a um episódio de AVE (NORRVING; KISSELA, 2011). Após a ocorrência do AVE, observa-se que mais de 80% dos sobreviventes apresentam fraqueza muscular contralateral à lesão encefálica e consideráveis limitações para deambulação o que compromete a participação social desses indivíduos (NAKAYAMA *et al*., 1994; LEBRAUSSER 2006; ALZAHRANI *et al*., 2011; NASCIMENTO *et al*., 2015).

No fim do século XIX, o neurologista Hughlings Jackson descreveu que os problemas estruturais resultantes de lesões no sistema nervoso central, incluindo os causados pelo AVE, poderiam ser categorizados em positivos ou negativos. As deficiências negativas foram, por definição, consideradas aquelas que representam a perda ou redução de uma função pré-existente, como perda de força muscular e de destreza; as deficiências positivas, por sua vez, os elementos adicionais não existentes pré-lesão, tais como padrões posturais anormais e hiperreflexia (espasticidade) (O'DWYER; ADA, 1996; REFSHAUGE *et al*., 2005).

Os fatores positivos, especialmente a espasticidade, eram considerados os principais contribuintes para as incapacidades pós-AVE, uma vez que as relações com a funcionalidade não estavam bem estabelecidas. Esta visão ainda é mantida por muitos clínicos que trabalham no processo de reabilitação desses pacientes

(CARR; SHEPHERD, 2006; NASCIMENTO *et al.,* 2012). Entretanto, diversas pesquisas científicas questionaram este postulado e demonstraram que a maioria dos pacientes após lesões encefálicas não apresenta espasticidade, apesar de uma maior resistência à movimentação passiva (hipertonia) (LANDAU, 1974, O'DWYER; ADA, 1996, O'DWYER *et al*., 1996). Ademais, uma mudança de paradigma na compreensão dos modelos de saúde-doença com maior atenção direcionada à funcionalidade, e não apenas às deficiências estruturais, incitou a realização de pesquisas que indicaram que presença de espasticidade não está relacionada à perda de funcionalidade em pacientes pós-AVE (ADA *et al*., 1998; SOMMERFIELD *et al*., 2004; HARRIS; ENG, 2007; FARIA-FORTINI *et al*., 2011). Nesse contexto, não apenas os fatores negativos começaram a ser mais investigados, mas também suas relações como contribuintes às limitações funcionais. Como exemplo, um estudo longitudinal acompanhou a evolução de espasticidade (uma deficiência positiva), fraqueza muscular (uma deficiência negativa) e contratura (uma deficiência secundária) em pacientes com AVE durante um ano e suas relações com incapacidades. A espasticidade contribuiu pouco para a limitação funcional e apenas aos quatro meses pós-lesão, sendo que a contratura foi preditora de função já aos dois meses pós lesão, com piora progressiva ao longo do tempo. A fraqueza muscular, por sua vez, sempre esteve correlacionada às limitações funcionais durante o período avaliado (CANNING *et al*., 2004). Esses dados, associados a outros estudos (HSU *et al*., 2003; HARRIS; ENG, 2007; ROBINSON *et* al., 2007; FARIA-FORTINI *et al*., 2011), indicaram que as deficiências negativas são os maiores contribuintes para as incapacidades pós-AVE, com possíveis contribuições de deficiências secundárias. De modo mais abrangente, perceba que, embora as definições de Hughlings Jackson tenham sido propostas em séculos anteriores, sua relação é notória com os pressupostos da Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF) como modelo que enfoca não apenas a condição de saúde, mas os diferentes domínios de funcionalidade e suas relações que norteiam contemporaneamente os modos de pensar e agir no processo de reabilitação (OMS, 2003).

A CIF foi desenvolvida com o propósito de oferecer uma estrutura que permita a visualização das consequências da condição de saúde na funcionalidade, auxiliando os profissionais de reabilitação na compreensão e descrição dos diferentes impactos que uma condição de saúde, como o AVE, pode ter na funcionalidade do indivíduo, bem como na definição de estratégias de avaliação e elaboração do plano de tratamento (OMS, 2003; SVESTKOVA, 2008). Segundo o modelo da CIF, as manifestações de uma condição de saúde são didaticamente divididas em duas partes: (i) Funcionalidade e Incapacidade, e (ii) Fatores Contextuais. Na primeira parte, reconhecem-se dois componentes. As funções e estruturas do corpo compreendem o primeiro componente e são, por definição, as partes anatômicas tais como, órgãos, membros e suas funções. Problemas nas funções ou na estrutura do corpo, tais como um desvio importante ou uma perda, são denominados *deficiências*. As atividades e a participação compreendem o segundo componente. Por definição, atividade é a execução de uma tarefa ou ação por um indivíduo. Problemas na execução de atividades são denominados *limitações em atividades*. Por definição, participação é o envolvimento do indivíduo em uma situação de vida. Dificuldades na participação social são denominadas *restrições*. Cada um dos componentes citados pode ser influenciado por fatores relacionados à condição de saúde e/ou por fatores relacionados à segunda parte, ou seja, os fatores contextuais (ambientais e pessoais), que podem exercer efeito positivo ou negativo na funcionalidade do indivíduo (OMS, 2003; SVESTKOVA, 2008).

No contexto do AVE, atualmente, a fraqueza muscular é descrita como a principal deficiência (ou deficiência negativa) estando diretamente relacionada à limitação de atividades e restrições na participação social (HARRIS; ENG, 2007; ALZAHRANI *et al*., 2011). Em 2004, Canning *et al.* demonstraram que a perda de força muscular contribuiu mais para as incapacidades do que a perda de destreza (outra deficiência negativa decorrente do AVE). Os esforços clínicos e científicos direcionados à tentativa de aumentar a força muscular pós-AVE estão relacionados à alta correlação entre grau de força muscular e desempenho em atividades de vida diária (ALZAHRANI *et al.,* 2011; FARIA-FORTINI *et al.,* 2011; DORSCH *et al.,* 2012). Dentre as principais atividades comprometidas após o AVE e que apresentam

relações significativas com a fraqueza muscular, destacam-se as limitações em marcha.

Após AVE, os indivíduos tipicamente apresentam redução da velocidade de marcha, do comprimento da passada e da cadência, além de assimetria temporal. Uma recente revisão sistemática reportou que indivíduos pós-AVE apresentam usualmente valores de velocidade de marcha entre 0.4 e 0.8 m/s (POLESE *et al*., 2013), ao passo que indivíduos idosos saudáveis apresentam valores entre 1.0 e 1.2 m/s (HOLLMAN *et al*., 2011). Estudos prévios (THAUT *et al*., 1997; THAUT *et al*., 2007) reportaram valores de comprimento de passada em indivíduos pós-AVE entre 0.50 a 0.64 m, enquanto o observado em indivíduos idosos saudáveis varia entre 1.1 e 1.4 m (HOLLMAN *et al*., 2011); bem como reportaram valores de cadência entre 50 a 63 passos/minuto, enquanto o observado em indivíduos idosos saudáveis varia entre 102 e 114 passos/minuto. Em relação à razão de simetria temporal do membro inferior parético em relação ao membro inferior não-parético, observam-se valores variando entre 0.40 e 0.64, enquanto 1.00 seria considerado simetria perfeita (THAUT *et al*., 1997; THAUT *et al*., 2007). Em síntese, indivíduos pós-AVE apresentam deficiência em força muscular e limitações em marcha com valores aproximadamente 50% inferiores em comparação a idosos saudáveis (NASCIMENTO *et al*., 2015; NASCIMENTO *et al.,* 2014; DORSCH *et al.,* 2012). Dessa forma, esforços contínuos são feitos na tentativa de identificar as mais eficazes formas de intervenção capazes de determinar modificações clínicas nas deficiências relacionadas à força muscular e nas limitações relacionadas à marcha de indivíduos pós-AVE, ambas foco de estudo da presente tese.

Fisioterapia baseada em evidências

A demanda por qualidade máxima do cuidado em saúde, combinada com a necessidade de uso racional de recursos tanto público quanto privado, tem contribuído para aumentar a pressão sobre os profissionais da área de reabilitação no sentido de assegurar a implementação de uma prática baseada em evidências científicas (SAMPAIO; MACINI, 2007). Por definição, fisioterapia baseada em

evidências é a integração entre pesquisa científica de alta qualidade, conhecimento prático e preferências do cliente (HERBERT *et al*., 2005; SARAGIOTTO *et al*., 2014; SILVA *et al*., 2014). Esta definição contemporânea difere da visão clássica na qual opiniões de expertos e as pesquisas de baixa qualidade eram consideradas como prática baseada em evidência na ausência de evidências de alta qualidade. No conceito atual, a prática somente deve ser considerada baseada em evidência quando é derivada de pesquisa científica de alta qualidade (HERBERT *et al*., 2005, SILVA *et al*., 2014). É importante ressaltar, entretanto, que essa definição não negligencia a recepção de informações não provenientes de pesquisas de alta qualidade quando tais pesquisas ainda não estiverem disponíveis. A definição apenas indica que o termo “fisioterapia baseada em evidência” deve ser restrito à prática da fisioterapia que está baseada em pesquisa científica de alta qualidade. Essa restrição muda o conceito prévio de reabilitação uma vez que incentiva pesquisadores a produzir pesquisa científica de alta qualidade e informa aos clínicos que o uso da melhor informação disponível para a tomada de decisões clínicas é essencial.

Um desafio aos consumidores da informação científica é identificar quais são as pesquisas clínicas de alta qualidade. Do ponto de vista do consumidor da informação, pesquisa clínica de alta qualidade é aquela confiável em relação aos seus resultados (apresenta poucos vieses) e é relevante para responder às questões clínicas (HERBERT *et al*., 2005). Essa visão não deve ser antagônica ao ponto de vista do produtor da informação. Este apenas difere do anterior no sentido de que é o responsável por produzir resultados confiáveis e eminentemente capazes de responder a perguntas clínicas reais. Nesse contexto, é possível compreender que a qualidade da pesquisa, apesar de ser influenciada, não é determinada apenas pelo desenho de um estudo científico, uma vez que perguntas clínicas diferentes podem ser respondidas por métodos diferentes. Entretanto, apesar do significativo aumento na produção de pesquisa clínica na área de fisioterapia, nem todos os estudos disponíveis são bem desenvolvidos ou capazes de responder a uma pergunta clínica específica.

Os maiores interesses de pesquisadores e clínicos envolvidos na área de reabilitação são: (i) pesquisas capazes de atestar a eficácia (ou ineficácia) de uma intervenção, e/ou (ii) pesquisas capazes de fornecer subsídios práticos que possam ser incorporados a uma intervenção. Em relação às pesquisas relacionadas à eficácia de intervenção, é consenso que os ensaios clínicos aleatorizados (ECA) são os estudos mais adequados para fornecer as evidências necessárias sobre os efeitos de uma intervenção (SAMPAIO; MANCINI, 2007; KOCAK *et al*., 2011). No entanto, usualmente, os resultados de apenas um desses estudos não são suficientes para esclarecer sobre determinada questão de pesquisa ou pergunta clínica o que pode ser justificado por inúmeros fatores tais como: diferenças no nível de incapacidade em uma mesma população de interesse, características específicas de uma intervenção, dificuldades em obtenção de amostra suficiente em um único estudo, dificuldades em obtenção de recursos para manutenção de um estudo, dentre outras (DEAN *et al.,* 2012; SCIANNI *et al.,* 2012; DEAN *et al.,* 2014; LIMA *et al.,* 2014). Dessa forma, inúmeros ensaios clínicos são realizados, e esse número elevado dificulta a obtenção de uma resposta clínica objetiva pelo fisioterapeuta ou profissional de reabilitação. Em números gerais, atualmente, estão disponíveis aproximadamente 20 mil estudos relacionados à eficácia de intervenções em fisioterapia, sendo que 16 mil correspondem a ensaios clínicos aleatorizados (*PEDro*, 2011; PADULA *et al*., 2012). Ao tomarmos como exemplo um tópico específico como ‘reabilitação da marcha pós-AVE’, somente na base de dados *PEDro* há cerca de 250 ensaios clínicos aleatorizados o que corresponde a 85% do total de publicações sobre o tema. Como a base de dados contém apenas estudos considerados nível A de evidência científica sobre estudos de intervenção, apenas 15% dos estudos incluídos são revisões sistemáticas ou guias clínicos, reforçando a necessidade de condensar toda essa quantidade de informação atualmente produzida para facilitar a tomada de decisão clínica.

Uma recente revisão sistemática (SILVA *et al*., 2014) indicou que dentre as principais barreiras para a implementação da fisioterapia baseada em evidências estão incluídas a falta de tempo dos profissionais para leitura científica, inabilidade para a compreensão da informação (e.g., análise estatística, linguagem), e

dificuldade para generalização e aplicação dos resultados. Especificamente em relação à reabilitação de indivíduos pós-AVE, Salbach *et al*. (2007), investigaram os possíveis fatores pessoais e organizacionais que afetavam a implementação da fisioterapia baseada em evidências por 240 fisioterapeutas canadenses que proviam atendimento a indivíduos com hemiparesia decorrente de AVE. Apesar de 93% considerarem a prática baseada em evidências necessária e 80% considerarem que ela melhora a qualidade do cuidado e auxilia a tomada de decisões clínicas, apenas 44% relataram ter recebido formação específica sobre prática baseada em evidência. Em relação ao acesso à evidência, apenas 47% receberam treinamento formal para busca e análise da informação, e somente 49% se julgaram responsáveis por conduzir suas próprias revisões. Surpreendentemente, 90% dos fisioterapeutas indicaram que o uso da evidência em sua prática clínica não é satisfatório.

Devido ao alto volume de artigos publicados – incluindo ensaios clínicos aleatorizados – e dificuldade de fisioterapeutas em implementar a evidência na prática clínica, devido à falta de tempo e treinamento adequado para leitura e síntese da evidência, estratégias devem ser adotadas de modo a facilitar o acesso clínico à informação de alta qualidade metodológica. Sumarizar o conteúdo quando há informações suficientes derivadas de pesquisa clínica de alta qualidade sobre um determinado tópico, e/ou produzir pesquisa experimental capaz de influenciar diretamente a prática clínica em áreas de conhecimento ainda baseadas em crenças e opiniões de expertos deve ser responsabilidade de pesquisadores interessados em modificar a prática clínica e estimular as relações entre pesquisa e clínica.

Duas fontes de informação capazes de sintetizar o conhecimento disponível com potencial para direcionar a prática clínica são os Guias Clínicos (*Guidelines*) e as Revisões Sistemáticas. Essas duas fontes de informação, por sua vez, cooperam entre si num ciclo contínuo em que revisões sistemáticas são as fontes de evidência mais fortes para as recomendações estabelecidas nos guias clínicos, e os guias clínicos sinalizam as áreas em que a evidência disponível é insuficiente para guiar a

prática e carecem de maior pesquisa de alta qualidade. Por definição, Guias Clínicos são um conjunto de

> [...] afirmações que incluem recomendações com objetivo de otimizar o cuidado a pacientes; essas afirmações são baseadas em uma revisão sistematizada da evidência disponível, bem como na avaliação para estabelecimento de benefícios e riscos de possíveis cuidados alternativos (ANN, 2011).

Embora tenham a vantagem de conter o máximo de indicações clínicas sobre uma condição de saúde, o desenvolvimento de um Guia Clínico é um processo longo, e mesmo seu processo de atualização requer muito tempo e dedicação de inúmeros profissionais. Dessa forma, por vezes, a informação contida em Guias Clínicos não contempla o estado atual do nível de evidência e os profissionais devem recorrer a estudos experimentais ou preferencialmente às revisões sistemáticas para atualização da prática clínica. Revisões sistemáticas, por sua vez, são consideradas a melhor forma de sintetizar toda a informação existente sobre um determinado tópico específico com a vantagem de serem, usualmente, atualizadas com mais frequência do que os Guias Clínicos (HERBERT *et al*., 2005; PADULA *et al*., 2012).

Como indicado pelo nome, revisões sistemáticas são realizadas seguindo um método de características sistemáticas e explícitas. Uma boa revisão sistemática irá incluir: uma pergunta clínica precisa, descrição dos critérios de inclusão dos estudos, avaliação individual da qualidade dos estudos incluídos, descrição da extração dos dados e uma síntese dos resultados encontrados. De acordo com Herbert *et al*. (2005):

> Revisões sistemáticas de alta qualidade proveem uma descrição detalhada, transparente e com diminuto risco de vieses da literatura científica. Revisões sistemáticas de ensaios clínicos aleatorizados ou controlados usualmente constituem a melhor fonte de informação acerca dos efeitos de uma dada intervenção (HERBERT *at al*., 2005).

Os resultados de uma revisão sistemática devem considerar fatores como contingente amostral e qualidade metodológica de cada estudo, utilizando, sempre que possível a combinação de dados por métodos estatísticos como a meta-análise (PADULA *et al*., 2012). Pelo fato de as revisões sistemáticas apresentarem dados

combinados das pesquisas clínicas incluídas, há um consequente aumento na precisão da informação fornecida ao clínico em relação ao tamanho de efeito de uma determinada intervenção (HERBERT *et al*., 2005).

Salbach *et al*. (2011) conduziram um estudo visando explorar as preferências de fisioterapeutas canadenses em relação a estratégias (educação, recursos, tecnologia) que poderiam facilitar o acesso e implementação das evidências clínicas para reabilitação de indivíduos pós-AVE na prática clínica. Os fisioterapeutas indicaram maior necessidade de tempo para pesquisas e de necessidade de acesso a computadores no ambiente de trabalho, e demonstraram interesse na realização de cursos presenciais que ensinassem as novas técnicas. A sugestão, entretanto, que mais emergiu no discurso dos profissionais foi a necessidade de síntese das informações por meio de revisões sistemáticas. Os profissionais sugeriram que as revisões fossem redigidas com informações específicas para auxiliar a prática clínica contendo: (i) pergunta clínica específica, (ii) informação detalhada sobre a intervenção, (iii) síntese do resultado por meio de meta-análise e (iv) mensagem final em linguagem não-técnica. É recomendado, portanto, que esforços sejam realizados por pesquisadores de modo a sumarizar a evidência proveniente de diferentes pesquisas clínicas visando fornecer respostas imediatas a clínicos e clientes por meio de revisões sistemáticas com meta-análise. Embora revisões sistemáticas sobre efeitos de intervenção sejam a melhor estratégia para fornecer as respostas clínicas necessárias, as mesmas são dependentes da existência de ensaios clínicos de alta qualidade. Sabemos que a realização de ensaios clínicos aleatorizados, por vezes, fica limitada por fatores como dificuldades de captação de recursos pecuniários e recrutamento de participantes (DEAN *et al.,* 2012; SCIANNI *et al.,* 2012; DEAN *et al.,* 2014; LIMA *et al.,* 2014). Nesse contexto, pesquisadores devem ainda, ser capazes de ajustar as perguntas clínicas de modo a concluir pesquisas de alta qualidade em tempo hábil que sejam capazes fornecer repostas imediatas para auxiliar intervenções clínicas para uma dada população.

O objetivo geral da presente tese foi fornecer evidências clínicas de alta qualidade sobre efeitos de intervenções destinadas à população de indivíduos pós-AVE e

fornecer indicações clínicas que possam potencializar o efeito de uma intervenção. Os desfechos clínicos estão relacionados à principal deficiência negativa (i.e., fraqueza muscular) e às limitações em marcha. O processo de definição dos estudos que compõem a tese teve início pela leitura criteriosa do *Clinical Guidelines for Stroke Management* (NATIONAL STROKE FOUNDATION, 2010), um guia clínico desenvolvido com o propósito de fazer recomendações clínicas para prevenção e tratamento de indivíduos pós-AVE, a partir de pesquisa clínica de alta qualidade. Foi realizada a leitura do capítulo referente à reabilitação com propósito de compreender o estado da evidência científica atual, identificar áreas de carência de informação científica e propor estudos capazes de auxiliar a prática clínica do fisioterapeuta em relação à (i) fraqueza muscular e (ii) limitações na marcha. Uma breve descrição dos achados encontrados é sintetizada, seguida pelas perguntas clínicas propostas que constituem os objetivos específicos da presente tese.

Reabilitação da força muscular e da marcha pós-AVE: evidências atuais e perspectivas futuras

O *Clinical Guidelines for Stroke Management* (NATIONAL STROKE FOUNDATION, 2010) é um Guia Clínico relacionado à prevenção, tratamento e reabilitação pós-AVE, publicado pelo *National Stroke Foundation*, uma organização sem fins lucrativos que trabalha para reduzir o impacto do AVE na comunidade australiana. A edição atual é composta por nove capítulos e provê uma série de recomendações baseadas em evidência científica para auxiliar a tomada de decisão clínica. Cada recomendação clínica, apresentada separadamente de acordo com a estratégia de intervenção, foi baseada nos critérios do *National Health and Medical Research Council* (NHMRC) para classificação dos níveis de evidência, no qual revisões sistemáticas de ensaios clínicos aleatorizados constituem o maior nível de evidência para efeitos de intervenção. As recomendações no guia clínico são apresentadas de acordo com o quadro da próxima página:

Quadro 1: Significado dos níveis de recomendação do *Clinical Guidelines for Stroke Management*

Nível da Recomendação	**Descrição**
A	Corpo de evidência suficiente para guiar a prática clínica
B	Corpo de evidência suficiente para guiar a prática clínica na maioria das situações
C	Corpo de evidência provê algum suporte para recomendações, mas cuidados devem ser tomados na aplicação da técnica
D	Corpo de evidência é fraco e a recomendação deve ser aplicada com cautela
Good Practice Point	Prática recomendada baseada em experiência clínica e opinião de expertos

Fonte: NATIONAL STROKE FOUNDATION (2010).

Foi realizada uma análise do Capítulo 6, relacionado à reabilitação de indivíduos com AVE, mais especificamente dos sub-itens 6.2.2 – Fraqueza Muscular e 6.3.4 – Deambulação, antes da definição dos estudos que compuseram a tese. Em sequência, estão apresentadas as estratégias de intervenção indicadas no guia clínico com respectivo nível de recomendação e evidência que sustentou a indicação. Dessa forma, foi possível identificar as estratégias com nível baixo de recomendação clínica e investigar o estado da evidência científica atual. Os objetivos específicos da presente tese, bem como os estudos e desenhos de estudo que a compõem foram determinados pela necessidade de fortalecer a evidência sobre cada estratégia de intervenção com baixo nível de recomendação decorrente de falta de pesquisa de alta qualidade.

Em relação à fraqueza muscular, o guia clínico indicou três possibilidades de intervenção com potencial para aumento de força muscular pós-AVE: *biofeedback* por eletromiografia em conjunto com reabilitação convencional, exercícios de resistência com progressão e eletroestimulação.

Biofeedback por eletromiografia em conjunto com reabilitação convencional (nesse caso o termo convencional não foi esclarecido pelo guia clínico) foi apresentado com nível de recomendação C. A recomendação é baseada nos resultados de uma revisão sistemática que investigou os efeitos de diferentes técnicas de fortalecimento

muscular para melhora de força muscular pós-AVE, dentre as quais apenas dois ensaios clínicos avaliaram a eficácia do *biofeedback* para fortalecimento muscular (ADA *et al*., 2006). O número de novos ensaios clínicos visando aumento de força ainda é insuficiente para uma revisão sistemática sobre o tema. Embora a ausência de forte recomendação no guia clínico sugira maiores investigações, esforços já foram feitos na tentativa de investigar os efeitos do *biofeedback* como alternativa para melhorar atividade (STANTON *et al*., 2011), ao invés de focar em força muscular. O nível de evidência relacionado ao uso de *biofeedback* para melhora de atividade pós-AVE é apresentado a seguir, na presente tese, em conjunto com as estratégias para melhora de atividade da marcha pós-AVE.

Exercícios de resistência com progressão foram apresentados com nível de recomendação B. A recomendação é baseada nos resultados de três revisões sistemáticas (ADA *et al*., 2006; PAK; PATTEN, 2008; HARRIS; ENG, 2010;). De modo geral, está bem estabelecido que programas de fortalecimento baseados em exercícios progressivos são benéficos para aumento de força, e não são prejudiciais (i.e., não resultam em aumento de espasticidade) a indivíduos pós-AVE. Entretanto, os tamanhos de efeito ainda apresentam-se pequenos e heterogeneidade foi descrita entre os estudos, refletindo, possivelmente diferentes critérios na seleção dos participantes, diferentes grupos musculares e diferentes características de intervenção (e.g., intensidades diferentes). Ensaios clínicos são recomendados de modo a estabelecer critérios específicos para as intervenções e subgrupo de população de indivíduos com AVE com maior potencial para se beneficiar dessa estratégia de intervenção. Novas revisões sistemáticas ficam, portanto, condicionadas à publicação de novos ensaios clínicos.

Eletroestimulação foi apresentada com nível de recomendação B. A recomendação é baseada nos resultados de apenas uma revisão sistemática (GLINSKY *et al*., 2007) que investigou os efeitos da eletroestimulação para fortalecimento em diferentes condições neurológicas, dentre as quais o AVE foi incluído. Embora 11 ensaios clínicos tenham sido incluídos, não há síntese dos resultados por meio de meta-análise, os resultados foram publicados há mais de sete anos, e foram

incluídas ambas eletroestimulação funcional e eletroestimulação cíclica. De acordo com de Kroon *et al*. (2002), o termo eletroestimulação deve ser dividido em duas categorias: eletroestimulação funcional e cíclica. Na eletroestimulação funcional, um ou mais músculos são eletricamente estimulados durante a realização de uma atividade específica, com o objetivo de melhorar o desempenho dessa atividade. Por outro lado, durante a eletroestimulação cíclica, um músculo ou grupo muscular é estimulado repetitivamente em limiar próximo à contração máxima com objetivo de fortalecimento muscular. Dado o fato de que essas categorias apresentam objetivos clínicos diferentes, bem como diferentes métodos de aplicação, torna-se importante avaliar seus efeitos separadamente. A ausência de evidência específica atualizada sobre efeito da eletroestimulação cíclica para aumento de força muscular, específica à população de indivíduos pós-AVE, motivou a realização do primeiro estudo da presente tese: *"Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review".*

Em relação às estratégias para melhorar a atividade de marcha pós-AVE, o guia clínico indicou três possibilidades de intervenção: treino intensivo e repetitivo da atividade ou partes da atividade, adição de terapia específica ao treino de marcha (*biofeedback*, marcha com auxílio mecanizado, pistas auditivas rítmicas, realidade virtual) e uso de órteses do tipo tornozelo-pé (AFO).

Treino intensivo e repetitivo da marcha (ou partes da marcha) foi apresentado com nível de recomendação A. A indicação é baseada em uma revisão sistemática com 14 ensaios clínicos aleatorizados, indicando melhora em velocidade de marcha (SMD 0.29, IC 95% 0.04 a 0.53) e em capacidade de marcha (diferença média (MD) 55 m, IC 95% 18 a 92), além de benefícios em escalas e testes funcionais (FRENCH *et al*., 2007; FRENCH *et al.,* 2010).

Biofeedback foi apresentado com nível de recomendação C. A indicação é baseada em duas revisões sistemáticas que incluíram *biofeedback* em sua estratégia de busca. A primeira revisão é não-específica, apresenta diferentes estratégias de intervenção usualmente conduzidas em indivíduos pós-AVE, e incluiu cinco ensaios

clínicos aleatorizados sobre efeito de *biofeedback* na marcha, sem eficácia comprovada (LANGHOME *et al*., 2009). A segunda revisão sistemática incluiu 13 ensaios clínicos aleatorizados e indicou que *biofeedback* por eletromiografia não foi superior à terapia convencional para melhorar comprimento do passo ou velocidade de marcha (WOODFORD *et al*., 2007). Embora o nível de recomendação no guia clínico ainda seja fraco, uma revisão sistemática recente incluiu 22 ensaios clínicos aleatorizados ou controlados e demonstrou que *biofeedback* foi mais eficaz para melhora de atividades gerais do membro inferior (incluindo marcha) do que terapia usual/placebo (SMD 0.49, IC 95% 0.22 a 0.75), e que os benefícios foram mantidos no período de um a cinco meses após o término da intervenção (SMD 0.41, IC 95% 0.06 a 0.75) (STANTON *et al*., 2011). Portanto, há evidência científica de alta qualidade suficiente para iminente atualização do guia clínico em relação à estratégia '*biofeedback*'.

Marcha com auxílio mecanizado (e.g., esteira ergométrica, movimentação mecânica) foi apresentada com nível de recomendação B. A indicação é baseada em duas revisões sistemáticas, sendo que a primeira, baseada em 11 ensaios clínicos aleatorizados, indicou que o treino com auxílio mecanizado aumenta as chances de adquirir marcha independente (RD 3.06, IC 95% 1.85 a 5.06) (MEHRHOLZ *et al.,* 2007). A segunda revisão sistemática sugeriu que em indivíduos capazes de deambular no início da intervenção, o treino em esteira com suporte parcial de massa corporal possa produzir maiores ganhos em velocidade de marcha (MD 0.09 m/s, IC 95% -0.02 a 0.20), embora os resultados não tenham atingido significância estatística (MOSELEY *et al.,* 2005). A versão mais recente, ainda não incluída no guia clínico, incluiu 44 ensaios clínicos (n=2568 participantes) e indicou que, embora o treino em esteira associado ao suporte parcial de peso não tenha aumentando as chances de marcha independente em comparação a demais intervenções fisioterapêuticas (RD 0.00, IC 95% -0.02 a 0.02), de modo geral, essa modalidade aumentou velocidade de marcha em 0.07 m/s (IC 95% 0.01 a 0.12) e capacidade de marcha em 26 m (IC 95% 2.5 a 50) (MEHRHOLZ *et al.,* 2014). Em adição, duas revisões sistemáticas recentes, ainda não incluídas no guia clínico, investigaram o efeito do treino em esteira ergométrica para melhora da marcha pós-AVE (ADA *et*

al., 2010; POLESE *et al.,* 2013). A primeira revisão incluiu seis ensaios clínicos aleatorizados e indicou que o treino ergométrico com suporte parcial de peso para indivíduos pós-AVE não-deambuladores resultou em maior número de indivíduos com marcha independente após quatro semanas (RD 0.23, IC 95% 0.15 a 0.30) e maior velocidade de marcha após seis meses (MD 0.12 m/s, IC 95% 0.02 a 0.21), em comparação ao treino de marcha em solo (ADA *et al*., 2010). A segunda revisão incluiu nove ensaios clínicos aleatorizados e indicou que o treino de marcha em esteira foi eficaz para melhora de velocidade de marcha (MD 0.14 m/s, IC 95% 0.09 a 0.19) e capacidade de marcha (MD 40 m, IC 95% 27 a 53), mas apresentou ganhos similares comparados ao treino de marcha em solo para velocidade de marcha (MD 0.05 m/s, IC 95% -0.12 a 0.21) e capacidade de marcha (MD -6 m, IC 95% -45 a 33) (POLESE *et al*., 2013). Em síntese, há evidência científica de alta qualidade suficiente para iminente atualização do guia clínico em relação à estratégia 'marcha com auxílio mecanizado'.

A estratégia 'pistas auditivas rítmicas' foi apresentada com nível de recomendação B. A indicação é baseada em uma revisão sistemática não-específica, sobre diversas estratégias de intervenção usualmente conduzidas em indivíduos pós-AVE, e incluiu três ensaios clínicos aleatorizados sobre efeito de pistas auditivas na marcha, sugerindo melhora em velocidade de marcha (SMD 0.91, IC 95% 0.40 a 1.42) e comprimento de passo (SMD 0.68, IC 95% 0.06 a 1.30) (van PEPPEN *et al*., 2004). Uma recente atualização incluiu três ensaios clínicos aleatorizados e apresentou resultados conflitantes, indicando que pistas auditivas não promoveram benefício adicional em velocidade de marcha (SMD 0.6, IC 95% -1.8 a 3.0) ou comprimento de passada (SMD 0.15, IC 95% -1.4 a 1.7) (VEERBEEK *et al*., 2014). O fato de as revisões apresentarem resultados conflitantes e terem incluído poucos ensaios clínicos com diferentes características de intervenção (e.g., uso de terapia musical e uso de pistas auditivas para guiar cadência) motivou a realização do segundo estudo da presente tese: *"Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review".*

Uso de realidade virtual foi apresentado com nível de recomendação C. A indicação é baseada na descrição de cinco ensaios clínicos, sem evidências sumarizadas em revisão sistemática. A ausência de evidência científica de alta qualidade, sumarizada em revisão sistemática para embasar a prática clínica motivou a realização do terceiro estudo da presente tese: ***"****Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis****".***

Uso de órteses do tipo tornozelo-pé (AFO) foi apresentado com nível de recomendação C. A indicação é baseada em uma revisão sistemática que incluiu 13 ensaios não-aleatorizados, com sugestão de que o uso de AFO está associado a uma tendência, não-significativa, para melhorar a velocidade de marcha em indivíduos com dorsiflexão insuficiente durante a marcha (LEUNG; MOSELEY, 2003). Embora o nível de recomendação no guia clínico ainda seja fraco, uma recente revisão sistemática identificou 13 ensaios clínicos aleatorizados ou controlados e os resultados da meta-análise indicaram que o uso de AFO aumentou velocidade de marcha em 0.06 m/s (IC 95% 0.03 a 0.08) e comprimento de passo ou passada em SMD 0.28 (IC 95% 0.05 a 0.51) em comparação à deambulação sem uso da órtese (TYSON; KENT, 2013). Em adição, os mesmos pesquisadores publicaram uma revisão sistemática, que incluiu 20 estudos experimentais sobre uso de AFO em participantes pós-AVE, indicando aumentos angulares estatisticamente significativos em tornozelo e joelho durante a marcha (TYSON *et al*., 2013). Em síntese, há evidência científica de alta qualidade suficiente para iminente atualização do guia clínico em relação ao uso de órteses AFO.

Embora o guia clínico tenha incluído o uso de AFO na lista de possíveis intervenções para melhora do desempenho da marcha pós-AVE, o uso de dispositivos de auxílio à marcha tais como bengalas ou muletas como estratégia de intervenção não foi mencionado. De acordo com Eng e Tang (2007), como o exercício é a forma de intervenção mais correntemente empregada na reabilitação de indivíduos pós-AVE, poucos estudos são direcionados à verificação dos efeitos de intervenção de dispositivos auxiliares (e.g., AFO, bengalas). Poucos estudos

(POLESE *et al*., 2012; MAGUIRE *et al*., 2010; BEAUCHAMP *et al*., 2009; BUURKE *et al*., 2005; KUAN *et al*., 1999; TYSON, 1999) avaliaram o efeito do uso de dispositivos auxiliares à marcha em variáveis como velocidade da marcha e comprimento do passo de indivíduos com AVE, com consideráveis variações no desenho do estudo, método empregado e características dos participantes, anulando a possibilidade de condução de uma revisão sistemática de alta qualidade sobre o tema. Diante do impasse de condução de uma revisão sistemática, e da impossibilidade de traçar direcionamentos clínicos adequados com o nível de evidência existente, um estudo experimental foi incluído na presente tese de modo a contribuir com a prática clínica: *"The provision of a cane provided greater benefit to the group of community-dwelling people with chronic stroke with speed between 0.4 and 0.8 m/s".*

Um quadro síntese contendo as estratégias de intervenção, o nível de recomendação do guia clínico, as evidências prévias e atuais, bem como as perspectivas futuras, foi incluído como APÊNDICE A.

1.1 Objetivos específicos

Apresentadas as devidas justificativas para a realização dos estudos propostos na presente tese, os objetivos específicos foram apresentados em formas de perguntas clínicas. As perguntas clínicas específicas foram:

Estudo 1
Eletroestimulação cíclica é eficaz para aumentar força muscular e melhorar atividade após AVE? Esses benefícios são mantidos após o período de intervenção?

Estudo 2
Treino de marcha associado a pistas auditivas rítmicas é superior ao treino de marcha isolado para melhorar velocidade de marcha, comprimento de passada, cadência e simetria pós-AVE?

Estudo 3

Treino de marcha associado ao uso de realidade virtual é eficaz para melhorar velocidade de marcha pós-AVE? Esse treinamento é superior ao treino de marcha sem uso de realidade virtual?

Estudo 4

A provisão de uma bengala a indivíduos com AVE crônico residentes em comunidade altera velocidade de marcha, comprimento de passo e cadência durante a marcha? O efeito da provisão de uma bengala é diferente quando os indivíduos são agrupados de acordo com a velocidade de marcha usual (velocidade <0.4 m/s, velocidade entre 0.4 e 0.8 m/s, e velocidade >0.8 m/s)?

A escolha do desenho de estudo foi determinada de acordo com a pergunta clínica proposta e com a evidência clínica disponível na literatura. Dessa forma, para responder às questões de 1 a 3, foram realizadas três revisões sistemáticas com meta-análise, e para responder à questão 4 foi conduzido um estudo experimental. O método utilizado para a condução das revisões sistemáticas foi apresentado na Parte 1 do capítulo seguinte, e o método utilizado para a condução do estudo experimental na parte 2.

2 MÉTODO

METHOD

2 MÉTODO

2.1 Parte 1: Revisões Sistemáticas

A Parte 1 desse capítulo apresenta o método comum utilizado para a condução das revisões sistemáticas incluídas na presente tese. Características específicas do método empregado em cada um dos estudos (i.e., estratégia de busca, bases de dados, critérios de inclusão) estão detalhadas no capítulo específico de cada estudo. Um quadro resumindo os critérios de inclusão por estudo foi apresentado nesta parte, bem como as perguntas clínicas de cada uma das revisões, visando facilitar a leitura.

2.2 Perguntas Clínicas

Estudo 1: Eletroestimulação cíclica é eficaz para aumentar força muscular e melhorar atividade após AVE? Esses benefícios são mantidos após o período de intervenção?
Estudo 2: Treino de marcha associado a pistas auditivas rítmicas é superior ao treino de marcha isolado para melhorar velocidade de marcha, comprimento de passada, cadência e simetria pós-AVE?
Estudo 3: Treino de marcha associado ao uso de realidade virtual é eficaz para melhorar velocidade de marcha pós-AVE? Esse treinamento é superior ao treino de marcha sem uso de realidade virtual?

2.3 Identificação e seleção dos estudos

As buscas foram conduzidas em bases de dados relacionadas à área da saúde, tais como: *MEDLINE*, *CINAHL*, *EMBASE* e *PEDro* sem restrições de data ou idioma (MICHALEFF *et al.*, 2011). As palavras-chave incluíram termos relacionados a *stroke*, e *randomised*, *quasi-randomised* ou *controlled trials*, e termos relacionados à intervenção específica. Uma estratégia de busca foi desenvolvida para cada uma

das bases de dados e para cada um dos estudos desenvolvidos. As estratégias de busca relacionadas a cada revisão sistemática foram incluídas como APÊNDICES B, C e D. Os títulos e resumos identificados a partir da estratégia de busca foram inicialmente verificados por dois revisores, de modo a identificar os potenciais ensaios clínicos a serem incluídos na revisão. A versão completa dos estudos pré-selecionados foi obtida e a lista de referências analisada para identificação de outros potenciais estudos. A seção *Método* dos estudos foi extraída e analisada independentemente por dois revisores seguindo critérios de inclusão pré-determinados (Quadro 2), dentre os quais se destaca a inclusão apenas de ensaios clínicos aleatorizados ou controlados. Ambos os revisores estavam cegados em relação aos autores, revista e resultados. Discordâncias foram resolvidas em consenso, após análise por um terceiro revisor.

2.4 Avaliação das características dos estudos

2.4.1 Qualidade

A qualidade metodológica dos estudos incluídos foi avaliada de acordo com a escala *PEDro,* descrita na base de dados *Physiotherapy Evidence Database* (www.pedro.org.au). A escala, composta por 11 itens, avalia a qualidade metodológica (validade interna e informação estatística) de ensaios clínicos aleatorizados. Cada item, exceto o primeiro, contribui com um ponto para o escore final de 10 pontos. Foi utilizada a pontuação dos estudos descrita no endereço eletrônico da base de dados. A pontuação dos estudos não incluídos na base de dados *PEDro* ou não pontuados foi realizada pelos autores do estudo.

2.4.2 Participantes

Foram incluídos estudos envolvendo participantes adultos (>18 anos de idade) com diagnóstico de hemiparesia decorrente de Acidente Vascular Encefálico, de ambos os sexos, independente do tempo lesão (Quadro 2). O número de participantes, idade e tempo pós-AVE foram registrados para descrever similaridade

entre estudos. Participantes incapazes de movimentar o membro parético (superior ou inferior) em toda amplitude de movimento contra ação da gravidade foram categorizados como *muito fracos*, e aqueles capazes de movimentar o membro em toda amplitude contra a ação da gravidade, mas com força muscular abaixo do normal foram categorizados como *fracos* (ADA *et al.*, 2006). Participantes cujo tempo de lesão na admissão do estudo era inferior a seis meses, foram categorizados como *subagudos*, e aqueles cujo tempo de lesão era superior a seis meses, foram categorizados como *crônicos* (ADA *et al.*, 2006). Participantes foram definidos como *deambuladores* quando a velocidade de marcha inicial era superior a 0.2 m/s, ou quando houvesse descrição de que os participantes eram capazes de deambular, de modo independente, com ou sem auxílio de dispositivos auxiliares à marcha (POLESE *et al.*, 2013; MEHRHOLZ *et al.*, 2014).

2.4.3 Intervenção e Medidas

A intervenção experimental considerada e as medidas de desfecho foram específicas a cada um dos estudos realizados. Um quadro resumindo os critérios de inclusão estabelecidos em cada um dos estudos é apresentado na sequência (Quadro 2).

Quadro 2: Síntese dos critérios de inclusão estabelecidos em cada revisão sistemática

Estudo 1: Eletroestimulação pós-AVE – critérios de inclusão
Desenho Ensaio clínico aleatorizado ou controlado
Participantes Adultos (> 18 anos) Diagnóstico de AVE Fraqueza muscular (Força muscular < 4)
Intervenção Eletroestimulação para aumento de força muscular (i.e., objetivo claramente estabelecido e/ou força é uma medida de desfecho)
Medida de desfecho Medida de força muscular como pico de força/torque e congruente com os músculos estimulados

Estudo 2: Uso de pistas auditivas pós-AVE – critérios de inclusão

Desenho
Ensaio clínico aleatorizado ou controlado

Participantes
Adultos (> 18 anos)
Diagnóstico de AVE
Deambuladores (velocidade de marcha > 0.2 m/s, ou capazes de deambular independentes com ou sem dispositivos de auxílio)

Intervenção
Treino de marcha associado a pistas auditivas rítmicas, determinando cadência durante a marcha

Medida de desfecho
Velocidade de marcha, comprimento de passada, cadência e simetria

Estudo 3: Uso de realidade virtual pós-AVE – critérios de inclusão

Desenho
Ensaio clínico aleatorizado ou controlado

Participantes
Adultos (> 18 anos)
Diagnóstico de AVE
Deambuladores (velocidade de marcha > 0.2 m/s, ou capazes de deambular independentes com ou sem dispositivos de auxílio)

Intervenção
Treino de marcha associado ao uso de realidade virtual imersiva ou não-imersiva, incluindo consoles comerciamente disponíveis

Medida de desfecho
Velocidade de marcha habitual

2.5 Análise dos dados

Informações sobre o método dos estudos (desenho, participantes, intervenção e medidas de desfecho) e resultados (número de participantes e médias e desvio-padrão) foram extraídas por dois revisores e checadas por um terceiro revisor. Caso informações necessárias não estivessem presentes na versão publicada dos estudos, detalhes adicionais foram solicitados ao autor de correspondência. Valores de pós-intervenção foram utilizados para estimar o tamanho de efeito agrupado entre os estudos. O tamanho de efeito foi extraído utilizando preferencialmente análise por *fixed effects model* e reportado como diferença padronizada de *Cohen* (SMD) em caso de desfechos representados por meio de diferentes unidades de medidas, e como diferença média ponderada (MD) em caso de medidas com

unidades equivalentes ou congruentes. Em ambos os casos, as diferenças foram apresentadas com os respectivos intervalos de confiança de 95% (IC 95%) (HIGGINS; GREEN, 2011).

Em caso de heterogeneidade estatística significativa entre os estudos (I^2>50%), o tamanho de efeito foi analisado utilizando *random effects model* para avaliar a robustez dos resultados (HIGGINS; GREEN, 2011). Análise de sensibilidade foi conduzida nos casos em que os resultados nos diferentes métodos foram conflitantes. As análises foram realizadas utilizando o programa estatístico *The MIX-Meta-Analysis Made Easy* – Versão 1.7 (BAX *et al*., 2006; 2009), considerando nível de significância de 5% (*two-tailed*). Quando os dados não estavam disponíveis para serem incluídos na meta-análise, a diferença entre os grupos de comparação foi descrita.

2.6 Parte 2: Estudo Experimental

A Parte 2 desse capítulo apresenta o método utilizado para a condução do estudo experimental incluído na presente tese, sendo iniciado pela pergunta clínica que direcionou o estudo.

2.7 Pergunta Clínica

Estudo 4: A provisão de uma bengala a indivíduos com AVE crônico residentes em comunidade altera velocidade de marcha, comprimento de passo e cadência durante a marcha? O efeito da provisão de uma bengala é diferente quando os indivíduos são agrupados de acordo com a velocidade de marcha usual (velocidade <0.4 m/s, velocidade entre 0.4 e 0.8 m/s, e velocidade >0.8 m/s)?

2.8 Delineamento do estudo

Foi realizado um estudo experimental para avaliar o efeito da provisão de uma bengala na velocidade de marcha, comprimento do passo e cadência de indivíduos

com hemiparesia decorrente de AVE. Os voluntários foram recrutados na comunidade geral ou em clínicas de atendimentos fisioterapêuticos. As medidas relacionadas à capacidade de deambular foram coletadas em único dia, em duas diferentes condições experimentais (i.e., deambulação com e sem auxílio de uma bengala ajustável). A ordem das condições de avaliação foi aleatorizada. Este estudo foi aprovado pelo Comitê de Ética em Pesquisa da Universidade Federal de Minas Gerais (ANEXO E), e todos os participantes assinaram o Termo de Consentimento Livre e Esclarecido (APÊNDICE E).

2.9 Amostra

Indivíduos com diagnóstico de AVE foram recrutados de acordo com os seguintes critérios de inclusão: (1) idade ≥ 18 anos; (2) tempo de lesão superior a seis meses; (3) habilidade para deambular ao menos 14 m; (4) não fazer uso habitual de dispositivos de auxílio à marcha (i.e., bengalas ou muletas); (5) capacidade para compreender e seguir instruções verbais. Os participantes foram excluídos quando apresentaram déficits cognitivos (escore< 24 pontos no Mini-exame do Estado Mental ou ajustados de acordo com o nível de escolaridade) (BRUCKI *et al.*, 2003) ou qualquer outra doença neurológica ou ortopédica associada. O *n* amostral foi determinado de modo a garantir variabilidade dos participantes em relação à capacidade de deambulação: *n* equivalente a dois participantes a cada variação de 0.1 m/s na velocidade de marcha (variação entre 0.1 m/s e 1.2 m/s), totalizando 24 participantes. Esforços foram feitos na tentativa de recrutar oito participantes com velocidade de marcha <0.4 m/s, oito participantes com velocidade de marcha entre 0.4 e 0.8 m/s, e oito participantes com velocidade de marcha >0.8 m/s.

Características dos participantes tais como idade, sexo, tempo pós-AVE, lado da hemiparesia, tônus muscular dos flexores plantares (Escala de *Ashworth* Modificada) (BOHANNON; SMITH, 1987), recuperação motora dos membros inferiores (Escala de *Fugl-Meyer*) (MAKI *et al.*, 2006), e coordenação (*Lower Extremity Motor Coodination Test*) (PINHEIRO *et al.*, 2014) foram coletadas para caracterização da amostra. Medidas de velocidade de marcha (habitual e máxima) foram coletadas

seguindo instruções de Nascimento et al. (2012), e uma análise por grupos baseada na classificação de incapacidade pela velocidade de deambulação habitual foi planejada. Para análise, os participantes foram divididos em três grupos: velocidade <0.4 m/s, velocidade entre 0.4 e 0.8 m/s, e velocidade >0.8 m/s) (PERRY *et al.*, 1995; DEAN *et al.*, 2014). Os pontos de corte foram definidos antes da coleta dos dados (SUN *et al*., 2010).

