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REVIEW ARTICLE

Effectiveness of walking training on balance, motor functions, activity, participation and quality of life in people with chronic stroke: a systematic review with meta-analysis and meta-regression of recent randomized controlled trials

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ABSTRACT

Purpose: To review and quantify the effects of walking training for the improvement of various aspects of physical function of people with chronic stroke.

Methods: We conducted a systematic search and meta-analysis of randomized controlled trials (RCTs) of chronic stroke rehabilitation interventions published from 2008 to 2020 in English or French. Of the 6476-screened articles collated from four databases, 15 RCTs were included and analyzed. We performed a meta-regression with the total training time as dependent variable in order to have a better understanding of how did the training dosage affect the effect sizes.

Results: Treadmill walking training was more effective on balance and motor functions (standardized mean difference (SMD)=0.70[0.02, 1.37], $p = 0.04$) and 0.56[0.15, 0.96], $p = 0.007$ respectively). Overground walking training improved significantly walking endurance (SMD = 0.38[0.16, 0.59], $p < 0.001$), walking speed (MD = 0.12[0.05, 0.18], $p < 0.001$), participation (SMD = 0.35[0.02, 0.68], $p = 0.04$) and quality of life (SMD = 0.46[0.12, 0.80], $p = 0.008$). Aquatic training improved balance (SMD = 2.41[1.20, 3.62], $p < 0.001$). The Meta-regression analysis did not show significant effect of total training time on the effect sizes.

Conclusion: Treadmill and overground walking protocols consisting of ≥30 min sessions conducted at least 3 days per week for about 8 weeks are beneficial for improving motor impairments, activity limitations, participation, and quality of life in people with chronic stroke.

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KEYWORDS
Overground walking; physical activity; stroke; treadmill walking; walking training

➤ IMPLICATIONS FOR REHABILITATION

- Treadmill walking training is effective for improving balance and motor functions.
- Overground walking training improved significantly walking endurance, walking speed, participation and quality of life.
- Treadmill and overground walking protocols consisting of ≥30 min sessions conducted at least 3 days per week for about 8 weeks are beneficial for improving motor impairments, activity limitations, participation, and quality of life in patient with chronic stroke.

Introduction

Stroke remains a major global health problem and its importance in public health is expected to increase [1–4] as many countries are undergoing population aging and health transitions associated with economic development [5,6]. According to the Global Burden of Stroke project, stroke is the second leading cause of death worldwide (11.8%) [7]. Moreover, stroke is a leading cause of long-term disability that can disrupt the ability of affected patients to walk, get in and out of their beds and chairs, and dress themselves [4,8,9]. One of the main goals for patients who have suffered a stroke to enable them to regain independence and improve quality of life (QoL) is recovering the ability to walk. In the chronic phase of stroke, motor recovery stabilizes and patients need to develop compensatory adaptations to their environments [10].

Physical inactivity due to poststroke disability can lead to an increased risk of cardiovascular diseases [11]. The American Heart Association recommends that people post-stroke engage in 20–60 min of aerobic exercise at least 3 days per week, supplemented with resistance training as well as balance and stretching exercises, to improve muscular strength, gait, and balance, and to prevent cardiovascular complications [12]. Cardiorespiratory training and, to a lesser extent, mixed training have been shown to reduce disability and improve mobility, balance, and cardiorespiratory fitness [13]. Moreover, a variety of physical exercises have been shown to be beneficial to people with chronic stroke [14], including walking trainings [15,16], treadmill training [17,18], progressive resistance training [19,20], and cycling [21], among others.

Walking is a low to moderate intensity aerobic exercise that can be performed with or without equipment, alone or with a

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group, and at one's own pace, making it an ideal form of exercise for people post-stroke. Treadmill walking is highly modifiable owing to a wide range of speed and inclination settings with the presence of support handrails, whereas overground walking does not require equipment and can be easily incorporated into daily life. The use of the walking robot has shown its effectiveness especially in the acute and subacute stage but financial access may limits its use [22,23]. The advantages of robot-assisted training, compared to treadmill training were suggested to be a longer training duration, reproducible symmetrical gait kinematic patterns of the leg movements, hands-free operation by a single therapist, and reduction in the physical load imposed upon the therapist [24,25]. A recent systematic review [24], suggests that stroke patients who receive electromechanical-assisted gait training in combination with physical therapy are more likely to achieve independent walking than patients receiving gait training without these devices.

The relative benefits of treadmill walking, overground walking and robot-assisted walking trainings remains unclear in terms of the improvement of balance, motor functions, activity, participation and quality of life in people with chronic stroke. In 2014 Peurala and colleagues [25] have explored the effectiveness of walking training on walking capacity and self-care in patients with stroke, but they did not assess the effect on motor functions, balance, participation and quality of life that are important goals of rehabilitation in particular in people with stroke. Therefore, the purpose of the present systematic review, meta-analysis and meta-regression was to review and quantify the effects of various walking training protocols versus other physical exercises for the improvement of balance, motor functions, walking endurance, walking speed, participation, and quality of life in people with chronic stroke.

Methods

This study was performed in accordance with a previously established protocol registered on the international prospective register of systematic reviews, PROSPERO (https://www.crd.york.ac.uk/PROSPERO/; registration number: CRD42018092246). Our study complies with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement [26]. Methodological issues were solved with the guidance of the Cochrane Handbook for Systematic Reviews of Interventions [27].

Description of the intervention

Walking is a physical activity in which the body advances at a slow to moderate pace by moving the feet in a coordinated fashion (*PubMed, Mesh Database*) [28]. Walking training is therefore any activity/exercise that involves walking including recreational or free-living walking within the community, walking for fitness, and competitive race-walking as well as rehabilitative walking training (e.g., walking with expensive robotics, body weight supported training, aquatic pool floor walking).

Comparators/controls

We considered all active control groups different from walking training interventions, and nonactive control groups including stretching training, massage, social and educational class, non-intervention, etc.

Identification and selection of studies

We conducted systematic searches of four electronic databases (Cochrane Library, Sciences Direct, Medline/PubMed and Scopus) for articles published in English or French from January 2008 to December 2018 and updated the search in August 2020. The search included terms relating to or describing walking training or any physical exercise therapy in people post-stroke. The search strategy was adapted to each database, combining keywords and MeSH terms where applicable. Reviews and retrieved publication references were hand-searched for potentially suitable articles. The full search process is presented in Supplementary Appendix 1.

Inclusion criteria

Included studies were randomized controlled trials (RCTs) fulfilling the following criteria: Participants were adult people post-stroke (age $\geq$18 years) diagnosed according to the World Health Organization definition [29] or confirmed by imaging for which 6 months has passed after their stroke; physical exercise during recovery included walking training (intervention group) or any other conventional rehabilitation therapy treatment, physical exercise, or placebo (comparison group); and outcome data included impairment level (balance, motor impairment), activity level (walking endurance and speed, functional independence), community participation, and/or QoL. Functional independence is an individual's ability to perform activities of daily living (ADLs).

