

REVIEW ARTICLE

EVIDENCE FOR THE EFFECTIVENESS OF WALKING TRAINING ON WALKING AND SELF-CARE AFTER STROKE: A SYSTEMATIC REVIEW AND META-ANALYSIS OF RANDOMIZED CONTROLLED TRIALS

Sinikka H. Peurala, PhD, PT¹, Auli H. Karttunen, MSc, PT², Tuulikki Sjögren, PhD, PT²,
Jaana Paltamaa³, PhD, PT and Ari Heinonen, PhD, PT²

From the ¹Validia Rehabilitation, Helsinki, ²Department of Health Sciences, University of Jyväskylä and ³School of Health and Social Studies, JAMK University of Applied Sciences, Jyväskylä, Finland

Objective: To examine the effect of randomized controlled trials of walking training on walking and self-care in patients with stroke.

Data sources: MEDLINE, CINAHL, Embase, PEDro, OT-Seeker, Central, and manual search to the end of August 2012.

Study selection: English, Finnish, Swedish, or German language walking training randomized controlled trials for patients over 18 years of age with stroke.

Data synthesis: The meta-analyses included 38 randomized controlled trials from 44 reports. There was high evidence that in the subacute stage of stroke, specific walking training resulted in improved walking speed and distance compared with traditional walking training of the same intensity. In the chronic stage, walking training resulted in increased walking speed and walking distance compared with no/placebo treatment, and increased walking speed compared with overall physiotherapy. On average, 24 training sessions for 7 weeks were needed.

Conclusion: Walking training improves walking capacity and, to some extent, self-care in different stages of stroke, but the training frequency should be fairly high.

Key words: stroke; rehabilitation; recovery of function; walking; outcome measures; International Classification of Functioning; Disability and Health.

J Rehabil Med 2014; 46: 387–399

Correspondence address: Sinikka H. Peurala, Validia Rehabilitation Lahti, Launeenkatu 10, FI-15100 Lahti, Finland. E-mail: sinikka.peurala@validia.fi or sinikka.peurala@gmail.com

Accepted Jan 21, 2014; Epub ahead of print Apr 10, 2014

INTRODUCTION

Stroke is a leading cause of disability in many western countries. The ability to perform basic activities of daily living is initially reduced in 3 out of 4 patients with stroke (1). The most severely affected activities are the abilities to transfer, dress and walk. However, it has been shown that early intensive physiotherapy is related to better and faster recovery in the aforementioned activities in patients with stroke (2–5). Recovery of walking to regain independence in daily life is one of

the main goals of stroke patients. It has been shown that to improve specific motor skills requires training in relevant tasks in patients with stroke (6). Traditional walking training includes walking with essential walking aids/orthosis combined with verbal and manual guidance. Additional rehabilitation tools during walking training consist of visual cues (7), concurrent cognitive tasks, i.e. dual tasks (8), musical feedback (9) and/or functional electrical stimulation (10). In addition, treadmill training with partial body weight support was introduced as a strategy for gait rehabilitation more than 10 years ago (11–13).

More recently, various electromechanical-assisted gait training devices have been developed. The Gait Trainer and the Driven Gait Orthosis were the first of these (14, 15). On the Gait Trainer, the patient is supported with a harness and the feet are placed on motor-driven footplates. On the Driven Gait Orthosis, the patient moves on a treadmill operated according to a pre-programmed physiological gait pattern and an exoskeleton-type robot. A Cochrane Review of electromechanical-assisted training for walking after stroke reported that the use of the Gait Trainer and Driven Gait Orthosis could reduce dependency in walking by 25% (16). One of the latest developments is the G-EO Walker, based on the end-effector principle. The patient is placed in a harness and stands on 2 foot-plates, the trajectories of which are freely programmable. This allows practice of simulated floor walking and climbing up and down stairs (17).

To date, evidence on the effects of walking training is either scarce or is mainly method-specific (13, 16). Moreover, it appears that the outcomes in terms of speed and functional walking ability obtained by different treatment modes have not been translated to yield comparable data (18). It is well known that after stroke the physical functioning recovery progress is rapid and partly spontaneous, but later the results achieved are slower and often becomes sustaining. Therefore it is reasonable to investigate the effect of walking training at different stages of stroke.

The purpose of this study was to investigate the evidence for the effect of walking training on walking and self-care in patients at different stages of stroke, i.e. in the acute, subacute and chronic stages of stroke. We linked the outcome measures of the International Classification of Functioning, Disability and Health (ICF) Mobility and Self-care domains according to the

international guidelines and other literature (19–23). In the Mobility domain we used only the category of Walking. Evidence on the effect of walking training was gathered by meta-analyses, in which stroke patients were divided into 3 rehabilitation subgroups. In addition, evidence was gathered about the number and quality of randomized controlled trials (RCTs).

MATERIAL AND METHODS

The search strategy was originally performed for physiotherapy interventions on stroke (Fig. 1) (24). In later updates, the key words in the search were “disease-specific”, and “exercise-specific”, i.e. walking, ambulation or gait. The full search strategies are available on request from the corresponding author, but the Ovid MEDLINE search strategy is given as an example in Appendix S1¹.

A systematic literature search was conducted in the Ovid MEDLINE database, the Cumulative Index to Nursing & Allied Health Literature, Embase, the Physiotherapy Evidence Database, the Cochrane Central Register of Controlled Trials, and by manual search. Two information specialists performed the searches in these electronic databases in conjunction with the researchers.

Only RCTs for patients over 18 years of age with stroke published in English, Finnish, Swedish or German were included in the study. In addition, only RCTs in which walking training was specified either as minutes separately from other therapy or as achieved walking distance during the intervention were included. Exclusion criteria were non-randomized and non-controlled pre-experimental studies and protocols. Studies were collected up to August week 4, 2012. Bibliographies of walking review articles, narrative reviews and abstracts published in conference proceedings were also evaluated for relevant publications.

In addition, citation tracking of all walking RCT article references was conducted. Inclusion of articles was based on agreement between 2 independent reviewers (SP & TS/JP/T-KT/HS/AK).

Methodological quality or risk of bias was assessed based on individual trial characteristics using the criteria of van Tulder et al. (25). The items concern internal validity related to selection bias, performance bias, attrition bias and detection bias. All 11 items were rated as “yes”, “no” or “don’t know”. If item A was rated “don’t know”, a request was sent to the authors to clarify whether the method of randomization was adequate. If 2 requests were not answered, the study was accepted, but the method remained rated as “don’t know”. RCTs were considered as high-level, acceptable or poor depending on the yes-rated items and number of subjects (see Appendix I) (26). Methodological quality and content analysis were evaluated by 2 blinded and independent assessors (SP & T-KT/HS/AK). Disagreements were resolved by consensus between the reviewers; where this was not possible the issue was decided by a third reviewer (TS, JP or AH). Inter-rater reliability for the methodological quality assessment was computed by Kappa statistics, in which Adequate is 0.40–0.74 and Excellent ≥ 0.75 (27).

The meta-analyses were performed in 3 rehabilitation subgroups as follows: (i) walking training vs no or placebo treatment, (ii) walking training vs overall physiotherapy, and (iii) specific walking training methods vs walking on the floor with walking aids and with the help of verbal and/or manual guidance of a therapist if needed, but not with any additional methods (hereafter termed traditional walking training). Specific walking training methods include tools that are not used in traditional walking training, e.g. auditory feedback during gait, and treadmill and electrical-assisted walking training. The meta-analyses in each rehabilitation subgroup were divided into 3 stroke groups: acute (less than 1 month after stroke), subacute (1–6 months after stroke) and chronic (more than 6 months after stroke).

In the meta-analyses, Cochrane Collaboration’s Review Manager 5.2 program was used to calculate pooled effect estimates for combinations of single study effects. The inverse-variance random-effects method was used. Random-effect meta-analysis assumes that effects that are

¹<https://doi.org/10.2340/16501977-1805>

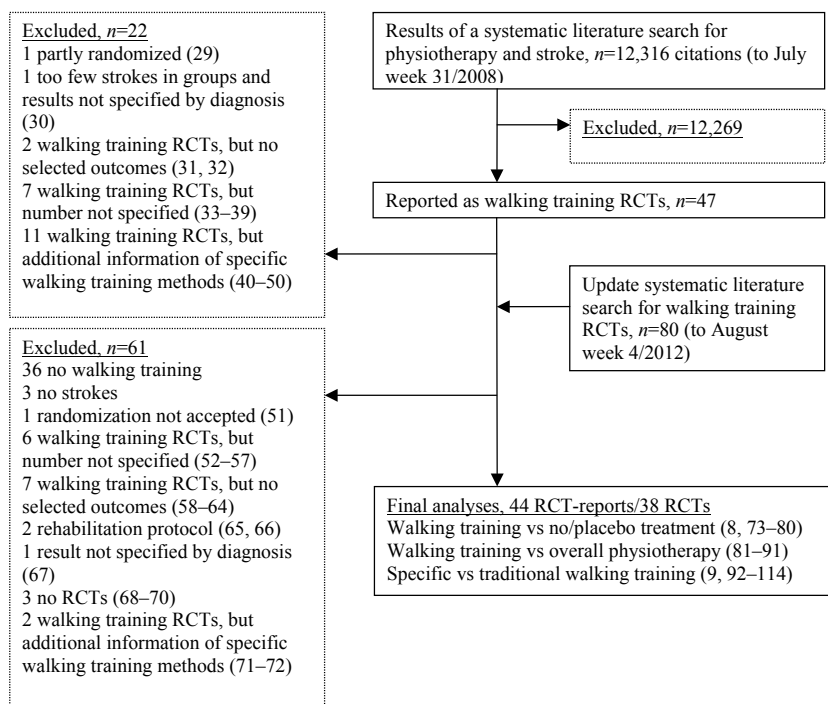


Fig. 1. Literature search concerning walking training in patients with stroke.

estimated are not identical in different studies but follow a distribution. The centre of this distribution describes the mean of the effects and its width the degree of heterogeneity. For continuous outcomes 2 summary statistics were available: the mean difference and the standardized mean difference, i.e. the effect size. The mean difference was used when studies had outcomes in the same scale (in all the walking parameters), whereas when outcomes in different scales were reported, the standardized mean difference was used (in Self-care).