2.10 Condições experimentais

Os participantes foram convidados a participar da pesquisa por meio de contato telefônico. Aqueles que concordaram em participar da pesquisa foram solicitados a comparecer ao laboratório, em único dia, por aproximadamente 45 minutos. Uma avaliação inicial sociodemográfica e física para fins de caracterização da amostra foi realizada, seguida por uma detalhada descrição das condições experimentais: (i) deambular independente, sem auxílio de dispositivos auxiliares; (ii) deambular independente, com auxílio de uma bengala de ponto único, ajustável, com pega ergonômica (FIGURA 1). Este tipo de bengala é descrita como preferida pela maioria dos pacientes e requer menor consumo energético em determinada velocidade (ALLET *et al.*, 2009; JEONG *et al.*, 2014).

A altura da bengala foi ajustada à altura do processo ulnar do membro superior não-parético de cada participante, estando os participantes em posição ortostática e cotovelo em extensão (ALLET *et al.*, 2009). Um fisioterapeuta foi responsável por fornecer as instruções e o treinamento de como deambular utilizando a bengala: “O Sr(a). vai dar o primeiro passo movendo a perna mais fraca e a bengala juntos para frente. Em seguida irá mover a perna boa. E assim sucessivamente”. Um período de prática de aproximadamente cinco minutos, ou até que o participante se sentisse confortável, foi permitido antes do início da coleta de dados.

Figura 1 - Bengala de ponto único, ajustável, com pega ergonômica, utilizada no presente estudo.
FONTE: ACERVO DO AUTOR

2.11 Medidas de desfecho

O desempenho durante a marcha foi mensurado por meio do Teste de Caminhada de 10 metros, e reportado por meio de variáveis clínicas: velocidade de marcha (m/s), comprimento do passo (m) e cadência (passos/minuto). Os participantes foram instruídos a deambular em sua velocidade de marcha habitual em um corredor plano de 14 metros, seguindo o comando: “Caminhe dessa cadeira até a seguinte cadeira, na sua velocidade habitual e confortável para andar”, em cada uma das condições experimentais. Tempo e número de passos utilizado pelos participantes para percorrer os 10 metros intermediários do corredor plano foi registrado, desconsiderando, assim, os períodos de aceleração e desaceleração (NASCIMENTO *et al.*, 2012). Esses dados foram utilizados para o cálculo dos valores de velocidade de marcha, comprimento do passo e cadência. Os comandos foram fornecidos sempre pelo mesmo pesquisador, e duas tentativas válidas para cada condição experimental foram registradas para análise dos dados.

2.12 Análise dos dados

Estatísticas descritivas, testes de normalidade (*Shapiro-Wilk*) e de homogeneidade de variância (*Levene*) foram realizados para todas as medidas. Os valores de média e desvio-padrão (DP) para as variáveis de desfecho – velocidade de marcha, comprimento do passo e cadência – ao andar com e sem auxílio da bengala foram apresentados. Diferença média de todas as variáveis de desfecho entre condições (andar com e sem bengala) foram calculadas e apresentadas com respectivo Intervalo de Confiança de 95% (IC 95%). Para determinar se a provisão da bengala apresentou efeito diferente de acordo com a medida inicial de velocidade de marcha, as diferenças médias (IC 95%) entre condições (andar com e sem bengala) entre grupos (<0.4 m/s, 0.4 a 0.8 m/s e >0.8 m/s), foram calculadas (DEAN et al., 2014).

3 ARTIGO 1

STUDY 1

Title: Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review

Abstract

Question: Does electrical stimulation increase strength after stroke and are any benefits maintained beyond the intervention period or carried over to activity? **Design:** Systematic review with meta-analysis of randomised or controlled trials. **Participants:** Adults who have had a stroke. **Intervention:** Cyclical electrical stimulation applied in order to increase muscle strength. **Outcome measures:** Strength measures had to be representative of maximum voluntary contraction and were obtained as continuous measures of force or torque, or ordinal measures such as manual muscle tests. Activity was measured using direct measures of performance that produced continuous or ordinal data, or with scales that produced ordinal data. **Results:** Sixteen trials representing 17 relevant comparisons were included in this systematic review. Effect sizes were calculated as standardised mean differences because various muscles were studied and different outcome measures were used. Overall, electrical stimulation increased strength by a standardised mean difference (SMD) of 0.47 (95% CI 0.26 to 0.68) and this effect was maintained beyond the intervention period (SMD 0.33, 95% CI 0.07 to 0.60). Electrical stimulation also improved activity (SMD 0.30, 95% CI 0.05 to 0.56) and this effect was also maintained beyond the intervention period (SMD 0.38, 95% CI 0.09 to 0.66). **Conclusion:** Cyclical electrical stimulation increases strength and improves activity after stroke. These benefits were maintained beyond the intervention period with a small-to-moderate effect size. The sustained effect on activity suggests that the benefits were incorporated into daily life. **Review registration:** PROSPERO (CRD42013003895).

[Nascimento LR, Michaelsen SM, Ada L, Polese JC, Teixeira-Salmela LF (2014) Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review. *Journal of Physiotherapy* 60(1): 22–30][1].

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INTRODUCTION

Recent data indicates that 30.7 million people in the world have experienced and survived a stroke.[1] After a stroke, the loss of ability to generate normal amounts of force is a major contributor to activity limitations and also contributes to participation restrictions.[2, 3] Consequently, there has been a move to implement strengthening interventions into rehabilitation after stroke. Strength training is commonly considered to be progressive resistance exercise, but any intervention that involves attempted repetitive effortful muscle contraction can result in increased motor unit activity and strength after stroke.[4] For example, electrical stimulation may have the potential to improve strength after stroke by increasing the activation of motor units and/or the cross sectional area of a muscle, even when patients are unable to undertake interventions involving resistance exercises.[5]

According to de Kroon et al[6], electrical stimulation can be broadly divided into two categories: functional electrical stimulation and cyclical electrical stimulation. In functional electrical stimulation, one or more muscles are electrically stimulated during the performance of an activity with the aim of improving that activity. In cyclical electrical stimulation, a muscle is repetitively electrically stimulated at near maximum contraction with the aim of strengthening that muscle. Given that these two categories of electrical stimulation have different purposes, as well as different methods of application, it is important to examine them separately. There have been two systematic reviews examining the efficacy of electrical stimulation at increasing strength after stroke. A Cochrane review[7] reported an effect size of 1.0 (95% CI 0.5 to 1.6) on wrist extensor strength; this was based on one randomised trial[8] of cyclical electrical stimulation to the wrist and finger extensors versus no intervention. A second review[5] reported a modest beneficial effect on strength based on 11 trials of both functional and cyclical electrical stimulation versus no intervention or any other intervention. However, a meta-analysis was not performed due to statistical heterogeneity. Furthermore, both reviews are now over five years old. In addition, there has been no examination of the efficacy of electrical stimulation compared with other strengthening interventions or the efficacy of different doses or modes of electrical stimulation.

Therefore, the aim of this systematic review was to examine the efficacy of cyclical electrical stimulation (from now on referred to as electrical stimulation). The specific research questions were:

1. Does electrical stimulation increase strength after stroke? Are any benefits maintained beyond the intervention period or carried over to activity?
2. What is the effect of electrical stimulation on strength after stroke compared to each other type of strengthening intervention?
3. What is the effect of different doses or modes of electrical stimulation on strength after stroke?

In order to make recommendations based on a high level of evidence, this review included only randomised or controlled trials. Subgroup analyses based on time after stroke and initial level of strength were planned.

METHOD

Identification and selection of trials

Searches were conducted in MEDLINE (1946 to December 2012), CINAHL (1986 to December 2012), EMBASE (1980 to December 2012) and PEDro (to December 2012) for relevant studies without date or language restrictions. Search terms included: words related to *stroke*; words related to *randomised*, *quasi-randomised* or *controlled trials*; and words related to *electrical stimulation* (such as electric stimulation, neuromuscular stimulation, nerve stimulation and functional stimulation) (see Appendix 1 on the eAddenda for the full search strategy). Title and abstracts were displayed and screened by two reviewers in order to identify relevant studies. Full text copies of peer-reviewed relevant papers were retrieved and their reference lists were screened to identify further relevant studies. The method section of the retrieved papers was extracted and reviewed independently by two reviewers using predetermined criteria (Box 1). Both reviewers were blinded to authors, journals and results. Disagreement or ambiguities were resolved by consensus after discussion with a third reviewer.

Assessment of characteristics of trials

Quality

The quality of the included trials was assessed by extracting PEDro scores from the Physiotherapy Evidence Database[26]. The PEDro scale is a 11-item scale designed for rating the methodological quality (internal validity and statistical information) of randomised trials. Each item, except for Item 1, contributes one point to the total PEDro score (range: 0–10 points). Where a trial was not included in the database, it was scored by a reviewer who had completed the PEDro Scale training tutorial.

Participants

Trials involving adult participants of either gender at any time following stroke were included. The number of participants, age and time since stroke were recorded in order to describe the trials. Participants who were unable to move a limb through full range of movement against gravity were categorised as *very weak*; participants who could move through full range against gravity, but had less than normal strength, were categorised as *weak*. At admission to the trial, participants who were less than six months after stroke were categorised as *sub-acute* and those who were more than six months after stroke were categorised as *chronic*.

Intervention

The experimental intervention was electrical stimulation that produced strong repetitive muscle contractions applied in order to increase muscle strength. The control intervention was defined according to each research question: (1) to examine the efficacy of electrical stimulation, the control intervention could be nothing, placebo or any other non-strengthening intervention; (2) to examine the effect of electrical stimulation compared with other strengthening interventions, the control intervention could be any other type of strengthening intervention; (3) to compare different doses or modes of electrical stimulation, the control intervention could be any other dose or mode.

Measures

The strength measurement had to be reported as peak force/torque generation and representative of maximum voluntary contraction (e.g., manual muscle test or dynamometry). When multiple measures of strength were reported, the measure that reflected the trained muscle/s was used. If it was appropriate to use the measures from several different muscles (i.e., these muscles had been targeted in the intervention), the means and SD of the individual measurements were summed.[4] For measurement of activity, direct measures of performance were used regardless of whether they produced continuous data (e.g., The Box and Block Test) or ordinal data (eg, Action Research Arm Test). Measures of general activity (e.g., Barthel Index) were used if they were the only available measure of activity.

Data analysis

Information about the method (i.e., design, participants, intervention and measures) and results (i.e., number of participants, mean and SD of strength and activity) were extracted by two reviewers and checked by a third reviewer. Where information was not available in the published trials, details were requested from the corresponding author.

Since more trials reported pre-intervention and post-intervention scores than change scores, post-intervention scores were used to obtain the pooled estimate of the effect of intervention immediately (i.e., post intervention) and long-term (i.e., after a period of no intervention). Sub-group analyses were performed for the primary outcome (i.e., strength measure) according to the time after stroke (sub-acute, chronic), and the initial level of strength (very weak, weak). If only the median and range of outcomes were available, additional data were requested from the author. The effect size was reported as Cohen's standardised mean difference (95% CI), because different outcome measures were used. A fixed-effects model was used. In the case of significant statistical heterogeneity ($I^2 > 50\%$), a random effects model was applied to check the robustness of the results. Post-hoc sensitivity analysis was performed if there was significant statistical heterogeneity. The analyses were performed using The MIX-Meta-Analysis Made Easy program[27] Version 1.7.[9, 10] Where data were not

available to be included in the pooled analysis, the between-group result was reported. For all outcome measures, the critical value for rejecting H_0 was set at a level of 0.05 (2-tailed).

RESULTS

Flow of trials through the review

The electronic search strategy identified 6796 papers (excluding duplicates). After screening titles, abstracts and reference lists, 64 potentially relevant full papers were retrieved. Forty-eight papers failed to meet the inclusion criteria; therefore 16 papers were included in this systematic review. One of the papers reported a trial with three arms (cyclical electrical stimulation group, no-intervention group and alternative strengthening intervention group). Therefore, 17 relevant comparisons were reported among the 16 included trials. Figure 1 presents the flow of papers through the review. See Appendix 2 on the eAddenda for a summary of the excluded papers.

Characteristics of included trials

The 16 trials involved 638 participants and investigated the efficacy of electrical stimulation for increasing muscle strength after stroke. Details of the individual trials are presented in Table 1. Thirteen trials compared electrical stimulation with nothing/placebo, providing data to answer the first study question.[8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]Three trials compared electrical stimulation with other strengthening interventions, providing data to answer the second study question.[16, 23, 24] One trial[25] compared different doses/modes of electrical stimulation (ie, the third study question). Additional information was obtained from the authors for four papers.[8, 11, 18, 21]

Quality

The mean PEDro score of the papers was 5 (range 2 to 7) (Table 2). The majority of trials: randomly allocated participants (88%); had similar groups at baseline (75%); had blinded assessors (56%); reported loss to follow-up of 15% or less (69%); reported between-group differences (81%); and reported point estimate and variability (94%). However, the majority of trials did not report that they concealed

allocation (81%) or carried out an intention-to-treat analysis (88%). All trials, except one, did not blind therapists and participants, which is difficult for this intervention involving near maximum muscle contraction.

Participants

The mean age of participants ranged from 52 to 75 years old. In the trials of sub-acute participants, the mean time after stroke ranged from 1 week to 6 months (nine trials), whereas in trials of chronic participants it ranged from 2 to 5 years (seven trials) including additional information from the authors for two trials.[11, 18]Ten trials included very weak participants and six trials included weak participants.

Intervention

The experimental intervention was electrical stimulation (ten trials), position-triggered electrical stimulation (one trial), EMG-triggered electrical stimulation (three trials), and a combination of EMG-triggered or position-triggered electrical stimulation and electrical stimulation (two trials). Ten trials delivered usual therapy to both experimental and control groups. Fourteen trials applied electrical stimulation to one or two muscles per limb with only two trials[13, 22] applying it to four different muscles.

Outcome measures

Measures of strength were mainly maximum voluntary force production, either continuous measures of force or torque (14 trials), or ordinal measures such as manual muscle tests (two trials). Most trials used direct measures of activity (five trials reported continuous data, and three trials reported ordinal data), and only one trial used an indirect measure. Seven trials did not measure activity.

Effect of electrical stimulation

Strength

The overall effect of electrical stimulation on strength immediately after intervention was examined by pooling post-intervention data from 11 trials with a mean PEDro score of 5.1, representing moderate quality (Figure 2a, see Figure 3a on the eAddenda for the detailed forest plot). Overall, the effect size was 0.47 (95% CI 0.26 to 0.68) in favour of electrical stimulation. Two trials,[8, 12] that were unable to be

included in the pooled analysis, also reported significant between-group differences in strength in favour of electrical stimulation. Maintenance of the benefit was examined by pooling post intervention data from five trials that measured strength beyond the intervention period. Overall, the increase in strength was maintained with an effect size of 0.33 (95% CI 0.07 to 0.60) (Figure 2b, see Figure 3b on the eAddenda for the detailed forest plot).

When the trials were grouped according to the initial level of strength, electrical stimulation increased the strength in very weak participants (eight trials) with an effect size of 0.40 (95% CI 0.17 to 0.65), and in weak participants (three trials) with an effect size of 0.66 (95% CI 0.21 to 1.11). When the trials were grouped according to the time after stroke, electrical stimulation increased the strength in sub-acute participants (six trials) with an effect size of 0.55 (95% CI 0.28 to 0.81), while in chronic participants (five trials) the effect size was 0.33 (95% CI −0.02 to 0.69).

Activity

The overall effect of electrical stimulation on activity immediately after intervention was examined by pooling post intervention data from six trials with a mean PEDro score of 5.7 out of 10 (Figure 4a, see Figure 5a on the eAddenda for the detailed forest plot). Overall, electrical stimulation improved activity with an effect size of 0.30 (95% CI 0.05 to 0.56). Of the two trials unable to be included in the pooled analysis, one trial[16] reported that most of the participants were not able to perform the activity tests, and one trial[8] reported a significant between-group effect on activity in favour of the electrical stimulation group. Maintenance of the benefit was examined by pooling data from the four trials that reported results beyond the intervention period. A significant improvement in activity was maintained with an overall effect size of 0.38 (95% CI 0.09 to 0.66) (Figure 4b, see Figure 5b on the eAddenda for the detailed forest plot).

Effect of electrical stimulation on strength compared with other strengthening interventions

The effect of electrical stimulation compared with other strengthening interventions was examined by three trials, with a mean PEDro score of 4 out of 10. The alternative strengthening interventions were maximum voluntary effort,[23] external resistance applied during proprioceptive neuromuscular facilitation,[16] or isotonic exercises.[24] Although two trials[16, 23]reported no significant difference between electrical stimulation and another strengthening intervention, a meta-analysis was not possible because only one trial[23] reported post-intervention data. The mean difference between groups in this trial was 4 *N* (95% CI −2.0 to 10.0). A third trial[24] did not report a between-group statistical comparison.

Effect of different dose/mode of electrical stimulation on strength

One trial,[25] with a PEDro score of 6 out of 10, compared the effect of electrical stimulation with EMG-triggered electrical stimulation. There was no significant difference in the ratio of paretic/non-paretic strength between the groups (MD 0.04, 95% CI −0.04 to 0.12).

DISCUSSION

This systematic review provides evidence that electrical stimulation can increase strength and improve activity after stroke, and that benefits are maintained beyond the intervention period. However, the evidence about whether electrical stimulation is more beneficial than another strengthening intervention is sparse, and the relative effect of different doses or modes is still uncertain.

This systematic review set out to answer three questions. The first examined whether *electrical stimulation increases strength and improves activity after stroke*. The meta-analyses show that the implementation of electrical stimulation has a moderate positive effect on strength, which is accompanied by a small-to-moderate positive effect on activity. The slightly smaller effect on activity may be because only one trial[22] applied electrical stimulation to more than two muscles per limb. This is unlikely to have a large impact on activities performed by that limb, because most

activities require contraction of many muscles at one time or another. The improvements in strength and activity were maintained beyond the intervention period with a small-to-moderate effect size, suggesting that the benefits were incorporated into daily life. Furthermore, meta-analyses of the subgroups suggest that electrical stimulation can be applied effectively to both weak and very weak people after stroke, subacutely, and may be applied chronically.

Two previous systematic reviews[5, 7] concluded that electrical stimulation was beneficial in increasing muscle strength after stroke. However, these conclusions were based on few trials, no meta-analysis and included trials of both cyclical and functional electrical stimulation. The results of the current systematic review provide stronger evidence of the efficacy of electrical stimulation for increasing strength and improving activity; this is because the conclusions are based on a meta-analysis of nine randomised trials and two controlled trials of reasonable quality. In addition, the trials included in the meta-analysis were similar with regard to the stimulation parameters (frequency and duration of the stimulus) and the amount of intervention delivered. Although the length of the individual sessions varied (mean 45 min per muscle, SD 38), the trials were very similar in their frequency (mean 4.6/wk, SD 0.7) and duration (mean 5.8 wk, SD 3.0) of intervention. The evidence appears strong enough to recommend that daily sessions of electrical stimulation with high repetitions of maximum muscle contractions be used to increase strength after stroke.

The second question examined whether *electrical stimulation is more effective than other strengthening interventions for increasing strength after stroke.* There are insufficient data to determine whether electrical stimulation is better than another strengthening intervention. Only three trials investigating this question were included and a meta-analysis could not be performed. Furthermore, the mean PEDro score of 4.0 from the three trials related to this question represents low quality, with considerable performance, attrition and detection bias present.

The third question examined *the most effective dose or mode of electrical stimulation for increasing strength after stroke.* There are insufficient data to provide evidence regarding the effect of different doses/modes of electrical stimulation. Only one trial[25] directly compared two different modes and found no difference between electrical stimulation and EMG-triggered electrical stimulation, with an effect size near zero.

This review has both strengths and limitations. The mean PEDro score of 5.0 for the 16 trials included in this review represents moderate quality. A source of bias in the included trials was lack of blinding of therapists and participants, since it is very difficult to blind therapists or participants during the delivery of complex interventions. Other sources of bias were lack of reporting concealed allocation or whether an intention-to-treat analysis was undertaken. On the other hand, the main strength of this review is that only trials where electrical stimulation was applied in order to increase strength and with a clear measure of force generation were included; this makes the results specific to the research questions. Additionally, publication bias inherent to systematic reviews was avoided by including studies published in languages other than English.[17, 24]

In conclusion, this systematic review provides evidence that cyclical electrical stimulation is effective (i.e., it results in a greater increase in muscle strength compared with placebo/nothing). Electrical stimulation appears to be effective regardless of the initial level of strength or the time after stroke and the benefits are maintained beyond the intervention period. Clinicians should therefore be confident in prescribing daily electrical stimulation for people after a stroke, when the primary objective of the intervention is to increase muscle strength. In particular, it may be a useful intervention in the presence of cognitive impairments or profound weakness when it is difficult for the person to carry out strengthening exercises independently. In addition, the results of this systematic review are valuable since they show that electrical stimulation can have a beneficial effect not only on strength but also on activity, with improvements maintained beyond the intervention period. Further

studies are necessary to investigate whether electrical stimulation is more effective than other strengthening interventions.

REFERENCES

1. Norrving B, Kissela B. The global burden of stroke and need for a continuum of care. Neurology. 2011;80(3 Suppl. 2):S5–S12.

2. Faria-Fortini I, Michaelsen SM, Cassiano JG, Teixeira-Salmela LF. Upper extremity function in stroke subjects: relationships between the international classification of functioning, disability, and health domains. J Hand Ther. 2011;24(3):257–264.

3. Robinson CA, Shumway-Cook A, Matsuda PN, Ciol MA. Understanding physical factors associated with participation in community ambulation following stroke. Disabil Rehabil. 2007;33(12):1033–1042.

4. Ada L, Dorsch S, Canning CG. Strengthening interventions increase strength and improve activity after stroke: a systematic review. J Physiother. 2006;52(4):241–248.

5. Glinsky J, Harvey L,Van Es P. Efficacy of electrical stimulation to increase muscle strength in people with neurological conditions: a systematic review. Physiother Res Int. 2007;12(3):175–194.

6. de Kroon JR, Lee JH, IJzerman MJ, Lankhorst GJ. Therapeutic electrical stimulation to improve motor control and functional abilities of the upper extremity after stroke: a systematic review. Clin Rehabil. 2002;16(4):350–360.

7. PomeroyVM,King L, PollockA, Baily-Hallam A, Langhorne P. Electrostimulation for promoting recovery of movement or functional ability after stroke. Cochrane Database Syst Rev. 2006;19(2):CD003241.

8. Powell J, Pandyan A, Granat M, Cameron M, Stott D. Electrical stimulation of wrist extensors in poststroke hemiplegia. Stroke. 1999;30:1384–1389.

9. Bax L, Yu LM, Ikeda N, Tsuruta H, Moons KG. Development and validation of MIX: comprehensive free software for meta-analysis of causal research data. BMC Med Res Methodol. 2006;6:50.

10. Bax L, Ikeda N, Fukui N, Yaju Y, Tsuruta H, Moons KG. More than numbers: the power of graphs in meta-analysis. Am J Epidemiol. 2009;169(2):249–255.

11. Bakhtiary A, Fatemy E. Does electrical stimulation reduce spasticity after stroke? A randomized controlled study. Clin Rehabil. 2008;22:418–425.

12. Bowman BR, Baker LL, Waters RL. Positional feedback and electrical stimulation: an automated treatment for the hemiplegic wrist. Arch Phys Med Rehabil. 1979;60:497–502.

13. Heckmann J, Mokrusch T, Krockel A, Warnke S, Stockert T, Neundorfer B. EMGtriggered electrical muscle stimulation in the treatment of central hemiparesis after stroke. Eur J Phys Med Rehabil. 1997;7(5):138–141.

14. Hui-Chan C, Ng S, Mak M. Effectiveness of a home-based rehabilitation programme on lower limb functions after stroke. Hong Kong Med J. 2009;15(3 Suppl. 4):42–46.

15. Kobayashi H, Onishi H, Ihashi K, Yagi R, Handa Y. Reduction in subluxation and improved muscle function of the hemiplegic shoulder joint after therapeutic electrical stimulation. J Electromyogr Kinesiol. 1999;9:327–336.

16. Kraft G, Fitts S, Hammond M. Techniques to improve function of the arm and hand in chronic hemiplegia. Arch Phys Med Rehabil. 1992;73:220–227.

17. Sentandreu Manó˜ TS, Salom Terrádez JR, Tomás JM, Meléndez Moral JC, de la Fuente Fernández T, José CC. Electrical stimulation in the treatment of the spastic hemiplegic hand after stroke: a randomized study. Med Clin. 2011;137(7):297–301.

18. Rosewilliam S, Malhotra S, Roffe C, Jones P, Pandyan A. Can surface neuromuscular electrical stimulation of the wrist and hand combined with routine therapy facilitate recovery of arm function in patients with stroke? Arch Phys Med Rehabil. 2012;93:1715–1721.

19. Shin H, Cho S, Jeon H, Lee Y, Song J, Jang S, et al. Cortical effect and functional recovery by the electromyography-triggered neuromuscular stimulation in chronic stroke patients. Neurosci Lett. 2008;442:174–179.

20. Winchester P, Montgomery J, Bowman B, Hislop H. Effects of feedback stimulation training and cyclical electrical stimulation on knee extension in hemiparetic patients. Phys Ther. 1983;63(7):1096–1103.

21. Yan T, Hui-Chan C. Transcutaneous electrical stimulation on acupuncture points improves muscle function in subjects after acute stroke: a randomized controlled trial. J Rehabil Med. 2009;41:312–316.

22. Yan T, Hui-Chan C, Li L. Functional electrical stimulation improves motor recovery ofthe lower extremity and walking ability of subjects withfirst acute stroke: a randomized placebo-controlled trial. Stroke. 2005;36:80–85.

23. Kimberley T, Lewis S, Auerbach E, Dorsey L, Lojovich J, Carey J. Electrical stimulation driving functional improvements and cortical changes in subjects with stroke. Exp Brain Res. 2004;154:450–460.

24. Lima MO, Lima FPS, Takeshi S, de Freitas T, Regina-Ribeiro S, Tortoza C, et al. Efecto de la estimulacion electrica neuromuscular y de los ejercicios isotônicos en los musculos flexores y extensores de la rodilla en pacientes hemiplejicos. Rev Neurol. 2008;46(3):135–138.

25. de Kroon JR, IJzerman MJ. Electrical stimulation of the upper extremity in stroke: cyclic versus EMG-triggered stimulation. Clin Rehabil. 2008;22: 690–697.

Websites

www.pedro.org.au

www.meta-analysis-made-easy.com

Box 1. Inclusion criteria.

Design
- Randomised or controlled trial

Participants
- Adults (>18 years old)
- Diagnosis of stroke
- Muscle weakness (Manual Muscle Test < Grade 4)

Intervention
- Electrical stimulation in order to increase strength (ie, it is clearly stated that the aim of the intervention is to increase strength or strength is an outcome measure)

Outcomes measures
- Strength measured as peak force/torque and congruent with the stimulated muscle/s

Comparisons
- Electrical stimulation versus placebo/nothing or non-strengthening intervention
- Electrical stimulation versus any other strengthening intervention
- Electrical stimulation versus different dose/mode of electrical stimulation

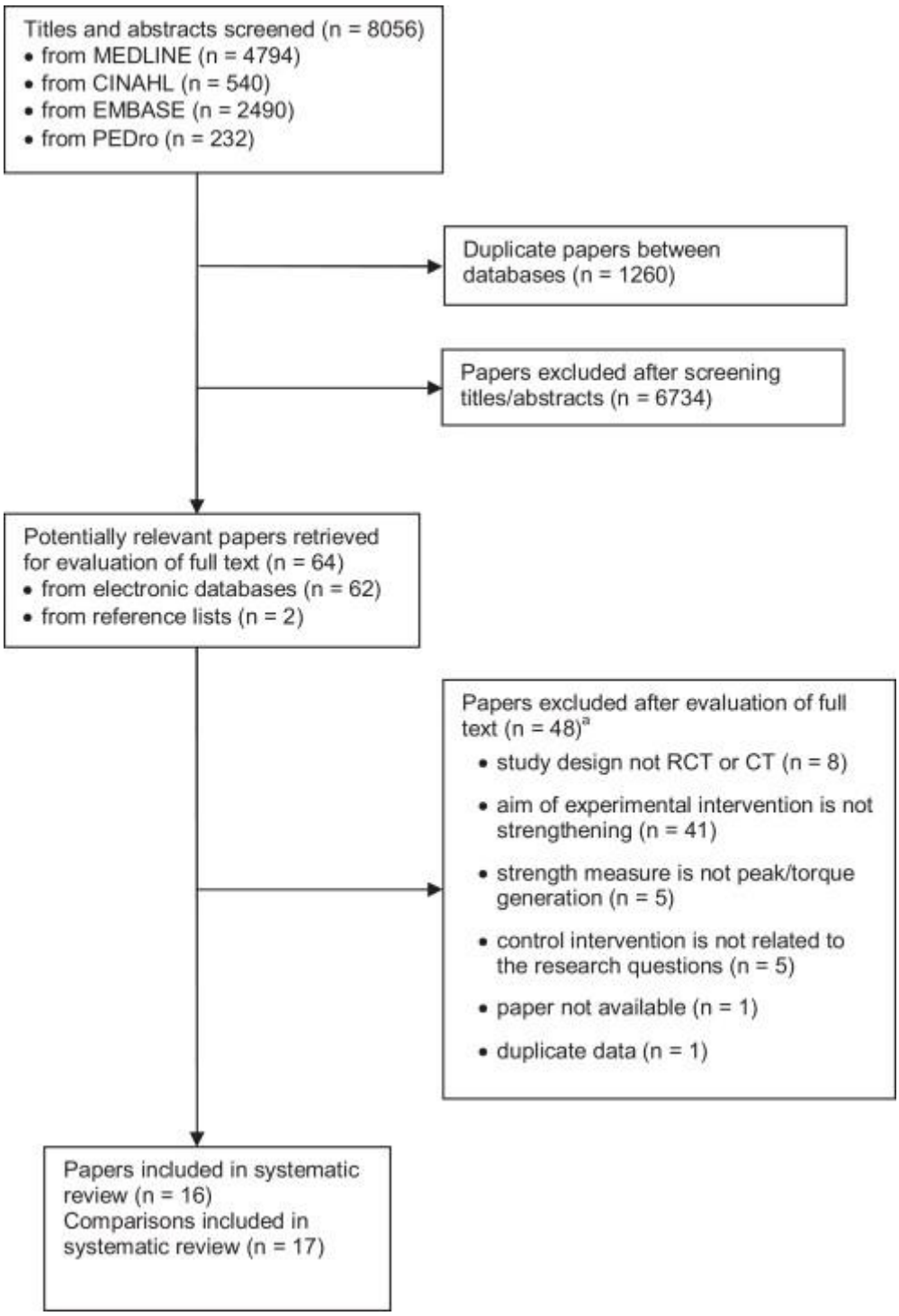


Figure 1.

Flow of studies through the review. [a]Papers may have been excluded for failing to meet more than one inclusion criterion.

Table 1 Characteristics of included papers (n=16)

Study	Design	Participants	Intervention	Electrical Stimulation	Outcome measures
Bakhtiary and Fatemy (2008)	RCT	n = 40 Age (yr) = 55 (range 42-65) Time since stroke (mth) = not reported Weakness = very weak	Exp = ES 9 min x 5/wk x 4 wk Con = nothing Both = usual therapy (Bobath)	Muscles = ankle DF Frequency = 100 Hz Duration = 4 s Progression = ↑ intensity	Strength = MMT (0-5); ankle DF Activity = not measured Timing: 0, 4 wk
Bowman, Baker and Waters (1979)	RCT	n = 30 Age (yr) = not reported Time since stroke (mth) = range 0.7 to 4 Weakness = weak	Exp = Position-triggered ES 100 contractions x 5/wk x 4 wk Con = nothing Both = usual therapy	Muscles = wrist extensors Frequency = 35 Hz Duration = 8 s Progression = ↑ # contractions	Strength = dynamometry (Nm); wrist ext Activity = not measured Timing: 0, 4 wk
de Kroon and Jzerman (2008)	RCT	n = 22 Age (yr) = 59 (SD 9) Time since stroke (months) = 22 (range 6-115) Weakness = weak	Exp = ES 30 min x 5/wk x 6 wk Con = EMG-triggered ES 30 min x 5/wk x 6 wk	Muscles = wrist and finger extensors Frequency = 35 Hz Duration = 6 s Progression = ↑ threshold	Strength = dynamometry (Kg); grip strength Activity = ARAT (0-57) Timing: 0, 4, 6, 12 wk
Heckmann et al (1997)	RCT	n = 28 Age (yr) = 52 (SD 23) Time since stroke (months) = 2 (SD 0.1) Weakness = very weak	Exp = EMG-triggered ES 15 contractions x 5/wk x 4wk Con = nothing Both = usual therapy (Bobath)	Muscles = elbow and wrist extensors; knee flexors and ankle PF Frequency = 80 Hz Duration = 1 s Progression = ↑ threshold	Strength = MMT (0-5); Σ wrist ext and PF Activity = Barthel Index Timing: 0, 4 wk
Hui-Chan, Ng and Mak (2009)	RCT	n = 109 Age (yr) = 57 (SD 8) Time since stroke (months) = 56 (SD 41) Weakness = weak	Exp = ES 60 min x 5/wk x 4 wk Con = nothing	Muscles = ankle DF and PF Frequency = 100 Hz Duration = not reported Progression = not reported	Strength = dynamometry (Nm); Σ DF and PF Activity = TUG (s) Timing: 0, 4, 8 wk
Kimberley et al (2004)	RCT *(Cross-over)*	n = 16 Age (yr) = 60 (SD 15) Time since stroke (months) = 35 (SD 25) Weakness = very weak	Exp = EMG-triggered ES + ES 6 hr x 3.3/wk x 3wk Con = voluntary effort + nothing 6 hr x 3.3/wk x 3wk	Muscles = wrist and finger extensors Frequency = 20 Hz Duration = 5 s Progression = not reported	Strength = dynamometry (N); finger ext Activity = BBT (# blocks) Timing: 0, 3 wk

Kobayashi et al (1999)	RCT	n = 24 Age (yr) = 64 (SD 11) Time since stroke (months) = 31 Weakness = very weak	Exp = ES 30 min x 5/wk x 6 wk Con = nothing Both = usual therapy	Muscles = shoulder abductors Frequency = 20 Hz Duration = 10 s Progression = not reported	Strength = dynamometry (N); shoulder abd Activity = not measured Timing: 0, 6 wk
Kraft et al (1992)	CT	n = 22 Age (yr) = 63 (SD 7) Time since stroke (months) = 21 (range 11) Weakness = weak	Exp = EMG-triggered ES 60 min x 3/wk x 12 wk Con 1 = nothing Con 2 = strengthening (PNF) 60 min x 3/wk x 12 wk	Muscles = wrist extensors Frequency = 30 to 90 Hz Duration = 10 s Progression = ↑ threshold	Strength = dynamometry (lb); grip strength Activity = JTHFT (s) Timing = 0, 12, 24, 48
Lima et al (2008)	CT	n = 17 Age (yr) = not reported Time since stroke (months) = not reported Weakness = weak	Exp = ES 15min x 10 sessions Con = strengthening (isotonic) 3 x 15 reps x 10 sessions	Muscles = knee extensors Frequency =50 Hz Duration = 10 s Progression = not reported	Strength = dynamometry (Nm/s); knee ext. Activity = not measured Timing: 0, 10 sessions
Mano et al (2011)	RCT	n = 18 Age (yr) = 74 (SD 7) Time since stroke (months) = 6 (SD 3) Weakness = very weak	Exp = ES 30 min x 3/wk x 8 wk Con = nothing Both = usual therapy	Muscles = wrist and finger extensors Frequency = 50 Hz Duration = 5 s Progression = ↑ # contractions	Strength = dynamometry (Kg); grip strength Activity = not measured Timing: 0, 8 wk
Powell et al (1999)	RCT	n = 60 Age (yr) = 68 (SD 12) Time since stroke (months) = 0.8 (SD 0.2) Weakness = very weak	Exp = ES 90 min x 5/wk x 8wk Con = nothing Both = usual therapy	Muscles = wrist and finger extensors Frequency =20 Hz Duration = 5 s Progression = ↑ # contractions	Strength = dynamometry, Nm (15 degrees); wrist ext Activity = ARAT (0-57) Timing: 0, 8, 20, 32 wk
Rosewilliam et al (2012)	RCT	n = 90 Age (yr) = 75 (SD 11) Time since stroke (months) = not reported Weakness = very weak	Exp = ES 60 min x 5/wk x 6wk Con = nothing Both = usual therapy	Muscles = wrist and finger extensors Frequency = 40 Hz Duration = 3 s Progression = ↑ intensity	Strength = dynamometry (N); wrist ext Activity = ARAT (0-57) Timing: 0, 6, 12, 24, 36 wk

Shin et al (2008)	RCT	n = 14 Age (yr) = 58 (SD 10) Time since stroke (months) = 19 (SD 6) Weakness = weak	Exp = EMG-triggered ES 30 min x 5/wk x 10wk Con = nothing	Muscles = wrist and finger extensors Frequency =35 Hz Duration = 5 s Progression = ↑ threshold	Strength = dynamometry, (Kg); wrist ext Activity = BBT (# blocks) Timing: 0, 10 wk
Winchester et al (1983)	RCT	n = 40 Age (yr) = 58 (SD 12) Time since stroke (months) = 2 (SD 1) Weakness = very weak	Exp = Positional-triggered ES + ES 30 min x 5/wk x 4 wk + 2hr x 5/wk x 4 wk Con = nothing Both = usual therapy	Muscles = knee extensors Frequency = 30 Hz Duration = 10 s Progression = ↑ # and duration of contractions	Strength = dynamometry (Nm); knee ext Activity = not measured Timing: 0, 4 wk
Yan, Hui-Chan and Li (2005)	RCT	n = 46 Age (yr) = 71 (SD 8) Time since stroke (months) = 0.3 (SD 0.1) Weakness = very weak	Exp = ES 30 min x 5/wk x 3wk Con = Sham stimulation 30 min x 5/wk x 3wk Both = usual therapy	Muscles = knee flexors and extensors, ankle DF and PF Frequency =30Hz Duration = not reported Progression = not reported	Strength = dynamometry (Nm); ankle DF Activity = TUG (s) Timing: 0, 3, 8 wk
Yan and Hui-Chan (2009)	RCT	n = 62 Age (yr) = 70 (SD 7) Time since stroke (months) = 0.3 (SD 0.1) Weakness = very weak	Exp = ES 60 min x 5/wk x 3 wk Con = nothing Both = usual therapy	Muscles = ankle DF and PF Frequency = 100 Hz Duration = not reported Progression = not reported	Strength = dynamometry (Nm); ankle DF Activity = TUG (s) Timing: 0, 3, 8 wk

groups and outcome measures listed are those that were analysed in this systematic review; there may have been other groups or measures in the paper. RCT = randomised clinical trial, CT = controlled trial, Exp = experimental group, Con = control group, ES = electrical stimulation, TENS = transcutaneous electrical nerve stimulation, DF = dorsiflexion, PF = plantarflexion, ext. = extensors; PNF = proprioceptive neuromuscular facilitation, MVC = maximum voluntary contraction, MMT = manual muscle test, BBT = box and block test, ARAT = action research arm test, MAL = motor activity log, JTHFT = Jebsen-Taylor hand function test, Σ = summed.

Table 2: PEDro criteria and scores for included papers (n = 16).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Bakhtiary and Fatemy (2008)	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Bowman, Baker and Waters(1979)	Y	N	N	N	N	Y	N	N	Y	N	3
de Kroon and Jzerman (2008)	Y	Y	N	N	N	Y	Y	N	Y	Y	6
Heckmann et al (1997)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Hui-chan, Ng and Mak (2009)	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Kimberley et al (2004)	Y	N	Y	Y	N	Y	Y	N	N	Y	6
Kobayashi et al (1999)	Y	N	N	N	N	N	Y	N	N	Y	3
Kraft et al (1992)	N	N	Y	N	N	N	Y	N	Y	Y	4
Lima et al (2008)	N	N	N	N	N	N	Y	N	N	Y	2
Mano et al (2011)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Powell et al (1999)	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Rosewilliam et al (2012)	Y	Y	Y	N	N	Y	N	Y	Y	Y	7
Shin et al (2008)	Y	N	Y	N	N	N	N	N	Y	Y	4
Winchester et al (1983)	Y	N	Y	N	N	N	N	N	Y	Y	4
Yan, Hui-Chan and Li (2005)	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Yan and Hui-Chan (2009)	Y	N	Y	N	N	Y	N	N	Y	Y	5

Y= yes; N=no

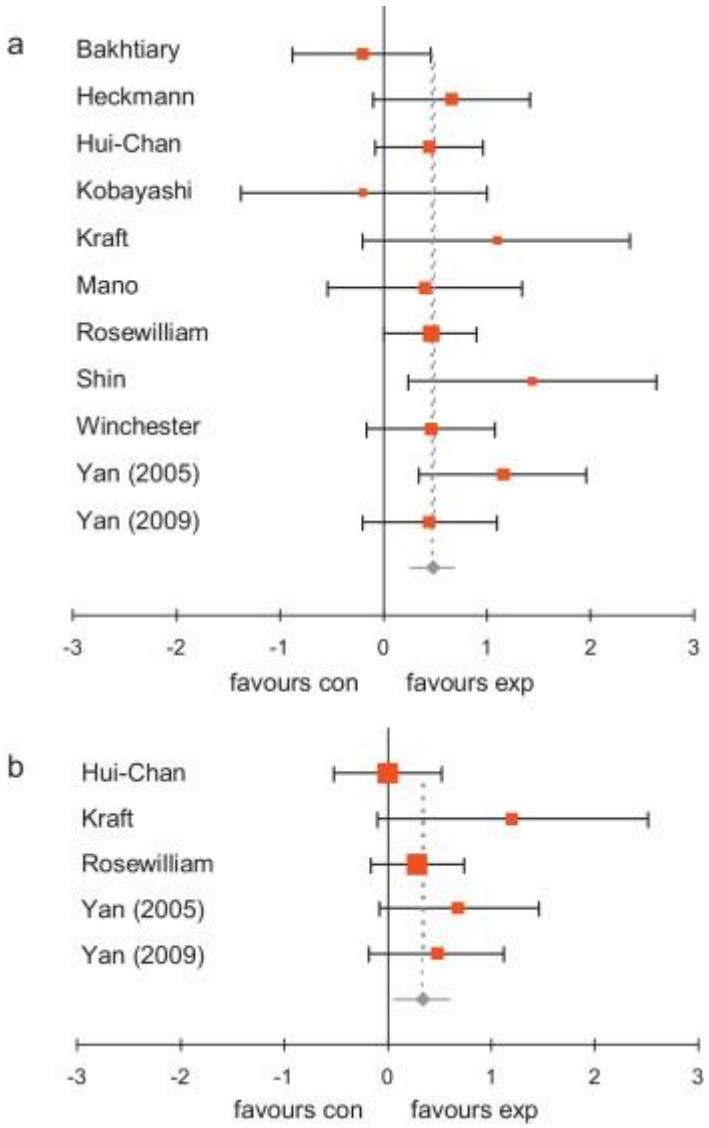


Figure 2.

(a) Standardised mean difference (95% CI) of effect of electrical stimulation versus nothing/placebo on strength immediately after intervention (n = 359). (b) Standardised mean difference (95% CI) of effect of electrical stimulation versus nothing/placebo on strength beyond the intervention period (n = 211).

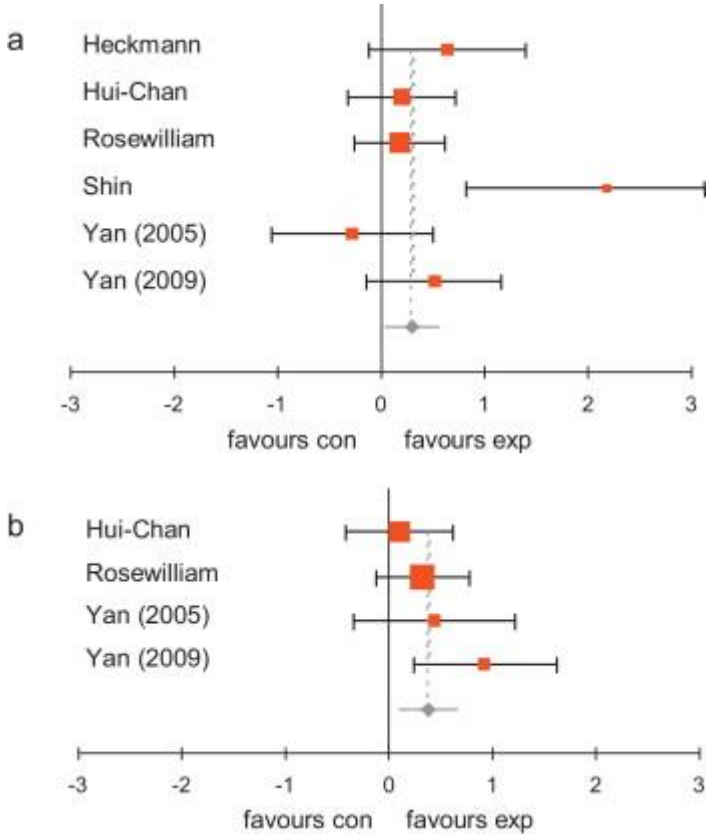


Figure 4.

(a) Standardised mean difference (95% CI) of effect of electrical stimulation versus nothing/placebo on activity immediately after intervention (n = 242). (b) Standardised mean difference (95% CI) of effect of electrical stimulation versus nothing/placebo on activity beyond the intervention period (n = 198).

4 ARTIGO 2

STUDY 2

Title: Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review

Abstract

Question: After stroke, is walking training with cueing of cadence superior to walking training alone in improving walking speed, stride length, cadence and symmetry? **Design:** Systematic review with meta-analysis of randomised or controlled trials. Participants: Adults who have had a stroke. **Intervention:** Walking training with cueing of cadence. **Outcome measures:** Four walking outcomes were of interest: walking speed, stride length, cadence and symmetry. **Results:** This review included seven trials involving 211 participants. Because one trial caused substantial statistical heterogeneity, meta-analyses were conducted with and without this trial. Walking training with cueing of cadence improved walking speed by 0.23 m/s (95% CI 0.18 to 0.27, I^2 = 0%), stride length by 0.21 m (95% CI 0.14 to 0.28, I^2 = 18%), cadence by 19 steps/minute (95% CI 14 to 23, I^2 = 40%), and symmetry by 15% (95% CI 3 to 26, random effects) more than walking training alone. **Conclusions:** This review provides evidence that walking training with cueing of cadence improves walking speed and stride length more than walking training alone. It may also produce benefits in terms of cadence and symmetry of walking. The evidence appears strong enough to recommend the addition of 30 minutes of cueing of cadence to walking training, four times a week for 4 weeks, in order to improve walking in moderately disabled individuals with stroke. **Review Registration:** PROSPERO (CRD42013005873).

[Nascimento LR, de Oliveira CQ, Ada L, Michaelsen SM, Teixeira-Salmela LF (2015) Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review. *Journal of Physiotherapy* 61(1): 10-15][2]

[2] Trabalho premiado como “Melhores trabalhos apresentados” no III Congresso Brasileiro de Fisioterapia Neurofuncional (COBRAFIN), Belo Horizonte, 2014. Resumo publicado no *Journal of Neurological Physical Therapy.*

INTRODUCTION

Recent data indicates that over 30 million people in the world have experienced and survived stroke.[1] Despite recent advances in medical and rehabilitation sciences, many individuals have residual walking disability after stroke, which has long-lasting implications for quality of life and ability to participate in activities of daily living.[2, 3] If walking performance is poor after stroke, community activity may be limited and people may become housebound and isolated from society.[4, 5]One of the main aims of rehabilitation is to enhance community ambulation skills.

