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Conventional physiotherapy and treadmill re-training for higher-level gait disorders in cerebrovascular disease

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Abstract

Objectives: to compare the therapeutic effects of two approaches to gait re-training—a schedule of conventional physiotherapy and treadmill re-training—in patients with higher-level gait disorders associated with cerebral multi-infarct states.
Design: single-blind crossover study involving a 4-week baseline period, 4 weeks of treadmill re-training and 4 weeks of conventional physiotherapy.
Setting: a large teaching hospital.
Subjects: patients with cerebral multi-infarct states who met the criteria for higher-level gait disorders. Computed tomographic brain scans showed at least one large vessel infarct, basal ganglia and white matter lacunes or extensive leukoaraiosis.
Interventions: a schedule of treadmill re-training and a specific schedule of physiotherapy containing 31 interventions in three treatment modules: (i) for gait ignition failure and turning; (ii) to improve postural alignment and enhance balance reactions; and (iii) for other components of cerebral multi-infarct state disordered gait.
Main outcome measures: spatial and temporal gait measures and activity of daily living assessments.
Results: we recruited 18 patients, mean (SD) age 79.1 (6.8) years. Patients walked an average of 7.9 (5.5) km on the treadmill and had an average of 6.7 (3.2) h of physiotherapy. There were clinically moderate but highly statistically significant ($P < 0.001$) improvements in the following indices: time taken to complete the sit-to-stand test; time taken to walk 10 m; number of steps over 10 m; walking velocity; right and left step lengths; and time taken to complete the 'S' test. There were no differences in the results obtained in each limb of the study.
Conclusion: there is no difference between the effects of conventional physiotherapy and treadmill re-training on the gait of patients with higher-level gait disorders associated with cerebral multi-infarct states. However, the improvements seen during the treatment period suggest that there is scope to improve the gait of this group of frail, elderly patients.

Keywords: *gait re-training, multi-infarct gait disorder, physiotherapy, treadmill*

Introduction

Cerebral multi-infarct states (CMIS) are a common manifestation of cerebrovascular disease. The literature has concentrated mainly on their association with cognitive impairment, so-called multi-infarct dementia [1, 2]. However, many CMIS patients present with relatively preserved cognitive abilities at a time when mobility may be severely affected with difficulty initiating gait, shuffling, instability while turning and poor balance [3–5]. Functionally, patients have difficulty rising out of a chair or getting out of bed, and problems of freezing and hesitation once walking is started and loss of the rhythm of walking. CMIS patients however have a comparatively long life expectancy—about 50% survive 6 years from the onset of symptoms [6]. Consequently, immobility is a major reason for institutionalization, with much morbidity from falls [5]. Loss of mobility matters most to patients with cerebrovascular disease [7].

Critically, there are no gross neurological deficits observable on bedside testing that account for these gait disorders and they are thus most probably disorders of higher cerebral functioning [8]. Frontal and basal ganglia infarcts along with extensive periventricular disease (leukoaraiosis) are the most likely cause [9–11].

Since higher-level gait disorder is a type of motor programming failure [8], it is reasonable to anticipate that these damaged programmes might be re-activated by training, especially since there is now considerable evidence of plasticity in the damaged adult nervous system which may be influenced by sensory input, particularly that from normal activity [12]. One way of creating input from more normal walking is in the 'forced' or 'assisted' walking situation of a treadmill. Here, the patient is required to enact the cyclical activity of walking but has the reassurance of parallel bars and a safety harness, while the movement of the treadmill drives the gait.

Previously, treadmill re-training has been used to achieve clinically important improvements for patients with hemiplegic strokes in combination with rehabilitation measures [13], in a single case study [14] and with partial body-weight support [15]. In paraplegic patients, Dietz *et al.* observed that co-ordinated stepping movements were induced by standing on a moving treadmill and that, with daily training, the amplitude of electromyographic activity increased [16]. This strongly supports the idea of induced plastic change normalizing neuronal activity as a result of activation of spinal locomotor centres. These spinal locomotor centres or central pattern generators are closely involved in the regulation of movement and there is evidence that training can modify the interaction between the central pattern generator programmes and peripheral reflex activity [17]. Normally, descending influences from the motor cortex, cerebellum and brainstem activate these central pattern generators.

In the patient with higher-level gait disorder, who has sustained extensive damage to supraspinal control, it may be assumed that descending drive is attenuated to the point where the threshold of activation is not exceeded. The rationale of treadmill re-training is that inputs from the periphery would act to reinforce or recalibrate existing but degraded programmes, permitting them to be more easily activated.

The conventional treatment of higher-level gait disorder is physiotherapist-administered gait re-training. The elements of such treatments have only recently been documented [18] and their relationship to the clinical features been clearly defined—an essential precursor to developing and evaluating rational physical therapies [19]. Conventional physiotherapy relies at least partly on verbal instructions while treadmill re-training might activate dormant or relatively inaccessible programmes via spinal mechanisms.