Data extraction and risk of bias assessment

The first and second authors screened titles and abstracts of all unique record for relevance independently. Full texts of selected papers were reviewed and extracted data were compiled in an Excel spreadsheet. Selections and ratings were compared for agreement and disagreement. Differences were discussed until consensus was reached between the first and second authors. If necessary, a third author was consulted. The corresponding authors of articles were contacted in cases of missing data. The risk of bias for each article was assessed by two reviewers using the Cochrane risk of bias tool [30] which allow categorizing the risk of bias in RCTs in seven domains: random sequence generation, allocation concealment, performance bias, detection bias, attrition bias, reporting bias, and other bias. For each item in the tool, the assessment of risk of bias is in two parts. The support for judgment provides a succinct free text description or summary of the relevant trial characteristic on which judgments of risk of bias are based and aims to ensure transparency in how judgments are reached. The second part of the tool involves assigning a judgment of high, low, or unclear risk of material bias for each item.

Data synthesis, subgroup and sensitivity analysis

We carried out subgroup analysis of comparable studies by stratifying the results by intervention type. Our subgroup analysis was focused on comparing different walking trainings. To ensure the robustness of evidence, we performed sensitivity analysis to assess the impact of studies with poor methodological quality by excluding them from the initial analysis. A pre-set cut-off point of $\geq$50% of the total PEDro score was used to select trials for the sensitivity analysis [31]. We assessed how sensitive the results of the meta-analysis were in relation to quality of included trials.

Statistical analysis

Statistical analyses were performed in Review Manager version 5.3 software under a random effects model [32]. Standardized mean differences (SMDs) with 95% confidence intervals (CIs) were reported [33]. The SMD is an index of intervention effect size relative to the variability observed in a study. A SMD of zero indicates no treatment effect compared to a control condition (equivalent effect). However, for the walking speed we calculated the mean differences (MDs). Thereby, the reader could have a better understanding of the absolute effect of the walking trainings on walking speed. Sample heterogeneity is reported in terms of I^2, the variance percentage attributable to study heterogeneity. An I^2 value of 50% or higher indicates the presence of substantial heterogeneity. The criterion for statistical significance was $p < 0.05$.

Results

A total of 6476 possibly relevant studies were identified in our electronic database searches. After removal of duplications, screening of titles and abstracts, and reviewing of full texts, 15 RCTs met the inclusion criteria and were included in the qualitative and quantitative analyses. A flowchart of the study selection process is presented in Figure 1.

Study characteristics

The 15 included studies involved 653 participants (324 in walking training intervention groups and 329 in control groups). These studies investigated the effects of walking training on balance and motor function, activity (endurance, walking speed, and functional independence), community participation, and quality of life. The sample characteristics are summarized in Table 1. The studies' durations ranged from 2 weeks to 48 weeks, with a predominant interval in the range of 4–12 weeks. Mean participant ages for the studies ranged from 50 to 76 years. The 15 studies were divided into five subgroups based on walking training intervention type: treadmill, $n = 4$; overground, $n = 7$; robot-assisted, $n = 3$; and aquatic training, $n = 1$.

Methodological quality and risk of bias assessment

The methodological quality assessment data for each of the included studies are reported in Table 2. In summary, the study ratings were as follows: 3 (20%) excellent methodological quality (high quality); 6 (40%) good methodological quality (moderate quality); 4 (26.67%) fair methodological quality (low quality); and 2 (13.33%) poor methodological quality.

Table 3 presents the risk of bias assessment in the included studies. Overall, 86.67% of studies presented low risk of bias with

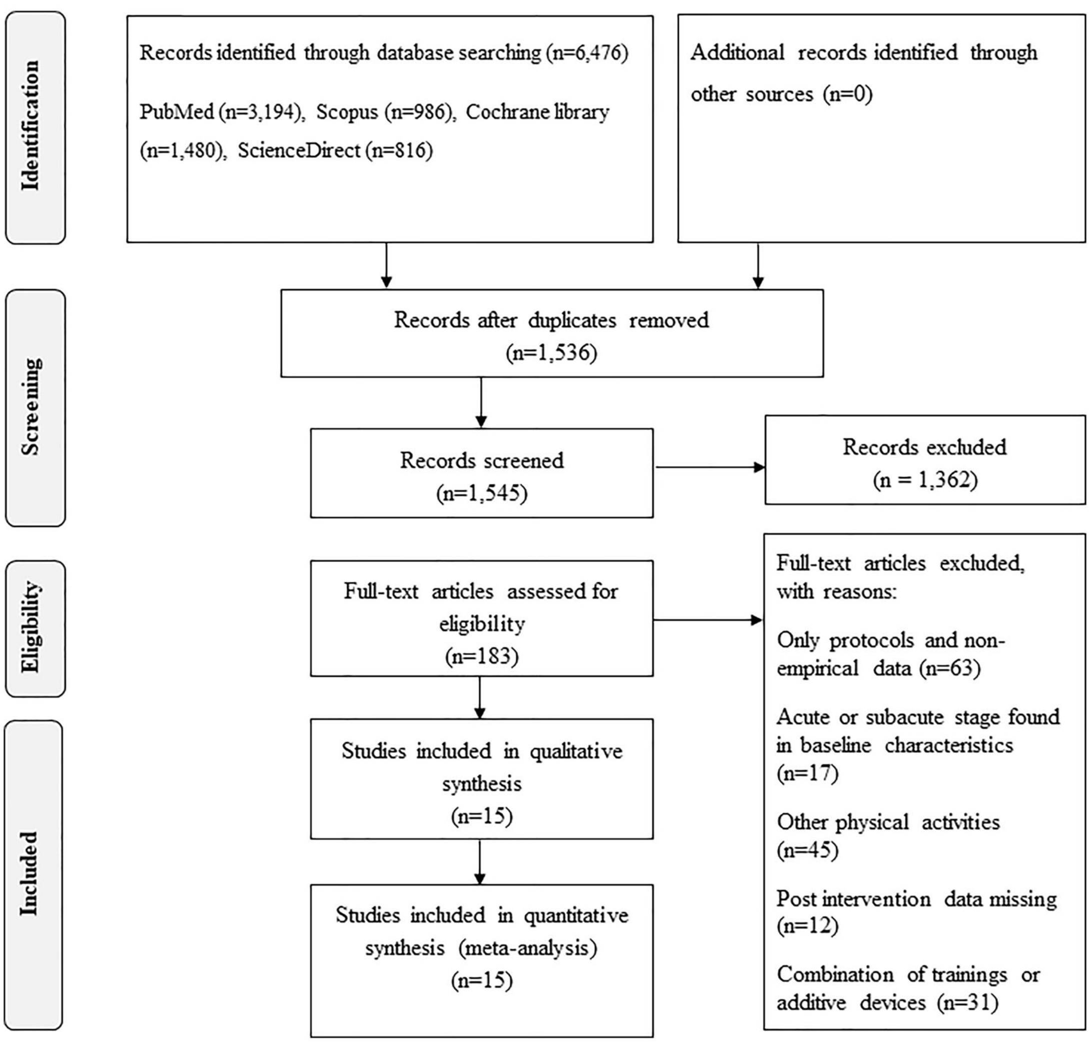

Figure 1. Flowchart of study selection.