After stroke, individuals typically demonstrate reduced walking speed, decreased stride length and cadence, as well as temporal asymmetry. A systematic review[6] of ambulatory people after stroke reported mean walking speeds ranging from 0.4 to 0.8 m/s, compared with 1.0 to 1.2 m/s in healthy, older adults.[7] Previous studies[8, 9] have also reported mean stride lengths ranging from 0.50 to 0.64 m in people after stroke, compared with 1.1 to 1.4 m in healthy, older adults, and mean cadence of 50 to 63 steps/minute, compared with 102 to 114 steps/minute in healthy, older adults.[7] Temporal symmetry of the affected leg to the non-affected leg is reported as ranging from 0.40 to 0.64, where 1.00 is symmetrical.[8, 9] In summary, walking parameters in ambulatory people after stroke are approximately half of the values expected in older, able-bodied adults.

One approach that has the potential to improve multiple parameters of walking after stroke is cueing of cadence delivered via an external auditory cue during walking. Using a metronome or specifically prepared music tapes, the patient's steps are matched to the beat of the metronome or music in order to synchronise motor responses into stable time relationships.[8, 9] The patient is asked to take steps according to the beat, so the rhythmic beat acts as a cue. If the beats are of a consistent frequency, this cueing will promote the temporal symmetry of walking. If the frequency of these consistent beats is increased, cadence and, therefore, speed will also increase. Whether stride length is also increased is an unanswered question. Therefore, cueing of cadence is an inexpensive adjunct to walking training,

whether overground or on a treadmill, that has the potential to improve walking after stroke.

Three previous reviews have examined cueing of cadence but these have not used meta-analysis.[10, 11, 12] All three reviews included studies of all neurological conditions, but reported the studies relating to stroke separately. Thaut and Abiru[10] concluded that rhythmic auditory stimulation has a strong facilitating effect on walking, based on three trials.[8, 9, 13]Bradt et al[11] concluded that it may increase walking parameters such as step length, cadence and symmetry, based on two trials.[8, 9] More recently, Wittner et al[12] concluded that there is moderate evidence that rhythmic auditory cueing improves walking speed and step length, but insufficient evidence of its effect on cadence and symmetry, based on three trials.[8, 9, 14] Two systematic reviews have examined the effect of exercise after stroke, which reported results on rhythmic auditory cueing separately. van Peppen et al[15] reported a standardised mean difference (SMD) of 0.91 (95% CI 0.40 to 1.42) on walking speed and 0.68 (95% CI 0.06 to 1.30) on step length, based on three trials,[8, 13, 16] whereas more recently, Veerbeek et al[17] reported a non-significant SMD of 0.6 (95% CI –1.8 to 3.0) on walking speed and 0.15 (95% CI –1.4 to 1.7) on stride length, based on two trials of early rehabilitation.[9, 18] Given that different trials have been examined in different reviews, a meta-analysis of the current evidence for this promising intervention is warranted.

The aim of this systematic review was to examine the efficacy of the addition of cueing of cadence to walking training for improving walking after stroke. The specific research question was:

> After stroke, is walking training with cueing of cadence superior to walking training alone in improving walking speed, stride length, cadence and symmetry?

In order to make recommendations based on a high level of evidence, this review included only randomised or controlled trials.

METHOD

Identification and selection of trials

Searches were conducted of Medline (1946 to August 2013), CINAHL (1986 to August 2013), EMBASE (1980 to August 2013) and PEDro (to August 2013) for relevant studies without date or language restrictions. The search strategy was registered at PubMed/Medline and the authors received notifications about potential papers related to this systematic review. Search terms included words related to *stroke*, words related to *randomised*, *quasi-randomised* or *controlled trials*, and words related to *cueing of cadence* (such as auditory cueing, rhythmic cueing, acoustic cueing and external cueing) (see Appendix 1 on the eAddenda for the full search strategy). In order to identify relevant studies, the titles and abstracts of the retrieved records were displayed and screened by two reviewers (LRN and CQO). Full paper copies of peer-reviewed relevant papers were retrieved and their reference lists were screened to identify further relevant studies. The method section of the retrieved papers was extracted and reviewed independently by two reviewers (LRN and CQO) using predetermined criteria (Box 1). Both reviewers were blinded to authors, journal and results. Disagreement or ambiguities were resolved by discussion with a third reviewer (LA).

Assessment of characteristics of trials

Quality

The quality of included trials was assessed by extracting PEDro scores from the Physiotherapy Evidence Database (www.pedro.org.au). The PEDro scale is an 11-item scale designed for rating the methodological quality (internal validity and statistical information) of randomised trials. Each item, except for Item 1, contributes one point to the total score (range 0 to 10 points). Where a trial was not included on the database, it was scored by a reviewer who had completed the PEDro Scale training tutorial.

Participants

Ambulatory adults at any time following stroke were included. Ambulatory was defined as having a walking speed of at least 0.2 m/s at baseline or when the

participants were able to walk without help, with or without walking aids. Studies were included when at least 80% of the sample comprised ambulatory participants. To assess the similarity of the studies, the number of participants and their age, time since stroke and baseline walking speed were recorded.

Intervention

The experimental intervention was any method of walking training accompanied by cueing of cadence delivered to individuals after stroke. The control intervention could be any walking training without cueing of cadence. To assess the similarity of the studies, the session duration, session frequency and program duration were recorded.

Measures

Four walking outcomes were of interest: speed, stride length, cadence and symmetry. To assess the appropriateness of combining studies in a meta-analysis, the timing of the measurements of outcomes and the procedure used to measure the different walking outcomes were recorded.

Data analysis

Information about the method (ie, design, participants, intervention and measures) and results (ie, number of participants and means (SD) of walking outcomes) were extracted by two reviewers and checked by a third reviewer. Where information was not available in the published trials, details were requested from the corresponding author.

The post-intervention scores were used to obtain the pooled estimate of the effect of intervention, using the fixed effects model. In the case of significant statistical heterogeneity ($I^2 > 50\%$), a random effects model was applied. Post-hoc sensitivity analysis was performed if the result of the random effects model was different from that of the fixed effect model. The analyses were performed using The MIX–Meta–Analysis Made Easy program Version 1.7.[19, 20] Where insufficient data were available for a study result to be included in the pooled analysis, the between-group difference

was reported. For all outcome measures, the critical value for statistical significance was set at a level of 0.05 (two-tailed). The pooled data for each outcome were reported as weighted mean differences (MD) with a 95% CI.

RESULTS

Flow of trials through the review

The electronic search strategy identified 3830 papers, but 23 were duplicates. After screening titles, abstracts and reference lists, 32 potentially relevant full papers were retrieved. Twenty-five papers failed to meet the inclusion criteria (see Appendix 2 on the eAddenda for a summary of the excluded papers) and, therefore, seven papers were included in the review (Figure 1).

Characteristics of included trials

The seven trials involved 211 participants and investigated the efficacy of cueing of cadence for improving walking speed (n = 7), stride length (n = 7), cadence (n = 6) and symmetry (n = 5) after stroke (Table 1). All included trials compared walking training with and without cueing of cadence.

Quality

The mean PEDro score of the trials was 4.4 (range 3 to 7) (Table 2). All of the trials had similar groups at baseline and reported between-group differences. The majority of the trials (86%) randomly allocated participants and reported point estimate and variability. However, the majority of the trials did not: report concealed allocation (86%), carry out an intention-to-treat analysis (86%), have blinded assessors (86%), or have less than 15% dropout (70%). No trials blinded participants or therapists, which is difficult or impossible during complex interventions.

Participants

The mean age of participants ranged across the trials from 55 to 72 years. The mean time after stroke ranged across the trials from 2 weeks to 15 months. The majority of trials (71%) comprised participants in the acute/sub-acute phases of stroke on admission to the trial.

Intervention

In all trials, the experimental intervention was overground walking training with cueing of cadence. Cueing of cadence was delivered via metronome beats in two trials,[21, 22] via music beats in three trials,[14, 18, 23] and via music enhanced by metronome beats in two trials.[8, 9] Participants undertook training for 10 to 30 minutes, once or twice a day, three to five times per week, for 3 to 6 weeks. The control group received overground walking training without cueing of cadence in all trials.

Outcome measures

Three trials[8, 9, 18] used foot sensors during a timed walk test to obtain the walking parameters, two trials[21, 22] used computerised platforms, and two trials[14, 23] used a timed walk measure.

Only two trials[9, 18] reported walking symmetry as a ratio of a temporal aspect of the affected leg to the non-affected leg. Walking symmetry for another three trials[8, 21, 22] was calculated from available data and reported as a ratio of a temporal aspect of the affected leg and the non-affected leg. Cycle time values were used for calculations in one trial,[21] support time was used in one trial,[22] and swing time was used in one trial.[8] Two trials[14, 23] did not provide data related to walking symmetry.

Walking speed was converted to m/s, stride length to m, cadence to steps/minute, and symmetry to a ratio where 1.0 is symmetrical.

Effect of cueing of cadence

Walking speed

The effect of cueing of cadence during walking training on speed was examined by pooling post-intervention data from seven trials involving 211 participants. There was substantial statistical heterogeneity (I^2 = 75%), indicating that the variation between the results of the trials is above the variation expected by chance. When a random effects model was applied, the mean effect was different and a sensitivity analysis was therefore performed. The sensitivity analysis revealed that the heterogeneity was not explained by the quality of the trials, assessor blinding, numbers of

participants or initial walking speed, but was explained by one trial that was so different from the other trials that the lower limit of the confidence interval of the meta-analysis did not cross that trial's mean effect; therefore, the meta-analyses were conducted both with this outlying trial[18] included and excluded. The data from the remaining six trials involving 171 participants indicated that walking training with cueing of cadence improved walking speed by 0.23 m/s (95% CI 0.18 to 0.27, $I^2 = 0$) more than walking training alone (Figure 2, see Figure 3 on the eAddenda for the detailed forest plot and the meta-analysis with the outlying trial included).

Walking stride length

The effect of cueing of cadence during walking training on stride length was examined by pooling post-intervention data from six trials involving 171 participants. Walking training with cueing of cadence improved walking stride length by 0.21 m (95% CI 0.14 to 0.28, $I^2 = 18\%$) more than walking training alone (Figure 4, see Figure 5 on the eAddenda for the detailed forest plot and the meta-analysis with the outlying trial included).

Walking cadence

The effect of cueing of cadence during walking training on cadence was examined by pooling post-intervention data from five trials involving 151 participants. Walking training with cueing of cadence improved walking cadence by 19 steps/minute (95% CI 14 to 23, $I^2 = 40\%$) more than walking training alone (Figure 6, see Figure 7 on the eAddenda for the detailed forest plot and the meta-analysis with the outlying trial included).

Walking symmetry

The effect of cueing of cadence during walking training on symmetry was examined by pooling post-intervention data from four trials involving 136 participants. Walking training with cueing of cadence improved walking symmetry by 13% (95% CI 11 to 16). There was, however, substantial statistical heterogeneity ($I^2 = 80\%$), indicating that the variation between the results of the trials was above the variation expected by chance. A random effects model was applied and the results indicated that

walking training with cueing of cadence improved walking symmetry by 15% (95% CI 3 to 26) more than walking training alone (Figure 8, see Figure 9 on the eAddenda for the detailed forest plot and the meta-analysis with the outlying trial included).

DISCUSSION

This systematic review provides evidence that walking training with cueing of cadence can improve walking parameters after stroke more than walking training alone. Meta-analysis with low statistical heterogeneity indicated that the addition of cueing of cadence produced more benefit in terms of walking speed and stride length than walking training alone. Meta-analysis with higher heterogeneity also suggested that the addition of cueing of cadence produced more benefit in terms of cadence and symmetry than walking training alone.

The pooled effect from the meta-analysis indicated that walking training with cueing of cadence resulted in 0.23 m/s faster walking and 0.21 m longer stride length than walking training alone. A recent meta-analysis[17] of rhythmic gait cueing produced non-significant results for walking speed and stride length, based on two trials with 97% statistical heterogeneity. A previous meta-analysis[15] of external auditory rhythms produced significant results for walking speed (MD 0.22 m/s) and stride length (MD 0.18 m), based on three trials. Although effect sizes from the earlier review[15] are similar to those found in our review, only one of the included trials is common to both reviews. Our review strengthens the evidence about the efficacy of the addition of cueing of cadence to walking training for increasing walking speed and stride length after stroke; this is because the conclusions are based on a meta-analysis of six trials that provided a specific intervention (ie, beats from metronome or beats from music delivered during walking).

These results have important clinical implications. The improvement of 0.23 m/s on walking speed appears to be clinically meaningful. According to Tilson et al,[24] people with sub-acute stroke, whose gait speed increases by at least 0.16 m/s, are more likely to experience a meaningful reduction in disability. A second study has also indicated that an improvement in gait speed of 0.13 m/s or more, over the course of

rehabilitation, is clinically important in people with stroke.[25] In addition, the improvement in walking speed was accompanied by an improvement in stride length, which suggests that the addition of cueing of cadence to walking training is not detrimental to the quality of movement. This is an important finding because clinicians have been cautious about increasing the tempo of beats during walking training in case any increases in cadence and speed occur at the expense of stride length, which would be undesirable. Moreover, the addition of cueing of cadence to walking training has larger effects than other interventions, such as treadmill training (MD 0.05 m/s, 95% CI –0.12 to 0.21, meta-analysis of three trials)[6] and virtual-reality training (MD 0.15 m/s, 95% CI 0.05 to 0.24, meta-analysis of five trials),[26] compared with walking training alone. Clinically, cueing of cadence is an easy intervention to implement, not only because it is inexpensive, but also because it can be applied in community settings and does not require close professional supervision for safety. Cueing of cadence can also be added to different walking interventions (eg, treadmill training) and may thereby increase the effect of the intervention.

This review has both limitations and strengths. The mean PEDro score of 4.4 for the included trials represents moderate quality. A source of bias in the included trials was lack of blinding of therapists and participants, since it is very difficult to blind either during the delivery of complex interventions. Other sources of bias were non-blinding of assessors, not reporting concealed allocation, or not reporting that an intention-to-treat analysis was undertaken. The number of participants per group (mean 15, range 5 to 39) was quite low, opening the results to small trial bias. In addition, maintenance of benefits beyond the intervention period was not examined. On the other hand, after removal of one trial,[18]statistical heterogeneity of the trials pooled in the meta-analysis was low for walking speed and stride length, leading to robust findings about the effect of cueing of cadence. Overall, the included trials were similar regarding their clinical characteristics. Most of trials included participants in the sub-acute phase of rehabilitation (five out of seven trials) and initial walking speed ranging between 0.23 and 0.63 m/s across trials, indicating that most of the participants could be classified as moderately disabled.[27] A major strength of this review is that only trials whose intervention was cueing of cadence via beats from a

metronome or beats from music during walking training were included; this constrains the results to a specific intervention. Although the session duration between trials included in the meta-analysis varied (mean 33 minutes, SD 22), the trials had similar session frequencies (mean 4.3 per week, SD 1.0), and program durations (mean 4.3 per week, SD 1.6). Publication bias inherent to systematic reviews was avoided by including studies published in languages other than English.[18] The evidence, therefore, appears strong enough to recommend the addition of cueing of cadence to daily walking training in order to increase walking speed and stride length after stroke. In addition, walking training with cueing of cadence may have positive effects on cadence and symmetry; however, additional randomised clinical trials are warranted in order to reduce the level of uncertainty related to the wide confidence intervals regarding the difference between groups for those outcomes.

In conclusion, this systematic review provides evidence that an inexpensive and easy-to-implement intervention – walking training with cueing of cadence – is more effective than walking training alone in improving walking after stroke. Walking training with cueing of cadence produced faster walking and longer stride length, and may have positive effects on cadence and symmetry. The results of a meta-analysis based on six trials indicate that the addition of 30 minutes of cueing of cadence to walking training four times a week for 4 weeks can be expected to improve walking in moderately disabled individuals with stroke. Future studies are recommended to verify if the benefits of cueing of cadence to walking training are maintained beyond the intervention period.

REFERENCES

1. Norrving B, Kissela B. The global burden of stroke and need for a continuum of care. Neurology. 2011;80(3 Suppl 2):S5–S12.

2. Carod-Artal FJ, Gonzalez-Gutie´ rrez JL, Herrero JA, Horan T, De Seijas EV. Functional recovery and instrumental activities of daily living: follow-up 1-year after treat-ment in a stroke unit. Brain Inj. 2002;16(3):207–216.

3. Robinson CA, Shumway-Cook A, Matsuda PN, Ciol MA. Understanding physical factors associated with participation in community ambulation following stroke. Disabl Rehabil. 2011;33(12):1033–1042.

4. Alzahrani M, Dean CM, Ada L. Relationship between walking performance and types of community-based activities in people with stroke: an observational study. Braz J Phys Ther. 2010;15(1):45–51.

5. Rand D, Eng JJ, Tang PF, Jeng JS, Hung C. How active are people with stroke?: use of accelerometers to assess physical activity Stroke. 2009;40(1):163–168.

6. Polese JC, Ada L, Dean CM, Nascimento LR, Teixeira-Salmela LF. Treadmill training is effective for ambulatory adults with stroke: a systematic review. J Physiother. 2013;59(2):73–80.

7. Hollman JH, McDade EM, Petersen RC. Normative spatiotemporal gait parameters in older adults. Gait Posture. 2011;34(1):111–118.

8. Thaut MH, McIntosh GC, Rice RR. Rhythmic facilitation of gait training in hemi-paretic stroke rehabilitation. J Neurol Sci. 1997;151(2):207–212.

9. Thaut MH, Leins AK, Rice RR, Argstatter H, Kenyon GP, McIntosh GC, et al. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-am-bulatory patients early poststroke: A single-blind, randomized trial. Neurorehabil Neural Repair. 2007;21:455–459.

10. Thaut MH, Abiru M. Rhythmic auditory stimulation in rehabilitation of movement disorders: a review of current research. Music Perception. 2010;27(4):263–269.

11. Bradt J, Magee WL, Dileo C, Wheeler BL, McGilloway E. Music therapy for acquired brain injury. Cochrane Database Syst Rev. 2010;7. http://dx.doi.org/10.1002/ 14651858.CD006787.pub2. Art No: CD006787.

12. Wittner JE, Webster KE, Hill K. Rhythmic auditory cueing to improve walking in patients with neurological conditions other than Parkinson's disease – what is the evidence? Disabil Rehabil. 2013;35(2):164–176.

13. Schauer M, Mauritz KH. Musical motor feedback (MMF) in walking hemiparetic stroke patients: randomized trials of gait improvement. Clin Rehabil. 2003; 17:713–722.

14. Park IM, Oh DW, Kim SY, Choi JD. Clinical feasibility of integrating fast-tempo auditory stimulation with self-adopted walking training for improving walking function in post-stroke patients: a randomized, controlled pilot trial. J Phys Ther Sci. 2010;22:295–300.

15. van Peppen RP, Kwakkel G, Wood-Dauphinee S, Hendriks HJ, Van der Wees PJ, Dekker J. The impact of physical therapy on functional outcomes after stroke: what's the evidence? Clin Rehabil. 2004;18(8):833–862.

16. Mandel AR, Nymark JR, Balmer SJ. Electromyographic versus rhythmic positional biofeedback in computerized gait retraining with stroke patients. Arch Phys Med Rehabil. 1990;71:649–654.

17. Veerbeek JM, van Wegen E, van Peppen R, van der Wees PJ, Hendriks E, Rietberg M, et al. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis PLoS ONE. 2014;9(2):e87987.

18. Argstatter H, Hillecke TH, Thaut M, Bolay HV. Musiktherapie in der neurologischen Rehabilitation. Neurol Rehabil. 2007;13(1):42–48.

19. Bax L, Yu LM, Ikeda N, Tsuruta H, Moons KG. Development and validation of MIX: comprehensive free software for meta-analysis of causal research data. BMC Med Res Methodol. 2006;13:50.

20. Bax L, Ikeda N, Fukui N, Yaju Y, Tsuruta H, Moons KG. More than numbers: the power of graphs in meta-analysis. Am J Epidemiol. 2009;169(2):249–255.

21. Kim J, Park S, Lim H, Park G, Kim M, Lee B. Effects of the combination of rhythmic auditory stimulation and task-oriented training on functional recovery of subacute stroke patients. J Phys Ther Sci. 2012;24:1307–1313.

22. Kim J, Oh D. Home-based auditory stimulation training for gait rehabilitation of chronic stroke patients. J Phys Ther Sci. 2012;24:775–777.

23. Hayden R, Clair AA, Johnson G. The effect of rhythmic auditory stimulation (RAS) on physical therapy outcomes for patients in gait training following stroke: A feasi-bility study. Int J Neurosci. 2009;119:2183–2195.

24. Tilson JK, Sullivan KJ, Cen SY, Rose DK, Koradia CH, Azen SP, et al. Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically impor-tant difference. Phys Ther. 2010;90(2):196–208.

25. Bohannon RW, Andrews AW, Glenney SS. Minimal clinically important differ-ence for comfortable speed as a measure of gait performance in patients under-going inpatient rehabilitation after stroke. J Phys Ther Sci. 2013;25(10):1223– 1225.

26. Rodrigues-Baroni JM, Nascimento LR, Ada L, Teixeira-Salmela LF. Walking training associated with virtual reality-based training increases walking speed of individ-uals with chronic stroke: systematic review with meta-analysis. Braz J Phys Ther. 2014. http://dx.doi.org/10.1590/bjpt-rbf.2014.0062. IN PRESS.

27. Schmid A, Duncan PW, Studenski S, Lai SM, Richards L, Perera S, et al. Improve-ments in speed-based gait classifications are meaningful. Stroke. 2007;38(7): 2096–2100.

Websites

www.pedro.org.au

www.meta-analysis-made-easy.com

Box 1. Inclusion criteria.

Design
- Randomised or controlled trials

Participants
- Adults (>18 years)
- Diagnosis of stroke
- Ambulatory (walking speed of at least 0.2 m/s at baseline or participants able to walk without help, with or without walking aids)

Intervention
- Experimental intervention is any method of walking training with cueing of cadence

Outcome measures
- Measures of walking (speed, stride length, cadence, symmetry)

Comparisons
- Walking training with cueing of cadence vs walking training alone

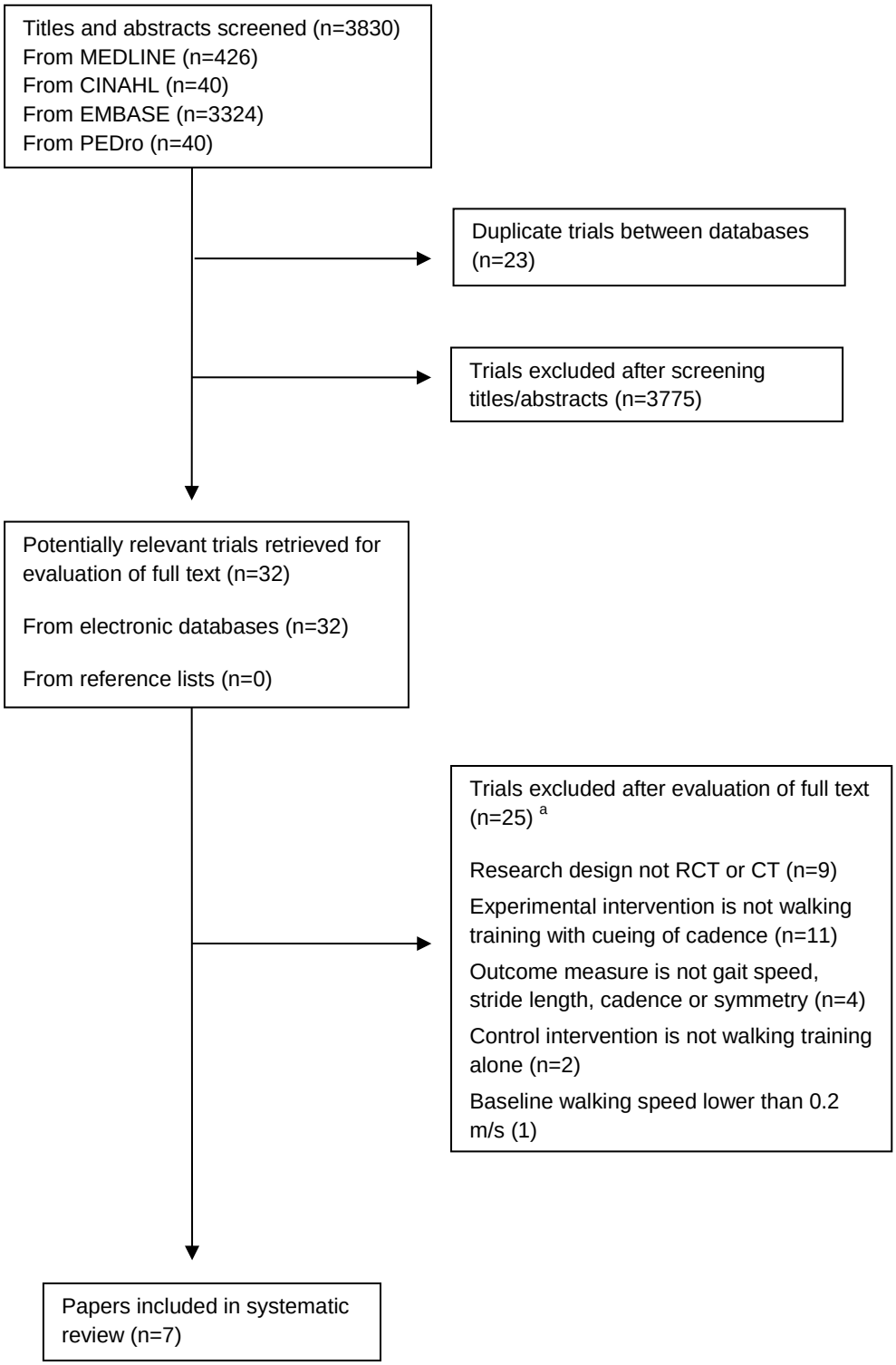


Figure 1.

Flow of studies through the review. [a]Papers may have been excluded for failing to meet more than one inclusion criterion.

Table 1 Characteristics of included papers (n=7)

Study	Design	Participants	Intervention	Progression	Outcome measures
Argstetter et al (2007)	RCT	n = 40 Age (yr) = 55-80 Time since stroke (mth) = <1 WS (m/s) = 0.23 (0.13)	Exp = CoC delivered via music (beats related to cadence) during walking training 10min x 5/wk x 4 wk Con = Walking training without CoC 10 min x 5/wk x 4 wk	CoC increased by 5-10% of the initial walking speed	- speed - stride length - cadence - symmetry Timing: 0, 4 wk
Hayden et al (2009)	CT	n = 10 Age (yr) = 55-80 Time since stroke (mth) = <1 WS (m/s) = 0.49 (0.32)	Exp = CoC delivered via music (beats related to cadence) during walking training 10min x 5/wk x 4wk Con = Walking training without CoC 10 min x 5/wk x 4 wk	CoC increased to match or slightly exceed patient's cadence by 1-3 beats/min	- speed - stride length - cadence Timing: 0, 4 wk
Kim et al (2012)[a]	RCT	n = 20 Age (yr) = 55(13) Time since stroke (mth) = 5 (2) WS (m/s) = 0.54 (0.22)	Exp = CoC delivered via metronome during walking training 30min x 3/wk x 5 wk Con = Walking exercises without CoC 30min x 3/wk x 5 wk Both = usual therapy	CoC increased by 5% of comfortable speed and by lowering volume of the metronome.	- speed - stride length - cadence - symmetry Timing: 0, 5 wk
Kim et al (2012)[b]	RCT	n = 20 Age (yr) = 65 (7) Time since stroke (mth) = 15 (3) WS (m/s) = 0.63 (0.13)	Exp = CoC delivered via metronome during walking training 10 min x 3/wk x 6 wk Con = Walking training without CoC 10 min x 3/wk x 6 wk	CoC increased by 20 beats/min every 2 min	- speed - stride length - symmetry Timing: 0, 6 wk
Park et al (2010)		n= 25 Age (yr) = 56 (12) Time since stroke (mth) = 15 (7) WS (m/s) = 0.37 (0.14)	Exp = CoC delivered via music (beats related to cadence) during walking training 2 x 30 min x 5/wk x 2 wk Con = Walking training without CoC 2 x 30 min x 5/wk x 2 wk	Not stated	-speed -stride length -cadence Timing: 0, 2 wk
Thaut et al (1997)	RCT	n = 20 Age (yr) = 72 (7) Time since stroke (mth) = 0.5 (0.1) WS (m/s) = 0.31 (0.20)	Exp = CoC delivered via musical feedback enhanced by metronome beats during walking training 2 x 30 min x 5/wk x 6wk Con = Walking training without CoC 2 x 30 min x 5/wk x 6wk Both: pre gait exercises if indicated	Cadence measured at the beginning of each session and CoC increased from 5-10% at the second and third quarter	- speed - stride length - cadence - symmetry Timing: 0, 6 wk

Thaut et al (2007)	RCT	n = 78 Age (yr) = 69 (11) Time since stroke (mth) = 0.7 (0.4) WS (m/s) = 0.23 (0.11)	Exp: CoC delivered via musical feedback enhanced by metronome beats during walking training 30 min x 5/wk x 3wk Con: Walking training without CoC 30 min x 5/wk x 3wk Both: pre gait exercises if indicated	Cadence measured at the beginning of each session and CoC increased 5% during the second quarter	- speed - stride length - cadence - symmetry Timing: 0, 3 wk

groups and outcome measures listed are those that were analyzed in this systematic review; there may have been other groups or measures in the paper. RCT = randomised clinical trial, WS = walking speed, CT = controlled trial, Exp = experimental group, Con = control group, CoC = cueing of cadence.

Table 2: PEDro criteria and scores for included papers (n = 7).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Argstatter et al (2007)	Y	N	Y	N	N	N	N	N	Y	Y	4
Hayden et al (2009)	N	N	Y	N	N	N	N	N	Y	Y	3
Kim et al (2012)[a]	Y	N	Y	N	N	N	Y	N	Y	Y	5
Kim et al (2012)[b]	Y	N	Y	N	N	N	N	N	Y	Y	4
Park et al (2010)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Thaut et al (1997)	Y	N	Y	N	N	N	N	N	Y	N	3
Thaut et al (2007)	Y	Y	Y	N	N	Y	N	Y	Y	Y	7

Y= yes; N=no

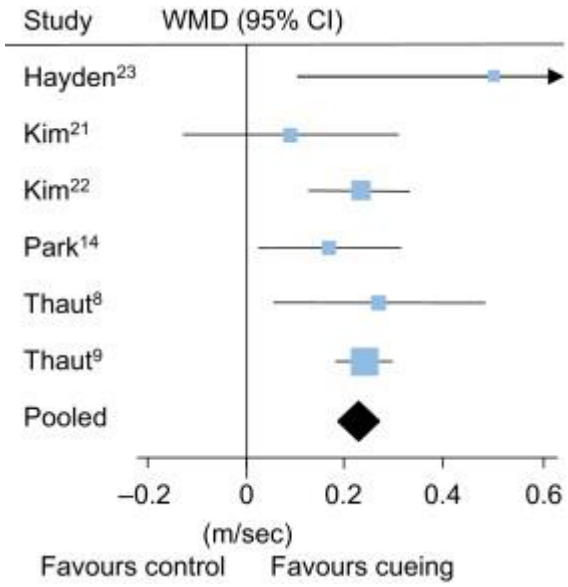


Figure 2.

Mean difference (95% CI) of walking training with cueing of cadence versus walking training alone for walking speed (n = 171).

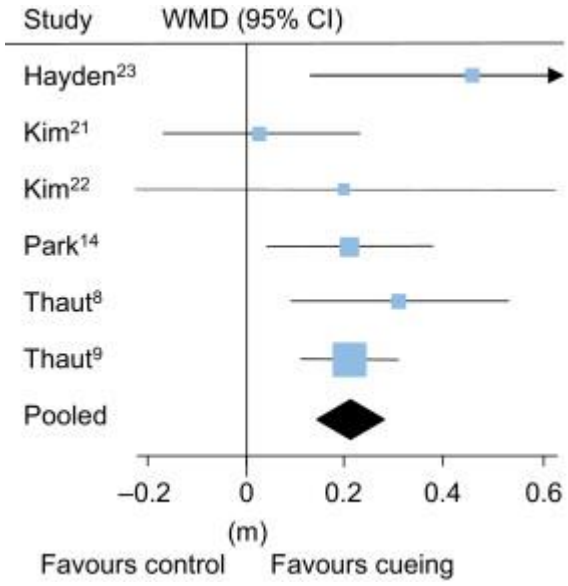


Figure 4.

Mean difference (95% CI) of walking training with cueing of cadence versus walking training alone for stride length. (n = 171).

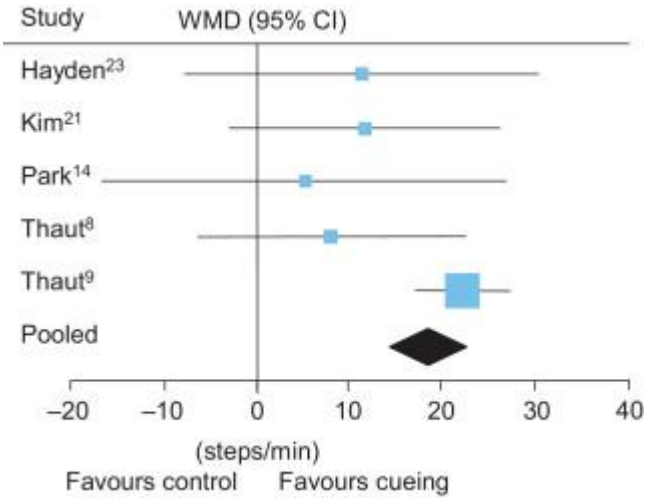


Figure 6.

Mean difference (95% CI) of walking training with cueing of cadence versus walking training alone for cadence (n = 151).

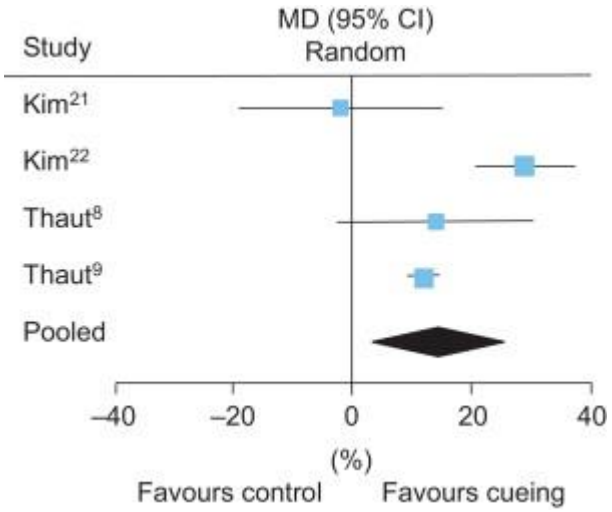


Figure 8.

Mean difference (95% CI) of walking training with cueing of cadence versus walking training alone for symmetry (n = 136).

5 ARTIGO 3

STUDY 3

Title: Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis

Abstract

Objective: To systematically review the available evidence on the efficacy of walking training associated with virtual reality-based training in patients with stroke. The specific questions were: Is walking training associated with virtual reality-based training effective in increasing walking speed after stroke? Is this type of intervention more effective in increasing walking speed, than non-virtual reality-based walking interventions? **Method:** A systematic review with meta-analysis of randomized clinical trials was conducted. Participants were adults with chronic stroke and the experimental intervention was walking training associated with virtual reality-based training to increase walking speed. The outcome data regarding walking speed were extracted from the eligible trials and were combined using a meta-analysis approach. **Results:** Seven trials representing eight comparisons were included in this systematic review. Overall, the virtual reality-based training increased walking speed by 0.17 m/s (IC 95% 0.08 to 0.26), compared with placebo/nothing or non-walking interventions. In addition, the virtual reality-based training increased walking speed by 0.15 m/s (IC 95% 0.05 to 0.24), compared with non-virtual reality walking interventions. **Conclusions:** This review provided evidence that walking training associated with virtual reality-based training was effective in increasing walking speed after stroke, and resulted in better results than non-virtual reality interventions.

[Rodrigues-Baroni JM, Nascimento LR, Ada L, Teixeira-Salmela LF (2014) Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis. *Brazilian Journal of Physical Therapy* 18(6): 502-512].

INTRODUCTION

After stroke, individuals often exhibit motor impairments, which are associated with activity limitations and social participation restrictions. Walking limitations is one of the main causes of disabilities after stroke, as the ability to walk is directly related to functional independence[1, 2]. According to Alzahrani et al.,[3], if walking performance is poor after stroke, activities at home and in the community will be limited, so that people may become housebound and isolated from society.

The mean walking speed after stroke varies from 0.4 to 0.8 m/s[4 - 6]. Walking speeds of less than 0.4 m/s define household ambulation; speeds between 0.4 and 0.8 m/s define limited community ambulation; and speeds greater than 0.8 m/s define full community ambulation. Consequently, a significant focus of interest in rehabilitation trials is to identify the effectiveness of interventions, which are able to increase walking speed after stroke, as greater speed is related to improved social participation and quality of life[3, 4]. Although previous systematic reviews have evidenced the efficacy of both overground and treadmill training in improving walking speed[5 - 7], new techniques and instruments can be added to usual walking training, to optimize the effect of interventions aimed at improving walking ability after stroke.

Some studies have suggested that virtual reality might be a useful tool in the rehabilitation of individuals after stroke, and its effect on walking speed have started being investigated[8 - 11]. By definition, virtual reality is the use of interactive simulations created with computer hardware and software to provide users with opportunities to engage in environments that appear and feel similar to real-world objects and events[5]. A wide variety of interfaces that allow the interactions with virtual environments is currently available. Components may be common devices, such as mouse, keyboards or joysticks, or more complex systems with cameras, sensors, and feedback devices, providing the users with the sensation of touching targets or deviating from objects, which are similar to obstacles present in the real world[11, 12].

According to Dobkin[13], the addition of virtual reality elements to walking interventions is advantageous, as it provides training in an enriched environment similar to the real

environment patients experience in daily life. In addition, virtual tasks have been described as more interesting and enjoyable by both children and adults, thereby, encouraging more time of practice and higher number of repetitions, which are considered to be important factors in the rehabilitation of individuals with neurologic disorders[8 , 14]. Concerning walking rehabilitation, the use of virtual environments enables therapists to progressively modulate the levels of difficulty of the tasks to challenge patients and to provide them with immediate feedback regarding their performance. Furthermore, clinicians are able to train tasks that are unsafe to practice in the real world, such as overcoming obstacles or crossing streets[8 , 13].

Two previous systematic reviews have examined the effect of walking training associated with virtual reality-based training in improving walking ability after stroke. A *Cochrane* [8] review reported a non-significant increase in walking speed of 0.07 m/s (95% CI:-0.09 to 0.23), based upon three randomised clinical trials. A more recent review[9] included four randomised clinical trials and indicated that the addition of virtual reality-based training was beneficial to walking ability after stroke. However, the authors reported clinical heterogeneity between the trials, and a meta-analysis was not performed. Therefore, the results regarding the addition of virtual reality-based training to walking interventions aimed at improving walking ability after stroke remain inconclusive. In addition, there were not found any reviews that separately examined the efficacy of walking training associated with virtual reality-based training and the superiority of this association, compared with other walking interventions.

Therefore, the aim of this systematic review was to examine the effect of the addition of virtual reality-based training to walking training for improving walking speed after stroke. The specific research questions were:

1. Is walking training associated with virtual reality-based training effective in increasing walking speed after stroke?
2. Is walking training associated with virtual reality-based training more effective than non-virtual reality-based interventions?

In order to make recommendations based upon a high level of evidence, this review planned to include only randomised or controlled trials.

METHOD

Identification and selection of trials

Searches were conducted at the MEDLINE (1946 to July 2013), PEDro (to July 2013), and EMBASE (1980 to July 2013) databases for relevant studies without language restrictions. Search terms included words related to*stroke*, *virtual reality training* (such as virtual reality, video-games, flow optic) and *gait* (Appendix 1). Titles and abstracts were displayed and screened by one reviewer to identify relevant studies. Full paper copies of relevant peer-reviewed papers were retrieved and their reference lists were also screened to identify further relevant studies. The selection of the retrieved papers was conducted by two reviewers, using predetermined criteria, which are summarized in the supplementary materials related to this paper (Appendix 1S[1]).

Assessment of characteristics of the trials

Quality

The quality of the included trials was assessed by extracting PEDro scores from the Physiotherapy Evidence Database[15]. PEDro is an 11-item scale designed for rating the methodological quality (internal validity and statistical information) of randomised trials. Each item, except for Item 1, contributes one point to the total score (range: 0 to 10 points). Where a trial was not included on the database, it was scored by a reviewer, who had completed the PEDro scale training tutorial.

Participants

Trials involving ambulatory adults after stroke were included. The number of participants, age, time since stroke, and baseline walking speed were recorded to assess the similarity of the studies.

Intervention

The experimental intervention was walking training associated with virtual reality-based training aimed at improving walking speed after stroke. Virtual reality was defined as a simulation of a real environment created by a computer software which allowed users to interact with elements within a simulated scenario by using different interfaces, such as mouse, keyboards, joysticks, gloves, and/or motion capture systems[11 , 12]. We included trials using any form of non-immersive or immersive virtual reality, and those that used commercially available gaming consoles[8].

The control intervention was defined according to the research questions: (i) to examine the efficacy of walking training associated with virtual reality-based training, the control intervention could be nothing/placebo or any other non-walking intervention; (ii) to examine the superiority of walking training associated with virtual reality-based training, the control intervention could be any other non-virtual reality walking intervention.

Outcome measure

The outcome measure of interest was comfortable walking speed, provided, in this review, in meters per second (m/s). The timing of the measurements and the procedure used to measure walking speed were recorded to assess the appropriateness of combining the studies in a meta-analysis.

Data analysis

Information about the method (i.e., design, participants, interventions, and outcome measures) and results (i.e., number of participants, and means (SD) of walking speed) were extracted by one reviewer and checked by a second one. Where information was not available in the published trials, details were requested from the corresponding author.

The post-intervention scores were used to obtain the pooled estimate of the effect of intervention. The effect size was obtained using the fixed effects model and reported as weighted mean differences (MD) with 95% confidence intervals (95% CI)**.** In the

case of significant statistical heterogeneity (I^2>50%), a random effects model was applied to check the robustness of the results. The analyses were performed using the MIX-Meta-Analysis Made Easy program Version 1.7[16 , 17]; the significance level for statistical heterogeneity was set at 5% (two-tailed). Where data were not available to be included in the pooled analysis, the between-group results were reported.

RESULTS

Flow of trials through the review

The electronic search strategy identified 999 relevant papers for the analysis of titles and abstracts. After screening titles and abstracts, 15 potentially relevant full papers to answer the research questions were retrieved. Following the analysis, according to the predetermined inclusion criteria, eight papers were retrieved. After data extraction, one paper[18] was removed from the review, because its results included duplicate data of a second paper[19]. Therefore, seven papers were included in this review (Figure 1).

Characteristics of the included trials

Seven randomized clinical trials involving 154 participants examined the efficacy of walking training associated with virtual reality-based training for increasing walking speed after stroke, and therefore were included in this review (Table 1). Since one of the trials[20] included two control groups, a total of eight comparisons were performed. Three trials[20 - 22] compared walking training associated with virtual reality-based training with nothing/placebo or non-walking intervention (Question 1). Five trials[19 , 20 , 23 - 25] compared walking training associated with virtual reality-based training with a non-virtual reality walking intervention (Question 2).

Quality

The mean PEDro score of the included trials was 6.1, ranging from 4 to 8 points (Table 2). All the trials randomly allocated participants, had similar groups at baseline, and reported point estimate and variability. The majority of trials reported concealed allocation (57%), had less than 15% drop-outs (57%), reported between-group differences (86%), and had blinded assessors (86%). However, the majority of

trials did not report whether and intention-to-treat analysis was undertaken (86%). Only one trial[22] blinded participants, and no trials blinded therapists, which is considered difficult or impossible during complex interventions.

Participants

The mean age of participants ranged from 52 to 66 years across trials. All trials included participants with time after stroke greater than six months (ranging from 10 to 72 months across trials), which defines chronic hemiparesis. The sample size of the included trials ranged between 14 and 30 participants, who were allocated to the experimental or control groups. All of the participants were ambulatory adults at the time of entry into the trial, with mean baseline walking speed ranging from 0.46 to 0.70 m/s across trials.

Intervention

In all trials, the experimental intervention was walking training associated with virtual reality-based training. Virtual reality-based training was associated with treadmill training in four trials[20 , 23 - 25], with video-games exercises in two trials[21 , 22], and with kinesiotherapy involving specific ankle movements in one trial[19]. Three trials[20 , 22 , 23] delivered usual therapy to both experimental and control groups.

The majority of trials delivered immersive virtual reality training to the experimental group. In these trials[20 , 23 -25], virtual images were coupled to the treadmill, and treadmill speed was changed as a function of the generated visual images. Non-immersive virtual reality was used in three trials[19 , 21 , 22]: two[21 , 22] employed video cameras to capture the patient's body image and to enable interactions with virtual objects; one trial[19] employed visual feedback on the computer screen and tactile feedback related to the patient's movements. Only one trial[21] used a commercially available virtual reality device (*Nintendo Wii*) during the delivery of the experimental intervention.

Outcome measures

The majority of trials used a timed walk measure based upon the 10-Meter Walk Test[26] to measure walking speed, with variations on the length of the corridor: 12[25],

10[20, 22], seven[19], six[24], and three meters[21]. One trial[23] used foot sensors during a timed walk test from a specific device (GAITRite; CIR System Inc, New Jersey) to measure walking speed. All the data in this review reflects comfortable gait speed and were converted to m/s.

Effect of walking training associated with virtual reality-based training on walking speed

The overall effect of walking training associated with virtual reality-based training on walking speed immediately after intervention was examined by pooling post-intervention data from three trials[20 - 22] with a mean PEDro score of 7.0, indicating good quality[27]. Virtual reality-based training increased walking speed by 0.17 m/s (95% CI 0.08 to 0.26; *fixed effects model* I^2=0%), compared with placebo/nothing or non-walking interventions (Figure 2A).

Effect of walking training associated with virtual reality-based training, compared with non-virtual reality walking interventions on walking speed

The superiority of walking training associated with virtual reality-based training on walking speed immediately after intervention was examined by pooling post-intervention data from five trials[19, 20, 23 - 25] with a mean PEDro score of 5.8, indicating moderate quality[27]. Virtual reality-based training increased walking speed by 0.15 m/s (95% CI 0.05 to 0.24; *fixed effects model* I^2=0%), compared with non-virtual reality walking interventions (Figure 2B).

DISCUSSION

This systematic review provided clinical evidence that walking training associated with virtual reality-based training was effective in increasing walking speed after stroke. Clinically, the results indicated that the addition of virtual reality-based training is more effective than no intervention, placebo, or non-walking interventions. The results also indicated that walking training associated with virtual reality-based training produced faster walking speed, compared with non-virtual reality walking interventions.

The meta-analysis demonstrated that the addition of virtual reality-based training increased walking speed by 0.17 m/s. This meta-analysis was the first to examine the efficacy of this type of intervention to improve walking speed with individuals after stroke. Importantly, these benefits appear to be clinically meaningful. For example, Tilson et al.[28] demonstrated that a between-group difference in walking speed after stroke greater than 0.16 m/s resulted in improvement in the patients' levels of disability, and suggested this value as a rehabilitation goal. The meta-analysis also demonstrated that walking training associated with virtual reality-based training produced 0.15 m/s faster walking, than other non-virtual walking interventions. A previous systematic review[8] have reported a non-significant between-group difference after the addition of virtual reality-based training. The inclusion of two extra clinical trials in the present meta-analysis increased its statistical power and strengthens the evidence the efficacy of the addition of virtual reality-based training for increasing walking speed after stroke.