Change values for outcomes and their standard deviations (SDs) were used, if they were available. If not, then the final values were used. If neither were reported, a request for this information was sent to the authors. If 2 requests were not answered the RCT was not entered into the meta-analyses. In studies in which multiple comparisons had been done, for example 2 or more intervention groups vs a control group, the number of controls in the group was divided amongst the comparisons. The overall effect was tested with the z-test, where the null hypothesis is that there is no difference between an intervention group and a control group. Poor-quality studies were not included in the meta-analyses.

Depending on the quality and number of RCTs, the meta-analysis evidence was rated in 4 categories: high, moderate, low or no evidence (see Appendix II) (28).

RESULTS

Altogether 44 papers reporting 38 RCTs (6 papers reported the same RCT twice) published during the period 1992–2012 fulfilled the inclusion criteria (Fig. 1 (8, 9, 73–114)). After contacting the authors, the randomization method used remained unclear in 3 studies (Table I). The methodological quality of the included RCTs was generally good: mean 6.0 (SD 1.6) yes scores, range 3–9 (Table I). In our quality assessment, the Kappa for interrater reliability was 0.80 (almost perfect agreement, $p < 0.001$).

Seven RCTs in 9 articles reported walking training compared with no or placebo treatment (8, 73–80). Eleven RCTs compared walking training with overall physiotherapy (81–91). Twenty-one RCTs in 24 articles were analysed in a subgroup of specific vs traditional walking training (9, 92–114).

Only outcome measures linked to the ICF Walking category, such as walking speed, walking distance, walking independence, and the Self-care domain were used. Table SI¹ shows the precise outcomes. Walking speed (m/s) was most often measured with the 10-m walk test (115). Walking distance was measured with the 6-min walk test (116), and walking independence was evaluated with the Functional Ambulatory Category (115). Outcome measures linked to Self-care were the Functional Independence Measure (117) and Barthel Index (118). In the Functional Ambulatory Category, Functional Independence Measure, and Barthel Index, a higher score denotes better functioning.

Walking training vs no/placebo treatment

All the patients analysed in this rehabilitation subgroup were in the chronic stage of stroke. High evidence showed that walking training increased walking speed compared with no/placebo treatment ($p = 0.03$, Fig. 2A) (8, 74, 76–77, 79–80). Data from one study (acceptable quality) were not available for the meta-analyses (75) and the quality of another study was poor (73) (Tables I and SI¹). High evidence also showed that walking training increased walking distance compared with no/placebo

Table I. Quality analysis of 44 randomized controlled trials (RCT) reports concerning walking training in stroke

Study	Randomization method acceptable ^a	Concealment of treatment allocation ^a	Group similarity ^a	Blinding of patient	Blinding of care provider	Blinding of outcome assessor	Determination of co-interventions	Compliance	Drop-outs and reasons ^b	Timing of outcomes similar	Intention-to-treat	Number of yes and quality level ^b
<i>Walking training vs No/placebo treatment</i>												
Ada et al., 2003 (8)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Don't know	7 High
Chu et al., 2004 (73)	Don't know	No	Yes	Don't know	No	Yes	Don't know	Yes	Yes	Don't know	Yes	5 Poor
Kang et al., 2012 (74)	Yes	Yes	Yes	No	No	Yes	Don't know	Don't know	Yes	Yes	Don't know	6 High
Luft et al., 2008 (75)	Yes	Don't know	Yes	No	No	Yes	Don't know	Don't know	No	Yes	No	4 Acceptable
Macko et al., 2005 (76)	Yes	No	Yes	No	No	No	Don't know	Yes	Yes	Don't know	Don't know	4 Acceptable
Moore et al., 2010 (77)	Yes	No	Yes	No	No	Don't know	Yes	Don't know	No	Yes	Don't know	4 Acceptable
Salbach et al., 2005 (78)	Yes	Yes	Yes	No	Don't know	Yes	Don't know	Yes	Yes	Yes	No	7 High
Salbach et al., 2004 (79)	Yes	Yes	Yes	No	Don't know	Yes	Don't know	Yes	Yes	Yes	No	7 High
Yang et al., 2007 (80)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Yes	8 High
<i>Walking training vs Overall physiotherapy</i>												
Dias et al., 2007 (81)	Yes	Yes	Yes	No	No	Yes	Don't know	Don't know	Don't know	Yes	Don't know	5 Acceptable
Duncan et al., 2011 (82)	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	8 Acceptable
Fisher et al., 2011 (83)	Yes	Don't know	Yes	No	No	Don't know	Don't know	Yes	Yes	Yes	Yes	6 Acceptable
Globas et al., 2012 (84)	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	9 High
Hoyer et al., 2012 (85)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Yes	8 High
Jonsdottir et al., 2010 (86)	Yes	Don't know	Yes	Don't know	No	Yes	Don't know	Don't know	Yes	Yes	Yes	6 Acceptable
Kuys et al., 2011 (87)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Yes	8 High
Mayr et al., 2007 (88)	Yes	Don't know	Yes	No	No	Yes	Don't know	Don't know	Yes	Yes	Yes	6 Acceptable

Table 1. *Contd.*

Study	Randomization method acceptable ^a	Concealment of treatment allocation ^a	Group similarity ^a	Blinding of patient	Blinding of care provider	Blinding of outcome assessor	Determination of co-interventions	Compliance	Drop-outs and reasons ^a	Timing of outcomes similar	Intention-to-treat	Number of yes and quality level
Park et al., 2011 (89)	Yes	Yes	Yes	No	No	Yes	Don't know	No	Yes	Yes	No	6 Acceptable
Yang et al., 2005 (90)	Yes	Yes	Yes	Don't know	Don't know	No	Yes	Don't know	Yes	Yes	Yes	7 High
Yen et al., 2008 (91)	Yes	Yes	Yes	No	No	No	Don't know	Yes	Yes	Yes	Yes	7 High
<i>Specific vs Traditional walking training</i>												
Ada et al., 2010 (92)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	No	Yes	7 High
da Cunha-Filho et al., 2001 (93)	Yes	Don't know	Yes	No	Don't know	Don't know	Don't know	Yes	No	No	No	3 Poor
da Cunha et al., 2002 (94)	Yes	Don't know	Yes	Don't know	Don't know	Don't know	Yes	Yes	Yes	Yes	No	6 Acceptable
Dean et al., 2010 (95)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Yes	8 High
Eich et al., 2004 (96)	Yes	Yes	Yes	No	No	Yes	Don't know	Yes	Yes	Yes	Yes	8 High
Hidler et al., 2009 (97)	Yes	Don't know	Yes	Don't know	Don't know	Don't know	Yes	Don't know	Don't know	Yes	No	4 Acceptable
Husemann et al., 2007 (98)	Yes	Yes	Yes	Don't know	Don't know	Yes	Yes	Don't know	No	Yes	Don't know	6 Acceptable
Kosak & Reding, 2000 (99)	Don't know	Don't know	Yes	No	No	Don't know	Yes	Don't know	Yes	Yes	Don't know	4 Poor
Langhammer & Stanghelle, 2010 (100)	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	9 High
Morone et al., 2011 (101) & 2012 (102)	Yes	Don't know	No	No	No	Yes	Don't know	Yes	Yes	Don't know	Yes	5 Acceptable
Morris et al., 1992 (103)	Yes	Yes	Yes	Don't know	Don't know	Yes	Yes	Don't know	No	Yes	Don't know	6 Acceptable
Ng et al., 2008 (104)	Yes	Don't know	No	No	No	No	Don't know	Yes	Yes	Yes	Yes	5 Acceptable
Nilsson et al., 2001 (105)	Yes	Don't know	Yes	No	No	Yes	Yes	Don't know	Yes	Yes	No	6 Acceptable
Olawale et al., 2011 (106)	Yes	No	Yes	No	No	Don't know	Don't know	Don't know	Yes	Yes	Don't know	4 Acceptable
Peurala et al., 2005 (107)	Yes	Yes	Yes	No	No	Don't know	Don't know	Yes	Yes	Yes	No	6 High
Peurala et al., 2009 (108)	Yes	Yes	Yes	No	No	Don't know	Don't know	Yes	Yes	Yes	No	6 High
Pohl et al., 2002 (109)	Yes	Don't know	Yes	No	No	Yes	Don't know	Don't know	Yes	Yes	No	5 Acceptable
Pohl et al., 2007 (110)	Yes	Yes	Yes	No	No	No	Don't know	Yes	Yes	Yes	Yes	7 High
Schaeur & Mauritz, 2003 (9)	Yes	No	Yes	No	No	Don't know	Don't know	Don't know	Don't know	Yes	Don't know	3 Poor
Schwartz et al., 2009 (111)	Don't know	Don't know	Yes	No	No	Don't know	Don't know	Don't know	Don't know	Yes	Yes	4 Poor
Tong et al., 2006 (112)	Yes	Don't know	No	No	No	No	Yes	Yes	Yes	Yes	Yes	6 Acceptable
Thaut et al., 1997 (113)	Yes	Yes	Yes	Don't know	Don't know	Yes	Don't know	Don't know	Don't know	Yes	Don't know	5 Acceptable
Thaut et al., 2007 (114)	Yes	Yes	Yes	Yes	No	Yes	Don't know	Don't know	Don't know	Yes	Don't know	6 Acceptable

The methodological quality of the RCTs was rated using criteria and decision rules modified from van Tulder et al. (2003) (25).