Table 1. Characteristics of included studies.

		Intervention			Control					
Study	N	Mean age, year	Stroke severity at baseline	Type	Mean age, year	Stroke severity at baseline	type	Duration (weeks)	Outcomes	Reported results
Ada et al. [34]	102	70 ± 11	Spasticity (0–4; mean ± SD): 0.76 ± 0.87	Treadmill and overground trainings	68 ± 12	Spasticity (0–4; mean ± SD): 0.93 ± 1.08	No intervention	16	Gait ability, participation, and health status	Four months of treadmill training resulted in better walking
Fischer et al. [35]	20	60 ± 14	NR	Robot assisted gait training	60 ± 14	NR	Usual care	8	Walking ability and balance	Both groups showed significant improvement but no significant difference
Globas et al. [36]	38	68.6 ± 6.7	NIHSS score (0-42; mean ± SD): 4.2 ± 2.5	High intensity treadmill training	68.7 ± 6.1	NIHSS score (0-42; mean ± SD): 4.7 ± 2.9	Usual care	12	Endurance, speed, balance, strength, QoL	Experimental intervention improves cardiovascular fitness and gait.
Gordon et al. [37]	128	64.9 ± 11.1	Barthel Index (mean ± SD): 94.3 ± 8.1	Walking overground trainings	63.4 ± 9.4	Barthel Index (mean ± SD): 91.5 ± 9.7	Massage	12	Functional status, QoL	Aerobic walking improves the physical health component of quality of life and endurance
Hornby et al. [38]	48	57 ± 10	Spasticity (0–4; mean ± SD): 0.8 ± 0.9	Robotic-assisted locomotor training (LT)	57 ± 11	Spasticity (0–4; mean ± SD): 1.0 ± 1.2	Therapist assisted usual care	2	Walking speed, participation, QoL	Therapist-assisted training facilitates greater improvements in walking ability
Kim et al. [16]	22	50.1 ± 10.2	MMSE (0-30; mean ± SD): 27.36 ± 1.68	Community walking training program (overground trainings)	50.7 ± 7.2	MMSE (0-30; mean ± SD): 27.18 ± 1.77	usual care	4	Walking speed and endurance, participation	overground trainings is effective on walking function and social participation
Kim et al. [39]	20	69.1 ± 3.2	NR	Walking aquatic dual task training	68 ± 3.1	NR	Usual care	6	Balance and gait ability	Aquatic dual-task training has a positive effect on balance and gait.
Malagoni et al. [40]	12	62.5 ± 13.8	MMSE (0-30; mean ± SD): 27.6 ± 1.4	Structured home-based exercise	70.7 ± 9.0	MMSE (0-30; mean ± SD): 26.6 ± 1.2	Standard care	10	Walking ability, balance,	Experimental group improved balance, walking ability, QoL
Mayo et al. [41]	87	67.7 ± 14.4	NR	Mobility exercise and brisk walking	67.8 ± 12.3	NR	Stationary cycling	48	Endurance, physical function, participation, QoL	Both programs were equally effective in maintaining walking capacity
Mudge et al. [42]	60	76	NR	Circuit class training	71	NR	social and educational class	4	Gait speed, endurance, confidence and self-reported mobility	Circuit-based rehabilitation leads to improvements in gait endurance
Olawale et al. [43]	60	56.8 ± 6.4	NR	Treadmill walking trainings	57.2 ± 5.9	NR	Usual care	12	Walking ability (speed and endurance)	Experimental training improved walking function
Park et al. [44]	25	59.3 ± 8.4	NR	Community-based ambulation training	56.9 ± 7.7	NR	Usual care	4	Walking ability and balance confidence	Community-based ambulation training can improve walking ability
Shaughnessy et al. [45]	64	64.3 ± 9.2	NR	Treadmill training	64.3 ± 9.2	NR	Stretching training	24	Self-efficacy and outcome expectations for exercise, QoL	No statistically significant between-group differences
Stein et al. [46]	24	57.6 ± 10.7	NR	Robotic-device walking training	56.6 ± 15.1	NR	Exercise group program	6	Gait velocity, gait endurance, balance and functional ambulation profile	No significant differences between the two groups
Yen et al. [47]	14	57.3 ± 16.4	Brunstrom stage of lower extremity: 4	Usual body weight supported treadmill training	56 ± 12.6	Brunstrom stage of lower extremity: 4 – 5	Usual care only	4	Balance, walking speed	Additional gait training may improve balance and gait performance

NR: Not reported; LT: Locomotor training; QoL: Quality of life.

respect to random sequence generation, 73.33% with incomplete outcome data, 60% with allocation concealment, 40% with blinding of outcome assessment, 33.33% with selective reporting while 80% presented high risk of bias with respect to blinding of participants and personnel criteria.

Table 2. Methodological quality assessment of included studies with PEDro scale.

Study	A	B	C	D	E	F	G	H	I	J	Score/10	Level
Ada et al. [34]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9	1
Fischer et al. [35]	Y	Y	Y	NC	N	Y	Y	Y	Y	N	7	2
Globas et al. [36]	Y	Y	Y	NC	NC	Y	Y	Y	Y	Y	8	1
Gordon et al. [37]	Y	Y	Y	N	N	Y	Y	N	Y	N	6	2
Hornby et al. [38]	Y	Y	Y	N	N	N	Y	N	Y	N	5	3
Kim et al. [16]	Y	Y	Y	N	N	Y	N	N	Y	N	5	3
Kim et al. [39]	Y	Y	Y	N	N	NC	Y	Y	Y	N	6	2
Malagoni et al. [40]	Y	Y	Y	N	N	N	Y	Y	Y	N	6	2
Mayo et al. [41]	Y	Y	N	N	NC	Y	N	Y	Y	N	5	3
Mudge et al. [42]	Y	Y	N	N	Y	Y	Y	Y	Y	N	7	2
Olawale et al. [43]	Y	N	N	N	N	N	Y	N	Y	N	3	4
Park et al. [44]	Y	Y	Y	N	NC	N	Y	N	Y	N	5	3
Shaughnessy et al. [45]	Y	N	N	N	N	NC	Y	N	Y	N	3	4
Stein et al. [46]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8	1
Yen et al. [47]	Y	Y	Y	N	N	N	Y	N	Y	Y	6	2

Y: yes; N: no; NC: not clear; A: random allocation; B: concealed allocation; C: groups similar at baseline; D: participant blinding; E: therapist blinding; F: assessor blinding; G: <15% dropout; H: intention-to-treat analysis; I: between group difference reported; J: point estimate and variability reported.
Levels: 1 = score 8–10 (excellent quality); 2 = score 6–7 (good quality); 3 = score 4–5 (fair); 4 = score <4 (poor quality).