This review examined the effect of the addition of virtual reality-based training to various types of walking intervention after stroke. Although various types of walking training have been employed across trials (i.e., treadmill training[20, 23-25], exercises using videogames[21, 22], or ankle exercises[19]), overall, the included trials were similar in terms of session duration (mean 41 min, SD 18), session frequency (mean 3.3/wk, SD 0.5), program duration (4 weeks, SD 1), participants' characteristics, and aim of intervention. In addition, statistical analysis (I^2=0%) indicated that the trials were clinical and statistically similar, which allowed for the data to be combined in meta-analyses. The data suggested similarity across trials and indicated lack of clinical or statistical heterogeneity, supporting the clinical evidence that the addition of virtual reality-based training is effective in improving walking speed after stroke.

Although the improvement in walking speed was superior with the addition of virtual reality-based training, other factors not examined in this review, such as clients' values and expectations, clinical expertise, and costs of implementation should be taken into consideration before deciding the most appropriate type of intervention for each client. The gaming industry has recently released low-cost virtual reality

systems, such as *Nintendo Wii*,*Kinect,* and *Playstation*, thus facilitating the access of rehabilitation centers and home users to this technology[29, 30]. However, only one trial[21] included in this review used commercially available devices, and the between-group difference was not clinically significant for walking speed (mean difference: 0.04 m/s, 95% CI:-0.22 to 0.30). Subgroup analysis based upon the type of virtual reality delivered could not be performed, because there were not enough trials. Thus, new clinical trials examining the efficacy of the addition of virtual reality-based training using commercially available devices are encouraged.

This review has both strengthens and limitations. A source of bias in the included trials was lack of blinding of therapists and participants, since it is very difficult or unpractical to blind either during the delivery of complex interventions, such as walking training. In addition, the majority of the included trials did not report whether an intention-to-treat analysis was carried-out. On the other hand, the mean PEDro score of 6.1 for the included trials indicated good methodological quality[27]. One second positive aspect was the inclusion of trials that examined the same outcome measure - walking speed; this allowed the exhibition of results in weighted mean difference, which is clinically intelligible. Furthermore, the inclusion of only trials whose intervention was walking training associated with virtual reality-based training constraints the results to a specific intervention.

CONCLUSIONS

This systematic review provided clinical evidence for the efficacy of the addition of virtual reality-based training to walking training in improving walking speed after stroke, compared with placebo or no intervention. In addition, this review demonstrated that walking training associated with virtual reality-based training was more effective in improving walking speed, compared with non-virtual reality walking interventions. The results are based on a meta-analysis of seven randomized clinical trials with good methodological quality. Clinicians should, therefore, be confident in prescribing walking training associated with virtual reality-based training to improve walking speed after stroke. Other factors, such as clients' values and expectations,

clinical expertise, and costs of implementation should also be considered, when deciding on the most appropriate type of intervention for each client.

REFERENCES

1. Horvath M, Tihanyi T, Tihanyi J. Kinematic and kinetic analyses of gait patterns in hemiplegic patients. Facta Univ. 2011;1(8):25-35.

2. Robinson CA, Shumway-Cook A, Matsuda PN, Ciol MA. Understanding physical factors associated with participation in community ambulation following stroke. Disabil Rehabil. 2011;33(12):1033-42.

3. Alzahrani M, Dean C, Ada L. Relationship between walking performance and types of community-based activities in people with stroke: an observational study. Rev Bras Fisioter. 2011;15(1):45-51.

4. Schmid A, Duncan PW, Studenski S, Lai SM, Richards L, Perera S, et al. Improvements in speed-based gait classifications are meaningful. Stroke. 2007;38(7):2096-100.

5. Ada L, Dean CM, Vargas J, Ennis S. Mechanically assisted walking with body weight support results in more independent walking than assisted overground walking in non-ambulatory patients early after stroke: a systematic review. J Physiother. 2010;56(3):153-61.

6. Polese JC, Ada L, Dean CM, Nascimento LR, Teixeira-Salmela LF. Treadmill training is effective for ambulatory adults with stroke: a systematic review. J Physiother. 2013;59(2):73-80.

7. States RA, Salem Y, Pappas E. Overground gait training for individuals with chronic stroke: a Cochrane systematic review. J Neurol Phys Ther. 2009;33(4):179-86.

8. Laver KE, George S, Thomas S, Deutsch JE, Crotty M. Virtual reality for stroke rehabilitation. Cochrane Database Syst Rev. 2011;9:CD008349.

9. Moreira MC, de Amorim Lima AM, Ferraz KM, Benedetti Rodrigues MA. Use of virtual reality in gait recovery among post stroke patients-a systematic literature review. Disabil Rehabil Assist Technol. 2013;8(5):357-62.

10. Mouawad MR, Doust CG, Max MD, McNulty PA. Wii-based movement therapy to promote improved upper extremity function post-stroke: a pilot study. J Rehabil Med. 2011;43(6):527-33.

11. Saposnik G, Levin M, Outcome Research Canada (SORCan) Working Group. Virtual reality in stroke rehabilitation: a meta-analysis and implications for clinicians. Stroke. 2011;42(5):1380-6.

12. Peñasco-Martín B, de los Reyes-Guzmán A, Gil-Agudo Á, Bernal-Sahún A, Pérez-Aguilar B, de la Peña-González AI. Application of virtual reality in the motor aspects of neurorehabilitation. Rev Neurol. 2010;51(8):481-8.

13. Dobkin BH. Strategies for stroke rehabilitation. Lancet Neurol. 2004;3(9):528-36.

14. Thornton M, Marshall S, McComas J, Finestone H, McCormick A, Sveistrup H. Benefits of activity and virtual reality based balance exercise programmes for adults with traumatic brain injury: perceptions of participants and their caregivers. Brain Inj. 2005;19(12):989-1000.

16. Bax L, Yu LM, Ikeda N, Tsuruta H, Moons KG. Development and validation of MIX: comprehensive free software for meta-analysis of causal research data. BMC Med Res Methodol. 2006;6(1):50.

17. Bax L, Ikeda N, Fukui N, Yaju Y, Tsuruta H, Moons KG. More than numbers: the power of graphs in meta-analysis. Am J Epidemiol. 2009;169(2):249-55.

18. Mirelman A, Patritti BL, Bonato P, Deutsch JE. Effects of virtual reality training on gait biomechanics of individuals post-stroke. Gait Posture. 2010;31(4):433-7.

19. Mirelman A, Bonato P, Deutsch JE. Effects of training with a robot-virtual reality system compared with a robot alone on the gait of individuals after stroke. Stroke. 2009;40(1):169-74.

20. Kang HK, Kim Y, Chung Y, Hwang S. Effects of treadmill training with optic flow on balance and gait in individuals following stroke: randomized controlled trials. Clin Rehabil. 2012;26(3):246-55.

21. Fritz SL, Peters DM, Merlo AM, Donley J. Active video-gaming effects on balance and mobility in individuals with chronic stroke: a randomized controlled trial. Top Stroke Rehabil. 2013;20(3):218-25.

22. Kim JH, Jang SH, Kim CS, Jung JH, You JH. Use of virtual reality to enhance balance and ambulation in chronic stroke: a double-blind, randomized controlled study. Am J Phys Med Rehabil. 2009;88(9):693-701.

23. Cho KH, Lee WH. Virtual walking training program using a real-world video recording for patients with chronic stroke: a pilot study. Am J Phys Med Rehabil. 2013;92(5):371-80.

24. Jaffe DL, Brown DA, Pierson-Carey CD, Buckley EL, Lew HL. Stepping over obstacles to improve walking in individuals with poststroke hemiplegia. J Rehabil Res Dev. 2004;41(3A):283-92.

25. Yang YR, Tsai MP, Chuang TY, Sung WH, Wang RY. Virtual reality-based training improves community ambulation in individuals with stroke: a randomized controlled trial. Gait Posture. 2008;28(2):201-6.

26. Nascimento LR, Caetano LC, Freitas DC, Morais TM, Polese JC, Teixeira-Salmela LF. Different instructions during the ten-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. Rev Bras Fisioter. 2012;16(2):122-7.

27. Foley NC, Teasell RW, Bhogal SK, Doherty T, Speechley MR. The efficacy of stroke rehabilitation: a qualitative review. Top Stroke Rehabil. 2003;10(2):1-18.

28. Tilson JK, Sullivan KJ, Cen SY, Rose DK, Koradia CH, Azen SP, et al. Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically important difference. Phys Ther. 2010;90(2):196-208.

29. Saposnik G, Teasell R, Mamdani M, Hall J, McIlroy W, Cheung D, et al. Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. Stroke. 2010;41(7):1477-84.

30. Pompeu JE, Mendes FA, Silva KG, Lobo AM, Oliveira TP, Zomignani AP, et al. Effect of Nintendo Wii(tm)-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: a randomised clinical trial. Physiotherapy. 2012;98(3):196-204.

Box 1

Inclusion criteria

Design
- Randomised clinical trial or controlled trial

Participants
- Adults (>18 years)
- Diagnosis of stroke
- Ambulators

Intervention
- Gait training associated with virtual reality-based training

Outcome
- Comfortable gait speed

Comparisons
- Virtual reality-based intervention vs placebo/nothing or non-walking intervention
- Virtual reality-based intervention vs non-virtual reality walking intervention

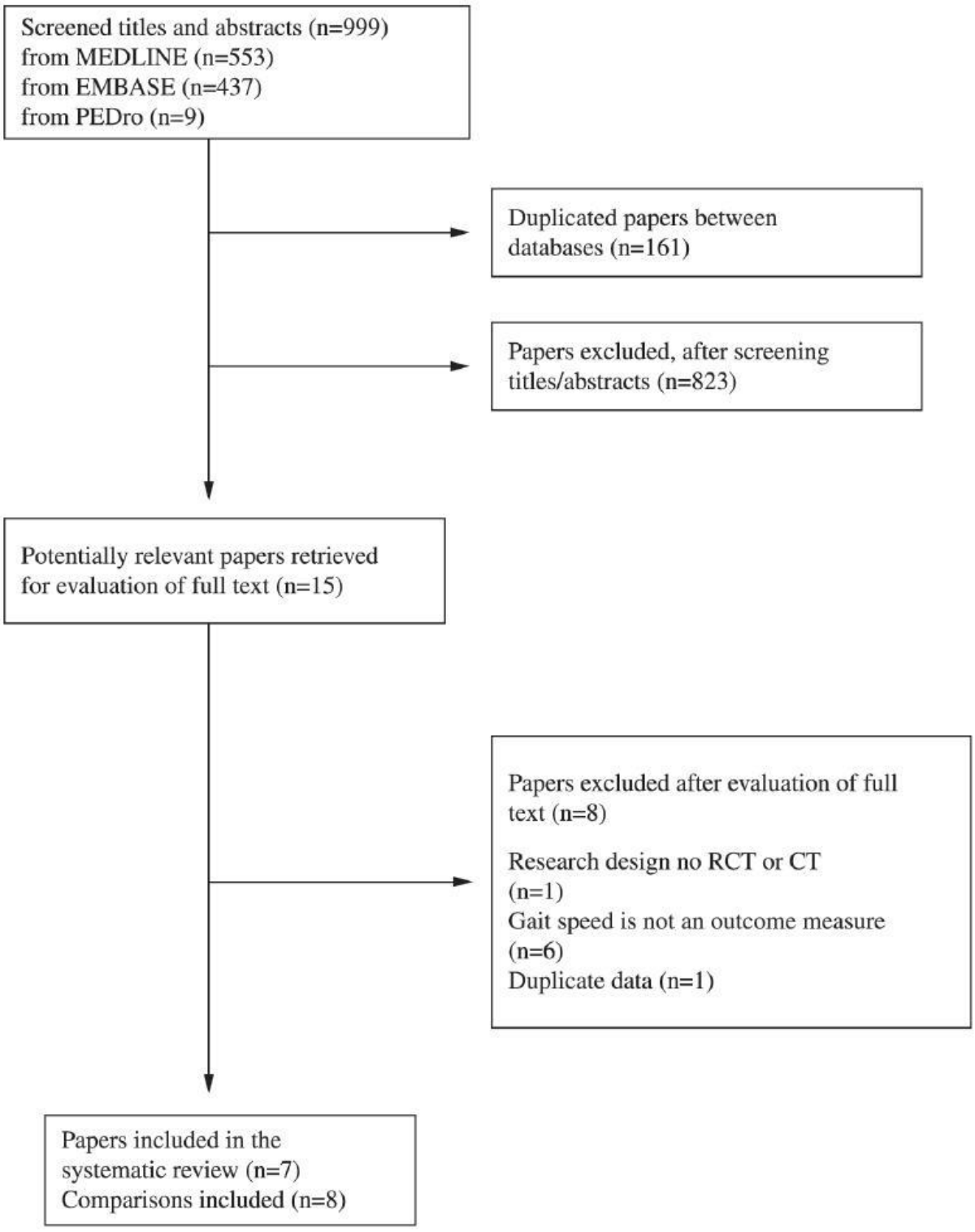


Figure 1. Flow of studies through the review. RCT = randomised clinical trial; CT = controlled trial.

Table 1. Characteristics of papers (n=7) included in the systematic review on the addition of virtual reality-based training after stroke.

Study	Design	Participants	Intervention	Walking speed measurements (week)
Cho and Lee[23]	RCT	n=14 Age (yr): 65 (4) Time since stroke (mth): 10 (2) WS: 0.53 (0.17)	Exp = Virtual reality-based treadmill training 30min x 3/wk x 6wk Con = Treadmill training 30min x 3/wk x 6wk Both = Usual therapy	0 and 6
Fritz et al.[21]	RCT	n=28 Age (yr): 66 (10) Time since stroke (mth): 36 (35) WS: 0.57 (0.30)	Exp = Video-game exercises 60min x 4/wk x 5wk Con = no intervention	0, 5 and 12
Jaffe et al.[24]	RCT	n=20 Age (yr): 62 (10) Time since stroke (mth): 45 (29) WS: not reported	Exp = Stepping over virtual obstacles in a treadmill 60min x 3/wk x 2wk Con = Stepping over foam obstacles in a hallway 30min x 3/wk x 2wk	0, 2 and 4
Kang et al.[20]	RCT	n=30 Age (yr): 56 (7) Time since stroke (mth): 14 (5) WS: 0.5 (0.2)	Exp = Virtual reality-based treadmill training 30min x 3/ wk x 4 wk Con1 = Treadmill training 30min x 3/ wk x 4 wk Con2 = stretching exercises 30min x 3/ wk x 4 wk All groups = Usual therapy	0 and 4
Kim et al.[22]	RCT	n=24 Age (yr): 52 (8) Time since stroke (mth): 24 (9) WS: 0.46 (0.15)	Exp = Video-game exercises 30min x 4/wk x 4wk Con = no intervention Both = Usual therapy	0 and 4
Mirelman et al.[19]	RCT	n=18 Age (yr): 62 (9) Time since stroke (mth): 48 (26) WS: 0.66 (0.27)	Exp = Ankle movements with targets and feedback provided by virtual reality 60min x 3/wk x 4wk Con = Ankle movements without feedback provided by virtual reality 60min x 3/wk x 4wk	0, 4 and 7
Yang et al.[25]	RCT	n=20 Age (yr): 61 (11) Time since stroke (mth): 72 (87) WS: 0.70 (0.44)	Exp = Virtual reality-based treadmill training 20min x 3/wk x 3wk Con = Treadmill training 20min x 3/wk x 3wk	0, 3 and 7

groups and outcome measures listed are those which were analysed in this systematic review, there may have been other groups or measures in the paper. RCT = randomised clinical trial, WS = walking speed at baseline (m/s), Exp = experimental group, Con = control group.

Table 2. *PEDro* criteria and scores for the papers (n=7) included in the systematic review on the addition of virtual reality-based training after stroke.

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Cho and Lee[23]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Fritz et al.[21]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Jaffe et al.[24]	Y	N	Y	N	N	N	Y	N	N	Y	4
Kang et al.[20]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Kim et al.[22]	Y	N	Y	Y	N	Y	N	N	Y	Y	6
Mirelman et al.[19]	Y	N	Y	N	N	Y	N	N	Y	Y	5
Yang et al.[25]	Y	Y	Y	N	N	Y	N	N	Y	Y	6

Y= yes; N=no.

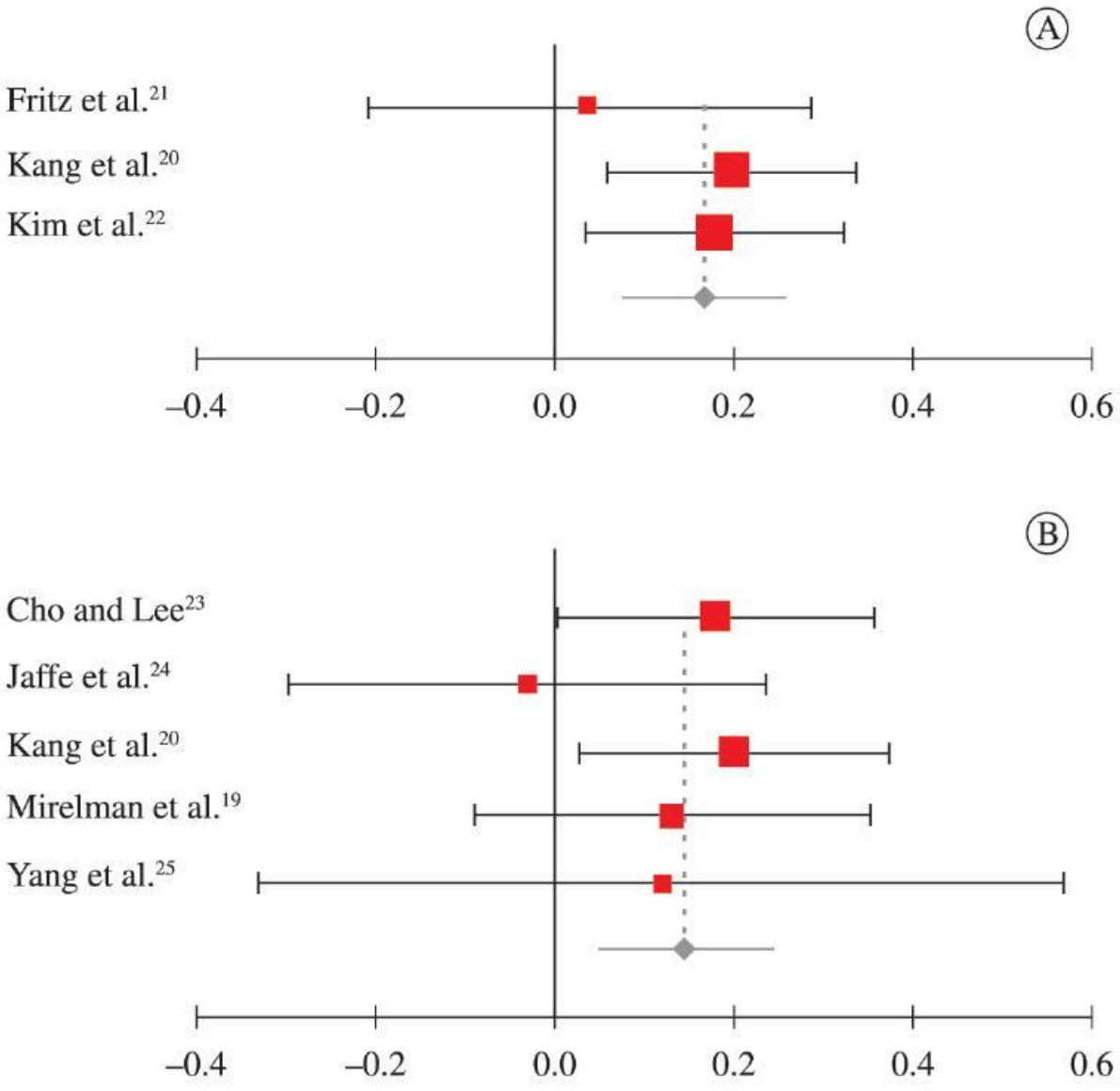


Figure 2. A. Mean difference (95% CI) of the effect of virtual reality-based intervention versus nothing/placebo or non-walking intervention on walking speed immediately after intervention (n=72). B. Mean difference (95% CI) of the effect of virtual reality-based intervention versus non-virtual reality walking intervention on walking speed immediately after intervention (n=92).

6 ARTIGO 4

STUDY 4

Title: The provision of a cane provided greater benefit to the group of community-dwelling people with chronic stroke with speed between 0.4 and 0.8 m/s

Abstract

Background: The most logical time to prescribe walking aids to people with stroke is after their independent walking has stabilized. Thus, the question as to whether walking aids can improve walking can be answered, without being confounded by natural recovery. The aims of this study were: (i) to investigate the effect of the provision of a cane on walking ability in ambulatory people after stroke; (ii) to examine if there is a differential effect according to participants' comfortable walking speed. **Method**: Twenty-four people with chronic stroke, who were not regular users of walking sticks, were evaluated under two different experimental conditions: walking with and without a cane. Walking was reported as speed (m/s), step length (m), and cadence (steps/min). Participants were categorized as slow (<0.4 m/s), intermediate (0.4-0.8 m/s), and fast walkers (>0.8 m/s). **Findings**: The provision of a cane to the intermediate walkers produced a 0.27 m/s (95% CI 0.18 to 0.36) increase in speed compared with the fast walkers, and a 0.12 m/s (95% CI 0.03 to 0.21) increase compared with the slow walkers. It also produced 0.05 m (95% CI 0.02 to 0.08) increase in step length and 20 steps/min (95% CI 12 to 28) increase in cadence compared with the fast walkers. **Interpretation**: The provision of a cane produced the most benefit in intermediate walkers, and was detrimental to the fast walkers. Canes can be prescribed to stroke survivors with moderate and severe walking limitations, but caution should be taken regarding their prescription for fast walkers.

[Nascimento LR, Ada L, Teixeira-Salmela LF (*submitted*). The provision of a cane provided greater benefit to the group of community-dwelling people with chronic stroke with speed between 0.4 and 0.8 m/s. *Clinical Biomechanics*].

INTRODUCTION

Although most stroke survivors regain their walking ability, their speed, step length, and cadence remain significantly reduced (Nascimento et al., 2015; Thaut et al., 2007). Deficits in the temporal and spatial parameters of walking, in combination with fear of falling and lack of confidence, have repercussions on the ability to ambulate in the community and participate in social activities (Allet et al., 2009, Robinson et al., 2007). Therefore, improving walking is one of the main ways to improve social participation and quality of life (Alzahrani et al., 2011; Schimid et al., 2007).

Walking aids are sometimes prescribed after stroke with the aim of improving safety and walking ability. However, there is no consensus regarding whether or when to prescribe these aids (Bateni and Maki, 2005; Polese et al., 2012). Walking aids are not usually prescribed early after stroke because it is believed that they will be detrimental to long-term walking ability. Although previous studies have indicated that a single-point cane is less detrimental than a quad stick (Buurke et al., 2005; Beauchamp et al., 2009; Allet et al., 2009), results regarding the prescription of a single-point cane remain inconclusive. In the first two months after stroke, when newly ambulatory people with stroke were given a cane during rehabilitation, it improved symmetry in a subset of very asymmetrical patients (Beauchamp et al., 2009), but worsened hip abductor muscle activation (Macguire et al., 2010). When newly ambulatory patients had practiced walking with a cane for two weeks, the removal of the cane did not decrease walking speed, but did decrease step length by 6 cm and increase step width by 2 cm (Kuan et al., 1999). By seven months after stroke, when slow walkers (0.45 m/s) who had been habitually using a cane had their cane removed, small clinically insignificant changes in muscle activation were observed with no changes in walking speed (Buurke et al., 2005). By ten months after stroke, when intermediate walkers (0.6 m/s) who had been habitually using a cane had their cane removed, there were also no changes in walking speed (Tyson et al., 1999). However, by seven years of habitual cane use, when it was removed in a group of fast walkers (0.84 m/s), walking speed decreased a small amount (by 0.08 m/s) (Polese et al., 2012).

The most logical time to prescribe walking aids to people with stroke is after their independent walking has stabilized. By this time, there is no likelihood of interfering with the development of independent walking, and the question as to whether walking aids can improve walking ability can be answered without being confounded by natural recovery. Therefore, the aim of this study was to investigate the effect of the provision of a single-point cane on walking (i.e., speed, step length, and cadence) in community-dwelling independently ambulating people with chronic stroke, i.e., people whose walking had stabilized and did not habitually use a walking cane. Furthermore, the prescription of a cane could be more helpful to people who already have some ability to ambulate around their community, in comparison to those who rarely venture outside their homes or to those who fully ambulate around their community. Sub-group analyses have demonstrated that people with stroke respond differently to walking interventions, according to their walking ability (Dean et al., 2014; Dean et al., 2012). Therefore, the specific research questions were:

1. What is the effect of the provision of a cane on speed, step length, and cadence in ambulatory people with chronic stroke?
2. Is there a differential effect according to comfortable walking speed (<0.4 versus 0.4-0.8 versus >0.8 m/s)?

METHOD

Design

An experimental study of the effect of the provision of a cane on walking speed, step length, and cadence was conducted. Volunteers with stroke were recruited from the local community and out-patient clinics. Measures of walking were collected on one day in a research laboratory, under two different experimental conditions (i.e., walking with and without a cane). The order of the conditions was randomized and counterbalanced so that each order of data collection was equally represented across the sample. This study was approved by the Universidade Federal de Minas Gerais Ethical Review Board, and all participants provided written consent prior to data collection.

Participants

People with stroke were included if they: were ≥18 years old; had a mean time since the onset of stroke of at least six months; were able to walk at least 14 m independently; and were not regular users of walking sticks. They were excluded if they had cognitive deficits (scores < 24 out of 30 on the Mini-mental state examination) (Brucki et al., 2003) or any other neurological or orthopedic disorders.

Characteristics of participants, such as age, gender, side of weakness, time since stroke, cognition (Brucki et al., 2003), dexterity (Lower Extremity Coordination Test score, Pinheiro et al., 2014), tonus of the plantarflexor muscles (modified Ashworth scale, Bohannon and Smith, 1987), motor recovery (Fugl-Meyer Scale – lower limb section, Maki et al., 2006), were collected for characterization purposes. Comfortable and fast walking speed was collected (10-m walk test, Nascimento et al., 2012), and the participants were categorized as slow (<0.4 m/s), intermediate (0.4-0.8 m/s), and fast walkers (>0.8 m/s) according to their comfortable walking speed (Dean et al., 2014; Perry et al., 1995). These cut-off values were decided prior to data collection (Sun et al., 2010).

Experimental conditions

There were two experimental conditions – walking with and without a cane. The cane was a single-point cane with ergonomic handgrip. This type of cane is usually preferred by patients, and requires less oxygen use at a given speed (Jeong et al., 2014; Allet et al., 2009). The height of the cane was individually adjusted to the height of the ulnar process of each participant, and measured in a standing position with the elbow extended (Allet et al., 2009). A physiotherapist provided instructions on how to walk with the cane, and a minimum period of five minutes of practice was allowed. When necessary, extra time was allowed until participant was feeling comfortable to walk with the cane.

Measurement of walking

Walking was measured and reported as speed (m/s), step length (m), and cadence (steps/min). Time and number of steps were recorded, while participants

independently walked with their own low-heeled shoes over the middle 10-m of a 14-m track (to allow for acceleration and deceleration). They were instructed to walk at their comfortable speed following the command: “Walk at your normal speed on the walkway” (Nascimento et al., 2012). All commands were given by the same researcher, and two analyzable trials for each condition were registered, and the mean value was stored for analyses. Participants were closely supervised by a registered physiotherapist, and a period of rest between measurements was allowed as needed.

Data analysis

Descriptive statistics, tests for normality (Shapiro-Wilk), and homogeneity of variance (Levene) were carried out for all outcomes. Mean (SD) of speed, step length, and cadence of the participants walking with and without a cane were determined for all participants combined, and for the slow, intermediate, and fast walkers separately. Mean difference (95% CI) between conditions (i.e., with and without a cane) were calculated for all participants combined, and for the slow, intermediate, and fast walkers separately. Mean difference (95% CI) between conditions (with and without a cane) and between groups (slow, intermediate and fast walkers) were calculated.

RESULTS

Flow of participants through the study

A total of 50 stroke survivors were screened for eligibility from September to December, 2014. Of these, nine (18%) declined at first contact and 13 (26%) were excluded because they did not meet the inclusion criteria leaving 28 eligible to participate. Four (8%) were absent on the day of the test. Therefore, 24 volunteers (13 men and 11 women) participated in the study (Figure 1). Characteristics of the participants are reported in Table 1. The mean age of the participants was 61 years (SD 12), with a mean time since the onset of stroke of 6 years (SD 5). The mean comfortable speed during the 10MWT was 0.67 m/s (range 0.10-1.30 m/s), and participants were categorized as slow (< 0.4 m/s; n = 6), intermediate (0.4-0.8 m/s; n = 9), and fast walkers (> 0.8 m/s; n = 9).

Effect of a cane on speed, step length, and cadence for all participants

Table 2 provides the mean (SD) speed, step length, and cadence for both conditions (i.e., walking with and without a cane), and the mean differences (95% CI) between conditions. There was a small increase of 0.04 m (95% CI 0.03 to 0.06) in step length walking with the cane, compared with walking without the cane. There were no significant changes for speed (MD 0.05 m/s; 95% CI -0.01 to 0.11) or cadence (MD -3 steps/min; 95% CI -8 to 3).

Effect of a cane on speed, step length, and cadence according to walking speed

Table 3 provides the mean (SD) speed, step length, and cadence for both conditions (i.e., walking with and without a cane) separated according to participants' comfortable walking speed (slow, intermediate and fast walkers). The provision of a cane increased speed by 0.06 m/s (95% CI 0.01 to 0.10), step length by 0.04 m (95% CI 0.01 to 0.08), but not cadence, for the slow walkers. The provision of a cane increased speed by 0.18 m/s (95% CI 0.11 to 0.24), step length by 0.07 m (95% CI 0.05 to 0.09), but not cadence, for the intermediate walkers. The provision of a cane reduced speed by 0.09 m/s (95% CI 0.15 to 0.02), and cadence by 14 steps/min (95% CI 20 to 8), but not step length in the fast walkers.

The provision of a cane to the intermediate walkers produced a 0.27 m/s (95% CI 0.18 to 0.36) increase in speed compared with the fast walkers, and a 0.12 m/s (95% CI 0.03 to 0.21) increase compared with the slow walkers. It also produced 0.05 m (95% CI 0.02 to 0.08) increase in step length and 20 steps/min (95% CI 12 to 28) increase in cadence compared with the fast walkers.

DISCUSSION

The results of this study showed that the effect of the provision of a cane on walking after chronic stroke was different depending on participants' comfortable walking speed. Little or no effect on walking was observed when participants with different levels of walking ability were analysed all together. The provision of a cane produced the most benefit in intermediate walkers, smaller benefits in slow walkers and was

detrimental to walking speed and cadence of fast walkers. Furthermore, the benefit to intermediate walkers was significantly greater than that to slow walkers.

In this group of independent ambulatory people with stroke (0.67 m/s), the provision of a cane produced a non-significant increase of 0.05 m/s in speed, a non-significant decrease of 3 steps/min in cadence, and a statistically but not clinically significant increase of 4 cm in step length. In other words, the increased step length was balanced by a small decrease in cadence, resulting in a small increase in speed. Previously, people with stroke walking at 0.6 m/s did not decrease their walking speed when their cane was removed after 10 months of habitual use (Tyson et al., 1999). However, those walking at 0.84 m/s did decrease their walking speed when their cane was removed after 7 years of habitual use (Polese et al., 2012), probably due to loss of confidence (Polese et al., 2012; Polese et al., 2011).

In the current study, participants were divided into slow, intermediate and fast walkerson the basis of Perry's findings (Perry et al., 1995) that people with stroke who walked <0.4 m/s (slow) were largely housebound, those who walked 0.4-0.8 m/s (intermediate) were limited community ambulators and those who walked >0.8 m/s (fast) were unlimited community ambulators. Previous studies (Dean et al., 2014; Dean et al., 2012; Duncan et al., 2011) have found these cutoffs to produce useful categories. The provision of a cane produced most benefit to the intermediate walkers with an increase of 0.18 m/s in walking speed and 7 cm in step length, both of which are clinically meaningful (Tilson et al., 2010; Bohannon et al., 2013). Furthermore, this increase in walking speed was 0.12 m/s greater compared with the slower walkers, and 0.27 m/s compared with the fast walkers, indicating that the benefits were differential according to their comfortable walking speed. According to Kuan et al. (1999), a cane has the potential to increase stability during the single limb support phase, allowing sufficient time for the contralateral limb to swing, which may explain the observed improvements in both step length and speed. The persistent belief that the use of walking canes is detrimental to the quality of walking was not supported by the findings of this study, as the improvements in speed were not obtained at the expense of step length or cadence.

The provision of a cane also provided some benefit to the slow walkers with an increase of 0.06 m/s in walking speed and 4 cm in step length, although these changes are not clinically meaningful. Probably, the provision of a cane also improved stability and confidence for walking in this group of slow walkers, but other impairments, such as pronounced muscle weakness and lack of coordination may compromise their ability to improve walking. On the other hand, the provision of a cane reduced speed and cadence in the group of fast walkers. The provision of a cane to people who are already able to fully ambulate around their community without help may have introduced a confounding factor that reduced walking automaticity. Probably, part of their attentional resources was deviated to the new motor task (i.e., using a cane), thus, compromising walking performance. Similar decreases in speed and cadence have been reported for full community ambulatory post-stroke participants when performing a motor dual-task (Manaf et al., 2014; Yang et al., 2007).

The findings of the present study have certain implications for clinical practice. First, the study reinforces the need to target intervention to those who will most benefit. Given the heterogeneity of stroke, the ‘one size fits all’ approach runs the risk of not implementing worthwhile intervention or implementing it inappropriately (Dean et al., 2014). Second, canes should be prescribed for intermediate walkers with chronic stroke (i.e., after their walking had stabilized) without the fear that their use will negatively interfere with their walking pattern. Third, caution should be taken regarding the prescription of canes for fast walkers, because they have the potential to negatively interfere with walking. Last, canes may be prescribed for slow walkers, but they may have little effect on community ambulation. They may need additional interventions to enhance their community participation, e.g., the provision of electric wheelchairs or scooters may be a more appropriate intervention to maximize their opportunity to engage in activities outside the house (Alzahrani et al., 2011).

On the other hand, this study has some limitations. First, the small sample, in particular in the group of slow walkers reduces the generalizability of the results,

although this study is the largest carried out so far on the use of canes following stroke. Ironically, it was particularly difficult to recruit slow walkers because of difficulties in transporting them to the university laboratory, ie., their lack of community ambulation was restricting their life. Second, the effect of only one type of cane was evaluated in this study. A single-point cane was chosen for investigation because it has been shown to be less detrimental to walking (Buurke et al., 2005; Beauchamp et al., 2009; Allet et al., 2009). Other types of walking devices may have different effects on walking after stroke. Third, only the immediate effects of the provision of a cane after a short period of practice were measured. It would be useful for future studies to investigate the long-term effect of the provision of a cane, and its effect on daily activities that require acceleration, such as crossing streets to catch a bus or running to answer the phone.

In conclusion, this study indicated that the provision of a cane resulted in faster speed and longer step length in community-dwelling people after stroke with slow and intermediate walking speeds. Clinically-significant benefits were only observed in the group of intermediate walkers, and this suggests that slow walkers may need additional and/or other interventions to improve their community ambulation. Increases in speed were not obtained at the expense of step length, suggesting that the provision of the cane was not detrimental to the quality of movement. Therefore, canes can be prescribed to community-dwelling stroke survivors with moderate and severe walking limitations, but caution should be taken regarding their prescription for fast walkers.

REFERENCES

Allet L, Leeman B, Guyen E, Murphy L, Monnin D, Herrmann F, Schnider A (2009. Effect of different walking aids on walking capacity of patients with poststroke hemiparesis. *Arch Phys Med Rehabil.* 90:1408-1413. doi:10.1016/j.apmr.2009.02.010.

Alzahrani M, Dean C, Ada L (2011). Relationship between walking performance and types of community-based activities in people with stroke: an observational study. *Braz J Phys Ther.* 15(1):45-51. doi:10.1590/S1413-35552011005000002.

Bateni H, Maki B (2005). Assistive devices for balance and mobility: benefits, demands, and adverse consequences. *Arch Phys Med Rehabil.* 86:134-145.

Beauchamp MK, Skrela M, Southmayd D, Trick J, van Kessel M, Brunton K, Inness E, McIlroy WE (2009). Immediate effects of cane use on gait symmetry in individuals with subacute stroke. *Physioter Can.* 61:154-160. doi:10.3138/physio.61.3.154.

Bohannon RW, Smith MB (1987). Inter-rater reliability of a Modified Ashworth Scale muscle spasticity. *Phys Ther.* 67:206-207.

Bohannon RW, Andrews AW, Glenney SS (2013). Minimal clinically important difference for comfortable speed as a measure of gait performance in patients undergoing inpatient rehabilitation after stroke. *J Phys Ther Sci.* 25(10):1223-1225. doi:10.1589/jpts.25.1223.

Brucki SMD, Nitrini R, Caramelli P, Bertolucci PHF, Okamoto IH (2003). Suggestions for utilization of the mini-mental state examination in Brazil. *Arq Neuropsiquiatr.* 61:777-781. doi:10.1590/S0004-282X2003000500014.

Buurke JH, Hermens HJ, Erren-Wolters CV, Nene AV (2005). The effect of walking aids on muscle activation patterns during walking in stroke patients. *Gait Posture.* 22:154-170.

Dean CM, Rissel C, Sherrington C, Sharkey M, Cumming RG, Lord SR, Barker RN, Kirkham C, O'Rourke S (2012). Exercise to enhance mobility and prevent falls after stroke: the community stroke club randomized trial. *Neurorehabil Neural Repair.* 26(9):1046-1057. doi:10.1177/1545968312441711.

Dean CM, Ada L, Lindley RI (2014). Treadmill training provides greater benefit to the subgroup of community-dwelling people after stroke who walk faster than 0.4 m/s: a randomised trial. *J Physiother.* 60:97-101. doi:10.1016/j.jphys.2014.03.004.

Duncan PW, Sullivan KJ, Behrman AL, Azen SP, Wu SS, Nadeau SE, Dobkin BH, Rose DK, Tilson JK, Cen S, Hayden SK, LEAPS Investigative Team (2011). Body-weight-supported treadmill rehabilitation after stroke. 364(21):2026-2036. doi:10.1056/NEJMoa1010790.

Jeong Y, Jeong YJ, Kim T, Han SH, Jang SH, Kim YS, Lee KH (2014). A randomized comparison of energy consumption when using different canes, inpatients after stroke. *Clin Rehabil.* [Epub ahead of print].

Kuan T, Tsou J, Su F (1999). Hemiplegic gait of stroke patients: the effect of using a cane. *Arch Phys Med Rehabil.* 80:777-784.

Maguire C, Sieben JM, Frank M, Romkes J (2010). Hip abductor control in walking following stroke – the immediate effect of canes, taping and TheraTogs on gait. *Clin Rehabil.* 24:37-45. doi:10.1177/0269215509342335.

Maki T, Quagliato EMAB, Cacho EVA, Paz LPS, Nascimento NH, Inoue MMEA, Viana MA (2006). Reliability study on the application of the Fugl-Meyer scale in Brazil. *Braz J Phys Ther.* 10:177-183.

Manaf H, Justine M, Ting GH, Latiff LA (2014). Comparison of gait parameters across three attentional loading conditions during timed up and go test in stroke survivors. *Top Stroke Rahabil.* 21(2):128-136. doi:10.1310/tsr2102-128.

Nascimento LR, Oliveira CQ, Ada L, Michaelsen SM, Teixeira-Salmela LF (2015). Walking training with cueing of cadence improves speed and stride length after stroke more than walking training alone: a systematic review. *J Physiother.* 61:10-15 doi:10.1016/j.jphys.2014.11.015.

Nascimento LR, Caetano LC, Freitas DC, Morais TM, Polese JC, Teixeira-Salmela LF (2012). Different instructions during the tem-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. *Braz J Phys Ther.* 16(2):122-127. doi:10.1590/S1413-35552012005000008.

Perry J, Garrett M, Gronley JAK, Mulroy SJ (1995). Classification of walking handicap in the stroke population. *Stroke.* 26:982-989. doi:10.1161/01.STR.26.6.982

Pinheiro MB, Scianni AA, Ada L, Faria CD, Teixeira-Salmela LF (2014). Reference values and psychometric properties of the lower extremity motor coordination test. *Arch Phys Med Rehabil.* 95(8):1490-1497. doi:10.1016/j.apmr.2014.03.006.

Polese JC, Nascimento LR, Faria CDCM, Laurentino G, Rodrigues-de-Paula F, Ada L, Teixeira-Salmela LF (2011). Percepção de hemiplégicos crônicos sobre o uso de dispositivos auxiliares na marcha. *Rev Panam Salud Publica.* 30(3):204-208. doi:10.1590/S1020-49892011000900003.

Polese JC, Teixeira-Salmela LF, Nascimento LR, Faria CDCM, Kirkwood RN, Laurentino GC, Ada L (2012). The effects of walking sticks on gait kinematics and kinetics with chronic stroke survivors. *Clin Biomech.* 27:131-137. doi:10.1016/j.clinbiomech.2011.08.003.

Robinson CA, Shumway-Cook A, Matsuda PN, Ciol MA (2011). Understanding physical factors associated with participation in community ambulation following stroke. *Disabl Rehabil*. 33(12):1033-42. doi:10.3109/09638288.2010.520803.

Schmid A, Duncan PW, Studenski S, Lai SM, Richards L, Perera S, Wu SS (2007). Improvements in speed-based gait classifications are meaningful. *Stroke.* 38(7):2096-2100. doi:10.1161/STROKEAHA.106.475921

Sun X, Briel M, Walter SD, Guyatt GH (2010). Is a subgroup effect believable? Updating criteria to evaluate the credibility of subgroup analyses. *BMJ*. 340:850-854. doi:10.1136/bmj.c117.

Thaut MH, Leins AK, Rice RR, Argstatter H, Kenyon GP, McIntosh GC, Bolay HV, Fetter M (2007). Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial. *Neurorehabil Neural Repair.* 21:455-9. doi:10.1177/1545968307300523

Tilson JK, Sullivan KJ, Cen SY, Rose DK, Karadia CH, Azen SP, Duncan PW (2010). Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically important difference. *Phys Ther.* 90(2):196-208. doi:10.2522/ptj.20090079.

Tyson S (1999). Trunk kinematics in hemiplegic gait and effect of walking aids. *Clin Rehabil.* 13: 295-300. doi:10.1191/026921599666307333

Yang YR, Chen YC, Lee CS, Cheng SJ, Wang RY (2007). Dual-task-related gait changes in individuals with stroke. *Gait Posture.* 25(2):185-190. doi:10.1016/j.gaitpost.2006.03.007.

Table 1. Characteristics of participants.

Characteristic	All (n = 24)	Slow (n = 6)	Intermediate (n = 9)	Fast (n = 9)
Age *(yr)*, mean (SD)	61 (12)	70 (9)	66 (8)	51 (8)
Gender, number male (%)	13 (54)	4 (77)	6 (67)	3 (33)
Side of weakness, number right side (%)	13 (54)	2 (33)	3 (33)	8 (89)
Time since stroke *(yr)*, mean (SD)	6 (5)	5 (4)	7 (6)	6 (6)
Cognition *(MMSE, 0-30)*, mean (SD)	27 (3)	24 (3)	25 (2)	24 (3)
Dexterity – paretic *(LEMOCOT taps/s)*, mean (SD)	0.6 (0.6)	0.1 (0.1)	0.6 (0.3)	1.0 (0.8)
Dexterity – non-paretic *(LEMOCOT, taps/s)*, mean (SD)	1.3 (0.5)	1.1 (0.5)	1.2 (0.3)	1.5 (0.6)
Muscle tone (*Modified Ashworth Scale, 0-4*), n (%)				
0	6 (25)	0 (0)	3 (33)	3 (33)
1	6 (25)	1 (17)	4 (44)	1 (11)
1+	6 (25)	1 (17)	1 (11)	4 (44)
2	4 (17)	2 (33)	1 (11)	1 (11)
3	1(4)	1 (17)	0 (0)	0 (0)
4	1(4)	1 (17)	0 (0)	0 (0)
Motor recovery *(Fugl-Meyer LL, 0-34)*, mean (SD)	25 (7)	17 (6)	27 (4)	28 (5)
Comfortable walking speed (10MWT, m/s), mean (SD)	0.67 (0.35)	0.19 (0.06)	0.64 (0.11)	1.01 (0.15)
Fast walking speed (10MWT, m/s), mean (SD)	0.88 (0.52)	0.19 (0.06)	0.86 (0.16)	1.38 (0.33)

MMSE = Mini-mental state examination; LL = lower limb; LEMOCOT = Lower extremity motor coordination test

Table 2. Mean (SD) of both conditions for all participants (n=24) and mean difference (95 % CI) between conditions.

Outcome	Conditions		Difference between conditions
	With cane	Without cane	With minus without cane
Speed *(m/s)*	0.70 (0.30)	0.65 (0.30)	0.05 (-0.01 to 0.11)
Step length *(m)*	0.44 (0.17)	0.40 (0.17)	0.04 (0.03 to 0.06)
Cadence *(steps/min)*	89 (24)	92 (25)	-3 (-8 to 3)

Table 3. Mean (SD) of both conditions by walking speed, mean difference (95% CI) between conditions within groups, and mean difference (95% CI) between conditions between groups.