^aThese columns indicate the rating items needed for high-level RCTs with the total number of "yes" answers ≥ 6 and the number of patients ≥ 30 (25).

^bThe RCT was rated acceptable if the number of "yes" answers was ≥ 4 containing A, and poor if the number of "yes" answers was 0–3 or ≥ 4 , but A was "don't know" or if the number of patients in the group was ≤ 5 . Poor-quality studies were not accepted for meta-analysis.

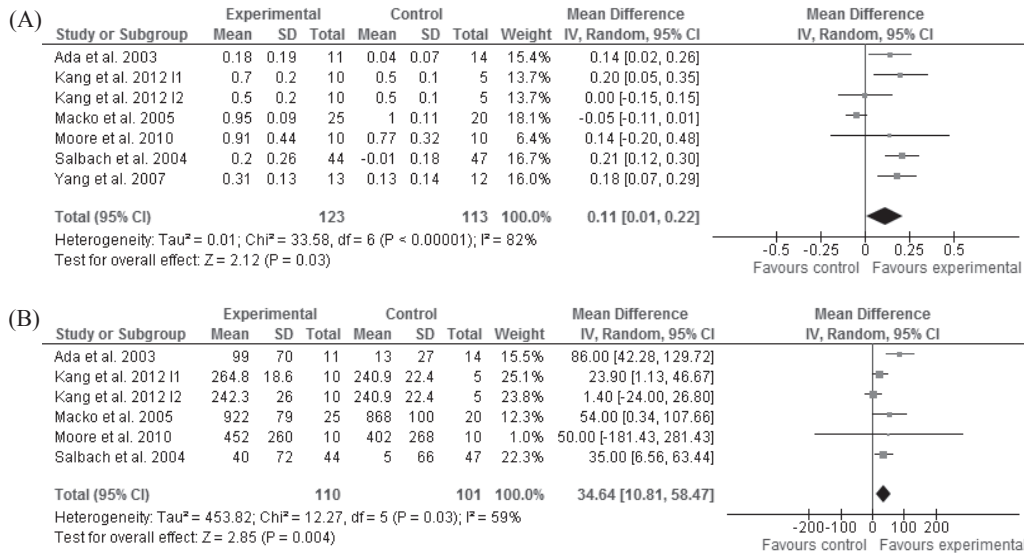


Fig. 2. Walking training vs no or placebo treatment in patients with stroke. (A) Walking speed (m/s). (B) Walking distance by 6-Min Walk Test (m). Weight percent refers to the value of the study in the meta-analysis according to the Total. SD: standard deviation; Total: number of patients; Random: random-effect meta-analysis (estimated effects are not identical in different studies but follow some distribution); 95% CI: 95% confidence interval; df: degrees of freedom.

treatment ($p=0.004$, Fig. 2B) (8, 74, 76–77, 79). These benefits in terms of walking speed and distance were achieved with walking training from 12 to 18 sessions during 4–6 weeks. Walking training time varied across studies from 30 to 60 min per session.

Walking training vs overall physiotherapy

Moderate evidence showed that walking training did not improve walking speed more than overall physiotherapy in the subacute stage of stroke ($p=0.21$, Fig. 3A) (82–83, 85, 87, 88). Whereas high evidence showed that walking training improved walking speed compared with overall physiotherapy in the chronic stage of stroke ($p<0.001$, Fig. 3A) (Tables I and SI¹) (81, 84, 86, 89–91, 106). The improvement in walking speed in the chronic stage of stroke was achieved with walking training from 12 to 36 sessions over 3–12 weeks. Walking training time in these studies varied from 20 to 60 min per session.

Moderate evidence showed that walking training did not improve walking distance in the subacute (82–83, 85, 87, 88) or chronic (81, 84, 89, 106) stages of stroke ($p=0.53$ and $p=0.34$, Fig. 3B), but there was a trend of improved walking independence compared with overall physiotherapy in the subacute stage of stroke ($p=0.06$, Fig. 3C) (85, 86).

Specific vs traditional walking training

Moderate evidence in the acute (94, 104–105, 108, 113–114) and high evidence in the subacute (96, 98, 103, 109–110) stage of stroke showed that specific walking training improved walking speed more than traditional walking training ($p<0.001$ and $p=0.03$, Fig. 4A). High evidence showed that specific and traditional walking training are comparable in gaining walking speed in the chronic stage of stroke ($p=0.65$, Fig. 4A) (97, 100, 106–107). The improved walking speed in the subacute

Table II. Level of evidence of walking training in the acute, subacute and chronic stage of stroke

Meta-analyses/ stage of stroke	Walking training vs no/placebo treatment	Walking training vs overall physiotherapy	Specific vs traditional walking training
Acute	No evidence	No evidence	Moderate for walking speed – Specific walking training better Low for walking distance – Comparable Moderate for walking independence – Specific walking training better
Subacute	No evidence	Moderate for walking speed and distance – Comparable Moderate for walking independence – Walking training trend to be better	Moderate for self-care – Comparable High for walking speed and distance – Specific walking training better Moderate for walking independence – Specific walking training better
Chronic	High for walking speed and distance – Walking training better	High for walking speed – Comparable Moderate for walking distance – Comparable	Low for self-care – Comparable High for walking speed and distance – Comparable Low for walking distance – Comparable Low for self-care – Comparable

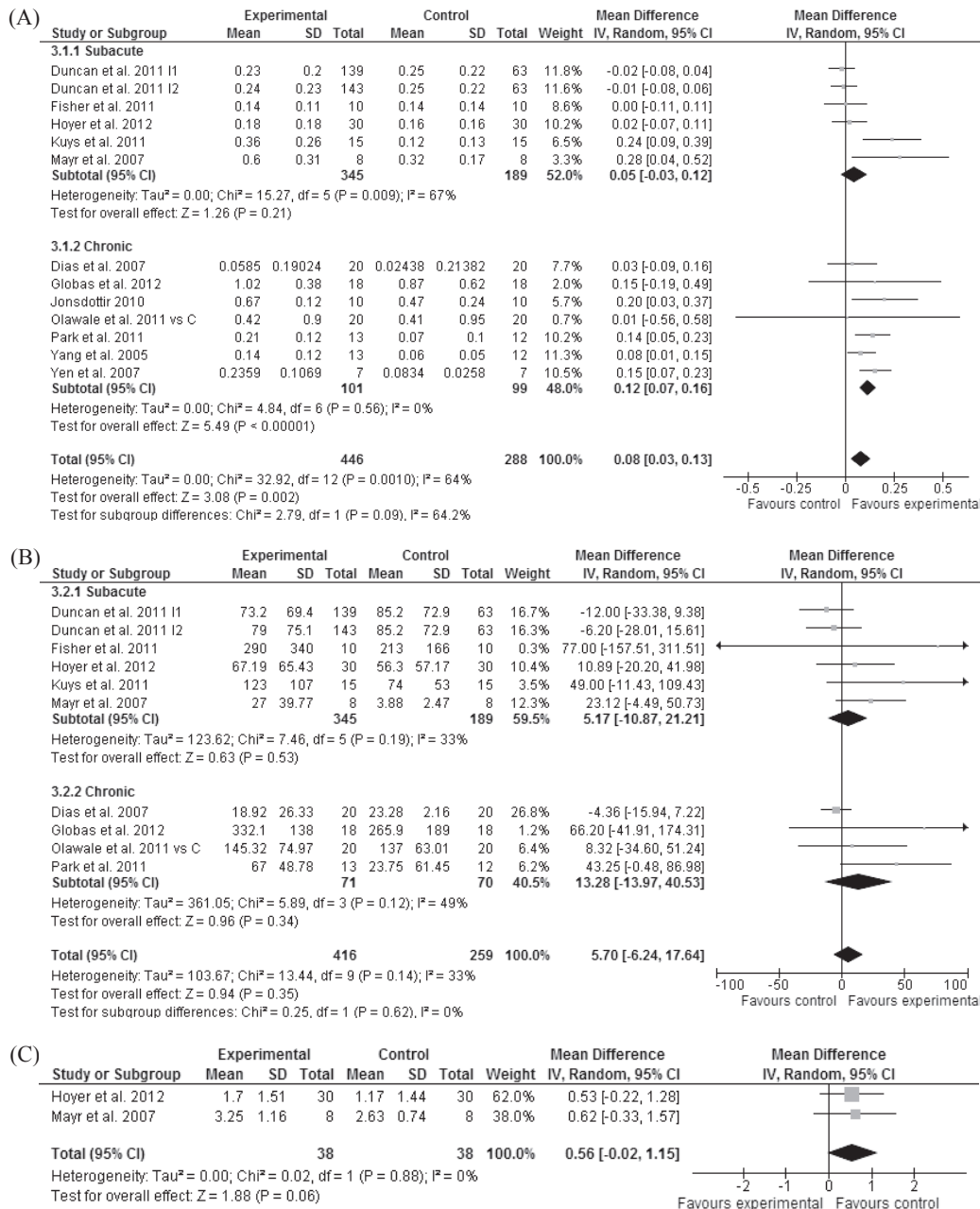


Fig. 3. Walking training vs overall physiotherapy in patients with stroke. (A) Walking speed (m/s). (B) Walking distance by 6-Min Walk Test (m). (C) Walking independence by Functional Ambulatory Category (categories 0–5). Weight percent refers to the value of the study in the meta-analysis according to the Total. SD: standard deviation; Total: number of patients; Random: random-effect meta-analysis (estimated effects are not identical in different studies but follow some distribution); 95% CI: 95% confidence interval; df: degrees of freedom.

stage of stroke was achieved with walking training from 20 to 30 sessions over 4–6 weeks. Walking training time in these studies varied from 20 to 60 min per session. Five studies were not included in the meta-analysis, because their quality was rated as poor (9, 99, 111), data were not available for the meta-analyses (99) or the data (93) were gathered from and analysed for the same group of subjects as that in the analysis (94) (Tables I and SI¹).