Table 4 presents the exercise modalities in the experimental group of the included studies. The median duration of sessions was 30 min, with a median frequency of 3 times per week. Protocols were conducted for a median period of 8 weeks.

Effectiveness of walking training on body function

The effects of walking training on balance and motor function are shown in Figures 2 and 3, respectively. A total of 6 studies involving 169 participants assessed balance impairments while a total of 3 studies involving 227 participants assessed motor functions impairments. Balance was evaluated with the Berg Balance Scale [36,38,39,41,46,47], Timed Up and Go [40], and/or Tinetti Balance Scale [35], and walking self-efficacy scale [34] whereas motor functioning was assessed with the Motricity Index [37], Stroke Impact Scale [45], and the 5-Chair Rise test [36]. Our meta-analysis showed a significant overall beneficial effect of walking training on balance (SMD = 0.64[0.06, 1.22], $p = 0.03$; $I^2 = 65\%$) and motor function (SMD = 0.43 [0.16, 0.69], $p = 0.002$; $I^2 = 0\%$). Subgroup analysis showed that treadmill training improved significantly balance (SMD = 0.70[0.02, 1.37]; $p = 0.04$;

Table 3. Evaluation of the risk of bias in the included studies by the Cochrane risk of bias assessment tool.

Studies	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Ada et al. [34]	+	−	?	?	+	?	+
Fischer et al. [35]	+	−	?	?	+	?	+
Globas et al. [36]	+	+	−	?	+	+	+
Gordon et al. [37]	+	?	−	+	+	+	+
Hornby et al. [38]	+	+	−	−	?	+	?
Kim et al. [39]	?	−	?	?	+	−	?
Kim et al. [16]	+	+	−	+	+	?	+
Malagoni et al. [40]	+	+	−	−	+	+	+
Mayo et al. [41]	+	+	−	+	+	+	+
Mudge et al. [42]	+	+	−	+	+	+	+
Olawale et al. [43]	?	?	−	−	?	−	+
Park et al. [44]	+	+	−	+	+	?	+
Shaughnessy et al. [45]	+	?	−	−	?	?	+
Stein et al. [46]	+	+	−	+	+	?	+
Yen et al. [47]	+	+	−	−	−	?	+

+: Low risk; −: High risk; ?: Unclear.

Table 4. Exercise modalities of experimental interventions.

Authors (year)	Volume/session, min	Frequency, times/week	Protocol duration, weeks	Total training time, min
Ada (2013)	30	3	8	720
Fischer (2011)	60	3	8	1440
Globas (2011)	30	3	12	1080
Gordon (2013)	30	3	12	1080
Hornby (2008)	30	3	4	360
Kim (2014)	60	5	4	1200
Kim (2016)	30	5	6	900
Malagoni (2016)	20	6	10	1200
Mayo (2013)	30	6	52	9360
Mudge (2009)	30	3	4	360
Olawale (2011)	25	3	12	900
Park (2011)	60	3	4	720
Shaughnessy (2012)	40	3	24	2880
Stein (2014)	60	3	6	1080
Yen (2008)	60	3	4	720
Median [P25; P75]	30[30; 60]	3[3; 3]	8[4; 12]	1000[720; 1200]

P = Percentile.

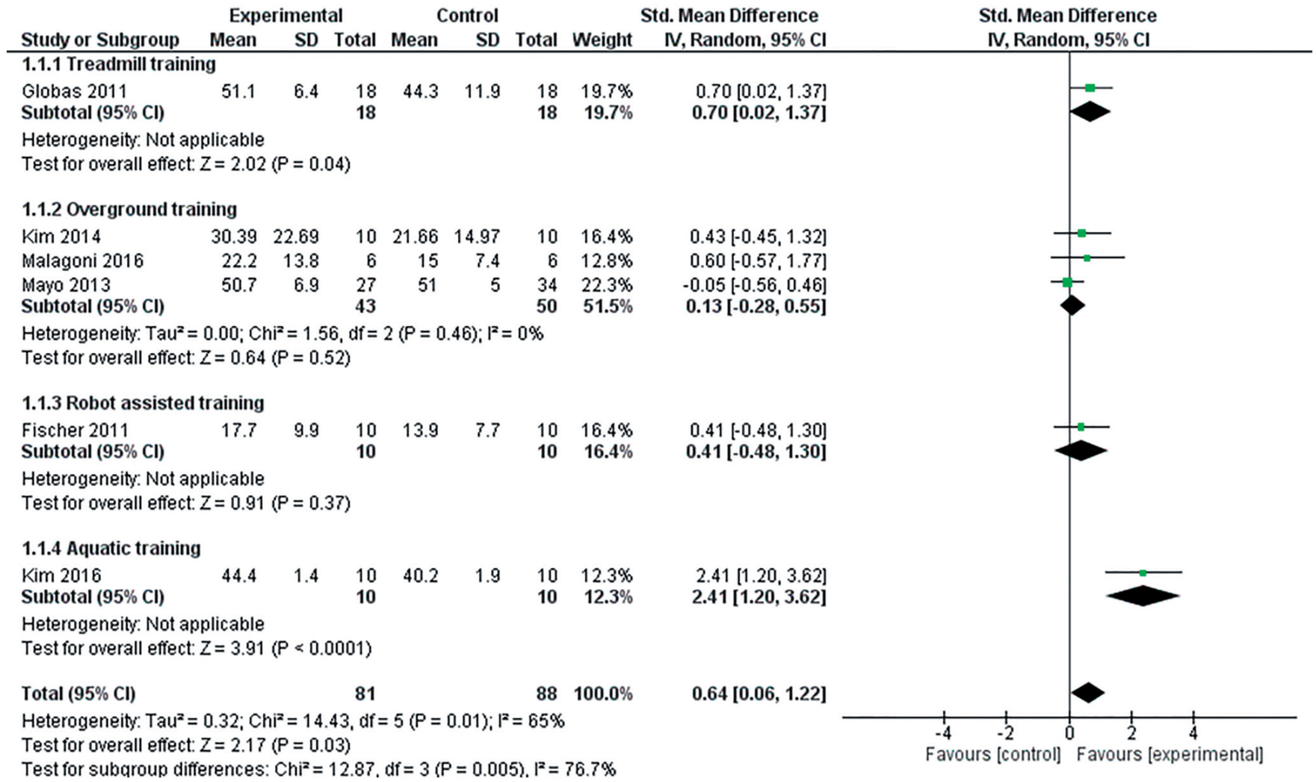

Figure 2. Forest plot showing walking training effect on balance. The effect is shown by the standardized mean difference (SMD) of each subgroup and overall effect; significance at $p < 0.05$.