Outcome	Groups						Difference between conditions within groups			Difference between conditions between groups	
	Slow *< 0.4 m/s*		Intermediate 0.4-0.8 m/s		Fast > 0.8 m/s		*Slow*	Intermediate	Fast	Intermediate minus slow	Intermediate minus fast
	With cane (n = 6)	Without cane (n = 6)	With cane (n = 9)	Without cane (n = 9)	With cane (n = 9)	Without cane (n = 9)	With minus without cane	With minus without cane	With minus without cane	With minus without cane	With minus without cane
Speed *(m/s)*	0.22 (0.08)	0.16 (0.07)	0.82 (0.15)	0.65 (0.14)	0.90 (0.11)	0.99 (0.13)	0.06 (0.01 to 0.10)	0.18 (0.11 to 0.24)	-0.09 (-0.15 to -0.02)	0.12 (0.03 to 0.21)	0.27 (0.18 to 0.36)
Step length *(m)*	0.21 (0.07)	0.17 (0.05)	0.46 (0.11)	0.40 (0.10)	0.58 (0.07)	0.57 (0.07)	0.04 (0.01 to 0.08)	0.07 (0.05 to 0.09)	0.01 (-0.01 to 0.04)	0.03 (0.0 to 0.06)	0.05 (0.02 to 0.08)
Cadence *(steps/min)*	60 (6)	58 (14)	106 (25)	100 (21)	92 (9)	106 (10)	2 (-11 to 13)	6 (-1 to 13)	-14 (-20 to -8)	4 (-7 to 15)	20 (12 to 28)

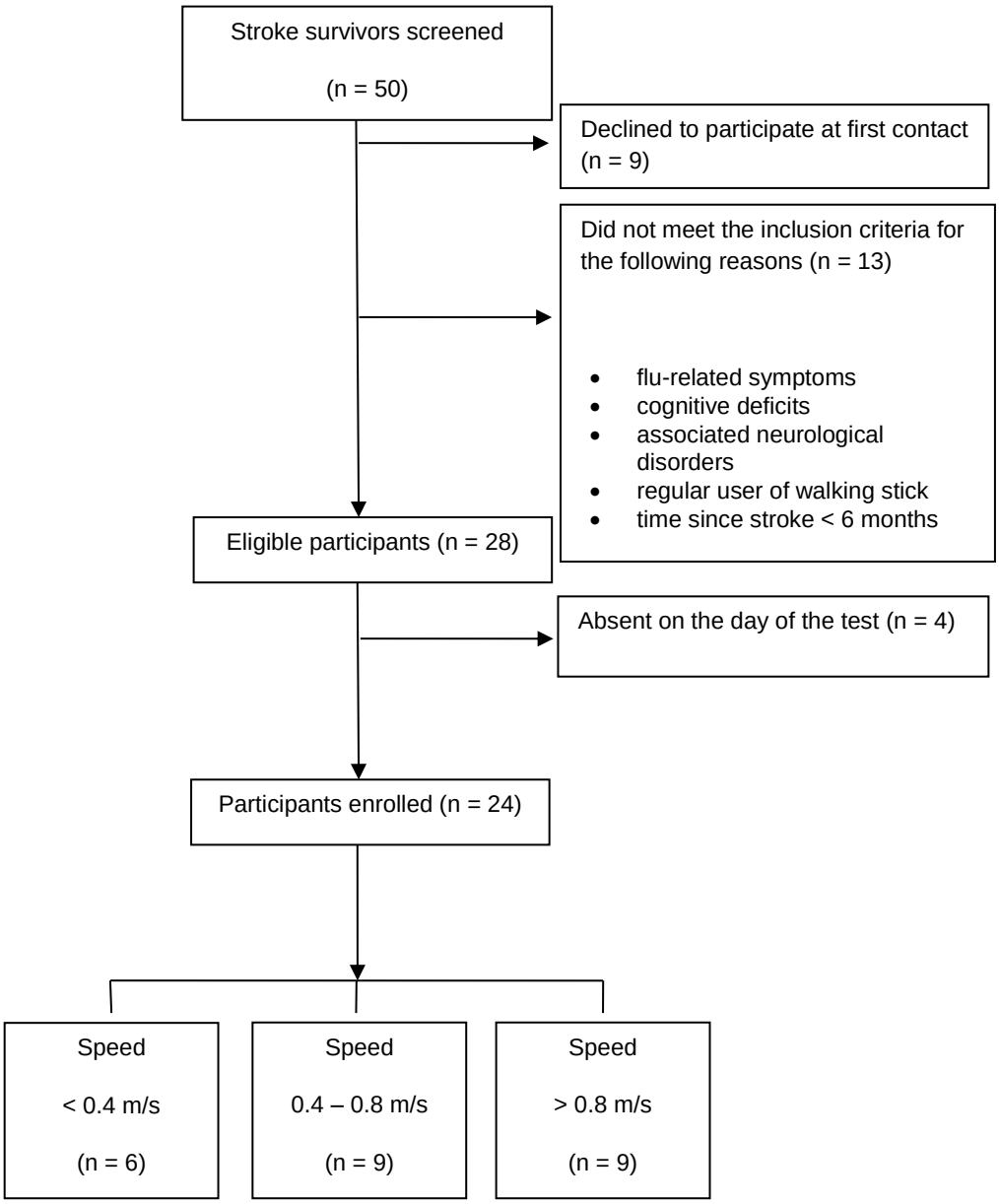


Figure 1. Flow of participant recruitment into the study.

7 CONSIDERAÇÕES FINAIS

FINAL CONSIDERATIONS

7 CONSIDERAÇÕES FINAIS

O presente trabalho foi estruturado de modo a realizar contribuições clínicas à prática do profissional de reabilitação, visando melhorar incapacidades de indivíduos com AVE, relacionadas a deficiências em força muscular e a limitações em marcha. As principais contribuições clínicas serão descritas nos parágrafos sequentes de modo a sumarizar os achados da presente tese e fornecer informações sobre efeitos de intervenção em linguagem objetiva e não-técnica.

Os resultados do presente trabalho indicaram que o uso de eletroestimulação cíclica em indivíduos pós-AVE, considerados fracos ou muito fracos, é capaz de promover aumento moderado de força muscular e, consequente, melhora na capacidade e/ou desempenho de atividades. Sessões diárias de 45 minutos de eletroestimulação cíclica, durante um período de seis semanas, com elevado número de contrações musculares máximas são recomendadas para indivíduos na fase aguda ou crônica do AVE para promover aumento de força muscular. A intervenção pode ser uma boa alternativa para ganhos de força muscular em pacientes com deficiências cognitivas ou fraqueza acentuada, quando se torna difícil a realização independente de exercícios de resistência. Os resultados indicaram que os efeitos de intervenção são mantidos além do período de intervenção.

Os resultados do presente trabalho indicaram, ainda, que duas diferentes estratégias de intervenção podem ser adicionadas ao treino de marcha usual para potencializar os efeitos de intervenção: treino de marcha associado ao uso de pistas auditivas e treino de marcha associado ao uso de realidade virtual. Adição de 30 minutos de pistas auditivas determinando cadência ao treino de marcha, quatro vezes por semana, durante quatro semanas é recomendada para melhorar velocidade de marcha, comprimento do passo, cadência e simetria de indivíduos com AVE. Trata-se de uma estratégia simples e de fácil aplicação, que pode ser aplicada em diferentes ambientes (i.e., clínico, hospitalar ou comunitário) e não requer supervisão constante de um profissional para questões relacionadas à segurança. Novos

estudos devem ser realizados para verificar se os efeitos de intervenção são mantidos além do período de intervenção.

Treino de marcha associado ao uso de realidade virtual, embora não tenha as mesmas facilidades de implementação comparadas ao uso de pistas auditivas, também se mostrou eficaz para aumentar a velocidade de marcha de indivíduos pós-AVE. Adição de elementos de realidade virtual ao treino de marcha, por 40 minutos, três vezes por semana, durante quatro semanas é recomendada para melhorar velocidade de marcha pós-AVE. A recomendação é baseada no agrupamento de estudos que incluíram diferentes tipos de realidade virtual existentes, e uma análise de subgrupos considerando a especificidade de cada tipo não foi possível devido ao baixo número de ensaios clínicos. Dessa forma, estudos explorando os diferentes tipos de realidade virtual são encorajados, principalmente para avaliar a eficácia de dispositivos comercialmente disponíveis para uso na prática clínica.

O presente trabalho avaliou, ainda, o efeito da provisão de uma bengala simples com pega ergonômica na marcha de indivíduos pós-AVE da comunidade, separados em grupos de acordo com a velocidade de deambulação confortável: indivíduos lentos (velocidade <0.4 m/s), indivíduos intermediários (velocidade entre 0.4 e 0.8 m/s) e indivíduos rápidos (velocidade >0.8 m/s). Os resultados sugeriram que bengalas não devem ser prescritas a indivíduos rápidos, mas podem ser prescritas a indivíduos lentos e intermediários, sem que haja prejuízo na qualidade do movimento. Benefícios clinicamente importantes com o uso da bengala foram obtidos pelos indivíduos com velocidade intermediária em relação à velocidade de marcha e comprimento do passo. Outras estratégias de intervenção tais como prescrição de *scooters* ou cadeiras elétricas podem ser mais indicadas para melhorar a participação social dos indivíduos lentos, mas carecem de maiores investigações.

Dessa forma, o presente trabalho, estruturado de acordo com o raciocínio teórico da Classificação Internacional de Funcionalidade e Saúde, contribuiu com achados

clínicos para linha de pesquisa de Estudos em Reabilitação Neurológica do Adulto do Programa de Pós-Graduação em Ciências da Reabilitação, apresentado evidências clínicas de efeitos de intervenções destinadas à melhora de força muscular e da marcha de indivíduos com incapacidades decorrentes de AVE.

REFERÊNCIAS

REFERENCE LIST

REFERÊNCIAS

ADA, L.; VATTANASILP. W.; O'DWYER, N. Does spasticity contribute to walking dysfunction following stroke? **Journal of Neurology, Neurosurgery and Psychiatry**., v. 64, p. 628-635. 1998.

ADA, L.; DORSCH, S.; CANNING, C.G. Strengthening interventions increase strength and improve activity after stroke: a systematic review. **Aust J Physiother**., v. 52, n. 4, p. 241-248. 2006.

ADA, L.; DEAN, C.M.; VARGAS, J.; ENNIS, S. Mechanically assisted walking with body weigth support results in more independent walking than assisted overground walking in non-ambulatory patients early after stroke: a systematic review. **J Physiother**., v. 56, n. 3, p.153-161. 2010.

AAN (American Academy of Neurology). **Clinical Practice Guideline Process Manual 2011**. Ed. St. Paul, MN: The American Academy of Neurology. 2011.

ALLET, L.; LEEMAN, B.; GUYEN, E.; MURPHY, L.; MONNIN, D.; HERRMANN, F.; SCHNIDER, A. Effect of different walking aids on walking capacity of patients with poststroke hemiparesis. **Arch Phys Med Rehabil**., v. 90, p.1408-1413. 2009.

ALZAHRANI, M.; DEAN, C.; ADA, L. Relationship between walking performance and types of community-based activities in people with stroke: an observational study. **Braz J Phys Ther**, v. 15, n. 1, p. 45-51. 2011.

BAX, L.; YU, L.M.; IKEDA, N.; TSURUTA, H., MOONS, K.G. Development and validation of MIX: compheensive free software for meta-analysis of causal research data. **BMC Med Res Methodol**., v. 13, p. 50. 2006.

BAX, L.; IKEDA, N.; FUKUI, N.; YAJU, Y.; TSURUTA, H.; MOONS, K.G. More than numbers: the power of graphs in meta-analysis. **Am J Epidemiol**., v. 169, n. 2, p. 249-255. 2009.

BEAUCHAMP, M.K.; SKRELA, M.; SOUTHMAYD, D.; TRICK, J.; van KESSEL, M.; BRUNTON, K.; INNESS, E.; MCILROY, W.E. Immediate effects of cane use on gait symmetry in individuals with subacute stroke. **Physioter Can**., v. 61, p. 154-160. 2009.

BOHANNON, R.W.; SMITH, M.B. Inter-rater reliability of a Modified Ashworth scale muscle spasticity. **Phys Ther**., v. 67, p. 206-207. 1987.

BUURKE, J.H.; HERMENS, H.J.; ERREN-WOLTERS, C.V.; NENE, A.V. The effect of walking aids on muscle activation patterns during walking in stroke patients. **Gait Posture**., v. 22, p. 154-170. 2005.

CANNING, C.G.; ADA, L.; ADAMS, R.; O'DWYER, N.J. Loss of strength contributes more to physical disability after stroke than loss of dexterity. **Clin Rahabil**., v. 18, n. 3, p. 300-308. 2004.

CARR, J.H; SHEPHERD, R.B. The changing face of neurological rehabilitation. **Braz J Phys Ther**, v. 10, n. 2, p. 147-156. 2006.

de KROON, J.R.; van der LEE, J.H.; IJZERMAN, M.J.; LANKHORST, G.J. Therapeutic electrical stimulation to improve motor control and functional abilities of the upper extremity after stroke: a systematic review. **Phys Ther**., v. 16, n. 4, p. 350-360. 2002.

DEAN, C.M.; RISSEL, C.; SHERRINGTON, C.; SHARKEY, M.; CUMMING, R.G.; LORD, S.R.; BARKER, R.N.; KIRKHAM, C.; O'ROURKE, S. Exercise to enhance mobility and prevent falls after stroke: the community stroke club randomized trial. **Neurorehabil Neural Repair**., v. 26, n. 9, p. 1046-1057. 2012.

DEAN, C.M.; ADA, L.; LINDLEY, R.I. Treadmill training provides greater benefit to the subgroup of community-dwelling people after stroke who walk faster than 0.4 m/s: a randomised trial. **J Physiother**., v. 60, p. 97-101. 2014.

DORSCH, S.; ADA, L.; CANNING, C.G.; ALZHARANI, M.; DEAN, C. The strength of the ankle dorsiflexors has a significant contribution to walking speed in people who can walk independently after stroke: an observational study. **Arch Phys Med Rehabil**., v. 93, n. 6, p. 1072-1076. 2012.

ENG, J.J.; TANG, P.F. Gait training strategies to optimize walking ability in people with stroke: a synthesis of the evidence. **Expert Rev Neurother**., v. 7, n. 10, p. 1417-1436. 2007.

FARIA-FORTINI, I.; MICHAELSEN, S.M.; CASSIANO, J.G.; TEIXEIRA-SALMELA, L.F. Upper extremity function in stroke subjects: relationships between the international classification of functioning, disability, and health domains. **J Hand Therap**., v. 24, n. 3, p. 257-264. 2011.

FRENCH, B.; THOMAS, L.H.; LEATHLEY, M.J.; SUTTON, C.J.; MCADAM, J.; FORSTER, A.; LANGHORNE, P.; PRICE, C.I;. WALKER, A.; WATKINS, C.L. Repetitive task training for improving functional ability after stroke. **Cochrane Database Syst Rev**., v 17., n. 4, CD006073. 2007.

FRENCH, B.; THOMAS, L.H.; LEATHLEY, M.J.; SUTTON, C.J.; MCADAM, J.; FORSTER, A.; LANGHORNE, P.; PRICE, C.I;. WALKER, A.; WATKINS, C.L. Does repetitive task training improve functional activity after stroke? A Cochrane systematic review and meta-analysis. **J Rehabil Med**., v. 42, n. 1, p. 9-14. 2010.

GLINSKY, J.; HARVEY, L.; VAN ES, P. Efficacy of electrical stimulation to increase muscle strength in people with neurological conditions: a systematic review. **Physiother Res Int**., v. 12, p. 3, p. 175-194. 2007.

HARRIS, J.E.; ENG, J.J. Paretic upper-limb strength best explains arm activity in people with stroke. **Phys Ther**., v. 87, n. 1, p. 88-97. 2007.

HARRIS, J.E.; ENG, J.J. Strength training improves upper-limb function in individuals with stroke: a meta-analysis. **Stroke**., v. 41, n. 1, p. 136-140. 2010.

HERBERT, R.; JAMTVEDT, G.; MEAD, J.; HAGEN, K. **Practical evidence-based physiotherapy**. Edinburgh; New York: Butterwoth-Heinemann. 2005.

HIGGINS, J.; GREEN S. **Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0**. The Cochrane Collaboration. 2011.

HOLLMAN, J.; MCDADE, E.; PETERSEN, R. Normative spatiotemporal gait parameters in older adults. **Gait Posture**., v. 34, n. 1, p. 111-118. 2011.

HSU, A.L.; TANG, P.F.; JAN, M.H. Analysis of impairments influencing gait velocity and asymmetry of hemiplegic patients after mild to moderate stroke. **Arch Phys Med Rehabil**., v. 84, v. 8, p. 1185-1193. 2003.

JEONG, Y.; JEONG, Y.J.; KIM, T.; HAN, S.H.; JANG, S.H.; KIM, Y.S.; LEE, K.H. A randomized comparison of energy consumption when using different canes, inpatients after stroke. **Clin Rehabil**., [epub ahead of print]. 2014.

KAISER, E. Aspectos epidemiológicos nas doenças coronariana e cerebrovascular. **SOCERJ**, v. 17, n. 1, p. 11-18. 2004.

KOCAK, F.; UNVER, B.; KARATOSUN, V. Level of evidence in four selected rehabilitation journals. **Arch Phys Med Rehabil**., v. 92, p. 299-303. 2011.

KUAN, T.; TSOU, J.; SU, F. Hemiplegic gaito f stroke patients: the effect of using a cane. **Arch Phys Med Rehabil**., v. 80, p. 777-784. 1999.

LANDAU, W.M. Spasticity: the fable of a neurological demon and the emperor's new therapy (editorial). **Arch Neurology**., v. 31, p. 217-219. 1974.

LANGHORNE, P.; COUPAR, F.; POLLOCK, A. Motor recovery after stroke: a systematic review. **Lancet Neurol**., v. 8, n. 8, p. 741-754. 2009.

LEBRASSEUR, N.K.; SAYERS, S.P.; OUELLETTE, M.M.; FIELDING R.A. Muscle impairments and behavioral factors mediate functional limitations and disability following stroke. **Phys Ther**, v. 86, n. 10, p. 1342-1350. 2006.

LEUNG, J.; MOSELEY, A.M. The impact of ankle-foot orthosis on walking gait and muscle activity in adult hemiplegia. **Physiotherapy**., v. 89, p. 29-55. 2003.

LESSA, I. Epidemiologia das doenças cerebrovasculares no Brasil. **Rev Soc Cardiol**, v. 9, n. 4, p. 509-517. 1999.

LIMA, R.M.; MICHAELSEN, S.M.; NASCIMENTO, L.R.; POLESE, J.C.; PEREIRA, N.D.; TEIXEIRA-SALMELA, L.F. Addition of trunk restraint to home-based modified constraint-induced therapy does not bring additional benefits in chronic stroke individuals with mild and moderate upper limb impairments: A pilot randomized controlled trial. **NeuroRehabilitation**., v. 35, p. 391-404. 2014.

MAGUIRE, C.; SIEBEN, J.M.; FRANK, M.; ROMKES, J. Hip abductor control in walking following stroke – the immediate effect of canes, taping, and TheraTogs on gait. **Clin Rehabil**., v. 24, p. 37-45. 2010.

MAKI, T.; QUAGLIATO, E.; CACHO, E.; PAZ, L.; NASCIMENTO, N.; INOUE, M.; VIANA, M. Reliability study on the application of the Fugl-Meyer scale in Brazil. **Braz J Phys Ther**., v. 10, p. 177-183. 2006.

MEHRHOLZ, J.; ELSNER, B.; WERNER, C.; KUGLER, J.; POHL, M. Electromechanical-assisted training for walking after stroke. **Cochrane Database Syst Rev**., v. 25, n. 7, CD006185. 2007.

MEHRHOLZ, J.; POHL, M.; ELSNER, B. Treadmill training and body weight support for walking after stroke. **Cochrane Database Syst Rev**., v. 19, n. 4, CD002840. 2014.

MOSELEY, A.M.; STARK, A.; CAMERON, I.D.; POLLOCK, A. Treadmill training and body weight support for walking after stroke. **Cochrane Database Syst Rev**., v. 19, n. 4, CD002840. 2005.

MICHALEFF, Z.A.; COSTA, L.O.; MOSELEY, A.M.; MAHER, C.G.; ELKINS, M.R.; HERBERT, R.D.; SHERRINGTON, C. CENTRAL, PEDro, PubMed, and EMBASE are the most comprehensive databases indexing randomized controlled trials of physical therapy interventions. **Phys Ther**., v. 91, n. 2, p. 190-197. 2011.

NAKAYAMA, H.; JORGENSEN, H.S.; RAASCHOU, H.O.; OLSEN, T.S. Compensation in recovery of upper extremity function after stroke: the Copenhagen Stroke Study. **Arch Phys Med Rehabil**, v. 75, n. 8, p. 852-857. 1994.

NASCIMENTO, L.R.; CAETANO, L.C.; FREITAS, D.C.; MORAIS, T.M.; POLESE, J.C.; TEIXEIRA-SALMELA, L.F. Different instructions during the tem-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. **Braz J Phys Ther**., v. 16, n. 2, p. 122-127. 2012.

NASCIMENTO, L.R.; RESENDE, R.A.; CARVALHO, A.C.; FONSECA, S.T.; TEIXEIRA-SALMELA, L.F. Marcha humana: teorias, contribuições musculares e implicações clínicas. **Ter Man**., v. 10, n. 50, p. 148-154. 2012.

NASCIMENTO, L.R.; TEIXEIRA-SALMELA, L.F.; POLESE, J.C.; ADA, L.; FARIA, C.D.C.M.; LAURENTINO, G. Strength deficits of the shoulder complex during isokinetic testing in people with chronic stroke. **Braz J Phys Ther**., v. 18, n. 3, p. 268-275. 2014.

NASCIMENTO, L.R.; OLIVEIRA, C.Q.; ADA, L.; MICHAELSEN, S.M.; TEIXEIRA-SALMELA, L.F. Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review. **J Physioter**, v. 61, n. 1, p. 10-15. 2015

NATIONAL STROKE FOUNDATION. **Clinical Guidelines for Stroke Management 2010.** Melbourne: Australia. 2010.

NORRVING, B.; KISSELA B. The global burden of stroke and need for a continuum of care. **Neurology**, v. 80, n. 3 (Supl.), p. S5-S12. 2011.

O'DWYER NJ..; ADA L. Reflex hyperexcitability and muscle contracture in relation to spastic hypertonia. **Current Opinion in Neurology**, v. 9, p. 451-455. 1996.

O'DWYER NJ..; ADA L.; NEILSON, P.D. Spasticity and muscle contracture following stroke. **Brain**, v. 119, p. 1737-1749. 1996.

OMS – ORGANIZAÇÃO MUNDIAL DE SAÚDE. **CIF: Classificação Internacional de Funcionalidade, Incapacidade e Saúde.** São Paulo: EDUSP. 325p. 2003.

PADULA, R.; PIRES, R.; ALOUCHE, S.; CHIAVEGATO, L.; LOPES, A.; COSTA, L. Analysis of reporting of systematic reviews in physical therapy published in Portuguese. **Braz J Phys Ther**., v. 16, n. 4, p. 281-289. 2012.

PAK, S.; PATTEN, C. Strengthening to promote functional recovery poststroke: an evidence-based review. **Top Stroke Rehabil**., v.15, n.3, p.177-199. 2008.

PERRY, J.; GARRETT, M.; GRONLEY, J.K.; MULROY, S.J. Classification of walking handcap in the stroke population. **Stroke**., v. 26, n. 6, p. 982-989. 1995.

PINHEIRO, M.B.; SCIANNI, A.A.; ADA, L.; FARIA, C.D.; TEIXEIRA-SALMELA, L.F. Reference values and psychometric properties of the lower extremity motor coordination test. **Arch Phys Med Rehabil**., v. 95, n. 8, p. 1490-1497. 2014.

POLESE, J.C.; TEIXEIRA-SALMELA, L.F.; NASCIMENTO, L.R.; FARIA, C.D.; KIRKWOOD, R.N.; LAURENTINO, G.C.; ADA, L. The effects of walking sticks on gait kinematics and kinetics with chronic stroke survivors. **Clin Biomech**., v. 27, n. 2, p. 131-137. 2012.

POLESE, J.C.; ADA, L.; DEAN, C.M.; NASCIMENTO, L.R.; TEIXEIRA-SALMELA, L.F. Treadmill training is effective for ambulatory adults with stroke: a systematic review. **J Physiother**., v. 59, n. 2, p. 73-80. 2013.

REFSHAUGE, K.; ADA, L.; ELLIS, E. **Science-based rehabilitation: theories into practice.** Edinburgh; New York: Butterwoth-Heinemann. 2005.

ROBINSON, C.A.; SHUMWAY-COOK, A.; MATSUDA, P.N.; CIOL, M.A. Understanding physical factors associated with participation in community ambulation following stroke. **Disabil Rehabil**., v. 33, n. 12, p. 1033-1042. 2007.

ROYAL COLLEGE OF PHYSICIANS. **National clinical guidelines for stroke**. 2.ed. London: Intercollegiate Stroke Working. 2004.

SCIANNI, A.; TEIXEIRA-SALMELA, L.F.; ADA, L. Challenges in recruitment, attendance and adherence of acute survivors to a randomized trial in Brazil: a feasibility study. **Braz J Phys Ther.**, v. 16, n. 1, p. 40-45. 2012.

SALBACH, N.M.; JAGLAL, S.B.; KORNER-BITENSKY, N.; RAPPOLT, S.; DAVIS, D. Practioner and organizational barriers to evidence-based practice of physical therapists for people with stroke. **Phys Ther**., v. 87, n. 10, p. 1284-1303. 2007.

SALBACH, N.M.; VEINOT, P.; JAGLAL, S.B.; BAYLEY, M.; ROLFE, D. From continuing education to personal digital assistants: what do physical therapists need to support evidence-based practice in stroke management? **J Eval Clin Pract**., v. 17, n. 4, p. 786-793. 2011.

SAMPAIO, R.F.; MANCINI, M.C. Estudos de revisão sistemática: um guia para síntese criteriosa da evidência científica. **Braz J Phys Ther**., v. 11, n. 1, p. 83-89. 2007.

SARAGIOTTO, B.T.; COSTA, L.C.; OLIVEIRA, R.F.; LOPES, A.D.; MOSELEY, A.M.; COSTA, L.O. Description of research design of articles published in four Brazilian physical therapy journals. **Braz J Phys Ther**., v. 18, n. 1, p. 56-62. 2014.

SILVA, T.M.; COSTA, L.; GARCIA, A.; COSTA, L.O.P. What do physical therapists think about evidence-based practice? A systematic review. **Manual Therapy**., 2014. doi: 10.1016/j.math.2014.10.009.

SOMMERFELD, D.; SVENSSON, A.K.; HOLMQVIST, L.; VONARBIN, M. Spasticity after stroke: its occurrence and association with motor impairments and activity limitations. **Stroke**., v. 35, p. 134-140. 2004.

STANTON, R.; ADA, L.; DEAN, C.M.; PRESTON, E. Biofeedback improves activities of the lower limb after stroke: a systematic review. **J Physiother**., v. 57, n. 3, p. 145-155. 2011.

SUN, X.; BRIEL, M.; WALTER, S.D.; GUYATT, G.H. Is a subgroup effect believable? Updating criteria to evaluate the credibility of subgroup analyses. **BMJ**., v. 340, p. 850-854. 2010.

SVESTKOVA, O. International classification of funtioning, disability and health of World Health Organization (ICF). **Prague Med Rep**, v. 109, n. 4, p. 268-274. 2008.

TYSON, S. Trunk kinematics in hemiplegic gait and effect of walking aids. **Clin Rehabil**., v. 13, p. 295-300. 1999.

TYSON, S.F.; KENT, R.M. Effects of an ankle-foot orthosis on balance and walking after stroke: a systematic review and pooled meta-analysis. **Arch Phys Med Rehabil**., v. 94, n. 7, p. 1377-1385. 2013.

TYSON, S.F.; SADEGHI-DEMNEH, E.; NESTER, C.J. A systematic review and meta-analysis of the effect of an ankle-foot orthosis on gait biomechanics after stroke. **Clin Rehabil**., v. 27, n. 10, p. 879-891. 2013.

THAUT, M.H.; LEINS, A.K.; RICE, R.R.; ARGSTATTER, H.; KENYON, G.P.; MCINTOSH, G.C.; BOLAY, H.V.; FETTER, M. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial. **Neurorehabil Neural Repair**., v. 21, p. 455-459. 2007.

THAUT, M.H.; MCINTOSH, G.C.; RICE, R.R. Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. **J Neurol Sci**., v. 151, n. 2, p. 207-212. 1997.

UEMURA, K.; PISA, Z. Trends in cardiovascular disease mortality in industrialized countries since 1950. **World Health Stat Q**, v. 41, n. 3-4, p. 155-178. 1988.

van PEPPEN, R.P.; KWAKKEL, G.; WOOD-DAUPHINEE, S.; HENDRIKS, H.J.; van der WEES, P.J.; DEKKER, J. The impact of physical therapy on functional outcomes after stroke: what's the evidence? **Clin Rehabil**., v. 18, n. 8, p. 833-862. 2004.

VEERBEEK J.M.; van WEGEN, E.; van PEPPEN, R.; van der WEES P.J.; HENDRIKS, E.; RIETBERG, M. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis. **PLoS ONE**., v. 9, n. 2, p. e87987. 2014.

WOODFORD, H.; PRICE., C. EMG biofeedback for the recovery of motor function after stroke. **Cochrane Database Syst Rev**., v. 18, n. 2, CD004585. 2007.

ANEXO A

THE UNIVERSITY OF SYDNEY

Student Cotutelle Agreement

This Agreement **is made on 1 August 2012**

Between

Universidade Federal de Minas Gerais (UFMG)
located on 6627 Avenida Antônio Carlos, Belo Horizonte, Minas Gerais, Brazil, CNPJ number 17.217.985/0001-04, hereby represented by the Dean Professor Clélio Campolina Diniz,

and

The University of Sydney, Australia
located on The University of Sydney NSW 2006 – Australia ABN 15 211 513 464, CRICOS Provider 00026A, represented by Dean Professor Bruce Robson

and

Lucas Rodrigues Nascimento, Contria, 1500, ap 1203B, Grajau. 30430460, Belo Horizonte, Minas Gerais, Brazil (**'the Student'**)

('the Parties')

Background

A. The University of Sydney and UFMG have entered into a Principal Cotutelle Agreement, dated August 2012.

B. The Sydney Medical School and the Faculty of Health Sciences at the University of Sydney and the Post-Graduate Program in Rehabilitation Science of the Physical Therapy Department, Physical Education, Physiotherapy and Occupational Therapy School at Federal University of Minas Gerais, UFMG share a developing commitment to cooperative research collaboration.

C. Lucas Rodrigues Nascimento, male, was born on 15th December, 1983 in Joao Monlevade – Minas Gerais – Brazil; 11028341, CPF 061.455.386-51 and passport number FG 137244, desires to undertake a doctoral degree jointly offered and awarded by the University of Sydney and UFMG

D. The Parties have agreed to enter into a cotutelle arrangement for Lucas Rodrigues Nascimento on the terms set out in this Agreement.

Agreed Terms

1. Definitions and Interpretation

1.1 Definitions

In this Agreement:

Academic Year:

(a) at the University of Sydney means from August 2012 to July 2013; and

(b) at the UFMG means from March 2011 to July 2012 and August 2013 to March 2015.

Intellectual Property means all registered and unregistered rights, titles and interests in relation to present and future copyright, trade marks, designs, know-how, patents, confidential information and all other intellectual property as defined in article 2 of the Convention establishing the World Intellectual Property Organisation 1967;

Jointly Awarded Degree means Doctor of Philosophy PhD by the University of Sydney and by UFMG Doctor in Rehabilitation Sciences, area Human Functional Development.
Supervisor means an appropriately qualified employee of the University of Sydney or the UFMG who is jointly responsible for supervising the conduct and progress of the Student's candidature, including by means of instruction, advice and mentoring.

2. Term of Agreement

2.1 This Agreement is effective from 1 August 2012 and ends on the date of the Student's graduation, unless it is terminated at an earlier time in accordance with **clause 2.2**.

2.2 This Agreement may be terminated at any time by any of the Parties giving written notice to the other Parties of the suspension or termination of the Student's candidature.

3. Administration

3.1 The Student will offer himself for the Jointly Awarded Degree on the basis of research undertaken in the area of Physical Therapy: *Muscular factors – strength and patterns of muscular activation related to knee hyperextension of individuals with hemiparesis.*

3.2 The Student's candidature will be divided between the University of Sydney and the UFMG, with a minimum of 30% of the candidature to be undertaken at each institution.

3.3 The Student will be based and spend the their time in attendance at the University of Sydney and the UFMG as follows:

(a) Academic Year March 2011 to July 2012: UFMG;

(b) Academic Year August 2012 to July 2013: The University of Sydney; and

(c) Academic Year August 2013 to March 2015: UFMG.

(d) Educational activities of PhD student at the Federal University of Minas Gerais: Attend the compulsory units of study of the Post-Graduate Program in Rehabilitation Sciences, present at Qualifying Examination; present and discuss data with the local supervisor (Dr Luci Fuscaldi Teixeira-Salmela); participate in national and international scientific meetings; prepare an submit scientific article on the topic of the thesis; collect data for the research project, and write the thesis.

(e) Educational activities of PhD student at the University of Sydney: present and discuss data with the local supervisor (Dr Louise Ada); participate in national and international scientific meetings; prepare and submit scientific article the topic of the thesis; refine the research project, and collect data for the research project.

3.4 Unless otherwise agreed by the Parties in writing (noting the potential impact on the Student's insurance coverage), the Student will simultaneously enrol at the University of Sydney and the UFMG for each year of the candidature.

3.5 The Student will be entitled to the same rights and privileges (including library services and student support services) at the University of Sydney and the UFMG as other enrolled students.

3.6 UFMG will be responsible for administering the Student's candidature.

3.7 To the extent of any inconsistency between the rules and regulations of the University of Sydney and the UFMG the rules and regulations of the UFMG will apply to the Student's candidature.

4. Supervision

4.1 The PhD student develops her thesis under the joint responsibility of a supervisor in Australia and a supervisor in Brazil having both supervisors previously established collaboration.

4.2 The University of Sydney and the UFMG will each appoint a Supervisor.

4.3 The University of Sydney and the UFMG may change or substitute a Supervisor at any time.

4.4 At the date of this Agreement, the Supervisors are:

(a) The University of Sydney: Associate Professor Louise Ada and

(b) UFMG : Professor Dr Luci Fuscaldi Teixeira-Salmela.

4.5 Both supervisors are committed to full exert the tutor function with the PhD student. They jointly exercise the power granted in Australia and Brazil as thesis supervisors.

5. Thesis and Examination

5.1 The University of Sydney and UFMG will be responsible for organising and administering the examination process.

5.2 The earliest date for submission of a thesis by the Student for examination is seccnd semester, 2014.

5.3 The latest date for submission of a thesis by the Student for examination is first semester 2015.

5.4 The examiner(s) will be appointed by written agreement between the University of Sydney and UFMG.

5.5 The date of defense will be in March 2015.The thesis defense will be done once only and will be recognised by both institutions. The defense committee is made up of eight scientists appointed in parity by both partner institutions. At least one member of the defense committee must be external to the two institutions.

5.6 The division of fees borne by each party to meet the committee members at the time of the thesis defense is determined according to the following conditions:

(a) UFMG will assume to the board composition the burden that is traditionally taken for a thesis defense in Brazil: international dislocation accommodation expenses.

(b) Both institutions commit themselves, in the case of financial activities at the time of the defense to see all possible means so that the joint defense of the thesis takes place, including making use of distance communications such as video-conferencing.

5.7 The Student will submit a thesis for examination and thereafter present herself for examination at the UFMG in accordance with the rules and regulations UFMG subject to the following conditions:

(a) the Student will write and (where applicable) defend the thesis in Portuguese, and will include in the thesis a substantial abstract written in English;

(b) the Student will submit two copies of the thesis to the University of Sydney, of which one will be for the University of Sydney's use and retention;

(c) the Student will submit three copies of the thesis to the UFMG of which one will be for the UFMG use and retention.

5.8 Both institutions will respect the examination outcome, provided the process above is followed. In the event of a dispute between the University of Sydney and the UFMG regarding the examination outcome (due to incorrect procedures), the University of Sydney and the UFMG will jointly appoint a suitably qualified external person to re-examine the thesis and, if necessary, conduct an additional oral examination ('**External Re-Examiner**'). The decision of the External Re-Examiner will be final.

6. Graduation

6.1 If the conditions for graduation are met, the Jointly Awarded Degree will be conferred by UFMG and University of Sydney.

6.2 The Student is entitled to receive a testamur that:

(a) states that the Jointly Awarded Degree was undertaken by the Student through a cotutelle arrangement; and

(b) lists the names of both the University of Sydney and the UFMG.

6.3 The University of Sydney may also confer a testamur in accordance with **clause 6.2**, at its sole discretion.

7. Financial Arrangements

7.1 Unless otherwise agreed in writing by the University of Sydney and the UFMG, the Student will pay tuition fees at UFMG and be exempt from payment of tuition fees at the University of Sydney for the duration of the candidature.

7.2 Unless otherwise agreed in writing by the Parties, the Student will be responsible for all other personal costs in connection with the candidature, including all living, travel, insurance (including additional medical coverage, liability and accident insurance) and ancillary costs.

7.3 Unless otherwise agreed in writing by the University of Sydney and the UFMG, the supervisors will be responsible for the cost of any flights and accommodation required for a Superviscr or examiner to attend any oral or other examination.

7.4 The social security and civil responsibility of the PhD student will be assured under the following conditions:

(a) At the institution of his origin (UFMG) the PhD student must purchase private health insurance coverage.

(b) When enrolled at the University of Sydney as an overseas student, be solely responsible for the purchase and maintenance of Overseas Student Health Cover (OSHC) while staying in Australia, as a condition of the Student's visa.

8. Intellectual Property

8.1 Unless otherwise agreed by the Parties in writing, all Intellectual Property rights developed by the Student during his candidature will vest in Lucas Rodrigues Nascimento.

8.2 The University of Sydney and UFMG will not assert copyright ownership over the Student's doctoral thesis, as the copyright vests in the Student.

9. Student Accommodation

9.1 The Student will be responsible for organising his own accommodation.

9.2 The University of Sydney and the UFMG will provide information to the Student regarding temporary and longer-term accommodation on and off campus.

9.3 Neither the University of Sydney nor the UFMG guarantees that accommodation on campus will be available.

10. Student obligations

10.1 The Student will:

(a) at all times comply with and be bound by any relevant laws, rules, regulations and codes of practice applicable to the candidature, including in respect of:

a. any entry and visa requirements;

b. the research conducted by the Student; and

c. the Student's presence in or on land or buildings owned, occupied or under the control of the University of Sydney or the UFMG;

(b) obtain medical insurance for the duration of the Student's time at the UFMG

(c) if enrolled at the University of Sydney as an overseas student, be solely responsible for the purchase and maintenance of Overseas Student Health Cover (OSHC) while staying in Australia, as a condition of the Student's visa.

11. Indemnification

11.1 Subject to applicable laws, the University of Sydney and the UFMG indemnify and agree to keep indemnified ('**Indemnifying Institution**') the other institution ('**Indemnified Institution**') against all liability, loss, costs, damages or expenses (including legal costs and expenses) incurred or suffered by the Indemnified Institution as a result of any wilful misconduct or negligent act or omission by the Indemnifying Institution, or a material breach of this Agreement by the Indemnifying Institution.

11.2 Subject to applicable laws, the University of Sydney and the UFMG will not be liable to one another for incidental damages, such as loss of profits, revenue, goodwill or opportunities, and each institution's liability under this Agreement is reduced to the extent that any liability, loss, costs, damages or expenses arise from or are attributable to any wilful or negligent act or omission by the Indemnified Institution.

11.3 References to the Indemnifying Institution and the Indemnified Institution in this clause include the institution's directors, officers, employees, agents and students,

11.4 The University of Sydney and the UFMG will maintain adequate insurance protections for public liability and professional indemnity (which may be self-insurance) to cover their obligations under this Agreement, and will provide to the other institution a certificate of currency and renewals of such insurance, if requested to do so.

12. Force Majeure

12.1 Neither institution will be held responsible or liable, or be deemed to be in default or breach of this Agreement, for any delay, failure or inability to meet its obligations under this Agreement (other than any obligation to pay money) caused by or arising from any cause that is unavoidable or beyond the reasonable control of the institution, including war, warlike operations, riot, insurrection, orders of government, strikes, lockouts, public health emergencies, quarantines, disturbances or any act of God or other cause which frustrates the performance of this Agreement.

13. Nature of Agreement and Amendment

13.1 This Agreement is binding and constitutes the entire agreement between the Parties, in addition only to a Principal Agreement between the parties which has been agreed to by both parties and which sets out their general obligations regarding Cotutelle arrangements.

13.2 Nothing contained or implied in this Agreement is intended to create a partnership between any of the Parties or, except as otherwise provided in this agreement, establish any of the Parties as an agent or representative of any other party.

13.3 This Agreement and any Schedule to it may be amended, modified, extended or renewed only with the written, mutual consent of the Parties.

13.4 The Parties agree that this Agreement and all documents related to may be written in both English and the language chosen by UFMG with the Portuguese version prevailing.

Signed:

Lucas Rodrigues Nascimento
Candidate

Date: 24/07/2012

On behalf of:

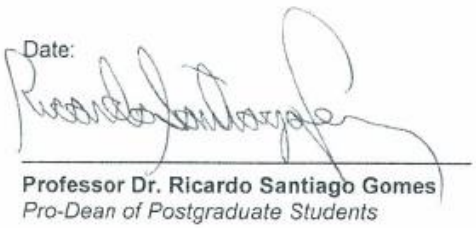
UFMG

Professor Dr Luci Fuscaldi Teixeira Samela
Supervisor

Date: 24/07/2012

Professor Dr. Clelio Campolina Diniz
Dean, UFMG

Date:



Professor Dr. Ricardo Santiago Gomes
Pro-Dean of Postgraduate Students

Date:

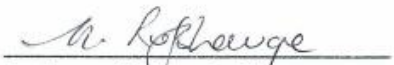
Professor Livia de Castro Magalhães
Coordinator of Postgraduate Program in Science of Rehabilitation

Date: 24/07/2012

The University of Sydney

Associate Professor Louise Ada
Supervisor

Date: 15/8/2012



Professor Kathryn Refshauge
Dean, Faculty of Health Sciences

Date: 15/8/2012

Professor Derrick Armstrong
Deputy Vice-Chancellor (Education) & Registrar

Date: 20 · 8 · 12

ANEXOS B, C e D

Artigos científicos complementares à tese publicados em revistas especializadas

ANEXO B

Revisão de Literatura

Marcha humana: teorias, contribuições musculares e implicações clínicas.

Human gait: theories, muscular contributions, and clinical implications.

Lucas Rodrigues Nascimento[1], Renan Alves Resende[2], Augusto Cesinando Carvalho[3], Sérgio Teixeira Fonseca[4], Luci Fuscaldi Teixeira-Salmela[4].

Programa de Pós-graduação em Ciências da Reabilitação, Departamento de Fisioterapia, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Minas Gerais, Brasil.

Resumo
Embora a marcha seja o principal modo de locomoção dos seres humanos, os mecanismos utilizados pelo sistema musculoesquelético para permitir a marcha humana são amplamente desconhecidos em função da dinâmica complexa do sistema e da redistribuição das forças de reação articular entre os segmentos corporais. Durante 40 anos, acreditou-se que minimizar o deslocamento do centro de massa durante a marcha seria o principal mecanismo para reduzir o esforço muscular. Porém, análises contemporâneas do comportamento motor apresentaram modelos biomecânicos que simulam a marcha e a caracterizam em uma perspectiva energética, na qual a integralidade estrutural do sistema musculoesquelético é considerada. Os objetivos dessa atualização foram identificar referenciais teóricos sobre a marcha humana, compreender ações e interações musculares e indicar implicações clínicas para compreensão de alterações relacionadas a marcha. O estudo identificou diferentes abordagens que guiam o estudo da marcha humana e possíveis métodos de análise e interpretação dos dados. Perspectivas contemporâneas ressaltaram a importância de estruturas passivas no armazenamento e transmissão de energia e métodos de dinâmica direta indicaram como elementos ativos do sistema musculoesqueletico podem atuar em diferentes regiões do corpo, excluindo análises puramente locais de ações musculares. A análise da marcha deve ser um início do processo de avaliação, a fim de gerar hipóteses que possam ser analisadas por meio de testes específicos. O tratamento deve ser baseado no modelo de capacidade versus demanda, modificando a capacidade estrutural dos elementos que compõem o sistema musculoesquelético ou reduzindo a demanda da tarefa, como indicado nos casos clínicos apresentados no estudo.
Palavras-chave: locomoção, biomecânica, dinâmica, sistema musculoesquelético, reabilitação.

Abstract
Although gait is the main means of locomotion, the musculoskeletal mechanisms related to human gait are not well known, due to the complex dynamics of these systems and the redistributions of reaction forces between body segments. Over 40 years, scientists believed that the main mechanisms responsible for reducing the muscular efforts during gait were related to the minimization of the displacements of the body center of mass. However, recent analyses of motor behavior proposed biomechanical models, which were able to simulate and describe human gait, based upon an energetic perspective, which covers the complexity of the musculoskeletal system. Therefore, the objectives of this study were: To identify the theoretical background related to gait, to analyze the muscular actions and interactions, and to show clinical implications related to gait disorders. The study identified different approaches, which usually guide gait studies, including the available methods for data analyzes and their interpretation. Current approaches emphasize the importance of the passive structures for energy absorption, storage, and transmission. Furthermore, direct dynamic approaches indicated how the active structures of the musculoskeletal system can act in several body areas, excluding the local analyses of muscular actions. Gait analyses should be initially assessed to generate hypotheses, which could be solved with specific tests. Interventions should be based upon the understanding and adjustments of the relationships between the task demands and the individuals' capabilities, as illustrated in the included clinical cases.
Key-words: locomotion, biomechanics, dynamics, musculo-skeletal system, rehabilitation.

Artigo recebido em 10 de Julho de 2012 e aceito em 22 de Setembro de 2012.

1. Doutorando em Ciências da Reabilitação pela Universidade Federal de Minas Gerais (Belo Horizonte, Brasil) e *The University of Sydney* (*Sydney*, Austrália).
2. Doutorando em Ciências da Reabilitação pela Universidade Federal de Minas Gerais (Belo Horizonte, Brasil) e *Queen's University* (*Kingston*, Canadá).
3. Professor Adjunto do Departamento de Fisioterapia da Universidade Estadual de São Paulo - UNESP, Presidente Prudente, São Paulo, Brasil.
4. Professor Titular do Departamento de Fisioterapia da Universidade Federal de Minas Gerais – UFMG, Belo Horizonte, Minas Gerais, Brasil.

Endereço para Correspondência:
Prof. Luci Fuscaldi Teixeira-Salmela, Ph.D.- Avenida Antônio Carlos, 6627, Campus Pampulha CEP: 31270-901 Belo Horizonte, MG-Brasil. *Email:* lfts@ufmg.br / lrn@ufmg.br

INTRODUÇÃO

Nada personifica mais o nível de independência e a percepção de qualidade de vida do que a capacidade de locomover-se de modo independente [1]. A marcha é o principal modo de locomoção dos seres humanos, sendo caracterizada por um deslocamento rítmico das partes do corpo com objetivo de movê-lo à frente mantendo postura e estabilidade dinâmica por meio da coordenação de múltiplos músculos e articulações simultaneamente [2,3].

Os mecanismos utilizados pelos músculos para permitir a marcha humana são amplamente desconhecidos em função da dinâmica complexa do sistema musculoesquelético e da redistribuição das forças de reação articular entre os segmentos corporais [4,5]. Tradicionalmente, músculos eram considerados apenas geradores ativos de energia a ser transmitida por meio de um circuito fixo e conectado por alavancas ósseas. Entretanto, evidências recentes ressaltam a importância dos músculos na redistribuição de energia mecânica entre os diversos segmentos corporais e do tecido conectivo – composto por tendões, fáscias e demais elementos elásticos – na transmissão e armazenamento de energia elástica. Potencialmente, energia elástica é convertida em energia cinética podendo minimizar a necessidade de geração de tensão ativa pelos elementos contráteis e, consequentemente, reduzir o gasto energético por unidade de distância percorrida durante a marcha [2,6,7].

É bem estabelecido que durante a marcha humana normal os sistemas locomotor e cardiorrespiratório operam de modo a manter a progressão do corpo à frente e estabilidade dinâmica adequada, utilizando o menor gasto energético necessário para suprir as demandas da tarefa [6,8]. Durante 40 anos, acreditou-se que minimizar o deslocamento do centro de massa durante a marcha seria o principal mecanismo para reduzir o esforço muscular e, em consequência, minimizar o gasto energético [8,9]. Dessa forma, hipóteses relacionadas exclusivamente à movimentação cinemática durante a marcha foram descritas como determinantes da tarefa, desconsiderando as propriedades passivas do sistema musculoesquelético na geração e transmissão de energia. Análises e perspectivas contemporâneas do comportamento motor questionam tais postulações e apresentam modelos biomecânicos que simulam a marcha humana e a caracterizam em uma perspectiva energética na qual a integralidade estrutural do sistema musculoesquelético é considerada [2,8,10].

Nesse contexto, os objetivos dessa revisão foram: (i) identificar importantes referenciais teóricos utilizados para a compreensão da marcha e apresentar modelos dinâmicos representativos da tarefa, (ii) compreender ações e interações musculares na geração do movimento e (iii) indicar implicações clínicas para a compreensão de patologias da marcha humana.

TEORIAS E MODELOS RELACIONADOS À MARCHA HUMANA

Teoria dos Seis Determinantes da Marcha

Uma das mais influentes teorias relacionadas à marcha humana foi proposta por Saunders et al. [9] e, por mais de quatro décadas, foi aceita como fato, apesar da ausência de confirmações experimentais. A premissa da "Teoria dos seis determinantes da marcha" está relacionada à hipótese de ligação entre dois conceitos que tradicionalmente descrevem a marcha humana. O primeiro está relacionado à definição de marcha como meio de locomoção dos seres humanos para modificar sua posição no espaço com menor gasto energético possível. O segundo, por sua vez, descreve que minimizar o deslocamento do centro de massa seria o principal mecanismo para reduzir o esforço muscular durante a marcha [8,9]. Embora o raciocínio que postule a hipótese seja aparentemente lógico e aceitável, as conclusões geradas não são assertivas e evidências científicas revelaram que alguns determinantes descritos – inclinação e rotação pélvica e manutenção da flexão de joelho na fase de apoio – resultavam em mínima redução do deslocamento vertical do corpo e, consequentemente, em pouca influência na trajetória do centro de massa e no gasto energético [11,12].