Low evidence showed that specific walking training did not improve walking distance more compared with traditional walking training in the acute (94, 108) stage of stroke ($p = 0.71$, Fig. 4B). High evidence showed that specific walking training increased walking distance more ($p < 0.001$), in the subacute (96, 110), but not in the chronic (97, 100, 106–107) stage of stroke, compared with traditional walking training ($p = 0.43$, Fig. 4B) (77, 88). The improved walking distance in the sub-

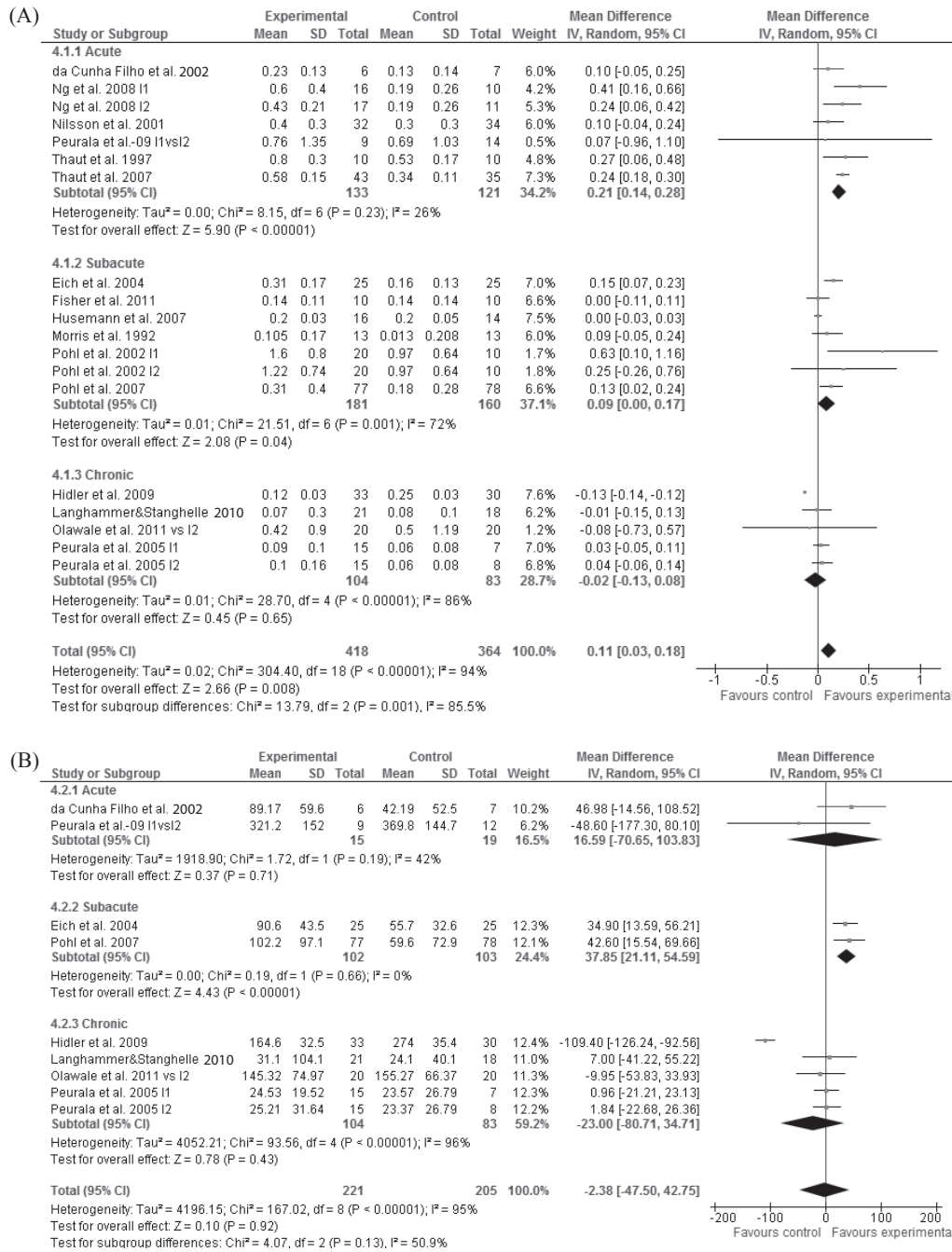


Fig. 4. Specific vs traditional walking training in patients with stroke. (A) Walking speed (m/s). (B) Walking distance by 6-Min Walk Test (m). (C) Walking independence by Functional Ambulatory Category (categories 0–5). Weight percent refers to the value of the study in the meta-analysis according to the Total. SD: standard deviation; Total: number of patients; Random: random-effect meta-analysis (estimated effects are not identical in different studies but follow some distribution); 95% CI: 95% confidence interval; df: degrees of freedom.

acute stage of stroke was achieved with walking training from 20 sessions over 4 weeks or 30 sessions over 6 weeks. In both studies walking training time was 20 min per session. Two poor-quality studies were not included in the meta-analysis (Tables I and SI¹) (93, 99). All the included studies used the 6-min walk test as an outcome measure.

Moderate evidence showed that specific walking training improved walking independence more than did traditional walking training in the acute ($p=0.001$, (101, 104, 105, 108) and subacute (109, 110) stages of stroke ($p=0.001$, Fig. 5A). A single study with low evidence indicated that specific walking training did not improve walking independence compared with