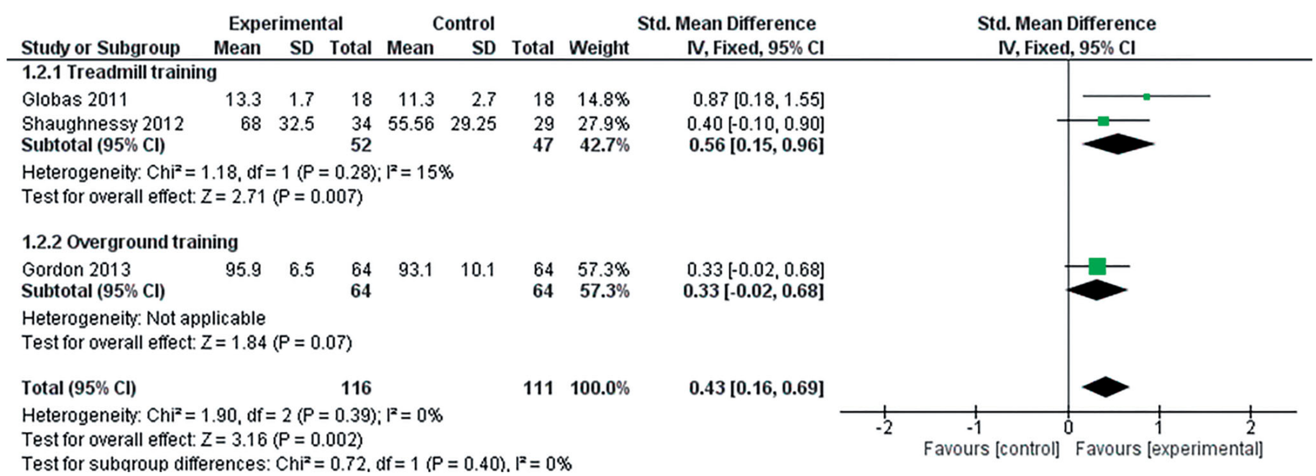

Figure 3. Forest plot showing walking training effect on motor function. The effect is shown by the SMD of each subgroup and overall effect; significance at $p < 0.05$.

I^2=0%) and motor function (SMD = 0.56[0.15, 0.96]; $p = 0.007$; I^2=15%) in people with chronic stroke.

Effect of walking training on activity limitation

The effects of walking training on endurance, walking speed, and functional independence are shown in Figures 4–6, respectively. Walking endurance was measured by 6-min walk test [16,34,36–38,40–44,46] and 3-min walk test [35] while walking speed was measured by 10-meter walk test [16,34–36,39,41–44,46], 8-meter walk test [35], and gait rite [46]. Functional independence was evaluated by the Frencay Activity Index [38], Rivermead mobility Index [36], Instrumental activity of daily living [37], physical functioning scale [40], community balance and mobility scale [41], physical activity and disability scale [42], California Functional Evaluation 40 (CAFE 40) [46]. Analysis of all walking training types together showed significant positive effects of the interventions on walking endurance (SMD = 0.30[0.13, 0.47]; $p < 0.001$; I^2=0%) and walking speed (SMD = 0.09[0.04, 0.14]; $p < 0.001$; I^2=0%). Subgroup analyses showed that overground training protocols improved walking endurance (SMD = 0.38[0.16, 0.59]; $p < 0.001$; I^2=0%) and walking speed (SMD = 0.12[0.05, 0.18]; $p < 0.001$; I^2=0%). Our meta-analysis did not show a significant effect of walking training on functional independence (SMD = 0.10[−0.14, 0.34]; $p = 0.4$; I^2=0%).

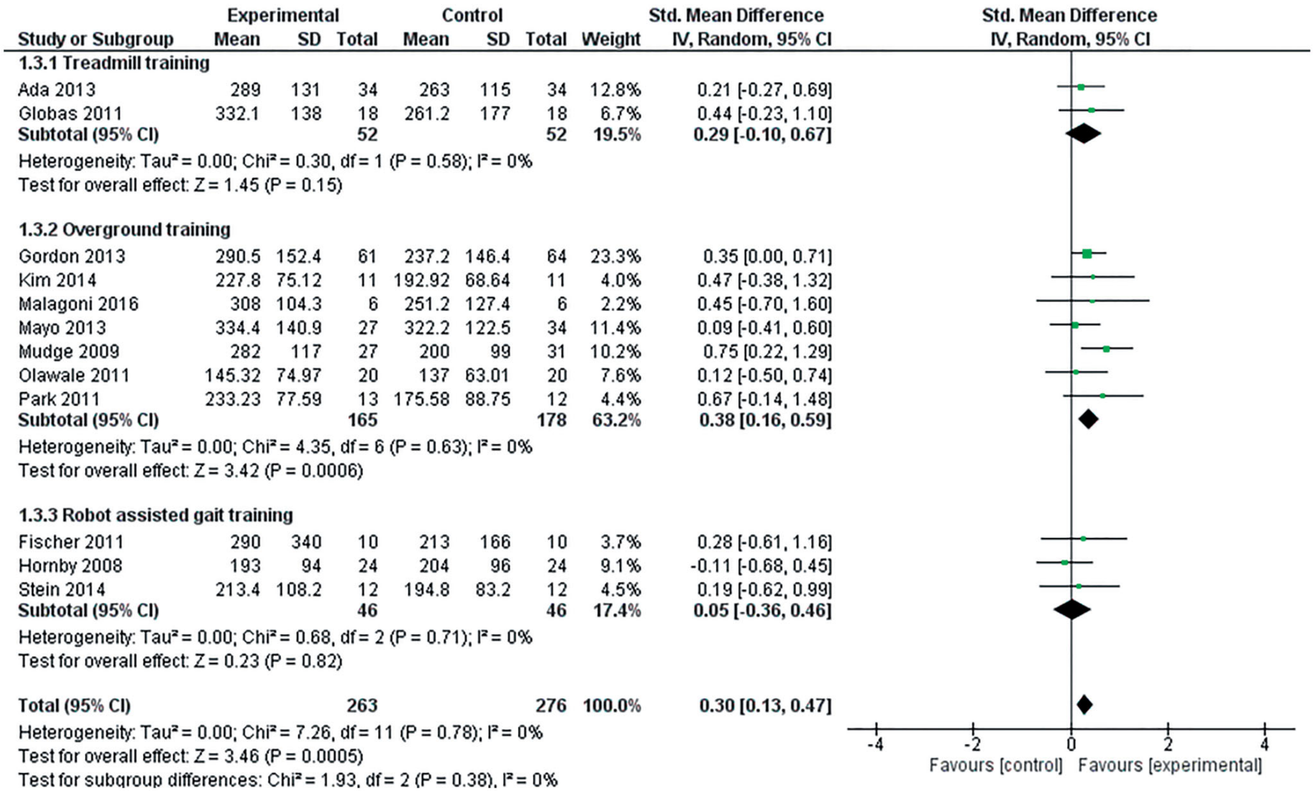

Figure 4. Forest plot showing walking training effect on walking endurance. The effect is shown by the SMD of each subgroup and overall effect; significance at $p < 0.05$.