Como exemplo é possível analisar a marcha característica de determinadas crianças com paralisia cerebral que mantêm flexionados os joelhos para permitir a locomoção. Embora, dadas as características e adaptações teciduais do sistema musculoesquelético dessas crianças, esse seja o padrão adotado para permitir emergência de marcha funcional, um alto gasto energético é necessário para manter a locomoção em função de uma maior necessidade de geração de tensão ativa para sustentar o peso corporal e a, conseqüente, maior excursão angular do membro de balanço [8,13]. Evidências adicionais demonstraram ainda que tentativas voluntárias de indivíduos saudáveis para controlar excursões angulares de segmentos corporais foram insignificantes para suavizar o deslocamento do centro de massa [14,15].

Essas tentativas de controlar o padrão de marcha humana baseando-se em alterações no deslocamento do centro de massa relacionadas aos seis determinantes da marcha humana resultaram similarmente em aumentos consideráveis do gasto energético [16-18]. Nesse contexto, Kuo e Donelan (8) propuseram que a "Teoria dos seis determinantes da marcha" seja analisada como hipótese ao invés de um fato, e as observações sejam, portanto, descritas como eventos cinemáticos, e não determinantes, da marcha humana. Essa análise direciona clínicos a não basearem intervenções em reabilitação por orientações de como o indivíduo deva caminhar, mas buscar compreender as deficiências em estrutura e função do corpo que determinam a emergência de um ob-

servado padrão de marcha ou modificar fatores contextuais para otimizar a marcha do paciente.

Modelos de marcha humana

O modelo de pêndulo invertido foi uma das primeiras tentativas para compreender a dinâmica da marcha humana com baixo gasto energético. O modelo discorre que o membro inferior de apoio comporta-se como um pêndulo invertido capaz de conservar energia mecânica não requerendo, em consequência, trabalho muscular para produzir movimento durante a marcha [8,12]. Modelos avançados de marcha dinâmica reconhecem essa analogia ao pêndulo invertido como um importante avanço no conhecimento relacionado à redução do gasto energético durante a marcha.

De acordo com Kuo e Donelan [8], embora o modelo de pêndulo invertido seja capaz de explicar diferenças na variação de energia entre marcha e corrida, o mesmo não é capaz de quantitativamente explicar essa variação em função da velocidade de marcha. A priori, o mecanismo de pêndulo invertido prediz que a marcha não requer trabalho ou outras forças ativas produzidas pelo sistema musculoesquelético. Dessa forma, uma vez iniciada a marcha, não haveria razões de gasto energético para manutenção de um movimento que conservaria energia [2,8]. Portanto, embora o modelo seja importante para compreender como a marcha humana pode ser econômica, não explica a necessidade de gasto energético para sua manutenção.

Com o objetivo de incluir o gasto energético nas análises realizadas, os modelos de marcha dinâmica – definida como locomoção gerada eminentemente por propriedades passivas do sistema musculoesquelético na dinâmica de movimentação dos membros inferiores – avançaram na tentativa de explicar a necessidade de gasto energético durante a marcha. De acordo com McGeer [19], a compreensão e coordenação da marcha humana podem ser simplificadas por meio de vantagens provenientes da dinâmica passiva baseada em propriedades passivas do sistema e aproveitamento de energia gravitacional. Modelos robóticos constituídos simulando tais propriedades do sistema musculoesquelético foram capazes de descer rampas levemente inclinadas sem necessidade de controle ativo ou *input* extra de energia além da gravitacional. Entretanto, esses modelos demonstraram, ainda, que a deambulação em superfícies planas requer alguma necessidade de *input* de energia adicional [2,20].

De acordo com Kuo [21], a adição de energia nessas condições é necessária apenas porque energia mecânica é dissipada ao final de cada passo quando o membro de referência toca o solo, em um mecanismo denominado colisão mecânica. Em princípio, a restauração dessa energia dissipada poderia ser executada em qualquer momento durante a marcha, mas modelos em computadores demonstraram que a estratégia mais efetiva é a reposição de energia por meio de impulso em flexão plantar segundos antes da colisão mecânica do membro contralateral com o solo [2,8]. Demonstrou-se, ainda, que os modelos que melhor mimetizavam a anatomia humana – tecido conectivo, interações e continuidade do tecido muscular – em princípios de coordenação multi-articular, modulavam tamanho do passo e velocidade de marcha, sendo a primeira variável influenciada pelo impulso durante a flexão plantar e a segunda por ajustes de rigidez no sistema [2,8]. Os modelos propostos indicam como tendões e outros componentes conectivos, baseados em características viscoelásticas, são utilizados durante a marcha inicialmente armazenando energia e retornando-a ao sistema como energia mecânica. Nesse contexto, raciocínios clínicos direcionados à reabilitação da marcha devem envolver avaliação não apenas dos componentes ativos, mas também da manutenção da capacidade das estruturas passivas em associação às ativas para lidar com a demanda imposta pela tarefa.

Na tentativa de interpretar como as forças atuam sobre as articulações durante o ciclo da marcha, a dinâmica inversa Newton-Euler é o método mais conhecido e comumente utilizado para avaliação da marcha. Esse método permite o cálculo dos momentos e potências articulares, e das forças intersegmentares resultantes [22] a partir de um modelo que considera pé, perna e coxa segmentos corporais rígidos conectados por articulações conjuntas [23]. A força de reação do solo e as acelerações dos segmentos são inseridas nas equações de movimento Newton-Euler começando pelo pé e terminando pela coxa para obter os momentos articulares resultantes de tornozelo, joelho e quadril. Uma vantagem desse método é que não é necessário criar um modelo dos segmentos proximais à coxa para calcular os momentos articulares resultantes de tornozelo, joelho e quadril, pois a cinética de segmentos como tronco e cabeça é incluída na força de reação do solo. Assim, a utilização dos momentos articulares resultantes obtidos a partir do método de dinâmica inversa possibilitou, até o momento, grandes avanços no entendimento de alterações presentes em indivíduos com disfunções musculoesqueléticas.

Apesar dos avanços obtidos, entendimento acerca da contribuição de grupos musculares ou músculos específicos a partir da utilização do método de dinâmica inversa para geração de marcha humana é ainda limitado. Para tal, a contribuição instantânea de músculos individuais para a aceleração e potência dos segmentos deve ser obtida e as acelerações e potências geradas pelos mesmos devem ser consistentes com o movimento avaliado. Assim, diversos métodos [24-27] foram propostos para preencher essa lacuna. Dentre eles, modelos biomecânicos do sistema musculoesquelético associados a simulações da atividade do sistema nervoso para ativação muscular apresentaram potencial para in-

tegrar as propriedades estruturais em sistema neuro-músculo-esquelético e compreender como forças musculares individuais e suas interações contribuem para a aceleração dos segmentos, quando interpretados em uma perspectiva biomecânica independente de controle motor central [10,28]. Esses modelos computacionais capazes de reproduzir simulações da marcha humana tornaram-se importantes ferramentas para compreensão da dinâmica muscular em função da incapacidade dos sistemas de análise de movimento para mensurar quantidades biomecânicas de forma direta [10,29].

Zajac et al. [10] conduziram um estudo visando compreender a dinâmica muscular na marcha ajustando os padrões de ativação muscular para replicar dados experimentais previamente coletados. Simulações dinâmicas que reproduziram a cinemática e cinética da marcha de indivíduos saudáveis, deambulando em velocidade equivalente a 1,5 m/s, foram realizadas em um modelo neuro-músculo-esquelético composto por 14 músculos, elementos elásticos e distribuição de massa equivalente à humana [10,30]. Os resultados apresentados contradizem pressupostos clássicos assumidos em análises lineares indicando a transmissão de energia entre os segmentos e ação de músculos distais influenciando segmentos não diretamente relacionados à sua fixação óssea.

Entre os principais resultados encontrados por Zajac et al [10] estão a contribuição dos flexores plantares para suporte e progressão do tronco à frente durante a fase de apoio da marcha e a importância da energia elástica armazenada por esse grupo muscular para a redução da quantidade de energia gerada durante a fase de impulsão. Apesar de tradicionalmente serem considerados músculos agonistas, gastrocnêmio e sóleo podem apresentar funções distintas das classicamente descritas durante a marcha. De acordo com Zajac et al [10], enquanto a energia produzida por gastrocnêmio é destinada a acelerar coxa, perna e pé durante o apoio final, o sóleo é responsável por acelerar o tronco à frente, tarefa que é realizada primariamente por meio de transferência da energia absorvida durante as fases iniciais do apoio. O método de análise empregado pelos autores foi capaz de demonstrar como músculos distais influenciam e controlam diretamente movimentos proximais, por meio de transmissão miofascial do fluxo de energia no sistema músculo-esquelético. Clinicamente, torna-se relevante, portanto, uma análise do movimento não apenas local, mas considerar as influências distais e as interações no sistema. Além disso, foi demonstrado que para exercerem suas funções durante a fase de impulso, os flexores plantares não precisam necessariamente gerar alta tensão ativa por meio de elementos contráteis, pois grande parte da energia absorvida por eles durante a fase inicial de apoio unipodal é armazenada, principalmente no tendão e aponeurose calcanear, sendo convertida em energia mecânica para permitir o avanço do membro.

Associado ao fato de que músculos ativos não necessariamente representam músculos que estão gerando energia, mas que podem estar contraindo apenas para transferir energia entre segmentos, e que grande parte da energia da marcha é proveniente do uso da dinâmica passiva, esses achados sugerem que a ativação simultânea de músculos é necessária para permitir distribuição de energia mecânica no sistema e garantir estabilidade dinâmica durante a marcha. Classicamente, o mecanismo de contrações musculares simultâneas tem sido descrito como patológico e representativo de ineficiência de função muscular ou alto gasto energético, entretanto esse mecanismo de co-ativação parece ser necessário para obter estabilidade articular e coordenação do movimento [7,31]. A ativação muscular permite ajustar o nível de rigidez muscular passiva garantindo distribuição adequada de energia mecânica e estabilidade dinâmica por meio de ajuste contínuo das propriedades do sistema musculoesquelético de acordo com as demandas do ambiente, evitando que o mesmo se torne instável. Dessa forma, a ativação muscular para o ajuste da rigidez envolve a utilização de fluxo contínuo de informações e estabilidade é um processo inerente à capacidade do sistema em se antecipar a perturbações durante a marcha [32,33]. Intervenções direcionadas à reabilitação da marcha devem, portanto, priorizar a integridade estrutural do sistema musculoesquelético favorecendo aumento de mobilidade elástica, força e ajuste de rigidez, além de criar situações funcionais no ambiente terapêutico para permitir que o paciente explore as propriedades desse sistema - força, rigidez, massas e comprimentos segmentares, e informações extraídas do ambiente [13,32,34].

IMPLICAÇÕES CLÍNICAS E CONSIDERAÇÕES FINAIS

A complexidade do sistema musculoesquelético e das possíveis interações entre suas diversas partes durante a marcha implicam necessidade de melhor entendimento dos possíveis fatores contribuintes para o surgimento de um padrão de movimento clinicamente considerado inadequado. Por isso, embora em diversos protocolos desenvolvidos a análise de marcha seja realizada como parte final do processo de avaliação, é fortemente recomendado que sua avaliação seja conduzida durante a parte inicial do processo de avaliação, possibilitando, assim, a elaboração de hipóteses a serem testadas posteriormente por meio de testes específicos durante o restante do processo de investigação. Em função das inúmeras relações intersegmentares já demonstradas na literatura, basear a elaboração de hipóteses causais apenas em fatores locais incorre em grande probabilidade de insucesso durante a avaliação e, consequentemente, durante o tratamento do paciente. Assim, entender e saber avaliar padrões de movimentos proximais e distais ao local de queixa do paciente que pos-

sam contribuir para a disfunção apresentada se torna mandatório.

Baseado em um modelo teórico de capacidade versus demanda, lesões musculoesqueléticas ocorrem quando a demanda imposta sobre o sistema musculoesquelético supera a capacidade do sistema para lidar com a demanda imposta. Assim, fatores como excesso ou limitação de movimento, modificações de momento e velocidade de ocorrência de movimentos específicos e o excesso ou redução da contribuição relativa de cada grupo muscular durante a marcha podem contribuir para o aumento da demanda imposta sobre o sistema. Por ser a ocorrência de lesões dependente da capacidade do indivíduo, alterações dos padrões de movimento durante a marcha consideradas menos importantes para indivíduos com maior capacidade podem ser significativas para indivíduos com redução de sua capacidade, como indivíduos idosos, com alterações neurológicas ou com histórico recente de lesão.

Apesar da maior amplitude de movimento durante a marcha ocorrer no plano sagital, diversos estudos demonstraram a importância dos movimentos que ocorrem nos planos frontal e transverso para o bom desempenho e, consequentemente, a importância de uma avaliação adequada para a compreensão de possíveis mecanismos de lesão e inferências sobre reabilitação [35-37]. Dessa forma, apesar da maior dificuldade e relativa subjetividade durante a avaliação clínica dos movimentos nesses planos, um esforço deve ser feito na tentativa de incluir e padronizar a forma de avaliação dos mesmos [38]. Especificamente em relação ao plano frontal, os movimentos de inclinação lateral do tronco, elevação e depressão pélvica, e inversão e eversão de calcâneo são os que apresentam maior potencial de observação, sendo também movimentos de grande relevância clínica. Para avaliação de movimentos no plano transverso, técnicas simples como a utilização de marcadores formados por bolas de isopor sobre os metatarsos e calcâneo e placas rígidas afixadas a cintas de neoprene com marcadores fixos por intermédio de uma haste sobre perna e a marcação dos côndilos femorais em sua região posterior são clinicamente úteis favorecendo a observação dos eventos cinemáticos e possibilitando maior compreensão da interação entre os segmentos corporais para elaboração de hipóteses causais a serem testadas, estando essa habilidade relacionada à experiência e treinamento do terapeuta. Dessa forma, a não inclusão dos planos frontal e transverso no processo de avaliação do fisioterapeuta poderá implicar, em muitos casos, o insucesso do tratamento.

Em pacientes com alterações na marcha decorrentes de lesões encefálicas como o Acidente Vascular Encefálico, os princípios aqui descritos podem ser utilizados em uma avaliação menos pontual e mais abrangente visando compreender como as alterações musculoesqueléticas apresentadas determinam o padrão de marcha emergente. Tradicionalmente, acreditou-se que as alterações ocorriam em função direta da lesão encefálica e da espasticidade dos principais grupos musculares [39,40]. Conceitos e pesquisas contemporâneas demonstraram, entretanto, que poucos indivíduos pós-AVE apresentam de fato espasticidade, e que as alterações observadas estão intimamente relacionadas a modificações no tecido muscular e conectivo: fraqueza muscular, contratura, alteração de rigidez muscular passiva e mudanças na curva comprimento-tensão [41,42]. Nesse contexto, terapias direcionadas a aumentar a capacidade de gerar força muscular (fortalecimento muscular progressivo) e permitir prática precoce e ativa da tarefa (esteira ergométrica) demonstraram-se mais eficazes para a reabilitação da marcha nessa população [43,44]. Os princípios que norteiam o presente artigo e as evidências científicas atuais sugerem que a reabilitação de pacientes crônicos deva considerar: (i) fortalecimento muscular progressivo na amplitude de movimento de atuação fisiológica da musculatura; (ii) modificação do padrão de uso no cotidiano; (iii) treino intensivo e repetitivo da tarefa.

O fortalecimento da musculatura em posições alongadas ou encurtadas poderá permitir adaptação tecidual à carga imposta, modificação do número de sarcômeros em série e, consequente, ação muscular em adequada relação comprimento-tensão adequada. Para manutenção dos ganhos obtidos, estratégias devem ser direcionadas para permitir uso cotidiano dessa musculatura na relação comprimento-tensão adequada [45]. Para tanto, o terapeuta deverá ser capaz, por vezes, de minimizar a demanda imposta pela tarefa controlando padrão cinemático, duração ou intensidade da atividade, dentre outros. Dispositivos de auxílio à marcha e órteses podem auxiliar nessa função sem prejuízos cinéticos ou cinemáticos no padrão de marcha [46,47]. De acordo com Kuo e Donelan [8], dispositivos de auxílio podem ser ainda desenvolvidos associados à eletroestimulação para auxiliar no *input* de energia ao sistema, previamente à colisão mecânica no contato inicial do pé com o solo. Por fim, o treino intensivo e repetitivo poderá permitir além de exploração ativa de possibilidades de ação, um treinamento focado não apenas no fortalecimento dos músculos paréticos, mas também na habilidade de injetar energia no sistema musculoesquelético no momento adequado [8,34]. Esses princípios combinados possibilitarão que indivíduos com AVE estabeleçam uma marcha em maior velocidade e com menor gasto energético, pois permitirá a utilização adequada dos elementos ativos e passivos que compõem o sistema musculoesquelético na geração, absorção e transferência de energia. A avaliação da marcha deve, portanto, identificar as características que definem a capacidade desse sistema e a demanda da tarefa visando ao equilíbrio nessa relação para permitir a emergência de um padrão de marcha adequado.

De modo geral, o presente estudo apresentou diferentes abordagens que guiam o estudo da marcha humana e possíveis métodos de análise e interpretação de dados. Abordagens relacionadas à marcha dinâmica ressaltam a importância de estruturas passivas no armazenamento e transmissão de energia, e métodos de análise contemporâneos indicaram como os elementos ativos do sistema musculoesquelético podem atuar em diferentes regiões do corpo humano para executar diferentes funções, excluindo análises puramente locais de ações musculares. Nesse contexto, recomenda-se a análise da marcha no início do processo de avaliação com o objetivo de gerar hipóteses que possam ser analisadas por meio de testes específicos. O tratamento deve ser baseado no modelo de capacidade versus demanda modificando a capacidade estrutural dos elementos que compõem o sistema musculoesquelético e/ou reduzindo a demanda da tarefa. Treinamento funcional deve ser então incluído visando à exploração ativa de novas possibilidades de ação.

REFERÊNCIAS BIBLIOGRÁFICAS

1. Patla A. A framework for understanding mobility problems in the elderly. In: Craik RL, Oatis CA, editors. Gait Analysis: theory and application. 1 ed. St. Louis: Mosby-Year Book; 1995.
2. Dean JC, Kuo AD. Elastic coupling of limb joints enables faster bipedal walking. J R Soc Interface 2009 6(35):561-73.
3. Teixeira-Salmela LF, Nadeau S, Milot MH, Gravel D, Requiao LF. Effects of cadence on energy generation and absorption at lower extremity joints during gait. Clin Biomech 2008 23(6):769-78.
4. Zajac FE. Understanding muscle coordination of the human leg with dynamical simulations. J Biomech 2002 35(8):1011-8.
5. Neptune RR, Zajac FE, Kautz SA. Muscle force redistributes segmental power for body progression during walking. Gait Posture 2004 19(2):194-205.
6. Turvey MT, Holt KG, Lafiandra ME, Fonseca ST. Can the transitions to and from running and the metabolic cost of running be determined from the kinetic energy of running? J Mot Behav 1999 31(3):265-78.
7. Nascimento LR, Bittencourt NFN, Resende RA, Teixeira-Salmela LF, Fonseca ST. Biomecânica aplicada ao voleibol: análise do complexo do ombro e implicações para avaliação e desempenho. Ter Man 2010;8(40):483-490.
8. Kuo AD, Donelan JM. Dynamic principles of gait and their clinical implications. Phys Ther 2010 90(2):157-74.
9. Saunders JB, Inman VT, Eberhart HD. The major determinants in normal and pathological gait. J Bone Joint Surg Am 1953 35-A(3):543-58.
10. Zajac FE, Neptune RR, Kautz SA. Biomechanics and muscle coordination of human walking: part II: lessons from dynamical simulations and clinical implications. Gait Posture 2003 17(1):1-17.
11. Gard SA, Childress DS. The influence of stance-phase knee flexion on the vertical displacement of the trunk during normal walking. Arch Phys Med Rehabil 1999 80(1):26-32.
12. Kuo AD. The six determinants of gait and the inverted pendulum analogy: A dynamic walking perspective. Hum Mov Sci 2007 26(4):617-56.
13. Fonseca ST, Holt KG, Fetters L, Saltzman E. Dynamic resources used in ambulation by children with spastic hemiplegic cerebral palsy: relationship to kinematics, energetics, and asymmetries. Phys Ther 2004 84(4):344-54.
14. Gard SA, Childress DS. The effect of pelvic list on the vertical displacement of the trunk during normal walking. Gait Posture 1997;5:233-8.
15. Kerrigan DC, Riley PO, Lelas JL, Della CU. Quantification of pelvic rotation as a determinant of gait. Arch Phys Med Rehabil 2001 82(2):217-20.
16. Massaad F, Lejeune TM, Detrembleur C. The up and down bobbing of human walking: a compromise between muscle work and efficiency. J Physiol 2007 15;582(Pt 2):789-99.
17. Gordon KE, Ferris DP, Kuo AD. Metabolic and mechanical energy costs of reducing vertical center of mass movement during gait. Arch Phys Med Rehabil 2009 90(1):136-44.
18. Ortega JD, Farley CT. Minimizing center of mass vertical movement increases metabolic cost in walking. J Appl Physiol 2005 99(6):2099-107.
19. McGeer T. Passive dynamic walking. International Journal of Robotics Research 1990;9:62-82.
20. Kuo AD. Choosing your steps carefully: trade-offs between economy and versatility in dynamic walking bipedal robots. IEEE Robotics and Automation Magazine 2007;14:18-29.

21. Kuo AD. Energetics of actively powered locomotion using the simplest walking model. J Biomech Eng 2002 124(1):113-20.
22. Soutas-Little RW. Motion analysis and biomechanics. J Rehabil Res Dev 1998;2:49-68.
23. Meglan D, Todd F. Kinetics of human locomotion. In: Rose J, Gamble JC, editors. Human walking.Baltimore: Williams and Wilkins; 1994. p. 73-9.
24. Farley CT, Farley. Biomechanics of walking and running: center of mass movements to muscle action. Exerc Sport Sci Rev 1998;28:253-85.
25. Zajac FE. Muscle coordination of movement: a perspective. J Biomech 1993;26 Suppl 1:109-24.
26. Zajac FE, Winters JM. Modeling musculoskeletal movement systems: joint and body-segment dynamics, musculotendinous actuation, and neuromuscular control. In: Winters JM, Woo S-Y, editors. Multiple muscle systems. 1 ed. New York: Springer-Verlag; 1990. p. 121-48.
27. Barnes S, Oggero E, Pagnacco G, Berne N. Simulation of human movement: goals, model formulation and considerations. In: Allard P, Cappozzo A, Lundberg A, Vaughan CL, editors. Three-dymensional analysis of human locomotion.New York: Wiley and Sons; 1997. p. 281-306.
28. Taga G. A model of the neuro-musculo-skeletal system for human locomotion. I. Emergence of basic gait. Biol Cybern 1995 73(2):97-111.
29. Zajac FE, Neptune RR, Kautz SA. Biomechanics and muscle coordination of human walking. Part I: introduction to concepts, power transfer, dynamics and simulations. Gait Posture 2002 16(3):215-32.
30. Neptune RR, Kautz SA, Zajac FE. Contributions of the individual ankle plantar flexors to support, forward progression and swing initiation during walking. J Biomech 2001 34(11):1387-98.
31. Silva PL, Fonseca ST, Ocarino JM, Goncalves GP, Mancini MC. Contributions of cocontraction and eccentric activity to stiffness regulation. J Mot Behav 2009 41(3):207-18.
32. Fonseca ST, Ocarino JM, Silva PLP. Ajuste da rigidez muscular via sistema fuso-muscular-gama: implicações para o controle da estabilidade articular. Rev Bras Fisioter 2004;8(3):187-95.
33. Ferris DP, Liang K, Farley CT. Runners adjust leg stiffness for their first step on a new running surface. J Biomech 1999 32(8):787-94.
34. Fonseca ST, Faria CDM, Ocarino JM, Mancini MC. Abordagem ecológica à percepção e ação: fundamentação para o comportamento motor. Braz J Mot Behav 2007;2(1):1-10.
35. Sled EA, Khoja L, Deluzio KJ, Olney SJ, Culham EG. Effect of a home program of hip abductor exercises on knee joint loading, strength, function, and pain in people with knee osteoarthritis: a clinical trial. Phys Ther 2010 90(6):895-904.
36. Drewes LK, McKeon PO, Paolini G, Riley P, Kerrigan DC, Ingersoll CD, et al. Altered ankle kinematics and shank-rear-foot coupling in those with chronic ankle instability. J Sport Rehabil 2009 18(3):375-88.
37. Lee SY, Hertel J, Lee SC. Rearfoot eversion has indirect effects on plantar fascia tension by changing the amount of arch collapse. Foot 2010 20(2-3):64-70.
38. Resende RA, Kirkwood RN, De Figueiredo EM. Cinemática da marcha de adultos jovens: dados normativos iniciais. Ter Man 2010;8(39):370-6.
39. Carr JH, Shepherd RB. The changing face of neurological rehabilitation. Rev Bras Fisioter 2006;10(2):147-56.
40. Bobath B. Adult Hemiplegia: Evaluation and Treatment. 3 ed. Oxford: Butterworth Heinemann; 1990.
41. Vaz DV, Brício RS, Aquino CF, Viana SO, Mancini MC, Fonseca ST. Alterações musculares em indivíduos com lesão do neurônio motor superior. Fisioter Pesq 2006;13(2):71-82.
42. O'Dwyer NJ, Ada L, Neilson PD. Spasticity and muscle contracture following stroke. Brain 1996 Oct;119 (Pt 5):1737-49.
43. Ada L, Dorsch S, Canning CG. Strengthening interventions increase strength and improve activity after stroke: a systematic review. Aust J Physiother 2006;52(4):241-8.
44. Dean CM, Ada L, Bampton J, Morris ME, Katrak PH, Potts S. Treadmill walking with body weight support in subacute non-ambulatory stroke improves walking capacity more than overground walking: a randomised trial. J Physiother 2010;56(2):97-103.
45. Aquino CF, Fonseca ST, Goncalves GG, Silva PL, Ocarino JM, Mancini MC. Stretching versus strength training in lengthened position in subjects with tight hamstring muscles: a randomized controlled trial. Man Ther 2010 Feb;15(1):26-31.
46. Polese JC, Teixeira-Salmela LF, Nascimento LR, Faria CD, Kirkwood RN, Laurentino GC, Ada L. The effects of walking sticks on gait kinematics and kinetics with chronic stroke survivors. Clin Biomech 2012 27(2):131-7.
47. Polese JC, Nascimento LR, Faria CD, Laurentino GE, Rodrigues-de-Paula F, Ada L, Teixeira-Salmela LF. Perception of patients with chronic hemiplegia regarding the use of assistive walking devices. Rev Panam Salud Publi-

ANEXO C

Different instructions during the ten-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis

Diferentes instruções durante teste de velocidade de marcha determinam aumento significativo na velocidade máxima de indivíduos com hemiparesia crônica

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Abstract

Objective: To evaluate the effects of different instructions for the assessment of maximum walking speed during the ten-meter walking test with chronic stroke subjects. **Methods:** Participants were instructed to walk under four experimental conditions: (1) comfortable speed, (2) maximum speed (simple verbal command), (3) maximum speed (modified verbal command–"catch a bus") and (4) maximum speed (verbal command + demonstration). Participants walked three times in each condition and the mean time to cover the intermediate 10 meters of a 14-meter corridor was registered to calculate the gait speed (m/s). Repeated-measures ANOVAs, followed by planned contrasts, were employed to investigate differences between the conditions (α=5%). Means, standard deviations and 95% confidence intervals (CI) were calculated. **Results:** The mean values for the four conditions were: (1) 0.74m/s; (2) 0.85 m/s; (3) 0.93 m/s; (4) 0.92 m/s, respectively, with significant differences between the conditions (F=40.9; p<0.001). Comfortable speed was significantly slower than the maximum speed, indicating that the participants were able to increase speeds when required. Significant differences were observed between the second condition with the third (p=0.002; 95%CI=-0.13 to -0.03) and the fourth conditions (p=0.004; 95%CI=-0.12 to -0.02) with no differences between the third and fourth conditions (p=1.00; 95%CI=-0.04 to 0.05). **Conclusions:** The results indicated that simple verbal commands were not sufficient to capture maximum gait speed with chronic stroke subjects. Thus, for clinical assessments and research purposes, where measurements of the maximum gait speed are necessary, modified verbal commands or demonstration strategies could be employed by physical therapists to ensure acurate information.

Keywords: mobility; stroke; verbal reinforcement; physical therapy.

Resumo

Objetivo: Avaliar os efeitos de diferentes instruções para avaliação da velocidade de marcha máxima de indivíduos hemiparéticos durante o teste de caminhada de 10 metros. **Métodos:** Os indivíduos deambularam em quatro condições experimentais: (1) velocidade habitual, (2) velocidade máxima (comando verbal simples), (3) velocidade máxima (comando verbal modificado: pegar ônibus), (4) velocidade máxima (comando verbal + demonstração). Solicitou-se a cada participante que deambulasse três vezes em cada condição, e a média do tempo necessário para percorrer os 10 metros intermediários de um corredor de 14 metros foi utilizada para cálculo da velocidade (m/s). A ANOVA de medidas repetidas, com contrastes pré-planejados, foi utilizada para comparação dos dados (α=5%), sendo apresentados valores de média, desvio-padrão e intervalos de confiança (IC) de 95%. **Resultados:** As médias de velocidade para as quatro condições foram: (1) 0,74m/s; (2) 0,85m/s; (3) 0,93m/s; (4) 0,92m/s, respectivamente, apresentando diferenças significativas entre as condições (F=40,9; p<0,001). A velocidade de marcha habitual diferiu das demais condições, indicando que os indivíduos foram capazes de aumentar a velocidade quando solicitados. Foram observadas diferenças significativas entre a segunda condição, a terceira (p=0,002; IC95%=-0,13 a -0,03) e a quarta (p=0,004; IC95%=-0,12 a -0,02), sendo que as duas últimas condições não diferiram entre si (p=1,00; IC95%=-0,04 a 0,05). **Conclusões:** Os resultados indicaram que comandos verbais simples não foram suficientes para captar velocidade de marcha máxima em indivíduos com hemiparesia crônica. Assim, em situações em que seja necessária a avaliação de velocidade máxima, deve-se utilizar estratégia de comando verbal modificada ou associada à demonstração para garantir acurácia da informação.

Palavras-chave: mobilidade; acidente vascular encefálico; reforço verbal; fisioterapia.

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Introduction

Cerebrovascular accident (CVA) is described as a clinical syndrome due to a reduction of blood supply to brain structures and is considered one of the greatest public health problems and a major cause of disability in the world[1-4]. Although individuals after a CVA may show sensitive and cognitive impairments, the motor impairments which include muscular weakness, hypertonia, abnormal movement patterns and physical deconditioning are the most frequent[5]. Musculoskeletal disorders are considered important impairments in individuals with CVA and usually determine limitations in performing functional activities and activities of daily living, such as gait and stair ascent and descent[2].

Individuals with hemiparesis commonly exhibit biomechanical gait changes. In general, they demonstrate decreased speed and cadence, prolonged swing phase, reduced range of motion, impaired balance and inability to transfer the weight into their paretic lower limb[3,6,7]. In addition, difficulties to change speed, direction, duration and intensity of muscular activity, resulting in uncoordinated motion of the paretic limb have also been described[3,6].

Gait speed is a spatial-temporal parameter commonly deficient after a CVA and scientific evidence demonstrated considerable associations between this variable and those related to indicators of function and quality of life in this population[8,9]. Therefore, gait speed has been used as a reference for defining prognoses, levels of independence and efficacy of interventions[8]. Since it is a reliable, sensitive to changes and easy to apply, gait speed has been used in clinical[3,6] and research settings[10].

Although individuals suffering from a CVA demonstrate considerable difficulty in increasing gait speed, studies[9,11] have indicated that they are able to modify gait speed when requested or in certain daily life situations, such as running to reach a bus or picking up the phone. However, previous studies have evaluated comfortable and maximum gait speeds only using simple verbal command[9,10,12-14], which is defined as a sequence of words directed from the therapist to the participant to obtain a motor specific response[15,16].

A simple verbal command can be a facilitator to enable the emergence of different motor behaviors and variations imposed by the tone of voice can directly influence motor responses[17]. In certain situations, a verbal component may not be enough to inform a patient of a particular set of desired responses[15,17] and specifically, may not be able to properly target individuals with chronic hemiparesis to allow the emergence of the maximum gait speed supported by each patient's system. Thus, in order to improve the understanding of the provided instructions, it may be possible to add non-verbal components to the usual information[15,18].

The association of other components to the traditional verbal components of tasks commands has been used to improve the performance of individuals during walking tests or during evaluations of the paretic upper limb. Guyatt et al.[19] reported the effect of verbal encouragement commands during walking tests and found larger values of travelled distance when participants received verbal encouragement commands. Based on these results, they established specific guidelines for test performance. In evaluations of the paretic upper limb, in which the individuals should perform the proposed tasks in the shortest possible time[20,21], the demonstration of the activity in maximum speed by the therapist has been shown to be an efficient method to assess individuals' capacity[22]. Although commands with additional information appeared to facilitate the understanding and optimize motor performance during task execution, studies which evaluated the effects of different instructions for the assessment of maximum gait speed in individuals with hemiparesis were not found.

Therefore, the objective of this study was to evaluate the effects of different instructions for the assessment of gait speed during the 10-meter walking test with individuals with chronic hemiparesis. The clinical questions were:

1. Can individuals with chronic hemiparesis increase their usual gait speed when requested?
2. Does the association of new instructional components to simple verbal commands determine significant increase in maximum gait speed?
3. Which instructional component associated with simple verbal commands determines the largest increases in maximum gait speed?

Methods

Design

An experimental study was conducted at the Motion Analysis Laboratory at the Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil. Individuals with chronic hemiparesis were recruited from the general community through advertisements were included, according the following criteria: (1) clinical diagnoses of unilateral CVA greater than six months of onset with associated hemiparesis of the lower limb; (2) age equal or above 20 years; (3) the ability to walk 14 meters independently; (4) absence of significant cognitive impairments which were identified by the Mini Mental State Exam (MMSE)[23,24] and (5) the absence of any other neurological or orthopedic conditions not related to CVA. Individuals who were unable to understand or carry out the proposed tests were excluded from the study. All included participants

provided consent, which was approved by the Ethics Research Committee of the UFMG, Belo Horizonte, MG, Brazil (nº. ETIC 0538.0.203.000-09).

Instruments and measures

Gait speed was evaluated by the 10-meter walking test, following the criteria described by Salbach et al.[12]. The test was performed on a flat 14-meter corridor, and the time required to cover the 10 intermediate meters was registered with a digital stopwatch, with the two initial and final meters being disregarded. Chairs were used to demonstrate the beginning and the end of the path to offer a visual target to the participants. The different instructions for the completion of the test were always provided by the same examiner and are described below.

Procedures

All participants took part in an initial assessment for clinical and demographic data and for the verification of the inclusion/exclusion criteria. Following this initial assessment, they were invited to perform the 10-meter walking test in four different experimental conditions being the last two randomized: (1) comfortable gait speed - participants were asked to walk in their comfortable and habitual speeds; (2) maximum gait speed (simple verbal command) - participants were requested to walk as fast as possible and safely, but without running; (3) maximum gait speed (modified verbal command: reach a bus) - participants received verbal command to walk as fast as possible and safely, but without running, to reach a bus which was about to pull out and (4) maximum gait speed (verbal command + demonstration) – participants were oriented to walk as fast as possible and safely, but without running, as previously shown by the therapist. Participants were oriented to walk three times in each specific condition, with 20 second rest intervals between each measurement. The time required to cover the intermediate 10 meters of the 14-meter corridor was recorded and further used to calculate gait speed (m/s). Mean speeds between the three performed trials in each condition were calculated.

Statistical analyses

Descriptive statistics were used for characterization purposes regarding the main clinical and anthropometric variables. Tests for normality (Shapiro-Wilk) and homogeneity of variance (Levene) were applied to all outcome variables. Based upon the normal data distribution, a multifactorial analysis of variance for repeated measures (ANOVA) followed by planned contrasts was employed to investigate differences between the evaluated conditions. All analyses were performed using the SPSS statistical program for *Windows*, version 15.0 with a significance level of 5%. The results were shown as means, standard deviations and 95% confidence intervals (95%CI) for the comparison between the different experimental conditions.

Results

The sample included 14 individuals (10 men) with a mean age of 58±4.94 years and time post CVA of 102±76.90 months. Their clinical characteristics are described in Table 1.

The mean gait speed registered in each condition was: (1) comfortable speed: 0.74±0.23 m/s; (2) maximum speed (simple verbal command): 0.85±0.27 m/s; (3) maximum speed (modified verbal command: reach a bus): 0.93±0.30 m/s; (4) maximum speed (verbal command + demonstration): 0.92±0.30 m/s (F=40.9; GL=3; p<0.001). Pre-planned contrasts revealed that the comfortable speed differed from the other conditions, indicating that the individuals were able to increase gait speed when requested (p<0.001; CI 95% [-0.27 to -0.06]).

The simple verbal command demonstrated gait speed values significantly lower in relation to the modified command conditions, indicating that new instructions could be incorporated to the assessments of maximum gait speeds in individuals with chronic hemiparesis. The mean differences between conditions 2 and 3 were 0.08 m/s (p=0.002; CI 95% [-0.13 to -0.03]) and between conditions 2 and 4 were 0.07 m/s (p=0.004; CI 95% [-0.12 to -0.02]). No significant differences were observed between the two last conditions, indicating that both modified instructions could be used for the evaluation of maximum gait speed (0.01 m/s; p=1.000; CI 95% [-0.04 the 0.05]). The values obtained in each experimental condition are shown in Figure 1.

Table 1. Characteristics of the participants.

Outcome variable	Participants (n=14)
Age (*years*), mean (SD)	58 (4.9)
Gender, number of men (%)	10 (71)
MMSE (0-30), mean (SD)	26.8 (4.1)
Side of hemiparesis, number of right (%)	6 (43)
Fulg-Meyer (0-34), mean (SD)	22.5 (5.2)
Time since stroke (*months*), mean (SD)	102 (76.9)
Tonus- Modified Ashworth Scale (0-4)	1 = 36%
	1+ = 7%
	2 = 21%
	3 = 22%
	4 = 14%

SD=Standard deviation; MMSE=Mini Mental State Examination.

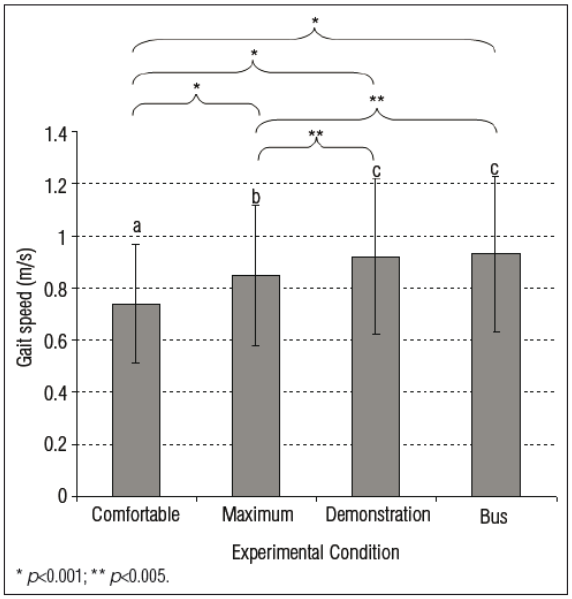

Figure 1. Mean and standard deviation of gait speed (m/s) for the four experimental conditions. For each column, different letters represent statistical significance between each condition.

Discussion

Measures of gait speed during short distances are often used as outcome measures in clinical practice and research to estimate the functional capacity and performance of individuals with CVA[8,12,25]. The clinical tests of gait speed are the most commonly administered and recommended for the evaluation of mobility of individuals post CVA, both in the community and in institutional settings, because they are easy to administrate, require no training or sophisticated equipments, and provide appropriate measures of mobility regarding the performance of daily living activities[26,27]. Furthermore, changes in gait speed are one of the main determining factors of functional improvements in this population and are significantly correlated with social and community performances of individuals with chronic hemiparesis[26,28].

The results of this study indicated that individuals with chronic hemiparesis were able to increase their comfortable gait speeds when asked to, suggesting that this ability is used in daily life situations which require immediate acceleration, such as walking quickly to reach a bus or get a phone call. These findings reinforce the importance of clinical evaluation of maximum gait speed in addition to the comfortable one. According to Perry et al.[8], from the maximum gait speed reached by these individuals, it is possible to estimate their levels of mobility and independence. For example, after three months of a CVA, the speed of 0.8 m/s suggests independent gait; values around 0.4 m/s indicate restricted mobility within the community and of 0.26 to 0.4 m/s, mobility restricted to home[8].

The maximum gait speed in this population is commonly evaluated by simple verbal commands provided by the therapist or the researcher during the test's instructions[9-13]. However, the non-employment of other incentive strategies to these simple verbal commands may underestimate the individuals' real capacities. The present findings indicated that the association of new instructional components to simple verbal commands determined significant increases in maximum gait speed. Thus, it is recommended that during clinical evaluations of maximum gait speed of individuals with chronic hemiparesis, the strategies of demonstration or modified verbal command (reach a bus) could be used to mimic the best performance of the individuals in their daily living situations.

Efforts have been made in an attempt to estimate the maximum gait speed in individuals with hemiparesis. Kollen, Kwakkel and Lindeman[9] suggested that, in the population of individuals post CVA, the maximum gait speed is 1.3 times greater than the comfortable ones after controlling for time, age, time since CVA onset and type of intervention to which the individual had been submitted. There is a concern in submitting individuals with hemiparesis to consecutive evaluations of gait speed related to the number of repetitions of the test to obtain valid and reliable measures, especially in relation to the maximal speed tests, which could lead to overload or put subjects at risk[29,30]. In this study, the mean of three repetitions were chosen for analyses, but current evidence[26] indicated that a single measure after a familiarization trial showed to be enough to capture real information concerning gait speed in clinical environment, without significant changes of the psychometric properties or measurement errors related to the evaluation. Thus, it is recommended, whenever possible, that clinical evaluations of maximum gait speed be performed instead of using estimates, because their use could provide different values for the actual gait speed. These findings reinforce the importance of establishing effective commands to allow the emergence of the maximum speed during the evaluations. The findings from this study showed that the use of the instructional modified components (reach a bus or demonstration) was able to determine significant increase in maximum gait speed of individuals with chronic hemiparesis, which was similar to the estimated values and facilitated the understanding and the specific actions of the activity.

Moreover, the results indicated important clinical implications related to gait training in this population, since it allows rehabilitation professionals to establish safe training goals in greater speeds, aiming for better preparation of individuals for the demands imposed by an independent lifestyle[9]. In

individuals with hemiparesis, training at speeds closer to the actual ones can provide increase in gait speeds, changes in kinematics and muscular activation patterns which could reflect into better social adaptation and independent community ambulation[11,31].

This study has some limitations related to the size and characteristics of the sample, which restrict the generalization of the results for the entire population of individuals with hemiparesis due to CVA. The findings from this study reflected the capacity of individuals with chronic hemiparesis with levels of motor recovery ranging between mild and moderate and without cognitive impairments. Therefore, future studies are needed to evaluate the effectiveness of the proposed commands for individuals in the acute phase or with more severe motor impairments. Other strategies may possibly be established for the evaluation of individuals with hemiparesis associated with cognitive impairments. Although the study provides information regarding the capacity of achieving maximum gait speed in a standardized research setting, other factors related to the natural characteristics of the environment could influence the performance of these individuals in their daily lives and should be investigated in future studies.

Conclusions

The results of this study indicated that individuals with chronic hemiparesis were able to increase gait speeds when requested. However, simple verbal commands were not sufficient to capture maximum gait speed in this population. Based upon these findings, during clinical trials or scientific research in which assessment of maximum gait speed is required, the strategy of modified verbal command or command associated with demonstration should be used to ensure accurate information. The proposed commands will allow therapists to establish training goals in higher but safe speeds, for motor and functional recovery of individuals with chronic hemiparesis.

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References

1. Royall College of Physicans. National clinical guidilines for stroke. Intercollegiate Stroke Working. 2ª ed. London; 2004.
2. Teixeira-Salmela LF, Oliveira ESG, Santana EGS, Resende GP. Fortalecimento muscular e condicionamento físico em hemiplégicos. Acta Fisiátrica. 2000;7(3):108-18.
3. Richards CL, Olney S. Hemiparetic gait following stroke. Part II: Recovery and physical therapy. Gait Posture. 1996;4(2):149-62.
4. Minelli C, Fen LF, Minelli DP. Stroke incidence, prognosis, 30-day, and 1-year case fatality rates in Matão, Brazil: a population-based prospective study. Stroke. 2007;38(11):2906-11.
5. Martins EF, De Sousa PH, De Araújo Barbosa PH, De Menezes LT, Souza Costa A. A Brazilian experience to describe functioning and disability profiles provided by combined use of ICD and ICF in chronic stroke patients at home-care. Desabil Rehabil. 2011;33(21-22):2064-74.
6. Olney S, Richards C. Hemiparetic gait following stroke. Part I: Characteristics. Gait Posture. 1996;4(2):136-48.
7. Trípoli F, Moreira SR, Oberg TD, Lima NMFV. Tarefas orientadas e biofeedback: efeitos na transferência de peso em hemiparéticos. Acta Fisiátrica. 2008;15(4):220-4.
8. Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke. 1995;26(6):982-9.
9. Kollen B, Kwakkel G, Lindeman E. hemiplegic gait after stroke: is measurement of maximum speed required? Arch Phys Med Rehabil. 2006;87(3):358-63.
10. Dobkin BH, Plummer-D'Amato P, Elashoff R, Lee J; SIRROWS Group. Internacional randomized clinical trial, stroke inpatient rehabilitation with reinforcement of walking speed (SIRROWS), improves outcomes. Neurorehabil Neural Repair. 2010;24(3):235-42.
11. Lamontagne A, Fung J. Faster is better: implications for speed-intensive gait training after stroke. Stroke. 2004;35(11):2543-8.
12. Salbach NM, Mayo NF, Higgins J, Ahmed S, Finch LE, Richards CL. Responsiveness and predictability of gait speed and other disability measures in acute stroke. Arch Phys Med Rehabil. 2001;82(9):1204-12.
13. Dean CM, Richards CL, Malouin F. Walking speed over 10 metres overestimates locomotor capacity after stroke. Clin Rehabil. 2001;15(4):415-21.
14. Duncan PW, Sullivan KJ, Behrman AL, Azen SP, Wu SS, Nadeau SE, et al. Protocol for the locomotor experience applied post-stroke (LEAPS) trial: a rondomized controlled trial. BMC Neurol. 2007;7:39.
15. Galdino LACS, Varise EM. Os efeitos do comando verbal na reabilitação física. Rev Neurociênc. 2010;18(1):95-102.
16. Cantagallo A, Spinazzola L, Rabuffetti M, Della Sala S. Verbal commands help the execution of endogenous movements in anarchic hand. Neuropsychol Rehabil. 2010;20(3):406-22.
17. Carr JH, Shepherd RB. The changing face of neurological rehabilitation. Rev Bras Fisioter. 2006;10(2):147-56.
18. Haguenauer M, Fargier P, Legreneur P, Dufour AB, Cogerino G, Begon M, et al. Short-term effects of using verbal instructions and demonstration at the beginning of learning a complex skill in figure skating. Percept Mot Skills. 2005;100(1):179-91.
19. Guyatt GH, Pugsley SO, Sullivan MJ, Thompson PJ, Berman L, Jones NL, et al. Effect of encouragement on walking test performance. Thorax. 1984;39(11):818-22.
20. Wolf SL, Catlin PA, Ellis M, Archer AL, Morgan B, Piacentino A. Assessing Wolf Motor Function Test as outcome measure for research in patients after stroke. Stroke. 2001;32(7):1635-9.
21. Faria-Fortini I, Michaelsen SM, Cassiano JG, Teixeira-Salmela LF. Upper extremity function in stroke subjects: relationships between the international classification of functioning, disability, and health domains. J Hand Ther. 2011;24(3):257-64.
22. Pereira ND, Michaelsen SM, Menezes IS, Ovando AC, Lima RCM, Teixeira-Salmela LF. Confiabilidade da versão brasileira do Wolf Motor Function Test em adultos com hemiparesia. Rev Bras Fisioter. 2011;15(3):257-65.
23. Bertolucci PHF, Brucki SMD, Campacci SR, Juliano Y. O Mini-Exame do Estado Mental em uma população geral: impacto da escolaridade. Arq Neuropsiquiatr. 1994;52(1):1-7.
24. Brucki SMD, Nitrini R, Caramelli P, Bertolucci PHF, Okamoto IH. Sugestões para o uso do Mini-Exame do Estado Mental no Brasil. Arq Neuropsiquiatr. 2003;61(3B):777-81.
25. Browden MG, Balasubramanian CK, Behrman AL, Kautz SA. Validation of a speed-based classification system using quantitative measures of walking performance poststroke. Neurorehabil Neural Repair. 2008;22(6):672-5.