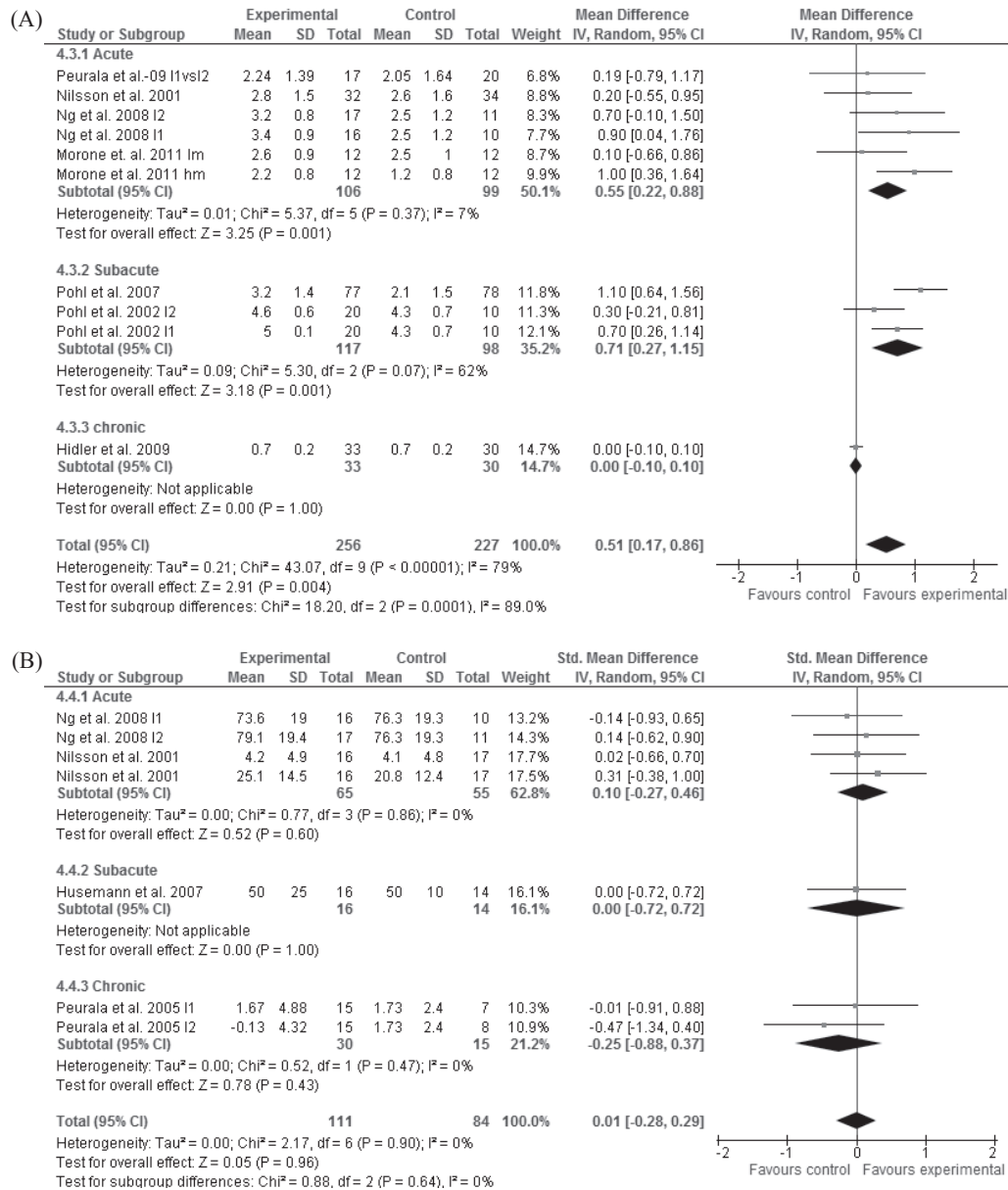


Fig. 5. Specific vs traditional walking training in patients with stroke. (A) Walking independence by Functional Ambulatory Category (categories 0–5). (B) Self-care (standardized mean difference (SMD), i.e. the effect size). Weight percent refers to the value of the study in the meta-analysis according to the Total. SD: standard deviation; Total, number of patients; Random: random-effect meta-analysis (estimated effects are not identical in different studies but follow some distribution); 95% CI: 95% confidence interval, df: degrees of freedom.

traditional walking in the chronic stage of stroke ($p = 1.0$, Fig. 5A) (97). In 6 studies data were not available for the meta-analyses (96, 98), the quality was rated as poor (99, 111) or the data (93) were gathered from and analysed for the same group of subjects as in the analysis (94) (Tables I and SI¹).

Moderate evidence indicated that specific and traditional walking training are comparable in terms of gains in self-care in the acute stage of stroke ($p = 0.60$, Fig. 5B) (104, 105). Single studies indicated with low evidence that specific walking training did not improve self-care compared with traditional walking in either the subacute ($p = 1.00$) (98) or chronic stages

of stroke ($p = 0.43$, Fig. 5B) (107). In one study data for the meta-analyses were not available (13), and in another study the outcome was not measured at the end of the intervention (101).

DISCUSSION

Our final analysis comprised 44 publications including 38 RCTs on various aspects of walking training post-stroke. Only RCTs in which walking training was specified either as minutes apart from other therapy or as achieved walking distance during the intervention were included in the analyses. The level of evi-

dence was determined on the basis of both the methodological quality and the results of the meta-analyses. The meta-analyses were run with walking and self-care outcome measures where available. High evidence is not supposed to change its magnitude and/or its direction accordingly to new studies.

We found high evidence that, in the chronic stage of stroke, walking training improved walking compared with no or placebo treatment or overall physiotherapy, but traditional and specific walking training methods were comparable (Table II). This result highlights the fact that, even in the chronic stage of stroke, significant changes in walking ability can be achieved. Furthermore, in line with previous studies (121), this evidence supports the notion that exercise therapy should be task-specific, suggesting that re-learning or improving walking after stroke can be done best with walking training.

In addition, high evidence was found that in the subacute stage of stroke, additional walking training tools such as musical feedback or body-weight-supported treadmill training improved walking better compared with same intensity traditional walking training (Table II). In the acute stage of stroke this evidence was moderate (Table II). Thus, we suggested that additional walking training tools should be used wherever possible in the acute and subacute stages of stroke.

Our analysis showed that walking speed is 0.21 m/s better in the acute and 0.09 m/s better in the subacute stage of stroke in specific walking training compared with traditional walking training, whereas in the chronic stage of stroke no such difference was observed between the training modalities. Fulk & Echternach (120) studied the minimal detectable change of gait speed in subjects undergoing rehabilitation after stroke. They found that the minimal detectable change at the 90% confidence level was 0.07 m/s with subjects who required physical assistance to walk, 0.18 m/s with subjects who required an assistive device to walk, and 0.36 m/s with subjects who were able to walk without physical assistance. The minimal detectable overall change was 0.30 m/s with patients in the acute and subacute stages of stroke (120). In our study, it can be speculated that within each stroke group minimal detectable walking speed was achieved.

Overall, our analyses showed that walking training from 12 to 36 sessions (mean 24 sessions) for 4–12 weeks (mean 7 weeks) was needed for effective improvements in walking speed and distance in patients with stroke. In general, walking training time in analysed studies varied from 20 to 60 min per session, but most commonly it was 30 or 45 min (mean 37 min). However, the level of evidence seemed to increase with longer training time (i.e. from 40 to 60 min per session). This suggests that the effective walking training frequency should be fairly high, on average 3–5 times per week, in sessions lasting from 20 to 60 min, in order to improve walking performance.

In a previous review, Dickstein (18) suggested that selection of the most appropriate method for walking training may be guided by a pragmatic approach. Although we agree with Dickstein's suggestion that walking training itself is the most important issue in walking rehabilitation, our analyses of specific walking training (as we defined it) produced significantly better results compared

with traditional walking training in the acute and subacute stages of stroke. Dickstein only had speed as an outcome and she used different subgroups in her analyses that made the comparison with our analysis somewhat different. In her review, she included other than RCTs in the analyses and did not take into account the level of the evidence of the meta-analysis in the conclusions.

This study had some limitations. First, we restricted our search to English, Finnish, Swedish, or German language publication, which may have resulted in publication bias. Secondly, in the present meta-analyses we focused only on the ICF Mobility domain, specifically walking speed, walking distance, walking independence, and ICF Self-care domain. Walking improvement is one of the main rehabilitation goals of patients with stroke, and the most common training in physiotherapy concerns walking (99, 122). In addition, in these patients the aspects of functioning that are most severely affected are transferring, dressing and walking (1). Thirdly, the analysed studies also included outcome measures of the other ICF components of body functions (e.g. spatio-temporal gait characteristics) and activity and participation (e.g. Berg Balance Scale), but we did not run a meta-analysis on these because they were very infrequent and were distributed across different subgroups. Fourthly, we did not use standard mean differences, which may have given more power to the statistics, but are difficult for a clinician to interpret; thus, we ran analyses as mean differences in order to provide clinicians with more practical results. Fifthly, the meta-analysis and results did not consist of follow-ups and therefore did not provide evidence about long-term effects. Sixthly, we excluded 12 RCTs that studied only different aspects of specific walking training (40, 44–50, 72, 104, 112, 107). Those single studies of different aspects give a more detailed picture of specific methods, such as speed-dependent treadmill training vs limited progressive treadmill training (45, 72).

These results indicate that the key issues in walking training are frequency and duration, i.e. number of sessions, training weeks and training minutes. In a systematic review and meta-analysis, Stoller et al. (123) studied training parameters in more detail, such as intensity of maximum heart rate reserve or resistance progression. They showed that patients with stroke may benefit from cardiovascular exercise during sub-acute stages to improve peak oxygen uptake and walking distance. Cardiovascular exercise was mainly performed by leg cycle ergometry, treadmill or stepper.

In conclusion, walking training produced training specific results in patients with stroke. Walking training, especially specific walking training, proved to be effective in improving walking speed, distance, and ability in different stages of stroke, thus improving mobility and, to some extent, self-care.

Clinical messages

- Walking training frequency should be fairly high; on average 3–5 times per week, in sessions lasting from 20 to 60 min, in order to be effective in improving walking performance.
- Walking training produces training specific results, i.e. improves walking speed, distance, and ability, that is, mobility and to some extent self-care.

ACKNOWLEDGEMENTS

The authors would like to thank the information specialists Anitta Pälvimäki at the Jyväskylä University Library and Irma Helldan at the Social Insurance Institute of Finland, physiotherapists and master students Tiina-Kaisa Tuupainen, Hanna Sahinoja at the Department of Health Sciences, University of Jyväskylä, for her help during the data collection, and Atte Hänninen, MSc, at the Department of Mathematical Information Technology, University of Jyväskylä, for statistical assistance.

This work was supported by the Social Insurance Institution of Finland (grants no. 31863) and Academy of Finland (grant no. 114291).