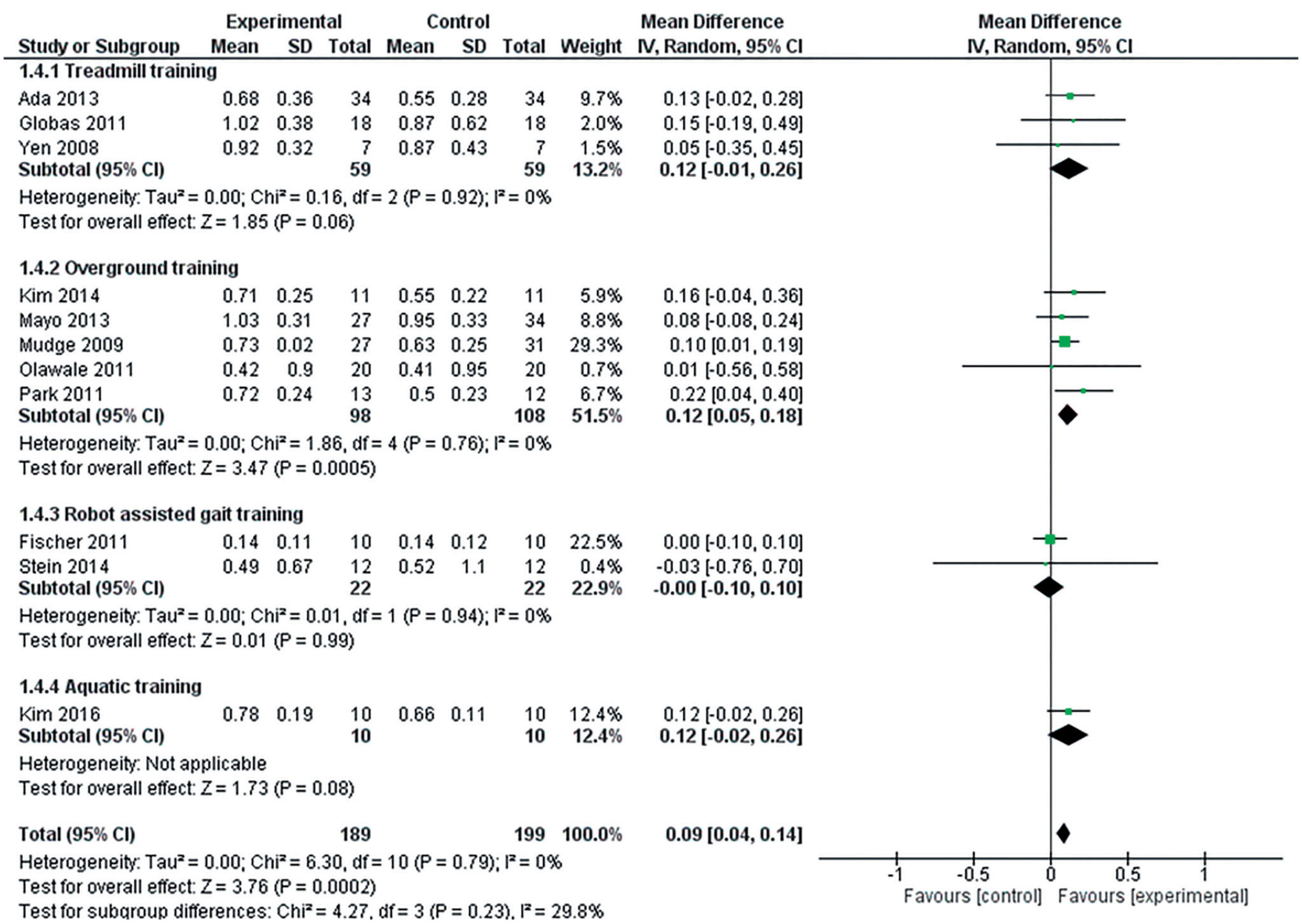

Figure 5. Forest plot showing walking training effect on walking speed. The effect is shown by the SMD of each subgroup and overall effect; significance at $p < 0.05$.

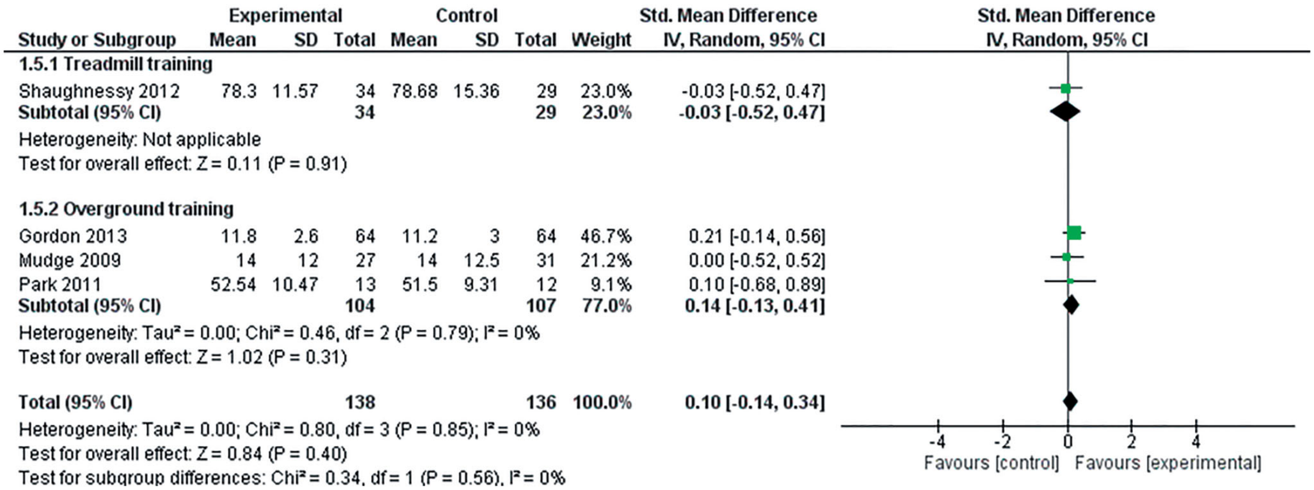

Figure 6. Forest plot showing the walking training effect on functional independence. The effect is shown by the SMD of each subgroup and overall effect; nonsignificant at $p < 0.05$.