26. Faria CD, Teixeira-Salmela LF, Neto MG, Rodrigues-de-Paula F. Performance-based tests in subjects with stroke: outcome scores, reliability and measurement errors. Clin Rehabil. 2011;[Epub ahead of print].

27. Jørgensen HS, Nakayama H, Raaschou HO, Olsen TS. Recovery of walking function in stroke patients: the Copenhagen Stroke Study. Arch Phys Med Rehabil. 1995;76(1):27-32.

28. Alzahrani M, Dean C, Ada L. Relationship between walking performance and types of community-based activities in people with stroke: an observational study. Rev Bras Fisioter. 2011;15(1):45-51.

29. Nadeau S, Arsenault AB, Gravel D, Bourbonnais D. Analysis of the clinical factors determining natural and maximal gait speeds in adults with a stroke. Am J Phys Med Rehabil. 1999;78(2):123-30.

30. Bohannon RW. Walking after stroke: comfortable versus maximum safe speed. Int J Rehabil Res. 1992;15(3):246-8.

31. Nascimento LR, Resende RA, Polese JC, Magalhães FAB, Teixeira-Salmela LF. Evidências sobre o efeito do fortalecimento muscular no desempenho motor e funcional de hemiparéticos crônicos: uma revisão sistemática. Ter Man. 2010;8(39):448-53.

ANEXO D

Treadmill training is effective for ambulatory adults with stroke: a systematic review

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Question: Does mechanically assisted walking increase walking speed or distance in ambulatory people with stroke compared with no intervention/non-walking intervention, or with overground walking? **Design**: Systematic review with meta-analysis of randomised trials. **Participants**: Ambulatory adults with stroke. **Intervention**: Mechanically assisted walking (treadmill or gait trainer) without body weight support. **Outcome measures**: Walking speed measured in m/s during the 10-m Walk Test and walking distance measured in m during the 6-min Walk Test. **Results**: Nine studies of treadmill training comprising 977 participants were included. Treadmill training resulted in faster walking than no intervention/non-walking intervention immediately after the intervention period (MD 0.14 m/s, 95% CI 0.09 to 0.19) and this was maintained beyond the intervention period (MD –0.12 m/s, 95% CI 0.08 to 0.17). It also resulted in greater walking distance immediately after the intervention period (MD 40 m, 95% CI 27 to 53) and this was also maintained beyond the intervention period (MD 40 m, 95% CI 24 to 55). There was no immediate, statistically significant difference between treadmill training and overground training in terms of walking speed (MD 0.05 m/s, 95% CI 0.12 to 0.21) or distance (MD –6 m, 95% CI –45 to 33). **Conclusion**: This systematic review provides evidence that, for people with stroke who can walk, treadmill training without body weight support results in faster walking speed and greater distance than no intervention/non-walking intervention and the benefit is maintained beyond the training period. **Review registration**: PROSPERO (CRD 42012002622). **[Polese JC, Ada L, Dean CM, Nascimento LR, Teixeira-Salmela LF (2013) Treadmill training is effective for ambulatory adults with stroke: a systematic review. *Journal of Physiotherapy* 59: 73–80]**

Key words: Stroke, Treadmill, Walking, Systematic review, Meta-analysis, Randomised controlled trials

Introduction

Although the majority of individuals achieve an independent gait after stroke, many do not reach a walking level that enables them to perform all their daily activities (Flansbjer et al 2005). Typically, the mean walking speed for the majority of community-dwelling people after stroke ranges from 0.4 m/s to 0.8 m/s (Duncan et al 1998, Eng et al 2002, Green et al 2002, Pohl et al 2002, Ada et al 2003). This slow speed frequently prevents their full participation in community activities. Additionally, people report a lack of ability to cover long distances after stroke, restricting their participation in work and social activities (Combs et al 2012). Moreover, walking ability has been found to be related to community participation (Robinson 2011).

While the goal of inpatient rehabilitation is independent and safe ambulation, once individuals return home, rehabilitation aims to enhance community ambulation skills by increasing walking speed and endurance. Lord et al (2004) found that the ability to confidently negotiate uneven terrain, private venues, malls and other public venues is the most relevant predictor of community ambulation. Therefore, in order to enhance community participation, rehabilitation has focused on identifying the best approach to optimise walking speed and walking distance. One approach to improving gait is the use of mechanically assisted walking devices, such as treadmills or gait trainers. Two Cochrane systematic reviews have examined these devices separately: Moseley et al (2005) reported on treadmill training and Mehrholz (2010) examined electromechanically-assisted training. We wanted to examine all devices that will help improve walking in the one review. In ambulatory stroke, mechanically assisted walking, whether by treadmills or gait trainers, allows an intensive amount of stepping practice by working as a 'forced use'. Mechanically assisted walking also facilitates the practice of a more normal walking pattern because it forces appropriate timing between lower limbs, promotes hip extension during the stance phase of walking and discourages common compensatory behaviours such as circumduction (Harris-Love et al 2001, Ada et al 2003, Moore et al 2010). We have already taken this approach in

What is already known on this topic: Mechanically assisted walking training, which can involve interventions such as treadmill training or electromechanical gait trainers, increases independent walking among people who have been unable to walk after stroke. However, previous systematic reviews have not drawn clear conclusions about the effect of treadmill training or gait trainers among ambulatory stroke survivors specifically.

What this study adds: Compared with no intervention or with an intervention with no walking training component, treadmill training improved walking speed and distance among ambulatory people after stroke. These benefits were maintained beyond the intervention period, but may not be greater than the effects of overground walking training.

relation to non-ambulatory stroke, where our systematic review demonstrated that mechanically assisted walking results in more independent walking (Ada et al 2010).

Therefore, this systematic review focuses on the efficacy of mechanically assisted walking for improving walking speed and distance in ambulatory people with stroke. Comparisons between mechanically assisted walking and overground walking were also examined in order to assist clinicians to decide the most appropriate intervention for adults with stroke. The specific research questions for this review were, in ambulatory people after stroke:

1. Does mechanically assisted walking result in immediate improvements in walking speed and distance compared with no intervention or a non-walking intervention?
2. Does it result in immediate improvements in walking speed and distance compared with overground walking?
3. Are any benefits maintained beyond the intervention period?

In order to make recommendations based on the highest level of evidence, this review included only randomised or quasi-randomised trials.

Box 1. Inclusion criteria.

Design
- Randomised or quasi-randomised trial

Participants
- Adults (> 18 yr)
- Stroke (> 24 hr)
- Ambulatory (Functional Ambulatory Category ≥ 3, walking speed ≥ 0.2 m/s at baseline or when the inclusion criteria stated 'able to walk without help, with or without walking aids' or, where mixed participants, data for ambulatory participants reported separately.)

Interventions
- Experimental. Mechanically assisted walking training (eg, treadmill training or a gait trainer) without body weight support
- Control. No intervention/non-walking intervention, or overground walking

Outcomes measured
- Walking speed
- Walking distance

Method

Identification and selection of studies

Searches for relevant studies were conducted of the following databases: Medline (1946 to April Week 1 2012, CINAHL (1986 to April Week 1 2012), EMBASE (1980 to April Week 1 2012) and PEDro (to April Week 1 2012), without language or date restrictions. Search terms included words relating to stroke, mechanically assisted walking, and locomotion (see Appendix 1 on the eAddenda for the full search strategy). In addition, we contacted authors about trials that we knew were in progress from trial registration. Titles and abstracts were displayed and screened by one reviewer to identify relevant studies. Only peer-reviewed papers were included. Full paper copies of relevant studies were retrieved and hand searching of reference lists was carried out to identify further relevant studies. The methods and abstracts of the retrieved papers were extracted so that reviewers were blinded to authors, journal, and outcomes. Two independent reviewers examined the papers for inclusion against predetermined criteria (Box 1). Conflict was resolved after discussion with a third reviewer.

Assessment of characteristics of studies

Quality: The quality of included studies was determined using PEDro scale scores extracted from the Physiotherapy Evidence Database (www.pedro.org.au). The PEDro scale rates the methodological quality of randomised trials with a score between 0 and 10 (Maher et al 2003). Where a study was not included on the PEDro database, it was scored by a reviewer following the PEDro guidelines.

Participants: Participants had to be ambulatory adults in the subacute or chronic phase after stroke. *Ambulatory* was defined as a score of at least 3 on the Functional Ambulatory Category (Holden et al 1984) or a walking speed of at least 0.2 m/s at baseline or when the included participants were able to walk without help, with or without walking aids. Studies were included when at least 80% of sample comprised ambulatory participants. Number of participants, age, time since stroke, and baseline walking speed were recorded to assess the similarity of the studies.

Intervention: The experimental intervention was mechanically assisted walking training, such as treadmill or gait trainer *without* body weight support because the participants were able to walk *a priori*. The control intervention was defined as no intervention or an intervention that did not involve walking training, ie, non-walking intervention. The experimental intervention was also compared with overground training. Session duration, session frequency, and program duration were recorded in order to assess the similarity of the studies.

Outcome measures: Two walking outcomes were of interest – speed (typically measured using 10-m Walk Test) and distance (typically measured using 6-min Walk Test). The timing of the measurements of outcomes and the procedure used to measure walking speed and distance were recorded in order to assess the similarity of the studies.

Data analysis

Data were extracted from the included studies by a reviewer and cross checked by another reviewer. Information about the method (ie, design, participants, intervention, outcome measures) and outcome data (ie, mean (SD) walking speed and walking distance) were extracted. Authors were contacted where there was difficulty with data.

The post-intervention scores were used to obtain the pooled estimate of the effect of intervention immediately (ie, post intervention) and beyond the intervention period (ie, after a period of no intervention). A fixed effects model was used. In the case of significant statistical heterogeneity ($I^2 > 50\%$), a random effects model was applied to check the robustness of the results. The analyses were performed using The MIX–Meta-Analysis Made Easy program[a] (Bax et al 2006, Bax et al 2009). The pooled data for each outcome were reported as the weighted mean difference (MD) (95% CI).

Results

Flow of studies through the review

The search returned 5305 studies. After screening the titles, abstracts and reference lists, 65 papers were retrieved for evaluation of full text. Fifty-six papers failed to meet the inclusion criteria and therefore nine papers (Pohl et al 2002, Ada et al 2003, Eich et al 2004, Weng et al 2006, Langhammer and Stanghelle 2010, Ivey et al 2011, Kuys et al 2011, Olawale et al 2011, Ada et al 2013) were included in the review. See Appendix 2 on the eAddenda for a summary of the excluded papers. Figure 1 outlines the flow of studies through the review.

Description of studies

Six randomised trials investigated the effect of mechanically assisted walking training on walking speed and walking distance, two on walking speed, and one on walking distance. The quality of the included studies is outlined in Table 1 and a summary of the studies is presented in Table 2.

Quality: The mean PEDro score of the included studies was 6.7. Randomisation was carried out in 100% of the studies, concealed allocation in 67%, assessor blinding in 67%, and intention-to-treat analysis in 44%. No studies blinded participants or therapists, due to the inherent difficulties associated with blinding physical interventions.

Participants: The mean age of participants across the studies ranged from 50 to 74 years. The mean time after stroke ranged from 1.6 to 27 months, and one study did not report this information. Participants were recruited from people living in the community in 55% of the trials.

Intervention: In all studies, the experimental group received treadmill training without body weight support. Participants undertook training for 25 to 40 min, 3–5/wk, for 2.5 to 26 wk. The control group received no intervention (three studies), a non-walking intervention (four studies), or overground walking (three studies).

Outcome measures: Walking speed was measured using the 10-m Walk Test (eight studies) and results were converted to m/s. Walking distance was measured using the 6-min Walk Test (seven studies) and results were converted to m.

Effect of intervention

Walking speed: The immediate effect of treadmill training versus no intervention or a non-walking intervention on walking speed was examined by pooling data from seven studies (Ada et al 2003, Eich et al 2004, Weng et al 2006, Ivey et al 2011, Kuys et al 2011, Olawale et al 2011, Ada et al 2013) involving 275 participants. Treadmill training increased walking speed 0.14 m/s (95% CI 0.09 to 0.19) more than no intervention/non-walking intervention (Figure 2a, see Figure 3a on the eAddenda for the detailed forest plot). The effect of treadmill training beyond the intervention period compared with no intervention/non-walking intervention on walking speed was examined by pooling data from four studies (Ada et al 2003, Eich et al 2004, Kuys et al 2011, Ada et al 2013) involving 167 participants. Treadmill training increased walking speed 0.12 m/s (95% CI 0.08 to 0.17) more than no intervention/non-walking intervention (Figure 2b, see Figure 3b on the eAddenda for the detailed forest plot).

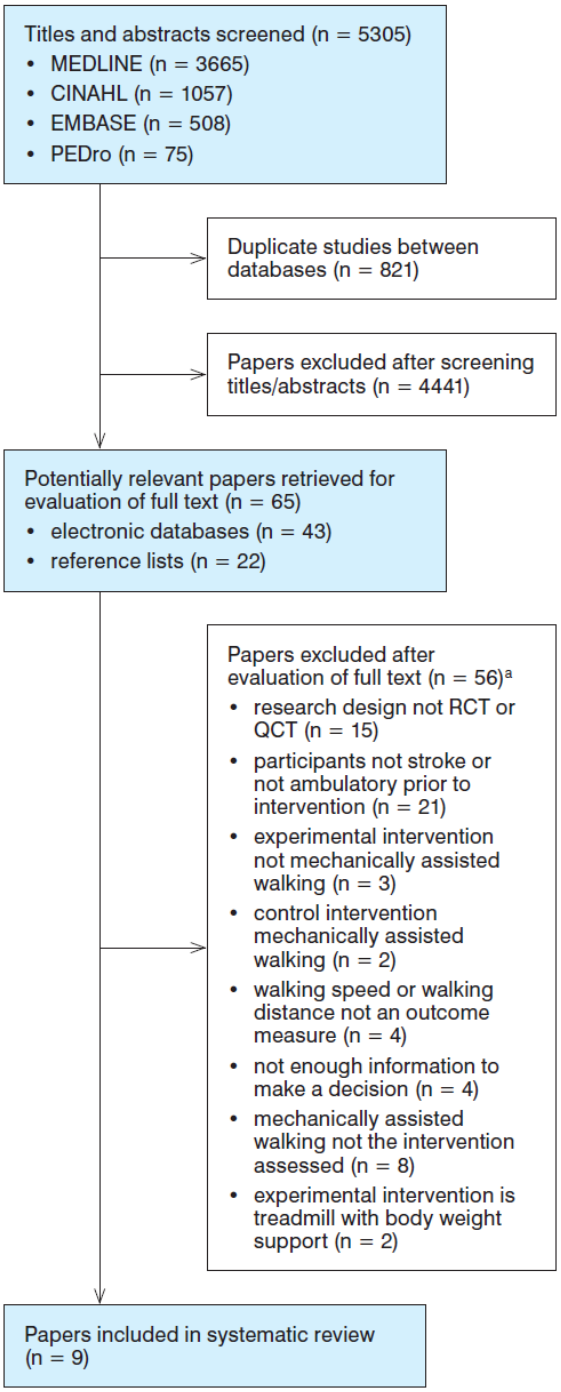

Figure 1. Flow of studies through the review. [a]Papers may have been excluded for failing to meet more than one inclusion criterion. RCT = randomised clinical trial, QCT = quasi-randomised clinical trial.

Table 1. PEDro criteria and scores for included studies (n = 9).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0 to 10)
Ada et al 2003	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Ada et al 2013	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Eich et al 2004	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Ivey et al 2011	Y	N	Y	N	N	N	Y	N	Y	Y	5
Kuys et al 2011	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Langhammer & Stanghelle 2010	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Olawale et al 2011	Y	N	Y	N	N	N	Y	N	N	Y	4
Pohl et al 2002	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Weng et al 2006	Y	Y	Y	N	N	N	Y	N	Y	Y	6

Y = yes, N = no

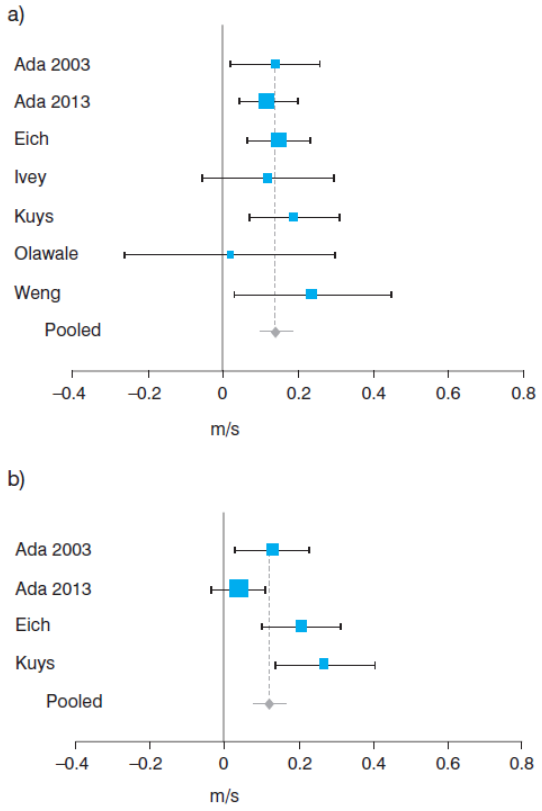

Figure 2. Mean difference (95% CI) of effect of treadmill training versus no intervention or a non-walking intervention for walking speed (m/s) a) immediately after the intervention period (n = 275) and b) beyond the intervention period (n = 167).

The immediate effect of treadmill versus overground training on walking speed was examined by pooling data from three studies (Pohl et al 2002, Langhammer and Stanghelle 2010, Olawale et al 2011) involving 119 participants. There was no significant difference in walking speed between treadmill training and overground training (MD 0.05 m/s, 95% CI –0.12 to 0.21) (Figure 4, see Figure 5 on the eAddenda for a detailed forest plot). No studies measured the effect of treadmill training versus overground walking on walking speed beyond the intervention period.

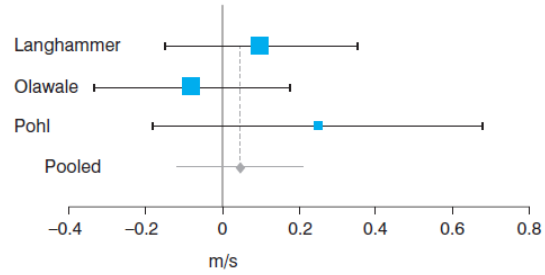

Figure 4. Mean difference (95% CI) of effect of treadmill training versus overground for walking speed (m/s) immediately after the intervention period (n = 119).

Table 2. Summary of included studies (n = 9).

Study	Design	Participants	Intervention	Outcome measures
Ada et al 2003	RCT	n = 29 Age (yr) = 66 (SD 12) Time since stroke (months) = 27 WS = Exp: 0.62 (SD 0.24); Con: 0.53 (SD 0.30)	Exp = TM 30 min x 3/wk x 4 wk Con = NW (strength, co-ord, balance) 30 min x 3/wk x 4 wk	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 4, 16 wk
Ada et al 2013	RCT	n = 102 Age (yr) = 67 (SD 12) Time since stroke (months) = 21 WS = Exp1: 0.51 (SD 0.27); Exp2: 0.49 (SD 0.29); Con: 0.50 (SD 0.24)	Exp = TM 30 min x 3/wk x 8 wk Con = no intervention	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 16, 26 wk
Eich et al 2004	RCT	n = 50 Age (yr) = 63 (SD 5) Time since stroke (months) = 1.6 WS = Exp: 0.40 (SD 0.17); Con: 0.44 (SD 0.22)	Exp = TM 30 min x 5/wk x 6 wk Con = no intervention Both = OG 30 min x 5/wk x 6 wk	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 6, 18 wk
Ivey et al 2011	RCT	n = 38 Age = 61 (SD 9) Time since stroke (months) = not reported WS = Exp: 0.54 (SD 0.27); Con: 0.49 SD (0.27)	Exp = TM 40 min x 3/wk x 26 wk Con = NW (stretch) 40 min x 3/wk x 26 wk	Distance = 6-min walk test Timing: 0, 26 wk
Kuys et al 2011	RCT	n = 30 Age (yr) = 68 (SD16) Time since stroke (months) = 1.7 WS = Exp: 0.34 (SD 0.20); Con: 0.58 (SD 0.36)	Exp = TM 30 min x 3/wk x 6 wk Con = no intervention Both = usual care 60 min x 3/wk x 6 wk	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 6, 18 wk
Langhammer and Stanghelle 2010	RCT	n = 39 Age (yr) = 74 (SD 12) Time since stroke (months) = 12 WS = Exp: 0.8 (SD 0.5); Con: 0.8 (SD 0.4)	Exp = TM 30 min x 5/wk x 2.5 wk Con = OG 30 min x 5/wk x 2.5 wk Both = usual care 170 min x 5/wk x 2.5 wk	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 2.5 wk
Olawale et al 2011	RCT	n = 60 Age (yr) = 56 (SD 6) Time since stroke (months) = 10 WS = Exp1: 0.36 (SD 0.95); Exp2: 0.39 (SD 1.19); Con: 0.39 (SD 0.90)	Exp = TM 25 min x 3/wk x 12 wk Con1 = OG 25 min x 3/wk x 12 wk Con2 = NW (stretch, strength, balance) 25 min x 3/wk x 12 wk All = usual care 35 min x 3/wk x 12 wk	Speed = 10-m walk test Distance = 6-min walk test Timing: 0, 12 wk
Pohl et al 2002	RCT	n = 60 Age (yr) = 59 (SD 11) Time since stroke (months) = 4 WS = Exp: 0.61 (SD 0.32); Con: 0.66 (SD 0.42)	Exp = TM 30 min x 3/wk x 4 wk Con = OG 45 min x 2/wk x 4 wk Both = usual care 45 min x 2/wk x 4 wk	Speed = 10-m walk test Timing: 0, 4 wk
Weng et al 2006	RCT	n = 26 Age (yr) = 50 (SD 13) Time since stroke (months) = 2 WS = Exp: 0.53 (SD 0.33); Con: 0.55 (SD 0.28)	Exp = TM 30 min x 5/wk x 3 wk Con = NW (exercise, stepping) 30 min x 5/wk x 3 wk Both = usual care 30 min x 5/wk x 3 wk	Speed = 10-m walk test Timing: 0, 3 wk

RCT= randomised controlled trial, WS = walk speed at baseline (m/s), Exp = experimental group, Con = control group, TM = treadmill walking, OG = overground walking, NW = non-walking intervention.

Walking distance: The immediate effect of treadmill training versus no intervention or a non-walking intervention on walking distance was examined by pooling data from six studies (Ada et al 2003, Eich et al 2004, Ivey et al 2011, Kuys et al 2011, Olawale et al 2011, Ada et al 2013) involving 249 participants. Treadmill training increased walking distance 40 m (95% CI 27 to 53) more than no intervention/non-walking intervention (Figure 6a, see Figure 7a on the eAddenda for the detailed forest plot). The effect of treadmill training versus no intervention/non-walking intervention on walking distance beyond the intervention period was examined by pooling data from four studies (Ada et al 2003, Eich et al 2004, Kuys et al 2011, Ada et al 2013) involving 167 participants. Treadmill training increased walking distance 40 m (95% CI 24 to 55) more than no intervention/non-walking intervention (Figure 6b, see Figure 7b on the eAddenda for the detailed forest plot).

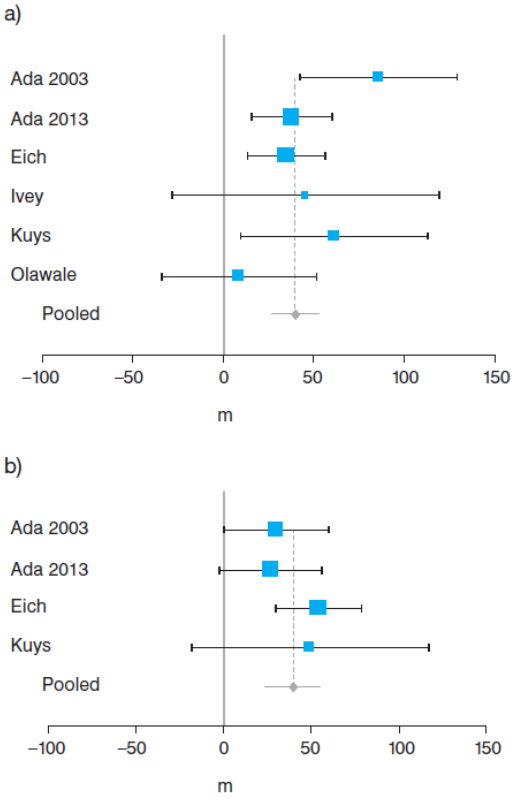

Figure 6. Mean difference (95% CI) of effect of treadmill training versus no intervention/non-walking intervention for walking distance (m) a) immediately after the intervention period (n = 249) and b) beyond the intervention period (n = 167).

The immediate effect of treadmill training versus overground on walking distance was examined by pooling data from two studies (Langhammer and Stanghelle 2010, Olawale et al 2011) involving 79 participants. There was no statistical difference in walking distance between treadmill training and overground training (MD −6 m, 95% CI −45 to 33) (Figure 8, see Figure 9 on the eAddenda for the detailed forest plot). No studies measured the effect of treadmill training versus overground walking on walking distance beyond the intervention period.

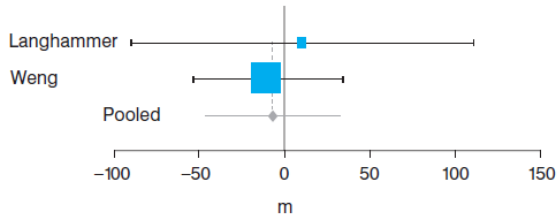

Figure 8. Mean difference (95% CI) of effect of treadmill training versus overground for walking distance (m) immediately after the intervention period (n = 79).

Discussion

This review provides evidence that treadmill training without body weight support is effective at improving walking in people who are ambulatory after stroke. Furthermore, the benefits appear to be maintained beyond the intervention period. However, whether treadmill training is more beneficial than overground training is not known.

Meta-analysis indicated that treadmill training produced benefits in terms of both walking speed and distance. Treadmill training produced 0.14 m/s faster walking and 40 m greater distance than no intervention/non-walking intervention immediately after intervention and these benefits were maintained beyond the intervention period. This effect is likely to be a conservative estimate of the effect of treadmill training, since some of the non-walking interventions given to the control group (such as strengthening) may have had some effect on walking. Importantly, these benefits appear to be clinically meaningful. For example, Tilson et al (2010) demonstrated that a between-group difference in walking speed after stroke of 0.16 m/s resulted in a 1-point improvement in the modified Rankin scale. Furthermore, there is no indication that the effect of treadmill training is different when carried out with subacute stroke undergoing hospital-based rehabilitation or with chronic stroke after discharge from formal rehabilitation. This may be because the length and frequency of treadmill training sessions delivered was similar across studies (mean length 30 min, SD 4; mean frequency 4/wk, SD 1) despite the variation in duration of training program (mean duration 9 wk, SD 7).

There are insufficient data to provide evidence as to whether treadmill training is better than overground training. Only three studies (Pohl et al 2002, Langhammer and Stanghelle 2010, Olawale et al 2011) investigating this question were found. Meta-analysis indicates no significant difference between treadmill training and overground training for both walking speed and distance. However, the confidence intervals are wide and include worthwhile effects in both cases, suggesting that further studies are necessary to answer this question.

Although we sought trials of any type of mechanically assisted walking training, all of the studies included in this review examined treadmill training. A previous Cochrane systematic review of treadmill training (Moseley et al 2005)

concluded that it did not have a statistically significant effect on walking speed (three studies) or distance (one study) compared with any other physiotherapy intervention in people who could already walk after stroke. Neither did treadmill training have a statistically significant effect on walking speed or distance when combined with other task-specific training (three studies). The inclusion of nine studies in the current meta-analysis is probably the main reason that our review came to a different conclusion.

This review has both limitations and strengths. A source of bias in the studies included in this review was lack of blinding of therapist and patients, since it is not possible to blind the therapist or the participants during the delivery of complex interventions. Another source of bias was lack of reporting whether an intention-to-treat analysis was undertaken. The number of participants per group (mean 21, SD 7.5) was quite low, opening the results to small trial bias. Only four of the nine included studies measured the outcomes after the cessation of intervention, which meant that the maintenance of the effect of intervention could not be evaluated well. In spite of these shortcomings, the mean PEDro score of 6.7 for the trials included in this review represents high quality. Another strength, unusual in rehabilitation studies, was that the outcome measures were the same, with walking speed always measured using the 10-m Walk Test and walking distance measured using the 6-min Walk Test. Finally, publication bias inherent to systematic reviews was avoided by including studies published in languages other than English.

This systematic review provides evidence that treadmill training without body weight support results in faster walking speed and greater distance than no intervention/non-walking intervention, both immediately after intervention and beyond the intervention period. Clinicians should therefore be confident in prescribing treadmill training for ambulatory stroke individuals when the primary objective of rehabilitation is to improve walking speed and distance, regardless of whether the individuals are at the subacute or chronic stage of their recovery. The parameters of gait training, such as speed, duration, and treadmill inclination, can be tailored to individuals to ensure training is challenging and to provide motivating feedback about the distance walked and the amount of work performed. ■

Footnotes: [a]The MIX–Meta-Analysis Made Easy program Version 1.7. http://www.meta-analysis-made-easy.com/

eAddenda: Appendix 1 and 2, and Figures 3a and 3b, 5, 7a and 7b, and 9, available at jop.physiotherapy.asn.au

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References

Ada L, Dean CM, Hall JM, Bampton J, Crompton S (2003) A treadmill and overground walking program improves walking in persons residing in the community after stroke: a placebo-controlled, randomised trial. *Archives of Physical Medicine & Rehabilitation*. 84: 1486–1491.

Ada L, Dean CM, Lindley R (2013) Randomized trial of treadmill training to improve walking in community-dwelling people after stroke: the AMBULATE trial. *International Journal of Stroke* doi: 10.1111/j.1747-4949.2012.00934.x.

Ada L, Dean CM, Vargas J, Ennis S (2010) Mechanically assisted walking with body weight support results in more independent walking than assisted overground walking in non-ambulatory patients early after stroke: a systematic review. *Journal of Physiotherapy* 56: 153–161.

Bax L, Yu LM, Ikeda N, Tsuruta H, Moons KG (2006) Development and validation of MIX: comprehensive free software for meta-analysis of causal research data. *BMC Medical Research Methodology* 13: 50.

Bax L, Ikeda N, Fukui N, Yaju Y, Tsuruta H, Moons KG (2009) More than numbers: the power of graphs in meta-analysis. *American Journal of Epidemiology* 169: 249–255.

Combs SA, Van Puymbroeck M, Altenburger PA, Miller KK, Dierks TA, Schmid AA (2012) Is walking faster or walking farther more important to persons with chronic stroke? *Disability & Rehabilitation* 5. [Epub ahead of print]

Duncan P, Richards L, Wallace D, Stoker-Yates J, Pohl P, Luchies C, et al (1998) A randomised, controlled pilot study of a home-based exercise program for individuals with mild and moderate stroke. *Stroke* 29: 2055–2060.

Eich HJ, Mach H, Werner C, Hesse S (2004) Aerobic treadmill plus Bobath walking training improves walking in subacute stroke: a randomised controlled trial. *Clinical Rehabilitation* 18: 640–651.

Eng JJ, Chu KS, Dawson AS, Kim MC, Hepburn KE (2002) Functional walk tests in individuals with stroke: relation to perceived exertion and myocardial exertion. *Stroke* 33: 756–761.

Flansbjer UB, Holmbäck AM, Downham D, Patten C, Lexell J (2005) Reliability of gait performance tests in men and women with hemiparesis after stroke. *Journal of Rehabilitation Medicine* 37: 75–82.

Green J, Forster A, Bogle S, Young J (2002) Physiotherapy for patients with mobility problems more than 1 year after stroke: a randomised controlled trial. *Lancet* 359: 199–203.

Harris-Love ML, Forrester LW, Macko RF, Silver KH, Smith GV (2001) Hemiparetic gait parameters in overground versus treadmill walking. *Neurorehablitation and Neural Repair* 15: 105–112.

Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L (1984) Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. *Physical Therapy* 64: 35–40.

Ivey FM, Ryan AS, Hafer-Macko CE, Macko RF (2011) Improved cerebral vasomotor reactivity after exercise training in hemiparetic stroke survivors. *Stroke* 42: 1994–2000.

Kuys SS, Brauer SG, Ada L (2011) Higher-intensity treadmill walking during rehabilitation after stroke is feasible and not detrimental to walking pattern or quality: a pilot randomised trial. *Clinical Rehabilitation* 25: 316–326.

Langhammer B, Stanghelle JK (2010) Exercise on a treadmill or walking outdoors? A randomised controlled trial comparing effectiveness of two walking exercise programmes late after stroke. *Clinical Rehabilitation* 24: 46–54.

Lord SE, McPherson KM, McNaugton HK, Rochester L, Weatherall M (2004) Community ambulation following stroke: how important and obtainable is it, and what

measures appear predictive? *Archives of Physical Medicine & Rehabilitation* 85: 234–239.

Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M (2003) Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy* 83: 713-721.

Mehrholz J, Werner C, Kugler J, Pohl M (2010) Electromechanical-assisted training for walking after stroke. *Cochrane Database of Systematic Reviews* 4: CD006185.

Moore JL, Roth EJ, Killian C, Hornby TG (2010) Locomotor training improves daily stepping activity and gait efficiency in individuals poststroke who have reached a 'plateau' in recovery. *Stroke* 41: 129–135.

Moseley AM, Stark A, Cameron ID, Pollock A (2005) Treadmill training and body weight support for walking after stroke. *Cochrane Database of Systematic Reviews* 4: CD002840.

Olawale OA, Jaja SI, Anigbogu CN, Appiah-Kubi KO, Jones-Okai D (2011) Exercise training improves walking function in an African group of stroke survivors: a randomised controlled trial. *Clinical Rehabilitation* 25: 442–450.

Pohl M, Mehrholz J, Ritschel C, Rückriem S (2002) Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomised controlled trial. *Stroke.* 33: 553–558.

Robinson CA, Shumway-Cook A, Matsuda PN, Ciol MA (2011) Understanding physical factors associated with participation in community ambulation following stroke. *Disability & Rehabilitation.* 33: 1033–1042.

Tilson JK, Sullivan KJ, Cen SY, Rose DK, Koradia CH, Azen SP, et al (2010) Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically important difference. *Physical Therapy* 90: 196–208.

Weng CS, Wang J, Pan XY, Yu ZZ, Wang G, Gao LP, et al (2006) [Effectiveness of backward walking treadmill training in lower extremity function after stroke]. *Zhonghua Yi Xue Za Zhi* 86: 2635–2638.

ANEXO E

Aprovação do projeto pelo Comitê de Ética em Pesquisa

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Parecer nº. ETIC 0538.0.203.000-09

Interessado(a): Profa. Luci Fuscaldi Teixeira-Salmela
Departamento de Fisioterapia
EEFFTO - UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 02 de dezembro de 2009, o projeto de pesquisa intitulado **"Influência do uso de dispositivos auxiliares em variáveis cinéticas, cinemáticas e espaço-temporais da marcha de hemiparéticos crônicos"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

APÊNDICE A

Quadro: Intervenções para melhora de força muscular e marcha pós-AVE: nível de evidência prévio, atualizações e perspectivas futuras.

Incapacidade	Intervenção	Nível	Evidências Utilizadas	Atualizações e Perspectivas Futuras
Fraqueza muscular	Biofeedback por EMG	C	Uma revisão sistemática não-específica (2 ECA), sem benefício de meta-análise.	Limitado número de ensaios clínicos para permitir atualizações; Foco em *biofeedback* para melhora de atividade.
	Exercícios de resistência	B	Três revisões sistemáticas apresentando resultados com tamanho de efeito pequeno-moderado, e heterogeneidade entre estudos.	Incentivo à condução de ensaios clínicos com maior homogeneidade nos critérios de intervenção e seleção dos participantes.
	Eletroestimulação	B	Uma revisão sistemática não-específica (11 ECA ou ECC). Dois tipos de eletroestimulação (cíclica e funcional), sem benefício de meta-análise.	**Revisão sistemática com meta-análise sobre eletroestimulação cíclica como parte do projeto dessa tese.**
Limitações em marcha	Treino intensivo e repetitivo da atividade	A	Uma revisão sistemática (14 ECA ou ECC). *Velocidade: SMD 0.29 (IC 95% 0.04 a 0.53)* *Capacidade: MD 55 m (IC 95% 18 a 92)*	Intervenção com nível de recomendação A.
	Biofeedback	C	Duas revisões sistemáticas (5 ECA e 13 ECA ou ECC). Ausência benefícios adicionais do treinamento em relação à velocidade de marcha ou capacidade.	Uma revisão sistemática (22 ECA ou ECC) sobre uso de *biofeedback* para melhora de atividades de membro inferior. *Efeito imediato: SMD 0.49 (IC 95% 0.22 a 0.75)* *Longo prazo: SMD 0.41 (IC 95% 0.06 a 0.75)*
	Marcha com auxílio mecanizado	B	Uma revisão sistemática (11 ECA ou ECC; esteira). *Marcha independente: RD 3.06 (IC 95% 1.85 a 5.06)* Uma revisão sistemática (15 ECA ou ECC; esteira + suporte). *Velocidade: MD 0.09 m/s (IC 95% -0.02 a 0.20)*	Atualização de revisão sistemática (44 ECA ou ECC) *Velocidade: MD 0.07 m/s (IC 95% 0.01 a 0.12)* *Capacidade: MD 26 m (IC 95%2.5 a 50)* Uma revisão sistemática (6 ECA; esteira + suporte; não-

			deambuladores) *Marcha independente: RD 0.23 (IC 95% 0.15 a 0.30)* *Velocidade: MD 0.12 m/s (IC 95% 0.02 a 0.21)* Uma revisão sistemática (9 ECA; esteira; deambuladores) *Velocidade: MD 0.14 m/s (IC 95% 0.09 a 0.19)* *Capacidade: MD 40 m (IC 95% 27 a 53)* Não é superior ao treino de marcha em solo.
Pistas auditivas rítmicas	B	Uma revisão sistemática não-específica (3 ECA) *Velocidade de marcha: SMD 0.91 (IC 95% 0.40 a 1.42)* *Comprimento de passo: SMD 0.68 (IC 95% 0.06 a 1.30)*	Uma atualização de revisão sistemática (3 ECA), resultados conflitantes. *Velocidade de marcha: SMD 0.6 (IC 95% -1.8 a 3.0)* *Comprimento de passada: SMD 0.15 (IC 95% -1.4 a 1.7)* **Revisão sistemática com meta-análise sobre pistas auditivas rítmicas como parte do projeto dessa tese.**
Realidade virtual	C	5 ECA, sem evidências sumarizadas em revisão sistemática com meta-análise.	**Revisão sistemática com meta-análise sobre treino de marcha associado à realidade virtual como parte do projeto dessa tese**.
Órteses tornozelo-pé	C	Uma revisão sistemática com estudos experimentais, sem indicação clara de benefício da técnica.	Uma revisão sistemática (13 ECA ou ECC) *Velocidade de marcha: MD 0.06 m/s (IC 95% 0.03 a 0.08)* *Comprimento de passo/passada: SMD 0.28 (IC 95% 0.05 a 0.51)*
Dispositivos de auxílio (marcha, bengala)	-	Não incluída.	**Estudo experimental sobre efeito de bengala no desempenho da marcha como parte do projeto dessa tese.**

ECA: ensaio clínico aleatorizado; ECC: ensaio clínico controlado; EMG: eletromiografia

APÊNDICE B

Material suplementar referente ao Estudo 1

Estratégia de Busca

1. exp Electric Stimulation/
2. exp Electric Stimulation Therapy/
3. “neuromuscular stimulation*”.mp.
4. electrostimulation*.mp.
5. exp Transcutaneous Electric Nerve Stimulation/
6. “Nerve stimulation*”.mp
7. (FES or TENS or ES or NMES).tw.
8. neuromuscular electric$ stimulation.mp.
9. exp Electroacupuncture/
10. (Electric$ adj5 stimulat$).tw.
11. (peroneal adj5 stimulate$).tw.
12. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13. exp Cerebrovascular Disorders/
14. exp Brain Ischemia/
15. exp Cerebral Hemorrhage/
16. Exp Brain Injuries/
17. exp “Intracranial Embolism and Thrombosis”/
18. exp Intracranial Aneurysm/
19. (Eva or cerebrovascular accident).mp.
20. (Stroke or apoplexy).mp.
21. (cerebral infarct$ or cerebral ischemis$ or cerebral thrombo$ or cerebral embolis$).mp.
22. (brain infarct$ or brain ischemis$ or brain thrombo$ or brain embolis$).mp.
23. (cerebral hemorrhage or cerebral haemorrhage or cerebral hematoma or cerebral haematoma).mp.
24. (brain hemorrhage or brain haemorrhage or brain hematoma or brain haematoma).mp.
25. exp Stroke/
26. exp Cerebral Infarction/
27. 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28. exp Hemiplegia/
29. exp Paresis/
30. (Hemiplegi$ or Hemipar$).mp.
31. 28 or 29 or 30
32. 12 and 27
33. 12 and 31
34. 32 or 33
35. limit 34 to humans

Estudos excluídos (n = 48).

Estudo	**Razões para exclusão**					
	1	**2**	**3**	**4**	**5**	**6**
Baker et al. (1979)	✓					
Bello, Rockson and Olaogun (2009)					✓	
Burridge et al. (2002)		✓				
Cauraugh et al (2000)		✓	✓			
Cauraugh and Kim (2002)		✓	✓			
Cauraugh and Kim (2003)	✓	✓	✓			
Cauraugh and Kim (2003)		✓	✓			
Cauraugh, Kim and Duley (2005)		✓	✓			
Chae et al. (1998)		✓				
Chae et al. (2009)		✓				
Cheng et al. (2010)		✓				
Church et al. (2006)		✓				
Conforto et al. (2010)		✓		✓		
Cozean, Pease and Hubbell (1998)		✓				
de Kroon et al. (2004)		✓		✓		
Faghri et al. (1994)		✓				
Faghri (1997)		✓				
Francisco et al. (1998)		✓				
Gabr, Levine and Page (2005)		✓				
Hara, Ogawa and Muraoka (2006)		✓				
Hara et al. (2008)	✓	✓		✓		
Hong, Choi and Lee (2012)	✓	✓				
Hsu et al. (2010)		✓				
Hummelsheim et al. (1996)	✓					

Hummelsheim et al. (1997)	✓				
Johansson et al. (2001)		✓			
Knutson et al. (2012)			✓		
Liu, You and Sun (2005)		✓			
Mangold et al. (2009)		✓			
Mann et al. (2005)		✓			
McDonnell et al. (2007)		✓			
Merletti (1978)		✓			
Mesci et al. (2009)		✓			
Ng and Hui-Chan (2007)					✓
Ng and Hui-Chan (2009)		✓			
Pehlivan and Armagan (2011)		✓			
Rydwik et al. (2006)		✓			
Sabut et al. (2011)		✓			
Sahin et al. (2012)		✓			
Shindo et al. (2011)		✓	✓		
Sonde et al. (1998)		✓			
Sonde et al. (2000)		✓			
Wang et al. (2002)		✓			
Wu et al. (2006)	✓	✓			
Yamaguchi et al. (2011)	✓				
Yavuzer et al. (2006)		✓			
Yavuzer et al. (2007)		✓			
Yozbatiran et al. (2006)		✓			

1 = Desenho de estudo não é ECA ou EC

2 = Eletroestimulação não foi direcionada para fortalecimento (i.e., não é objetivo e/ou não há medida de força)

3 = Medida de força não representativa de força máxima

4 = Grupo controle não é placebo, não-fortalecimento, outra forma de fortalecimento ou outra dose de ES

5 = Estudo não disponível

6= Dados duplicados

Gráficos detalhado

Study	Year	Experimental n/mean/SD	Control n/mean/SD	Weight	Association measure (95% CI)
Bakhtiary	2008	18/0.95/0.83	17/1.2/1.5	10.18%	-0.21 (-0.87 to 0.45)
Heckmann	1997	14/6.9/2.5	14/5.2/2.6	7.74%	0.67 (-0.09 to 1.42)
Hui-Chan	2009	28/38.9/16.9	29/31.2/18.3	16.28%	0.44 (-0.09 to 0.96)
Kobayashi	1999	6/63.2/22.6	5/68.8/34.9	3.18%	-0.19 (-1.38 to 0.99)
Kraft	1992	6/15.2/12.3	5/4.2/6.3	2.71%	1.09 (-0.18 to 2.36)
Mano	2011	10/3.46/2.01	8/2.67/1.99	5.09%	0.39 (-0.54 to 1.33)
Rosewilliam	2012	39/0.7/1.5	41/0.2/0.5	22.81%	0.45 (0.01 to 0.89)
Shin	2008	7/1.93/0.37	7/1.51/0.18	3.14%	1.44 (0.26 to 2.62)
Winchester	1983	20/45.2/28.3	20/31.9/29.4	11.39%	0.46 (-0.16 to 1.09)
Yan	2005	13/9/4.6	15/4.6/3	6.93%	1.15 (0.35 to 1.95)
Yan	2009	19/6.4/5.9	18/4/4.8	10.55%	0.44 (-0.21 to 1.09)
Pooled:				100%	0.47 (0.26 to 0.68)

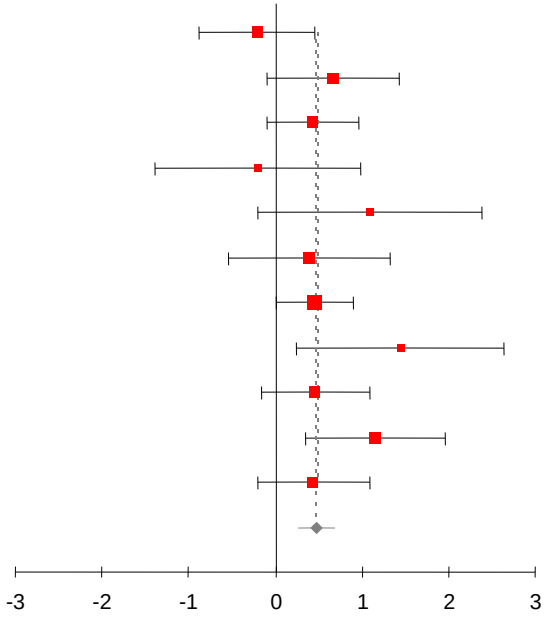

Figura 3a. Diferença media de *Cohen* (IC 95%) do efeito da eletroestimução versus não-intervenção/placebo em força muscular imediatamente após a intervenção (n = 359).