REFERENCES

- Jorgensen H, Nakayama H, Raaschou H, Olsen TS. Stroke. Neurologic and functional recovery the Copenhagen stroke study. *Phys Med Rehabil Clin N Am* 1999; 10: 887–906.
- Kwakkel G, Wagenaar RC, Koelman TW, Lankhorst GJ, Koetsier JC. Effects of intensity of rehabilitation after stroke. A research synthesis. *Stroke* 1997; 28: 1550–1556.
- Langhorne P, Dennis M, Kalra L, Shepperd S, Wade DT, Wolfe CD. Withdrawn: Services for helping acute stroke patients avoid hospital admission. *Cochrane Database Syst Rev* 2012; 1: CD000444.
- 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: 833–862.
- Kwakkel G, Kollen B, Twisk J. Impact of time on improvement of outcome after stroke. *Stroke* 2006; 37: 2348–2353.
- Kwakkel G, Wagenaar RC, Twisk JW, Lankhorst GJ, Koetsier JC. Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *Lancet* 1999; 354: 191–196.
- Jantra P, Monga TN, Press JM, Gervais BJ. Management of apraxic gait in a stroke patient. *Arch Phys Med Rehabil* 1992; 73: 95–97.
- Ada L, Dean CM, Hall JM, Bampton J, Crompton S. A treadmill and overground walking program improves walking in persons residing in the community after stroke: A placebo-controlled, randomized trial. *Arch Phys Med Rehabil* 2003; 84: 1486–1491.
- Schauer M, Mauritz K. Musical motor feedback (MMF) in walking hemiparetic stroke patients: randomized trials of gait improvement. *Clin Rehabil* 2003; 17: 713–722.
- Pomeroy VM, King LM, Pollock A, Baily-Hallam A, Langhorne P. Electrostimulation for promoting recovery of movement or functional ability after stroke. *Cochrane Database Syst Rev* 2006: 003241.
- Hesse S, Bertelt C, Schaffrin A, Malezic M, Mauritz KH. Restoration of gait in nonambulatory hemiparetic patients by treadmill training with partial body-weight support. *Arch Phys Med Rehabil* 1994; 75: 1087–1093.
- Malouin F, Potvin M, Prévost J, Richards CL, Wood-Dauphinee S. Use of an intensive task-oriented gait training program in a series of patients with acute cerebrovascular accidents. *Phys Ther* 1992; 72: 781–789.
- Moseley AM, Stark A, Cameron ID, Pollock A. Treadmill training and body weight support for walking after stroke. *Cochrane Database Syst Rev* 2005; (4): CD002840.
- Colombo G, Joerg M, Schreiber R, Dietz V. Tread-mill training of paraplegic patients using a robotic orthosis. *J Rehabil Res Dev* 2000; 37: 693–700.
- Hesse S, Uhlenbrock D. A mechanized gait trainer for restoration of gait. *J Rehabil Res Dev* 2000; 37: 701–708.
- Mehrholz J, Werner C, Kugler J, Pohl M. Electromechanical-assisted training for walking after stroke. *Cochrane Database Syst Rev* 2007; (4): CD006185.
- Hesse S, Waldner A, Tomelleri C. Innovative gait robot for the repetitive practice of floor walking and stair climbing up and down in stroke patients. *J Neuroeng Rehabil* 2010; 7: 30.
- Dickstein R. Rehabilitation of gait speed after stroke: a critical review of intervention approaches. *Neurorehabil Neural Repair* 2008; 22: 649–660.
- International Classification of Functioning, Disability and Health (ICF). World Health Organization: Geneva; 2001. Available from: <http://apps.who.int/classifications/icfbrowser/>.
- Cieza A, Geyh S, Chatterji S, Kostanjsek N, Ustün B, Stucki G. ICF linking rules: an update based on lessons learned. *J Rehabil Med* 2005; 37: 212–218.
- Salter K, Jutai JW, Teasell R, Foley NC, Bitensky J, Bayley M. Issues for selection of outcome measures in stroke rehabilitation: ICF activity. *Disabil Rehabil* 2005; 27: 315–340.
- Salter K, Jutai JW, Teasell R, Foley NC, Bitensky J, Bayley M. Issues for selection of outcome measures in stroke rehabilitation: ICF Participation. *Disabil Rehabil* 2005; 27: 507–28.
- Salter KL, Foley NC, Jutai JW, Teasell RW. Assessment of participation outcomes in randomized controlled trials of stroke rehabilitation interventions. *Int J Rehabil Res* 2007; 30: 339–342.
- Paltamaa J, Karhula M, Suomela-Markkanen T, Autti-Rämö I, eds. Basis of a good rehabilitation practice. From analysis of current practice and evidence to recommendations. A rehabilitation development project for severely disabled persons. Helsinki: Kela; 2011. Available from: <https://helda.helsinki.fi/handle/10138/24581>.
- van Tulder M, Furlan A, Bombardier C, Bouter L, Editorial Board of the Cochrane Collaboration Back Review Group. Updated method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group. *Spine* 2003; 28: 1290–1299.
- Anttila H. Evidence-based perspective on CP rehabilitation – reviews on physiotherapy, physiotherapy-related motor-based interventions and orthotic devices (Research Report 180). Helsinki: University of Helsinki; 2008.
- Salter K, Jutai JW, Teasell R, Foley NC, Bitensky J, Bayley M. Issues for selection of outcome measures in stroke rehabilitation: ICF activity. *Disabil Rehabil* 2005; 27: 315–40.
- The Finnish Medical Society Duodecim. Guidelines for evidence-base medicine work groups. Helsinki: The Finnish Medical Society Duodecim; 2008.
- Laufer Y, Dickstein R, Chefetz Y, Marcovitz E. The effect of treadmill training on the ambulation of stroke survivors in the early stages of rehabilitation: a randomized study. *J Rehabil Res Dev* 2001; 38: 69–78.
- Liston R, Mickelborough J, Harris B, Hann A, Tallis R. Conventional physiotherapy and treadmill re-training for higher-level gait disorders in cerebrovascular disease. *Age Ageing* 2000; 29: 311–318.
- Cozean C, Pease W, Hubbell S. Biofeedback and functional electric stimulation in stroke rehabilitation. *Arch Phys Med Rehabil* 1988; 69: 401–405.
- Ivey FM, Ryan AS, Hafer-Macko CE, Goldberg AP, Macko RF. Treadmill aerobic training improves glucose tolerance and indices of insulin sensitivity in disabled stroke survivors: a preliminary report. *Stroke* 2007; 38: 2752–2758.
- Intiso D, Santilli V, Grasso M, Rossi R, Caruso I. Rehabilitation of walking with electromyographic biofeedback in foot-drop after stroke. *Stroke* 1994; 25: 1189–1192.
- Kottink AI, Hermens HJ, Nene AV, Tenniglo MJ, van der Aa HE, Buschman HP, et al. A randomized controlled trial of an implantable 2-channel peroneal nerve stimulator on walking speed and activity in poststroke hemiplegia. *Arch Phys Med Rehabil* 2007; 88: 971–978.
- Lord S, McPherson KM, McNaughton HK, Rochester L, Weatherall M. How feasible is the attainment of community ambulation after stroke? A pilot randomized controlled trial to evaluate community-based physiotherapy in subacute stroke. *Clin Rehabil* 2008; 22: 215–225.