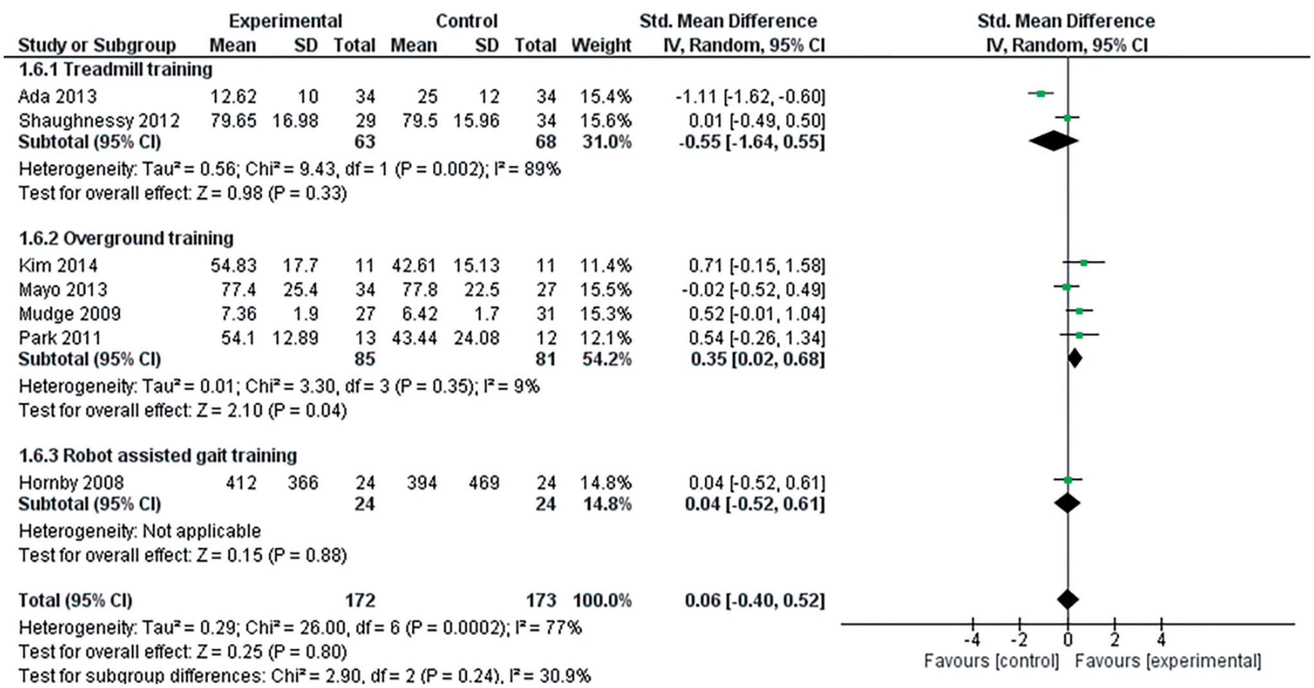

Figure 7. Forest plot showing walking training effect on participation. The effect is shown by the SMD of each subgroup and overall effect; nonsignificant at $p < 0.05$.

Effect of walking training protocols on social participation and quality of life

The effects of walking training on social participation and quality of life are shown in Figures 7 and 8, respectively. Participation was measured in the included studies by the Adelaide Activity Profile [34], modified Emory Functional Ambulation Profile [38], and Stroke Impact Scale [16,41,45], while quality of life was assessed by EuroQoL [34], short-form health survey SF-12 [36], and SF-36 [37,38,41],. Overall, no significant effect of walking training on participation was found (SMD = 0.06[−0.40, 0.52], $p = 0.80$, I^2=77%). Nevertheless, subgroup analyses showed a significant beneficial effect of overground training (SMD = 0.35[0.02, 0.68] $p = 0.04$, I^2=9%), but not treadmill or robot-assisted training. Overall, there was a significant effect of walking training on health-related quality of life (SMD = 0.40[0.06, 0.75]; $p = 0.02$, I^2=57%). In subgroup analyses, quality of life was significantly improved by overground training (SMD = 0.46[0.12, 0.80], $p = 0.008$, I^2=19%).

Sensitivity and meta-regression analysis

Treatment significance effects remained similar across different analyses after excluding trials with PEDro scores <5 [16,38,41, 43–45]. We conducted a meta-regression with the total training time as the dependent variable in order to have a better understanding of how did the training dosage affected the effect size. Results of meta-regression analyses are summarized in Table 5. There is no evidence of a significant effect of total training time on the effect sizes.

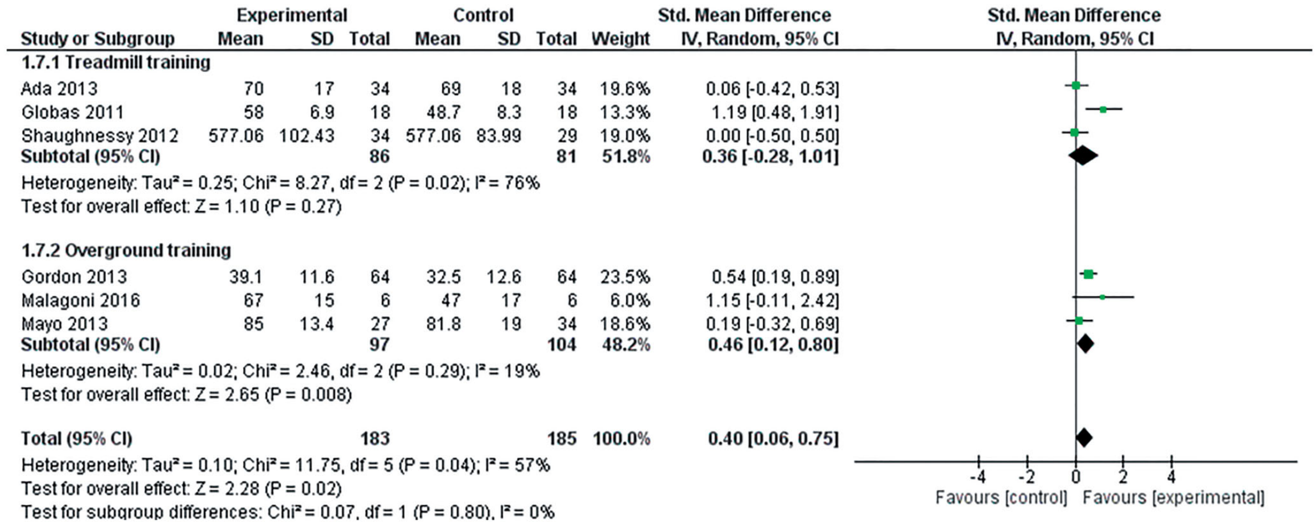

Figure 8. Forest plot showing walking training effect on quality of life (QoL). The effect is shown by the SMD of each subgroup and overall effect; significance at $p < 0.05$.

Table 5. Main results for the meta-regression of the effect of total training time on the effect sizes.