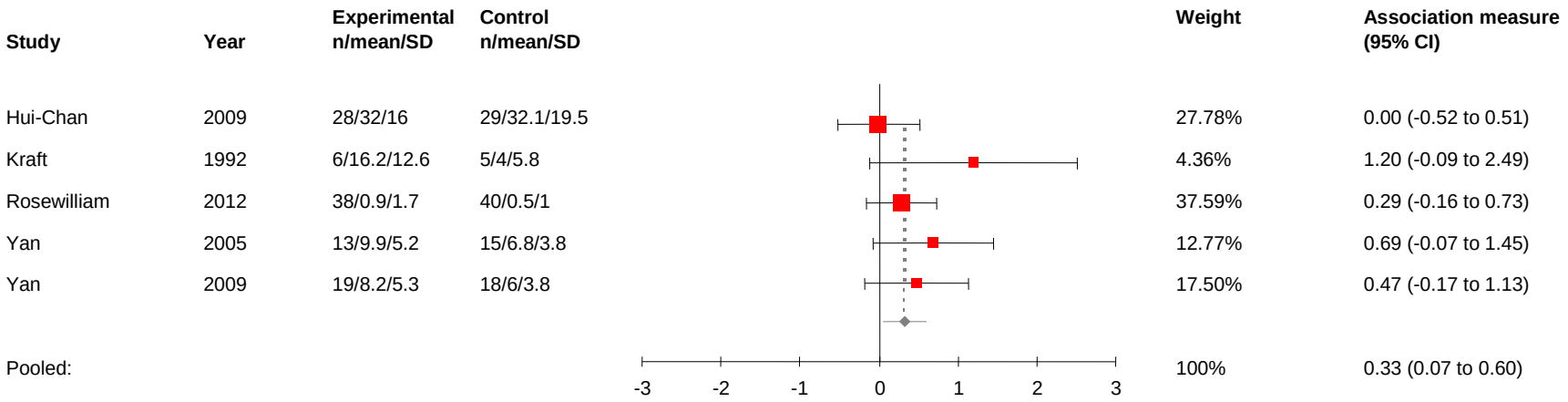

Figura 3b. Diferença media de *Cohen* (IC 95%) do efeito da eletroestimução versus não-intervenção/placebo em força muscular além do período de intervenção (n = 211).

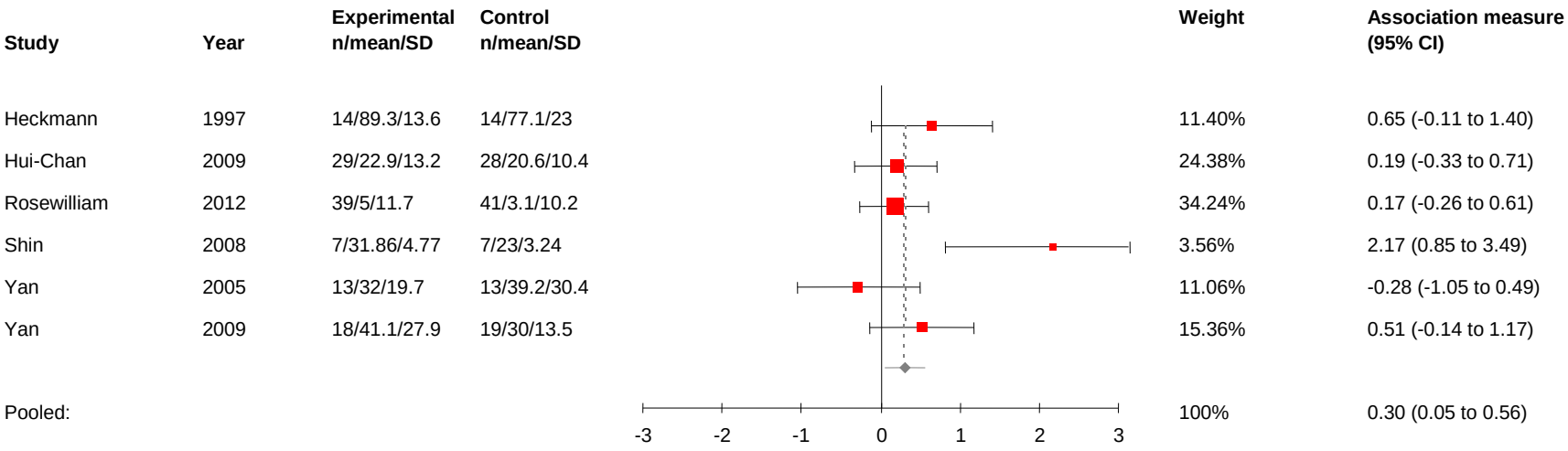

Figura 5a. Diferença media de *Cohen* (IC 95%) do efeito da eletroestimução versus não-intervenção/placebo em atividade imediatamente após a intervenção (n = 242).

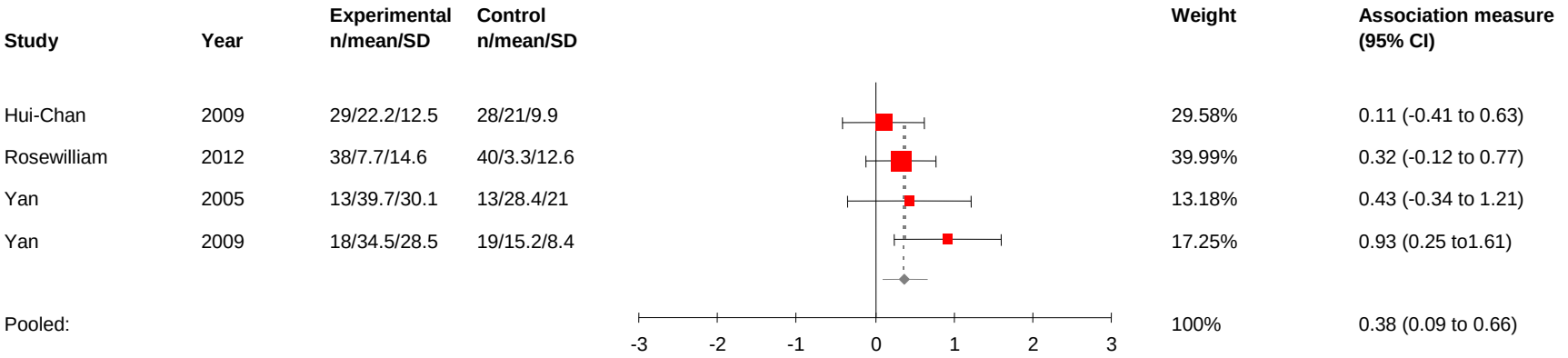

Figura 5b. Diferença media de *Cohen* (IC 95%) do efeito da eletroestimução versus não-intervenção/placebo em atividade além do período de intervenção (n = 198).

APÊNDICE C

Material suplementar referente ao Estudo 2

Estratégia de Busca

1. exp Cerebrovascular Disorders/
2. exp Cerebral Hemorrhage/
3. exp Brain Ischemia/
4. exp Brain Injuries/
5. exp Intracranial Aneurysm/
6. exp Stroke/
7. exp "Intracranial Embolism and Thrombosis"/
8. exp Cerebral Infarction/
9. (eva or cerebrovascular accident).mp.
10. apoplexy.mp.
11. (cerebral infarct$ or cerebral ischemi$ or cerebral thrombo$ or cerebral emboli$).mp.
12. (brain infarct$ or brain ischemi$ or brain thrombo$ or brain emboli$).mp.
13. (cerebral hemorrhage or cerebral haemorrhage or cerebral hematoma or cerebral haematoma).mp.
14. (brain hemorrhage or brain haemorrhage or brain hematoma or brain haematoma).mp.
15. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14
16. exp Hemiplegia/
17. exp Paresis/
18. (hemiplegi$ or hemipar$).mp.
19. 16 or 17 or 18
20. exp Gait Disorders, Neurologic/
21. exp Walking/
22. exp Gait/
23. exp Locomotion/
24. (walk$ or gait$ or ambulat$ or mobil$ or locomot$ or balanc$ or stride).mp.
25. 20 or 21 or 22 or 23 or 24
26. exp Cues/
27. cueing.mp.
28. (external rhythm$ or external stimul$ or external feedback).mp.
29. exp Music Therapy/
30. (auditory stimul$ or auditory feedback).mp.
31. (acoustic stimul$ or acoustic feedback).mp.
32. (music$ stimul$ or music$ feedback).mp.
33. (sensorial stimul$ or sensorial feedback).mp.
34. (audio or sound or rhythm$).mp.
35. 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34
36. 15 and 25 and 35
37. 19 and 25 and 35
38. 36 or 37
39. limit 38 to humans

Estudos excluídos (n = 25).

Estudos	Razões para exclusão					
	1	2	3	4	5	6
Boonsinsukh, et al. (2009)	✓					
Boonsinsukh, et al. (2011)	✓					
Bradley, et al. (1998)		✓				
Cheng, et al. (2004)		✓	✓			
Chouhan and Kumar (2012)			✓			
Chouhan and Kumar (2012)					✓	
Colbourne, et al. (1993)		✓				
Ford, et al. (2007)	✓					
Hausdorff and Ring (2008)	✓					
Jeong and Kim (2007)			✓			
Kang, et al. (2012)		✓				
Kim, et al. (2011)		✓				
Mandel, et al. (1990)		✓				
Malucci, et al. (2011)	✓					
Muto, et al. (2012)				✓		
Pelton, et al. (2010)	✓					
Petersen, et al. (1996)	✓	✓				
Prassas, et al. (1997)	✓					
Roerdink, et al. (2007)				✓		
Roerdink, et al. (2009)	✓					
Schauer and Mauritz (2003)		✓				
Suh, et al (2014)						✓
Sungkarat, et al. (2012)		✓				
Walker, et al. (2000)		✓				

Wong, et al. (2007)	✓	✓

1 = Desenho de estudo não é ECA ou EC

2 = Grupo experimental não realizou treino de marcha associado a pistas auditivas

3 = Medidade de desfecho não é velocidade de marcha, comprimento de passada, cadência ou simetria

4 = Grupo controle não realizou treino de marcha isolado

5 = Dados duplicados

6 = Velocidade de marcha dos participantes inferior a 0.2m/s

Gráficos detalhados

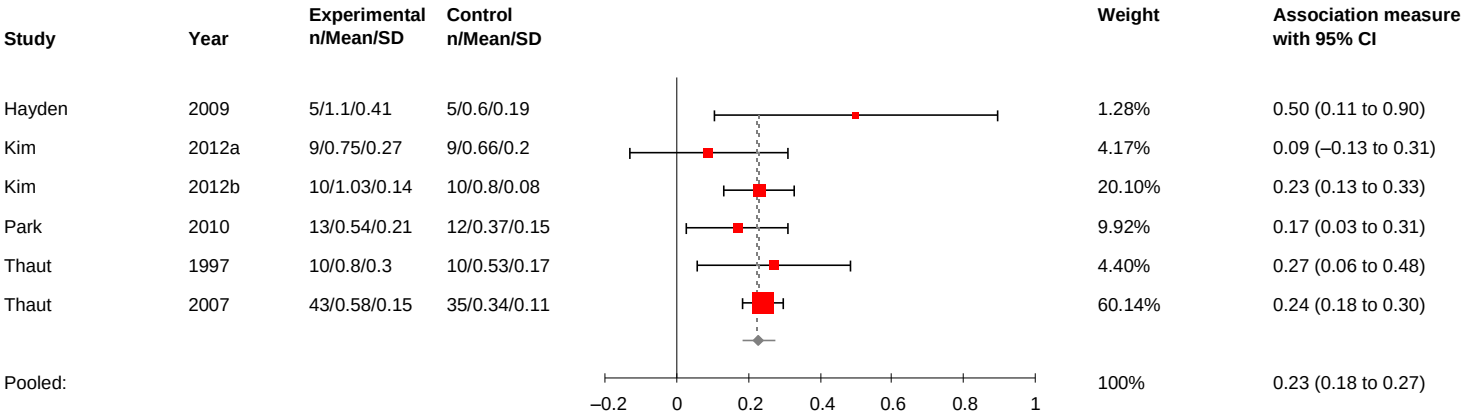

Figura 3. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em velocidade de marcha em m/s (n = 171).

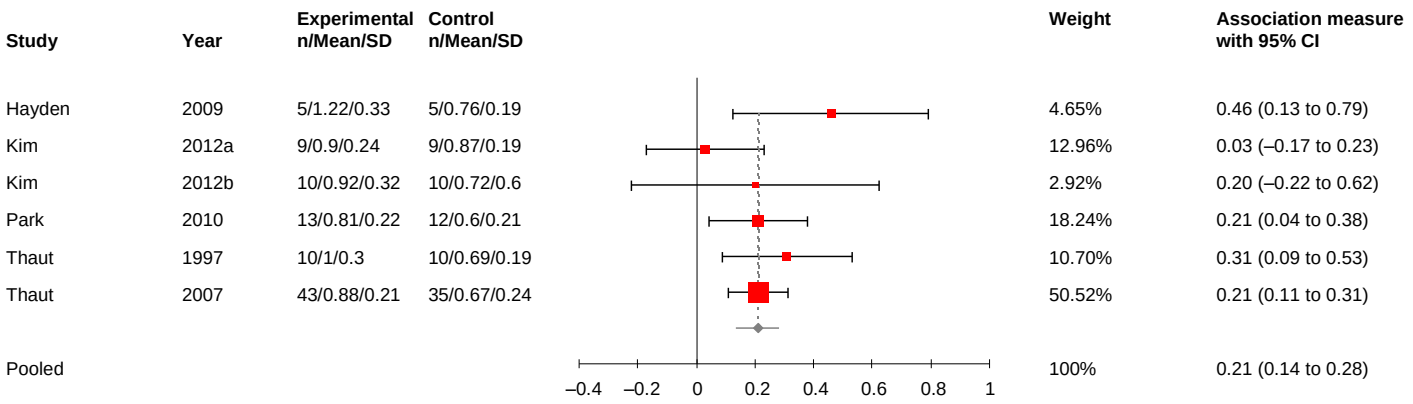

Figura 5. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em comprimento de passada em m (n = 171).

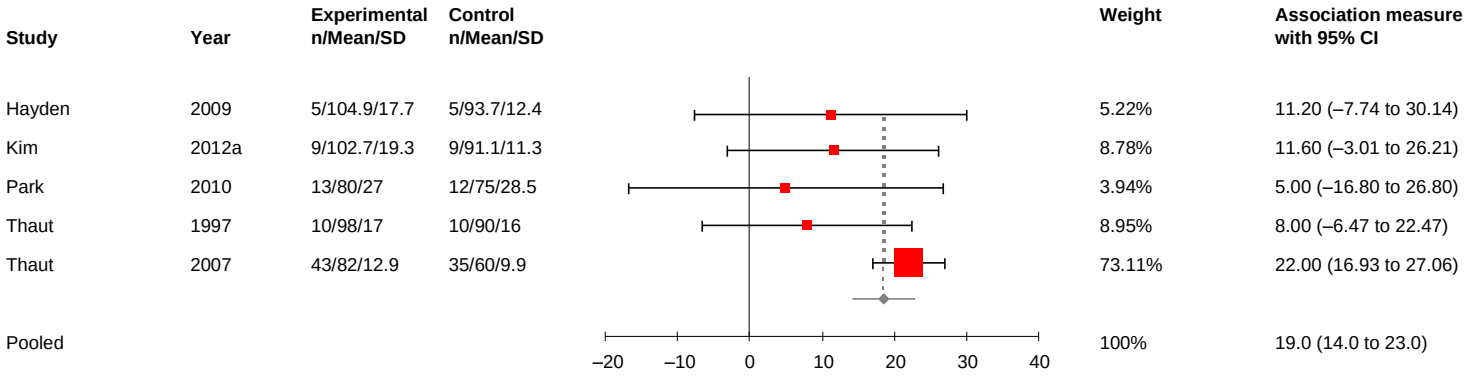

Figura 7. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em cadência em passos/minuto (n = 151).

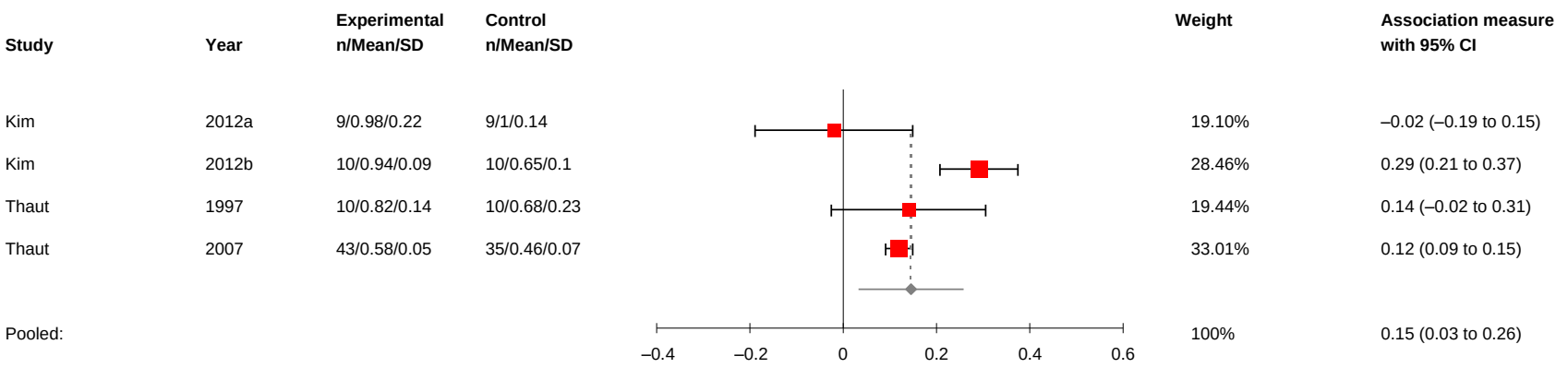

Figura 9. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em simetria (razão temporal entre membro parético e não-parético) (n = 136).

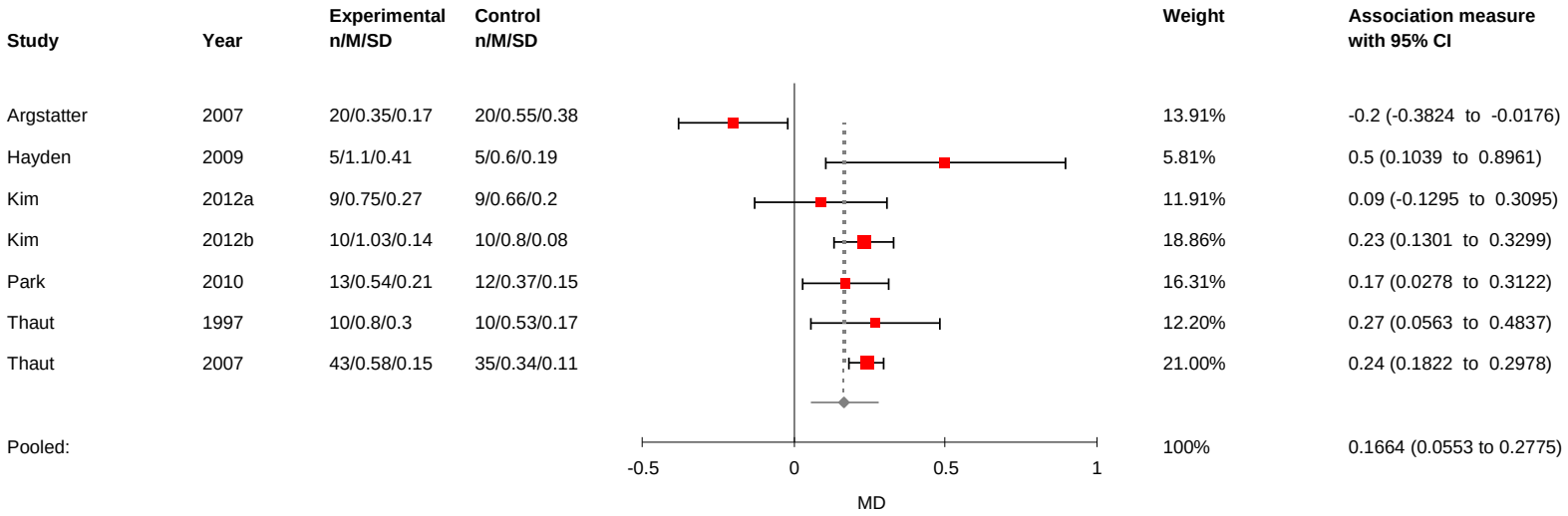

Figura 3b. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em velocidade de marcha em m/s, incluindo estudo *outlier* (n = 211), *random effects*.

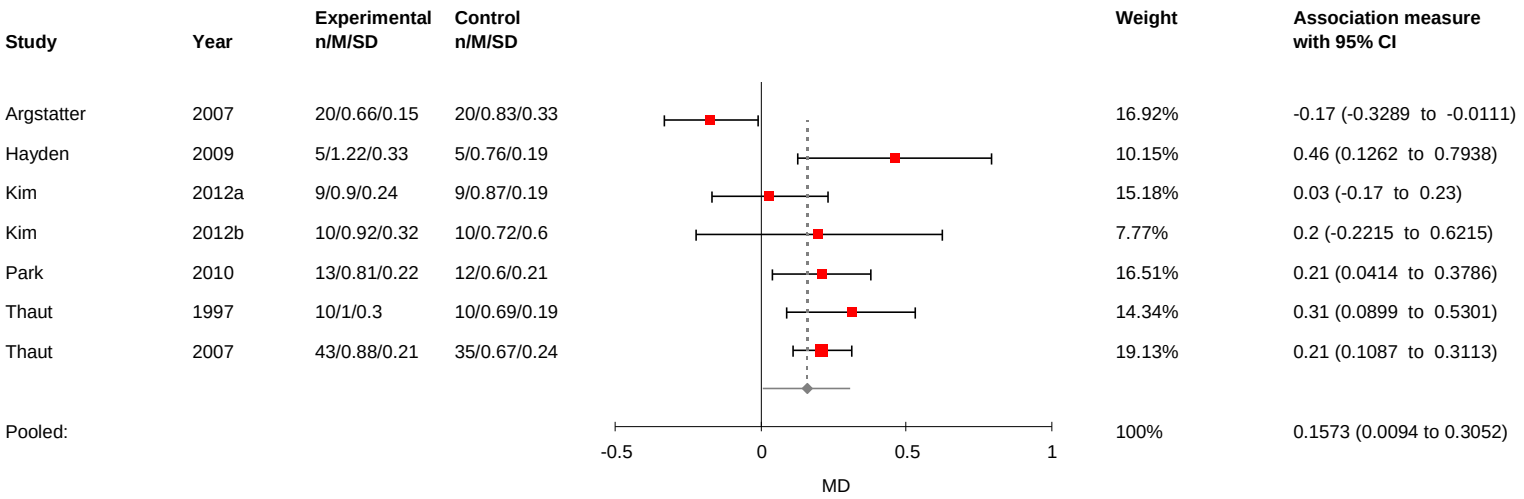

Figura 5b. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em comprimento de passada em m, incluindo estudo *outlier* (n = 211), *random effects*.

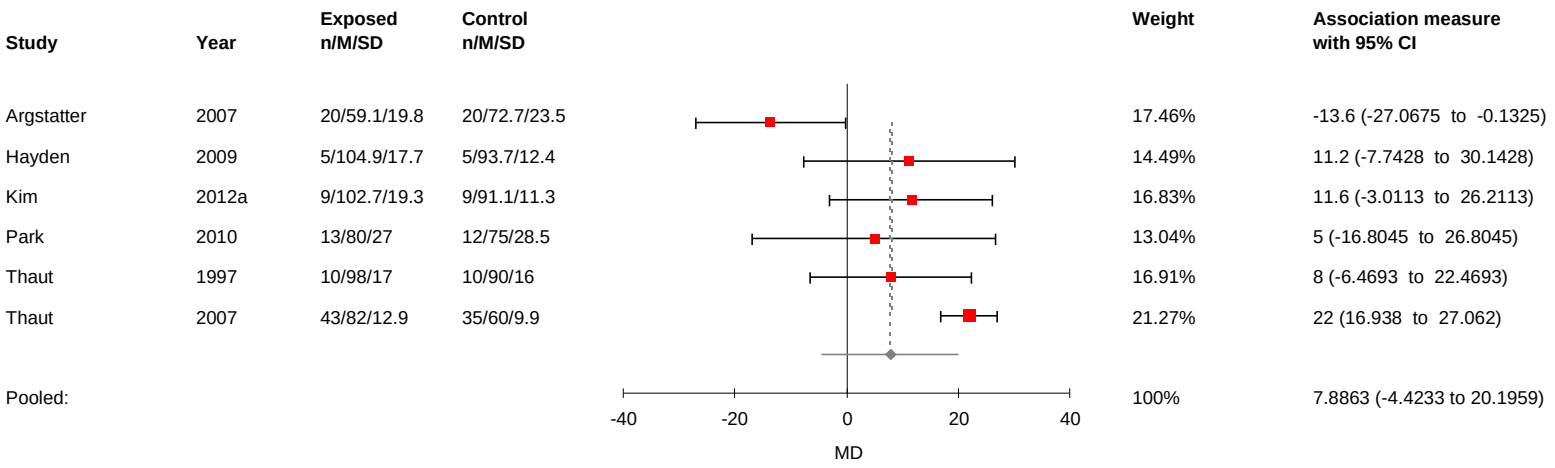

Figura 7b. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em cadência em passos/minuto, incluindo estudo *outlier* (n = 191), *random effects*.

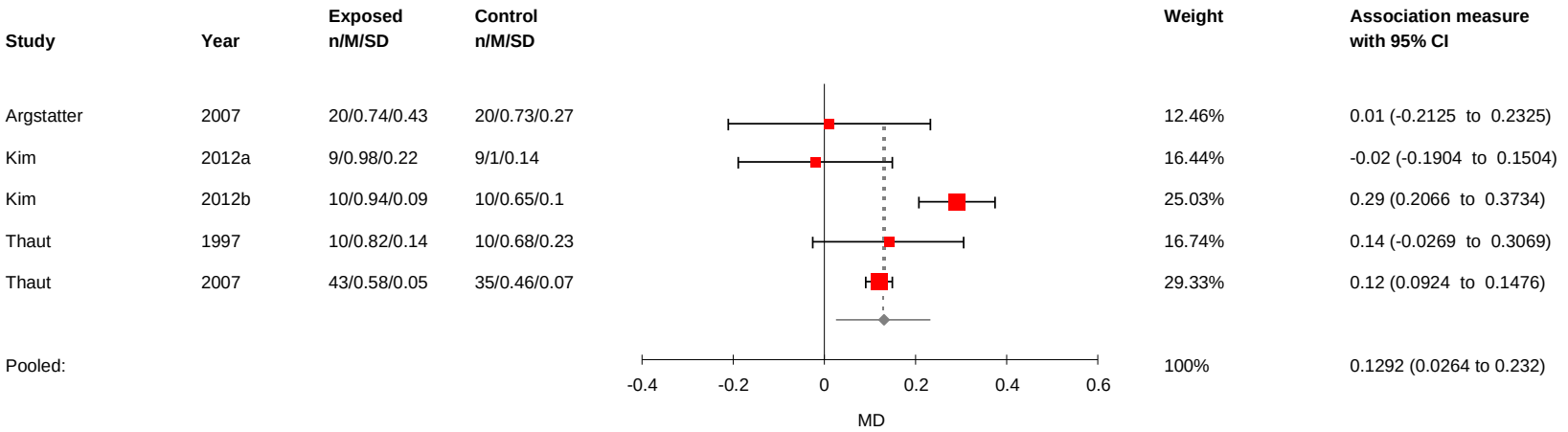

Figura 9b. Diferença média (IC 95%) do treino de marcha associado a pistas auditivas versus treino de marcha isolado em simetria (razão temporal entre membro parético e não-parético), incluindo estudo *outlier* (n = 136), *random effects*.

APÊNDICE D

Material suplementar referente ao Estudo 3

Estratégia de Busca

1. Cerebrovascular Disorders.mp. or exp Cerebrovascular Disorders/
2. Brain Ischemia.mp. or exp Brain Ischemia/
3. Cerebral Hemorrhage.mp. or exp Cerebral Hemorrhage/
4. Brain Injuries.mp. or exp Brain Injuries/
5. (Intracranial Embolism and Thrombosis).mp.
6. Intracranial Aneurysm.mp. or exp Intracranial Aneurysm/
7. (Eva or cerebrovascular accident).mp.
8. apoplexy.mp. or exp Stroke/
9. (cerebral infarct$ or cerebral ischemis$ or cerebral thrombo$ or cerebral embolis$).mp.
10. (brain infarct$ or brain ischemis$ or brain thrombo$ or brain embolis$).mp.
11. (cerebral hemorrhage or cerebral haemorrhage or cerebral hematoma or cerebral haematoma).mp.
12. (brain hemorrhage or brain haemorrhage or brain hematoma or brain haematoma).mp.
13. Cerebral Infarction.mp. or exp Cerebral Infarction/
14. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
15. Hemiplegia.mp. or exp Hemiplegia/
16. exp Paresis/ or Paresis.mp.
17. (Hemiplegi$ or Hemipar$).mp.
18. 15 or 16 or 17
19. exp Walking/ or Walking.mp.
20. Gait.mp. or exp Gait/ or exp Gait Disorders, Neurologic/
21. Locomotion.mp. or exp Locomotion/
22. (walk$ or gait$ or ambulat$ or mobil$ or locomot$ or balanc$ or stride).mp.
23. 19 or 20 or 21 or 22
24. User-computer interface/
25. computers/ or exp microcomputers/ or computer systems/ or software/
26. computer simulation/ or computer-assisted instruction/ or therapy, computer-assisted/
27. computer graphics/ or video games/ or *touch/
28. virtual reality.mp.
29. (computer adj3 (simulat$ or graphic$ or game$ or interact$)).tw.
30. video games.mp. or "Play and Playthings"/ or exp Video Games/ or exp Television/ or exp Electronics/
31. (haptics or haptic device$).tw.
32. optic flow.mp. or exp Optic Flow/
33. 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33
34. 14 or 18
35. 34 and 23 and 33
36. limit 35 to humans

Gráficos detalhados

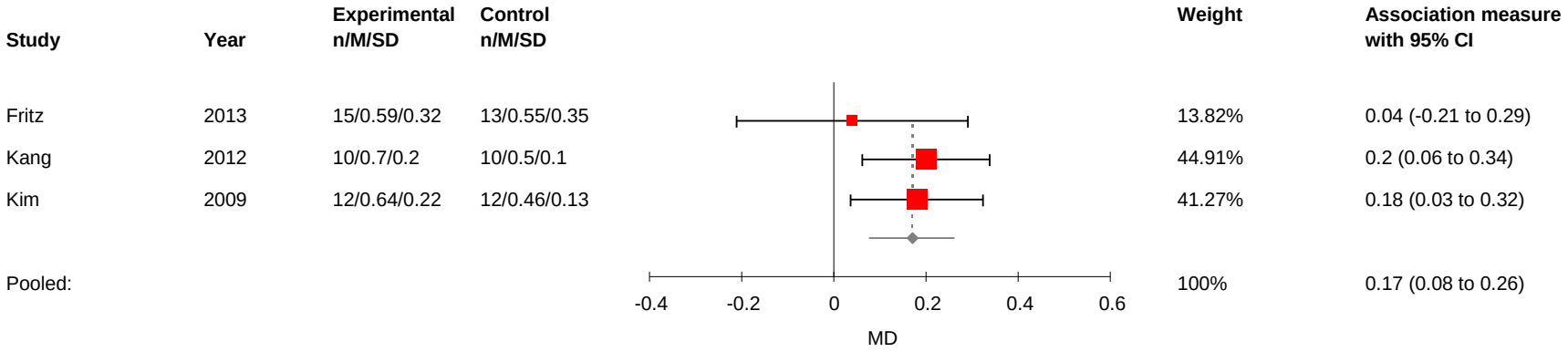

Figura 2 A – Diferença media (IC 95%) sobre o efeito do treino de marcha associado à realidade virtual versus não-intervenção/placebo ou intervenção não-específica aos membros inferiores em velocidade de marcha imediatamente após a intervenção (n = 72).

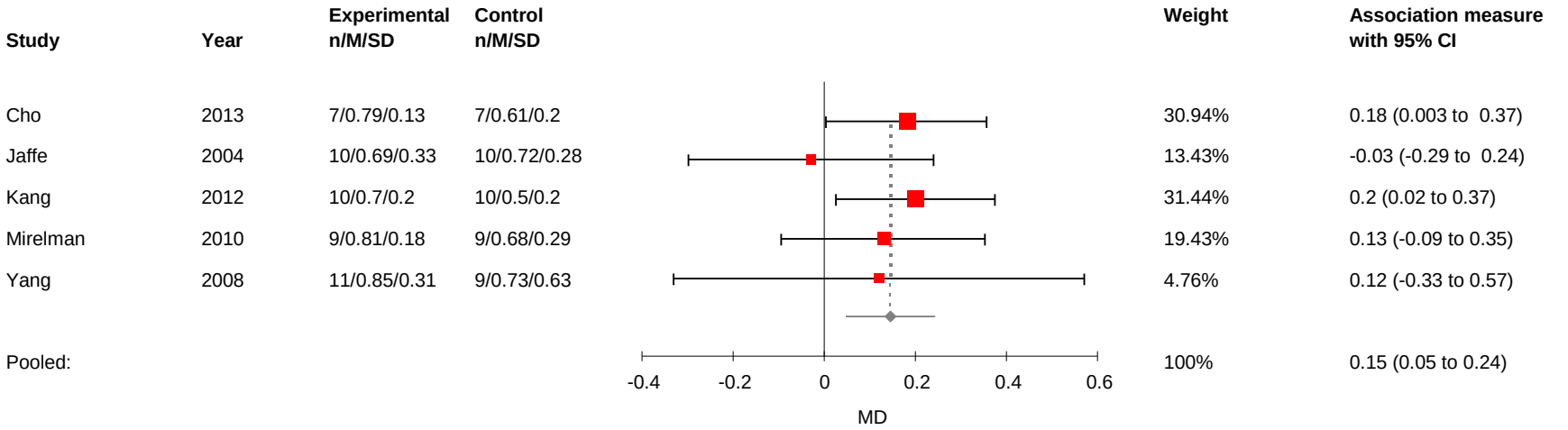

Figura 2 B – Diferença media (IC 95%) sobre o efeito do treino de marcha associado à realidade virtual versus treino de marcha isolado em velocidade de marcha imediatamente após a intervenção (n = 92).

APÊNDICE E

Termo de Consentimento Livre e Esclarecido

TÍTULO DO PROJETO

INFLUÊNCIA DO USO DE DISPOSITIVOS AUXILIARES NAS VARIÁVEIS CINÉTICAS, CINEMÁTICAS E ESPAÇO-TEMPORAIS DA MARCHA DE HEMIPARÉTICOS CRÔNICOS.

INFORMAÇÕES

Você está sendo convidado a participar de uma pesquisa a ser desenvolvida no Departamento de Fisioterapia da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais.

Este projeto de pesquisa tem como objetivo avaliar se o uso de dispositivos auxiliares melhora a capacidade de andar de indivíduos que sofreram derrame.

Para realizá-lo você será convidado a responder alguns questionários e realizar uma avaliação da sua marcha.

DESCRIÇÃO DOS TESTES A SEREM REALIZADOS

Avaliação

Inicialmente, serão coletadas informações específicas para a sua identificação, além de alguns parâmetros clínicos e físicos. A sua capacidade funcional será avaliada a partir do seu desempenho em testes muito utilizados na prática clínica e em estudos científicos. Todos esses testes são constituídos de tarefas que você realiza corriqueiramente no seu dia a dia.

Avaliação da marcha

Para realizar este teste, você será solicitado a caminhar num corredor em velocidades habitual e máxima, selecionadas por você, considerando a sua segurança e o seu conforto.

Para análise da marcha serão utilizados os seguintes procedimentos:

• Utilização do sistema de análise de movimento para avaliar o seu desempenho nos testes. Este sistema é constituído por câmeras que captam a imagem de marcadores, que são pequenas esferas de plástico, posicionados em locais específicos do seu corpo. Para posicionar estes marcadores, você deverá utilizar roupas apropriadas que permitam a exposição dos seus pés, pernas, coxas, tronco e braços. Estas roupas serão disponibilizadas pela equipe de pesquisa. Com fita dupla-face, anti-alérgica, serão posicionados os marcadores em pontos de referências do seu corpo. Estes marcadores refletem uma luz que é captada pelas câmeras do sistema de análise de movimento. Tais marcadores não provocam dor. A partir do posicionamento desses marcadores durante o seu desempenho no teste, é possível determinar os ângulos de diferentes partes do seu corpo (como do pé, da perna e da coxa) em diferentes momentos e, desta forma obter informações mais detalhadas e objetivas. Você caminhará normalmente sobre uma plataforma, em condições diferentes: utilizando a sua bengala ou muleta e sem a utilização destas. Você pisará sobre uma plataforma que captará informações sobre a transferência de peso do seu corpo.

Riscos

Os testes e procedimentos adotados não apresentam riscos específicos além daqueles presentes no seu dia-a-dia. Durante o teste, você pode vir a sentir-se fadigado. Caso isto aconteça, períodos de repouso serão permitidos entre um teste e outro. Qualquer tipo de desconforto vivenciado durante os testes deve ser revelado para que os pesquisadores tomem as devidas providências com o objetivo de minimizá-lo. Você poderá se desequilibrar enquanto caminha. Portanto, todos os testes serão acompanhados por uma pessoa posicionada ao seu lado.

Benefícios

Você não obterá benefícios imediatos por participar desta pesquisa. Na realidade, você estará contribuindo para a nossa melhor compreensão dos prováveis benefícios dos dispositivos auxiliares são realizados. A partir daí, poderemos indicá-los com maior segurança.

Confidencialidade

Você receberá um código que será utilizado em todos os seus testes e não será reconhecido individualmente.

Natureza voluntária do estudo

A sua participação é voluntária e você tem o direito de se retirar por qualquer razão e qualquer momento.

Pagamento

Você não receberá nenhuma forma de pagamento pela participação no estudo. Custos de transporte para o local dos testes e seu retorno poderão, se necessários, ser arcados pelos pesquisadores.

DECLARAÇÃO E ASSINATURA

Eu, _____

li e entendi toda a informação repassada sobre o estudo, sendo que os objetivos, procedimentos e linguagem técnica satisfatoriamente explicados. Tive tempo suficiente, para considerar as informações acima e tive a oportunidade de tirar todas as minhas dúvidas. Estou assinando este termo voluntariamente e tenho direito de agora, ou mais tarde, discutir qualquer dúvida que venha a ter com relação à pesquisa com:

Lucas Rodrigues Nascimento (31) 7591-6000

Janaine Cunha Polese (31) 3498-3217

Prof. Luci Fuscaldi Teixeira-Salmela (31) 3409-7403

Comitê de Ética em Pesquisa da UFMG (31) 3409-4592

Endereço: Avenida Antônio Carlos, 6627,

Pampulha, BH/MG Campus – UFMG –

Unidade Administrativa II – 2º andar.

Assinando esse termo de consentimento, estou indicando que concordo em participar deste estudo.

_____ _____

Assinatura do Participante Assinatura da Testemunha

Data:_____ Data:_____

RG: _____ RG: _____

CPF: _____ CPF: _____

End: _____ End: _____

Responsáveis

_____

Lucas R Nascimento / Janaine C Polese

_____

Prof. Luci F Teixeira-Salmela

APÊNDICE F

Currículo resumido do discente referente ao período do doutorado (2011-2015)

Produção Científica

Artigos completos publicados em periódicos

1. **NASCIMENTO, Lucas Rodrigues**, OLIVEIRA, Camila Quel, ADA, Louise, MICHAELSEN, Stella Maris, TEIXEIRA-SALMELA, Luci Fuscaldi. Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review. **Journal of Physiotherapy**, v.61, p.10-15. 2015.

2. LIMA, Renata Cristina Magalhães, MICHAELSEN, Stella Maris, **NASCIMENTO, Lucas Rodrigues**, POLESE, Janaíne Cunha, PEREIRA, Natália Duarte, TEIXEIRA-SALMELA, Luci Fuscaldi. Addition of trunk restraint to home-based modified constraint-induced movement therapy does not bring additional benefits in chronic stroke individuals with mild and moderate upper limb impairments: A pilot randomized controlled trial. **NeuroRehabilitation (Reading, MA)**. , v.35, p.391 - 404, 2014.

3. **NASCIMENTO, LUCAS R**, MICHAELSEN, STELLA M, ADA, Louise, POLESE, JANAINE C, TEIXEIRA-SALMELA, LUCI F. Cyclical electrical stimulation increases strength and improves activity after stroke: a systematic review. **Journal of Physiotherapy**, v.60, p.22 - 30, 2014.

4. LIMA, Renata Cristina Magalhães, **NASCIMENTO, Lucas Rodrigues**, MICHAELSEN, Stella Maris, POLESE, Janaíne Cunha, PEREIRA, Natália Duarte, TEIXEIRA-SALMELA, Luci Fuscaldi. Influences of hand dominance on the maintenance of benefits after home-based modified constraint-induced movement therapy in individuals with stroke. **Brazilian Journal of Physical Therapy / Revista Brasileira de Fisioterapia** , v.18, p.435 - 444, 2014.

5. **Nascimento, Lucas R.**, Teixeira-Salmela, Luci F., Polese, Janaine C., ADA, Louise, FARIA, CHRISTINA D. C. M., LAURENTINO, GLÓRIA E. C. Strength deficits of the shoulder complex during isokinetic testing in people with chronic stroke. Revista **Brazilian Journal of Physical Therapy / Revista Brasileira de Fisioterapia**, v.18, p.268 - 275, 2014.

6. RODRIGUES-BARONI, Juliana M, **NASCIMENTO, Lucas Rodrigues**, ADA, Louise, TEIXEIRA-SALMELA, Luci Fuscaldi. Walking training associated with virtual reality-based training increases walking speed of individuals with chronic stroke: systematic review with meta-analysis. **Brazilian Journal of Physical Therapy**, v.18, n.6, p.502-512, 2014.

7. RESENDE, Renan Alves, **NASCIMENTO, Lucas Rodrigues**, SILVA, Maria Clarice Lopes, PINHEIRO, Ana Cisalpino, FONSECA, Sérgio Teixeira da, KIRKWOOD, Renata Noce. Desenvolvimento de um modelo de pé segmentado para avaliação de indivíduos calçados. **Fisioterapia em Movimento (PUCPR. Impresso).** , v.26, p.95 - 105, 2013.

8. POLESE, Janaíne Cunha, ADA, Louise, DEAN, Catherine M, **NASCIMENTO, Lucas Rodrigues**, TEIXEIRA-SALMELA, Luci Fuscaldi. Treadmill training is effective for ambulatory adults with stroke: a systematic review. **Journal of Physiotherapy.** , v.59, p.73 - 80, 2013.

9. BRAGA, Isabela de Resende, RAMOS, Lidiane Mara Miranda, SILVA, Maria Clarice Lopes, **NASCIMENTO, Lucas Rodrigues**, POLESE, Janaíne Cunha, TEIXEIRA-SALMELA, Luci Fuscaldi. Correlações de força isométrica de elevação de ombro no plano escapular e de preensão palmar com medidas de capacidade e desempenho dos membros superiores em indivíduos com hemiparesia crônica. **Terapia Manual.** , v.10, p.12 - 18, 2012.

10. **Nascimento, Lucas R.**, Caetano, Lívia C. G., Freitas, Daniele C. M. A., Morais, Tatiane M., Polese, Janaine C., Teixeira-Salmela, Luci F. Different instructions during the ten-meter walking test determined significant increases in maximum gait speed in individuals with chronic hemiparesis. **Brazilian Journal of Physical Therapy**, v.16, p.122 - 127, 2012.

11 **NASCIMENTO, Lucas Rodrigues**, Polese, Janaine Cunha, Faria, Christina D.C.M., TEIXEIRA-SALMELA, Luci Fuscaldi. Isometric hand grip strength correlated with isokinetic data of the shoulder stabilizers in individuals with chronic stroke. **Journal of Bodywork and Movement Therapies**. , v.16, p.275 - 280, 2012.

12. **NASCIMENTO, Lucas Rodrigues**, RESENDE, Renan Alves, CARVALHO, Augusto Cesinando, FONSECA, Sérgio Teixeira da, TEIXEIRA-SALMELA, Luci Fuscaldi. Marcha humana: teorias, contribuições musculares e implicações clínicas. **Terapia Manual.** , v.10, p.537 - 543, 2012.

13. ARAUJO, Fabio Campos de, **NASCIMENTO, Lucas Rodrigues**, TEIXEIRA-SALMELA, Luci Fuscaldi, FONSECA, Sérgio Teixeira da, RESENDE, Renan Alves. Mecanismos de estabilização muscular da cintura escapular e relações com a cinemática do complexo do ombro: uma revisão da literatura. **Terapia Manual.** , v.10, p.346 - 352, 2012.

14. PEREIRA, Natália Duarte, OVANDO, Angélica Cristiane, MICHAELSEN, Stella Maris, ANJOS, Sarah Monteiro, LIMA, Renata Cristina Magalhães, **NASCIMENTO, Lucas Rodrigues**, TEIXEIRA-SALMELA, Luci Fuscaldi. Motor Activity Log-Brazil: reliability and relationships with motor impairments in individuals with chronic stroke. **Arquivos de Neuro-Psiquiatria**. , v.70, p.196 - 201, 2012.

15. Polese, Janaine Cunha, TEIXEIRA-SALMELA, Luci Fuscaldi, **NASCIMENTO, Lucas Rodrigues**, Faria, Christina Danielli Morais, KIRKWOOD, Renata Noce, Laurentino, Glória Carneiro, ADA, Louise. The effects of walking sticks on gait kinematics and kinetics with chronic stroke survivors. **Clinical Biomechanics (Bristol)**. , v.27, p.131 - 137, 2012.

16. MORAES, Geraldo Fabiano Souza, **NASCIMENTO, Lucas Rodrigues**, GLORIA, Adam Edwards, PAIVA, Célia Maria Rocha, LOPES, Thiago de Arruda Teixeira, PEREIRA, Shelley Caroline, SOUZA, Aline Cristina, OLIVEIRA, Edênia Santos Garcia, OLIVEIRA, Daniela Matos Garcia. Fortalecimento dos músculos estabilizadores da escápula e qualidade de vida de indivíduos com hemiparesia. **ConScientiae Saúde**. , v.10, p.356 - 362, 2011.

17. POLESE, Janaíne Cunha, **NASCIMENTO, Lucas Rodrigues**, FARIA, Christina Danielli Coelho de Morais, LAURENTINO, Glória Elizabeth Carneiro, RODRIGUES-DE-PAULA, Fátima, ADA, Louise, TEIXEIRA-SALMELA, Luci Fuscaldi. Percepção de hemiplégicos crônicos sobre o uso de dispositivos auxiliares na marcha. **Revista Panamericana de Salud Pública / Pan American Journal of Public Health**, v.30, p.204 - 208, 2011.

18. Glória, Adam Edwards, **NASCIMENTO, Lucas Rodrigues**, Paiva, Célia Maria Rocha e, Fernandes, Marcela Sales, LIMA, Renata Cristina Magalhães, MOURA, Regina Márcia Faria de. Treinamento global na pressão inspiratória máxima e funcionalidade de um indivíduo com hemiparesia crônica. **ConScientiae Saúde**. , v.10, p.555 - 562, 2011.

Capítulo de livro

1. **NASCIMENTO, Lucas Rodrigues**. Functional Disability Scales In: Encyclopedia of Quality of Life and Well-Being Research.1 ed.Dordrecht, Netherlands : Springer, 2014, p. 2370-2373.

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