36. Richards C, Malouin F, Wood-Dauphinee S, Williams J, Bouchard J, Brunet D. Task-specific physical therapy for optimization of gait recovery in acute stroke patients. *Arch Phys Med Rehabil* 1993; 74: 612–620.
37. Bogataj U, Gros N, Kljajic M, Acimovic R, Malezic M. The rehabilitation of gait in patients with hemiplegia: a comparison between conventional therapy and multichannel functional electrical stimulation therapy. *Phys Ther* 1995; 75: 490–502.
38. Kottink AI, Hermens HJ, Nene AV, Tenniglo MJ, Groothuis-Oudshoorn CG, IJzerman MJ. Therapeutic effect of an implantable peroneal nerve stimulator in subjects with chronic stroke and footdrop: a randomized controlled trial. *Phys Ther* 2008; 88: 437–448.
39. Burridge J, Taylor P, Hagan S, Wood D, Swain I. The effects of common peroneal stimulation on the effort and speed of walking: a randomized controlled trial with chronic hemiplegic patients. *Clin Rehabil* 1997; 11: 201–210.
40. Barbeau H, Visintin M. Optimal outcomes obtained with body-weight support combined with treadmill training in stroke subjects. *Arch Phys Med Rehabil* 2003; 84: 1458–1465.
41. Daly JJ, Hogan N, Perepezko EM, Krebs HI, Rogers JM, Goyal KS, et al. Response to upper-limb robotics and functional neuromuscular stimulation following stroke. *J Rehabil Res Dev* 2005; 42: 723–736.
42. Daly JJ, Roenigk K, Holcomb J, Rogers JM, Butler K, Gansen J, et al. A randomized controlled trial of functional neuromuscular stimulation in chronic stroke subjects. *Stroke* 2006; 37: 172–178.
43. Daly JJ, Sng K, Roenigk K, Fredrickson E, Dohring M. Intra-limb coordination deficit in stroke survivors and response to treatment. *Gait Posture* 2007; 25: 412–418.
44. Hornby TG, Campbell DD, Kahn JH, Demott T, Moore JL, Roth HR. Enhanced gait-related improvements after therapist-versus robotic-assisted locomotor training in subjects with chronic stroke: a randomized controlled study. *Stroke* 2008; 39: 1786–1792.
45. Sullivan K, Knowlton B, Dobkin B. Step training with body weight support: effect of treadmill speed and practice paradigms on poststroke locomotor recovery. *Arch Phys Med Rehabil* 2002; 83: 683–691.
46. Sullivan KJ, Brown DA, Klassen T, Mulroy S, Ge T, Azen SP, et al. Physical Therapy Clinical Research Network (PTClinResNet). Effects of task-specific locomotor and strength training in adults who were ambulatory after stroke: results of the STEPS randomized clinical trial. *Phys Ther* 2007; 87: 1580–1587.
47. Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. *Stroke* 1998; 29: 1122–1128.
48. Werner C, von Frankenberg S, Treig T, Konrad M, Hesse S. Treadmill training with partial body weight support and an electromechanical gait trainer for restoration of gait in subacute stroke patients: a randomized crossover study. *Stroke* 2002a; 33: 2895–2901.
49. Werner C, Bardeleben A, Mauritz K, Kirker S, Hesse S. Treadmill training with partial body weight support and physiotherapy in stroke patients: a preliminary comparison. *E J Neurol* 2002b; 9: 639–644.
50. Yagura H, Hatakenaka M, Miyai I. Does therapeutic facilitation add to locomotor outcome of body weight-supported treadmill training in nonambulatory patients with stroke? a randomized controlled trial. *Arch Phys Med Rehabil* 2006; 87: 529–535.
51. Smith PS, Thompson M. Treadmill training post stroke: are there any secondary benefits? A pilot study. *Clin Rehabil* 2008; 22: 997–1002.
52. Langhammer B, Stanghelle JK, Lindmark B. An evaluation of two different exercise regimes during the first year following stroke: a randomised controlled trial. *Physiother Theory Pract* 2009; 25: 55–68.
53. Mulroy SJ, Winstein CJ, Kulig K, Beneck GJ, Fowler EG, DeMuth SK, et al. Secondary mediation and regression analyses of the PTClinResNet database: determining causal relationships among the International Classification of Functioning, Disability and Health levels for four physical therapy intervention trials. *Physical Therapy Clinical Research Network. Phys Ther* 2011; 91: 1766–1779.
54. Daly JJ, Zimbleman J, Roenigk KL, McCabe JP, Rogers JM, Butler K, et al. Recovery of coordinated gait: randomized controlled stroke trial of functional electrical stimulation (FES) versus no FES, with weight-supported treadmill and over-ground training. *Neurorehab Neural Repair* 2011; 25: 588–596.
55. Toledano-Zarhi A, Tanne D, Carmeli E, Katz-Leurer M. Feasibility, safety and efficacy of an early aerobic rehabilitation program for patients after minor ischemic stroke: a pilot randomized controlled trial. *NeuroRehabilitation* 2011; 28: 85–90.
56. Sungkarat S, Fisher BE, Kovindha A. Efficacy of an insole shoe wedge and augmented pressure sensor for gait training in individuals with stroke: a randomized controlled trial. *Clin Rehab* 2011; 25: 360–369.
57. Chouhan S, Kumar S, Walker S, Lloyd C. Comparative study of the effects of rhythmic auditory cueing and visual cueing in acute hemiparetic stroke. *IJTRR* 2012; 19: 1–8.
58. Ivey FM, Hafer-Macko CE, Ryan AS, Macko RF. Impaired leg vasodilatory function after stroke: adaptations with treadmill exercise training. *Stroke* 2010; 41: 2913–2917.
59. Yang YR, Chen IH, Liao KK, Huang CC, Wang RY. Cortical reorganization induced by body weight-supported treadmill training in patients with hemiparesis of different stroke durations. *Arch Phys Med Rehabil* 2010; 91: 513–518.
60. Ploughman M, McCarthy J, Bosse M, Sullivan HJ, Corbett D. Does treadmill exercise improve performance of cognitive or upper-extremity tasks in people with chronic stroke? A randomized cross-over trial. *Arch Phys Med Rehabil* 2008; 89: 2041–2047.
61. Tilson JK, Wu SS, Cen SY, Feng Q, Rose DR, Behrman AL, et al. Characterizing and identifying risk for falls in the LEAPS study: a randomized clinical trial of interventions to improve walking poststroke. *Stroke* 2012; 43: 446–452.
62. Shaughnessy M, Michael K, Resnick B. Impact of treadmill exercise on efficacy expectations, physical activity, and stroke recovery. *J Neurosci Nurs* 2012; 44: 27–35.
63. Ivey FM, Ryan AS, Hafer-Macko CE, Macko RF. Improved cerebral vasomotor reactivity after exercise training in hemiparetic stroke survivors. *Stroke* 2011; 42: 1994–2000.
64. Langhammer B, Stanghelle JK. Can physiotherapy after stroke based on the bobath concept result in improved quality of movement compared to the motor relearning programme. *Physiother Res Int* 2011; 16: 69–80.
65. Dean CM, Rissel C, Sharkey M, Sherrington C, Cumming RG, Barker RN, et al. Exercise intervention to prevent falls and enhance mobility in community dwellers after stroke: a protocol for a randomised controlled trial. *BMC Neurol* 2009; 9: 38.
66. Batchelor FA, Hill KD, Mackintosh SF, Said CM, Whitehead CH. The FLASSH study: protocol for a randomised controlled trial evaluating falls prevention after stroke and two sub-studies. *BMC Neurol* 2009; 9: 14.
67. Freivogel S, Schmalohr D, Mehrholz J. Improved walking ability and reduced therapeutic stress with an electromechanical gait device. *J Rehabil Med* 2009; 41: 734–739.
68. Kuys SS, Brauer SG, Ada L, Russell TG. Increasing intensity during treadmill walking does not adversely affect walking pattern or quality in newly-ambulating stroke patients: an experimental study. *Aust J Physiother* 2008; 54: 49–54.
69. Dal Farra F, Boem D, Magni S, Bernasconi L, Monticone M. Efficacy of the Regent Suit training during a post-acute stroke rehabilitation process: description of a case report. *G Ital Med Lav Ergon* 2011; 33: 74–83.
70. Tyrell CM, Roos MA, Rudolph KS, Reisman DS. Influence of systematic increases in treadmill walking speed on gait kinemat-

- ics after stroke. *Phys Ther* 2011; 91: 392–403.
71. Dobkin BH, Plummer-D'Amato P, Elashoff R, Lee J, SIRROWS Group. International randomized clinical trial, stroke inpatient rehabilitation with reinforcement of walking speed (SIRROWS), improves outcomes. *Neurorehabil Neural Repair* 2010; 24: 235–242.
 72. Lau KW, Mak MK. Speed-dependent treadmill training is effective to improve gait and balance performance in patients with sub-acute stroke. *J Rehabil Med* 2011; 43: 709–713.
 73. Chu KS, Eng JJ, Dawson AS, Harris JE, Ozkaplan A, Gylfadóttir S. Water-based exercise for cardiovascular fitness in people with chronic stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2004; 85: 870–874.
 74. 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: 246–255.
 75. Luft AR, Macko RF, Forrester LW, Villagra F, Ivey F, Sorkin JD, et al. Treadmill exercise activates subcortical neural networks and improves walking after stroke: a randomized controlled trial. *Stroke* 2008; 39: 3341–3350.
 76. Macko RF, Ivey FM, Forrester LW, Hanley D, Sorkin JD, Katzell LI, et al. Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke: a randomized, controlled trial. *Stroke* 2005; 36: 2206–2211.
 77. Moore JL, Roth EJ, Killian C, Hornby TG. Locomotor training improves daily stepping activity and gait efficiency in individuals poststroke who have reached a “plateau” in recovery. *Stroke* 2010; 41: 129–135.
 78. Salbach NM, Mayo NE, Robichaud-Ekstrand S, Hanley JA, Richards CL, Wood-Dauphinee S. The effect of a task-oriented walking intervention on improving balance self-efficacy post-stroke: a randomized, controlled trial. *J Am Geriatr Soc* 2005; 53: 576–582.
 79. Salbach NM, Mayo NE, Wood-Dauphinee S, Hanley JA, Richards CL, Cote R. A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. *Clin Rehabil* 2004; 18: 509–519.
 80. Yang YR, Wang RY, Chen YC, Kao MJ. Dual-task exercise improves walking ability in chronic stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2007; 88: 1236–1240.
 81. Dias D, Lains J, Pereira A, Nunes R, Caldas J, Amaral C, et al. Can we improve gait skills in chronic hemiplegics? A randomized control trial with gait trainer. *Eura Medicophys* 2007; 43: 499–504.
 82. Duncan PW, Sullivan KJ, Behrman AL, Azen SP, Wu SS, Nadeau SE, et al. LEAPS Investigative Team. Body-weight-supported treadmill rehabilitation after stroke. *N Engl J Med* 2011; 364: 2026–2036.
 83. Fisher S, Lucas L, Thrasher TA. Robot-assisted gait training for patients with hemiparesis due to stroke. *Top Stroke Rehabil* 2011; 18: 269–276.
 84. Globas C, Becker C, Cerny J, Lam JM, Lindemann U, Forrester LW, et al. Chronic stroke survivors benefit from high-intensity aerobic treadmill exercise: a randomized control trial. *Neurorehabil Neural Repair* 2012; 26: 85–95.
 85. Hoyer E, Jahnsen R, Stanghelle JK, Strand LI. Body weight supported treadmill training versus traditional training in patients dependent on walking assistance after stroke: a randomized controlled trial. *Disabil Rehabil* 2012; 34: 210–219.
 86. Jonsdóttir J, Cattaneo D, Recalcati M, Regola A, Rabuffetti M, Ferrarin M, et al. Task-oriented biofeedback to improve gait in individuals with chronic stroke: motor learning approach. *Neurorehabil Neural Repair* 2010; 24: 478–485.
 87. Kuys SS, Brauer SG, Ada L. Higher-intensity treadmill walking during rehabilitation after stroke in feasible and not detrimental to walking pattern or quality: a pilot randomized trial. *Clin Rehabil* 2011; 25: 316–326.
 88. Mayr A, Kofler M, Quirbach E, Matzak H, Fröhlich K, Saltuari L. Prospective, blinded, randomized crossover study of gait rehabilitation in stroke patients using the Lokomat gait orthosis. *Neurorehabil Neural Repair* 2007; 21: 307–314.
 89. Park HJ, Oh DW, Kim SY, Choi JD. Effectiveness of community-based ambulation training for walking function of post-stroke hemiparesis: a randomized controlled pilot trial. *Clin Rehabil* 2011; 25: 451–459.
 90. Yang Y, Yen J, Wang R, Yen L, Lieu F. Gait outcomes after additional backward walking training in patients with stroke: a randomized controlled trial. *Clin Rehabil* 2005; 19: 264–273.
 91. Yen CL, Wang RY, Liao KK, Huang CC, Yang YR. Gait training-induced change in corticomotor excitability in patients with chronic stroke. *Neurorehabil Neural Repair* 2008; 22: 22–30.
 92. Ada L, Dean CM, Morris ME, Simpson JM, Katrak P. Randomized trial of treadmill walking with body weight support to establish walking in subacute stroke: the MOBILISE trial. *Stroke* 2010; 41: 1237–1242.
 93. da Cunha Filho IT, Lim P, Qureshy H, Henson H, Monga T, Protas E. A comparison of regular rehabilitation and regular rehabilitation with supported treadmill ambulation training for acute stroke patients. *J Rehabil Res Dev* 2001; 38: 245–255.
 94. da Cunha IT, Lim PA, Qureshy H, Henson H, Monga T, Protas EJ. Gait outcomes after acute stroke rehabilitation with supported treadmill ambulation training: a randomized controlled pilot study. *Arch Phys Med Rehabil* 2002; 83: 1258–1265.
 95. 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: 97–103.
 96. Eich H, Mach H, Werner C, Hesse S. Aerobic treadmill plus Bobath walking training improves walking in subacute stroke: a randomized controlled trial. *Clin Rehabil* 2004; 18: 640–651.
 97. Hidler J, Nichols D, Pelliccio M, Brady K, Campbell DD, Kahn JH, et al. Multicenter randomized clinical trial evaluating the effectiveness of the Lokomat in subacute stroke. *Neurorehabil Neural Repair* 2009; 23: 5–13.
 98. Husemann B, Muller F, Krewer C, Heller S, Koenig E. Effects of locomotion training with assistance of a robot-driven gait orthosis in hemiparetic patients after stroke: a randomized controlled pilot study. *Stroke* 2007; 38: 349–354.
 99. Kosak M, Reding M. Comparison of partial body weight-supported treadmill gait training versus aggressive bracing assisted walking post stroke. *Neurorehabil Neural Repair* 2000; 14: 13–19.
 100. Langhammer B, Stanghelle JK. Exercise on a treadmill or walking outdoors? A randomized controlled trial comparing effectiveness of two walking exercise programmes late after stroke. *Clin Rehabil* 2010; 24: 46–54.
 101. Morone G, Bragoni M, Iosa M, De Angelis D, Venturiero V, Coiro P, et al. Who may benefit from robotic-assisted gait training? A randomized clinical trial in patients with subacute stroke. *Neurorehabil Neural Repair* 2011; 25: 636–644.
 102. Morone G, Iosa M, Bragoni M, De Angelis D, Venturiero V, Coiro P, et al. Who may have durable benefit from robotic gait training? A 2-year follow-up randomized controlled trial in patients with subacute stroke. *Stroke* 2012; 43: 1140–1142.
 103. Morris ME, Matyas TA, Bach TM, Goldie PA. Electrogoniometric feedback: its effect on genu recurvatum in stroke. *Arch Phys Med Rehabil* 1992; 73: 1147–1154.
 104. Ng MF, Tong RK, Li LS. A pilot study of randomized clinical controlled trial of gait training in subacute stroke patients with partial body-weight support electromechanical gait trainer and functional electrical stimulation: six-month follow-up. *Stroke* 2008; 39: 154–160.
 105. Nilsson L, Carlsson J, Danielsson A, Fugl-Meyer A, Hellström K,