Variables & covariates	Coefficient	Standard error	95% CI	Z-value	*p*-Value
Balance					
Intercept	1.02	0.38	0.27–1.76	2.68	0.007
Total training time	−0.01	0.01	−0.01–0.01	−1.29	0.196
Walking endurance					
Intercept	0.39	0.11	0.18–0.59	3.69	0.001
Total training time	0	0	−0.01–0	−1	0.316
Walking speed					
Intercept	0.09	0.03	0.04–0.16	3.27	0.001
Total training time	0	0	1.09–0.01	−0.37	0.713
Functional independence					
Intercept	0.15	0.21	−0.27–0.56	0.68	0.496
Total training time	0	0.01	−0.01–0.01	−0.17	0.868
Participation					
Intercept	0.56	0.21	0.15–0.98	2.66	0.008
Total training time	−0.01	0.01	−0.02–0	−1.24	0.216
Quality of life					
Intercept	0.56	0.27	0.04–1.09	2.12	0.034
Total training time	0	0.01	−0.02–0.01	−0.76	0.445

Discussion

This study provides an updated review of the current evidence related to the use of walking training protocols to improve functioning in chronic stroke patients and a foundation for developing evidence-based exercise prescriptions for this diagnosis group. We compared the effectiveness of walking training protocols with that of other physical exercises. Of the 15 RCTs (659 participants) included in this study, 4 evaluated treadmill training, 7 evaluated overground walking training, 3 evaluated robot-assisted gait training, and 1 evaluated aquatic training. Overall, Treadmill and overground walking protocols consisting of ≥30 min sessions conducted at least 3 days per week for at about 8 weeks are beneficial for improving motor impairments, activity limitations, participation, and quality of life in chronic stroke patients.

Our meta-analysis results indicated that treadmill-walking training can improve balance and motor function in the chronic stroke phase. Similarly, Ilunga Tshiswaka et al. [15] found in their review that most studies evaluating overground or treadmill walking training demonstrated significant improvements in walking function. Furthermore, Rensink et al. [48] reported significant walking function improvement in their systematic review for groups of individuals using overground or treadmill training. In a systematic review, Pang et al. [49] found that aerobic exercise did not improve Berg Balance Scale scores; their findings are not in accordance with ours. Lloyd et al. [50] found no effect of training on motor impairments in a review involving only non-ambulatory people post-stroke. All studies included in the present meta-analysis recruited patients with a minimal level of walking ability and therefore some minimal level of balance.

In the chronic stroke phase, patients can continue to develop motor-compensation strategies and walking training provides an opportunity to develop such compensatory skills. Treadmill and robot-assisted protocols enable walking with a reduced balance requirement relative to overground walking [25]. Fall prevention is an important clinical consideration in ambulatory people post-stroke [51] and recovery of balance is essential for independence in daily living. Improvement of balance has been shown to be influenced by training intensity, with frequencies of at least five sessions a week of 30–60 min each producing significant improvements within 4 weeks [52]. Longer-term interventions (e.g., 12 weeks) appear to be needed to reduce the severity of motor impairments [36,53,54]

].Regarding activity limitations, our review showed that walking training programs improved walking endurance, walking speed, but not the functional independence. Specifically, only overground training protocols were found to be effective for improving both walking endurance and walking speed. These results underscore the fact that, even in the chronic stage of stroke, walking endurance can be improved. Recent studies issued similar conclusions [13,49,50]. Pang et al. [49] concluded from their meta-analysis that aerobic training was more effective for enhancing walking endurance and maximum walking velocity than mixed aerobic/strength training. Saunders et al. [13] found that a fitness program led to increased walking capacity and self-selected speed. Lloyd et al. [50] showed that assisted walking produced borderline significant improvement in walking endurance and walking independence. In a cohort study, Karttunen et al. [55] demonstrated that functional status and functional independence were improved by walking training. On the contrary, Pang et al. [49] and Saunders et al. [13] found no significant effect of walking training and cardiorespiratory training on Functional

Independence Measure (FIM) scores, though studies using other assessment tools (e.g., Barthel Index, Frenchay Activities Index, Nottingham Extended Activities of Daily Living Scale) did find significant effects of walking training on functional independence [36,56].

Walking endurance has been identified as a key area of difficulty for people with stroke [57]. Though any aerobic activity would be expected to improve cardiorespiratory endurance, overground walking appears to be more effective for improving walking endurance in this population than treadmill training, perhaps because the former is more challenging compared to the later that induces passive movements at speeds selected by patients in accordance with their individual comfort levels [53].

The commonly used FIM scale measures independence level in the performance of a wide range of daily activities, some of which are less likely to be influenced by exercise training (e.g., eating, grooming, swallowing, and bowel and bladder management). Katz-Leurer et al. [58] reported treatment effects selectively on FIM motor sub scores without a significant effect on total FIM scores.

Finally, it is noteworthy that our meta-analysis detected a significant effect of overground walking training on both participation and quality of life. Recent systematic reviews did not draw conclusions as to whether training can improve self-perceived health status or quality of life after stroke [13,49], both of which are under-evaluated variables, having been evaluated in a limited number of trials with inconsistent results. More research is required to clarify the effects of aerobic exercise on these important outcomes.

Walking remains a priority for functional independence in the chronic phase of stroke [59]. Thus far, most studies assessing walking interventions in chronic stroke populations have involved assisted programs, such as exercises supported by therapists, body-weight supporting equipment, and/or robotic equipment. The use of electromechanical devices may be feasible within a rehabilitation setting, though we could not find any reports that included the costs of such devices, and cost, space, and staff training requirements can pose barriers, particularly for community setting interventions. Of the 15 walking training studies reviewed here, only 2 were undertaken in a community setting, highlighting an important gap in post discharge continuation of fitness training, particularly in a group format [60]. Although none of the studies in our meta-analysis included cost estimations, one recent study demonstrated the cost-effectiveness [61] of a clinically effective community-based fitness training program for ambulatory people post-stroke. More health-economic data are needed to enable the development of such services.

Study strengths and limitations

The present study provides an updated review of the current evidence related to the use of walking training protocols to improve functioning in chronic stroke patients. Our methodology complies with the Cochrane's guidelines for systematic reviews of interventions and the PRISMA statements. Period of twelve years considered in this study gives a possibility of thorough analyzes concerning walking training in stroke rehabilitation; thereby providing an opportunity for a detailed review of the literature on this particular topic.

However, this study had some potential limitations. Firstly, because we restricted our search to studies published in English or French, relevant studies in other languages may have been missed. Secondly, this meta-analysis did not include follow-up analysis because many of the reviewed studies did not report follow-up data. Therefore, our results do not provide evidence of long-term effects.

Conclusion

The present meta-analysis indicates that treadmill and overground walking training programs are effective for improving, balance motor functioning, walking speed, endurance, participation and quality of life in people with chronic stroke. Hence, reductions in global disability indices following walking training may be mediated largely by mobility improvements. Walking training frequency should be fairly high (~3 times per week) for about 8 weeks and training sessions should last ≥30 min to be effective for improving walking performance.

Author contributions

Conceptualization was done by Félix Nindorera, Ildephonse Nduwimana, Jean-Louis Thonnard, and Oyéné Kossi. Protocol draft was done by Félix Nindorera, Ildephonse Nduwimana, Jean-Louis Thonnard, and Oyéné Kossi. Development of the search strategy was done by Félix Nindorera, Ildephonse Nduwimana, and Oyéné Kossi. Data extraction and synthesis was done by Félix Nindorera, Ildephonse Nduwimana. Writing of the original draft was done by Félix Nindorera. Writing – review & editing was done by Félix Nindorera, Ildephonse Nduwimana, Jean-Louis Thonnard, and Oyéné Kossi. Supervision by Oyéné Kossi.

Disclosure statement

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