Kristensen L, et al. Walking training of patients with hemiparesis at an early stage after stroke: a comparison of walking training on a treadmill with body weight support and walking training on the ground. *Clin Rehabil* 2001; 15: 515–527.

106. Olawale OA, Jaja SI, Anigbogu CN, Appiah-Kubi KO, Jones-Okai D. Exercise training improves walking function in an African group of stroke survivors: a randomized controlled trial. *Clin Rehabil* 2011; 25: 442–450.

107. Peurala SH, Tarkka IM, Pitkänen K, Sivenius J. The effectiveness of body weight-supported gait training and floor walking in patients with chronic stroke. *Arch Phys Med Rehabil* 2005; 86: 1557–1564.

108. Peurala SH, Airaksinen O, Huuskonen P, Jäkälä P, Juhakoski M, Sandell K, et al. Effects of intensive therapy using gait trainer or floor walking exercises early after stroke. *J Rehabil Med* 2009; 41: 166–173.

109. Pohl M, Mehrholz J, Ritschel C, Ruckriem S. Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomized controlled trial. *Stroke* 2002; 33: 553–558.

110. Pohl M, Werner C, Holzgraefe M, Kroczeck G, Mehrholz J, Wingendorf I, et al. Repetitive locomotor training and physiotherapy improve walking and basic activities of daily living after stroke: a single-blind, randomized multicentre trial (DEutsche GAngrainerStudie, DEGAS). *Clin Rehabil* 2007; 21: 17–27.

111. Schwartz I, Sajin A, Fisher I, Neeb M, Shochina M, Katz-Leurer M, et al. The effectiveness of locomotor therapy using robotic-assisted gait training in subacute stroke patients: a randomized controlled trial. *PM&R* 2009; 1: 516–523.

112. Tong RK, Ng MF, Li LS. Effectiveness of gait training using an electromechanical gait trainer, with and without functional electric stimulation, in subacute stroke: a randomized controlled trial. *Arch Phys Med Rehabil* 2006; 87: 1298–1304.

113. Thaut MH, McIntosh GC, Rice RR. Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. *J Neurol Sci* 1997; 151: 207–212.

114. 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-ambulatory patients early poststroke: a single-blind, randomized trial. *Neurorehabil Neural Repair* 2007; 21: 455–459.

115. Holden M, Gill K, Maglioni M, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. *Phys Ther* 1984; 64: 35–40.

116. Guyatt GH, Thompson PJ, Berman LB, Sullivan MJ, Townsend M, Jones NL, et al. How should we measure function in patients with chronic heart and lung disease? *J Chronic Dis* 1985; 38: 517–524.

117. Keith RA, Granger CV, Hamilton BB, Sherwin FS. The functional independence measure: a new tool for rehabilitation. *Adv Clin Rehabil* 1987; 1: 6–18.

118. Mahoney FI, Barthel DW. Functional evaluation: the Barthel Index. *Md State Med J* 1965; 14: 61–65.

119. Kwakkel G, Wagenaar RC, Twisk JW, Lankhorst GJ, Koetsier JC. Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial. *Lancet* 1999; 354: 191–196.

120. Fulk GD, Echtertnach JL. Test-retest reliability and minimal detectable change of gait speed in individuals undergoing rehabilitation after stroke. *J Neurol Phys Ther* 2008; 32: 8–13.

121. Latham NK, Jette DU, Slavin M, Richards LG, Procino A, Smout RJ, et al. Physical therapy during stroke rehabilitation for people with different walking abilities. *Arch Phys Med Rehabil* 2005; 86: S41–S50.

122. Jette DU, Latham NK, Smout RJ, Gassaway J, Slavin MD, Horn SD. Physical therapy interventions for patients with stroke in inpatient rehabilitation facilities. *Phys Ther* 2005; 85: 238–248.

123. Stoller O, de Bruin ED, Knols RH, Hunt KJ. Effects of cardiovascular exercise early after stroke: systematic review and meta-analysis. *BMC Neurol* 2012; 12: 45.

124. Peurala SH, Kantanen MP, Sjögren T, Paltamaa J, Karhula M, Heinonen A. Effectiveness of constraint-induced movement therapy on activity and participation after stroke: a systematic review and meta-analysis of randomized controlled trials. *Clin Rehabil*. 2012; 26: 209–223

APPENDIX II. Criteria for determining level of evidence in meta-analyses of randomized controlled trials (RCT) for walking training in stroke (28) (from ref 124, published with permission)

Evidence	Criteria
High	At least 2 high-quality RCTs with parallel results
Moderate	High-quality RCT or several high-quality RCTs with some contradictions in results or several acceptable-quality RCTs with parallel results
Low	High-quality RCTs with notable contradictions of results or at least 1 acceptable RCT
No evidence	Poor-quality RCT or RCTs or no RCTs

APPENDIX I. Criteria for evaluating methodological quality or risk for bias of randomized controlled trials (RCT) for walking training in stroke (from ref 124, published with permission)

Methodological quality of RCT (26)	Yes scores of van Tulder evaluation (maximum 11)	Demands of special criteria in van Tulder evaluation (24)	Other criteria
High	≥6	Method of randomization adequate (A) Concealed allocation (B) Groups similar at baseline regarding the most important prognostic indicators (C) Drop-out rate described and acceptable (I)	≥30 subjects in a study
Acceptable	≥4	Method of randomization adequate (A)	
Poor	≥4 or 0–3 or	Method of randomization NOT adequate (A) N/A N/A	N/A N/A Number of subjects ≤5 in intervention or control group

The methodological quality of the RCTs was rated using criteria and decision rules modified from van Tulder et al. (25). These include 11 items presented in Table I. All items were rated as “yes”, “no” or “don’t know”.
N/A: not applicable.