In this work we examine and compare the therapeutic effects of two approaches to gait re-training for patients with higher-level gait disorders in CMIS: a schedule of physiotherapy based on conventional approaches, and a schedule of treadmill re-training. We hypothesize that treadmill gait re-training will be more effective than conventional physiotherapy in patients with higher-level gait disorders associated with CMIS.

Methods

Patients

We recruited 18 patients from the elderly inpatient and outpatient population of a large teaching hospital: 12 men and six women, mean (SD) age 79.1 (6.8) years. Their clinical features and computerized tomographic brain scan results are shown in Table 1.

Higher-level gait disorders were defined as: a gait disturbance out of proportion to the deficits observed in strength, tone, co-ordination and sensation noted on bedside testing and not attributable to lack of motivation. Computerized tomographic brain scans showed at least one of the following: at least one large vessel infarct, basal ganglia and white matter lacunes, or extensive leukoaraiosis. We excluded patients with severe cognitive impairment or significant physical impairments from other causes. None of the patients was having any other rehabilitation treatment during the course of this trial. The protocol was passed by the Salford and Trafford research ethics committee and all subjects gave written informed consent before participation.

A power calculation based on similar studies indicated that with 20 patients it would be possible to detect a difference of 0.6 standard deviations with an 80% power at a significance level of 5%.

Design of the trial

Following a clinical assessment, patients entered a programme involving a 4-week baseline period and then, in a cross-over design, 4 weeks of treadmill re-training and 4 weeks of conventional physiotherapy. The baseline period allowed patients to become familiar with the outcome measures and controlled for any learning effect consequent upon the performance of repeated tests. We randomized patients to two groups, to receive either conventional physiotherapy first (eight patients) or treadmill re-training first (10 patients), subsequently crossing over to the other limb of the trial. There was no washout period as it was felt that it was unlikely that gait measures would return to their baseline values during a period compatible with a practical trial design. The study had a single-blind design, outcome measures being performed by a blinded assessor, while all interventions were provided by a second physiotherapist. During the treatment,

Table 1. Clinical features of patients

Patient	Clinical features: Gait	Other	Computed tomography brain scan
1	Ignition failure, freezing, shuffling	TIAs, osteoarthritis	Leukoaraiosis
2	Broad-based gait, disequilibrium	Hypertension, old CVA, TIAs, falls	Multiple infarcts—right frontal and parietal
3	Disequilibrium	Hypertension, falls	Low-density areas—right frontal
4	Disequilibrium, slow gait	Old CVA, prostatectomy, falls	Single infarction, leukoaraiosis
5	Disequilibrium, slow gait	Old CVA, falls	Multiple infarcts including basal ganglia, leukoaraiosis
6	Ignition failure, shuffling, disequilibrium	TIAs, IHD, peptic ulcer disease	Multiple infarcts including basal ganglia, leukoaraiosis
7	Broad-based gait, disequilibrium	TIAs, diabetes mellitus, epilepsy, prostatism	Multiple infarcts, leukoaraiosis
8	Disequilibrium	Hypertension, asthma, falls	Leukoaraiosis
9[a]	Ignition failure, shuffling, freezing	Anxiety	No scan
10	Shuffling, ignition failure, freezing, disequilibrium	Hypertension, TIAs, falls, dislocated right shoulder	Multiple infarcts including basal ganglia
11	Short steps, disequilibrium	Hypertension, diabetes mellitus	Multiple infarcts including basal ganglia
12	Ignition failure, freezing, shuffling, disequilibrium	Atrial fibrillation	Leukoaraiosis
13	Freezing, ignition failure, disequilibrium	Falls	Leukoaraiosis, subcortical vascular state
14	Ignition failure, shuffling freezing, disequilibrium	Hypertension, diabetes mellitus, old CVA, IHD, falls	Basal ganglia infarct, leukoaraiosis
15	Shuffling, ignition failure, disequilibrium	Hypertension, TIAs, polycythaemia rubra vera	Multiple infarcts including basal ganglia
16	Ignition failure, shuffling, freezing	Osteoarthritis, depression, THR	Leukoaraiosis
17	Disequilibrium	Hypertension, TIA, falls	Leukoaraiosis
18	Ignition failure, shuffling, freezing, disequilibrium	Old CVA	Multiple infarcts including basal ganglia, leukoaraiosis

[a]Patient refused to have a computerized tomographic brain scan performed but had a clinical history and gait disorder compatible with cerebral multiple infarcts and was thus included in the study.
TIA, transient ischaemic attack; CVA, cerebrovascular accident; IHD, ischaemic heart disease; THR, total hip replacement.

patients attended three times weekly with each session lasting up to 60 min.

Interventions

For this study we developed a schedule of physiotherapy (described in detail elsewhere [18]) specific for the gait disorders associated with CMIS. Essentially it contains 31 interventions in three treatment modules:

1. Five interventions for gait ignition failure and turning;
2. 16 interventions to improve postural alignment and enhance balance reactions and;
3. 10 interventions for other components of CMIS disordered gait.

In developing this schedule we drew on recognized interventions for the gait ignition failure seen in both Parkinson's disease [20, 21] and gait apraxia [22, 23] and also the disequilibrium seen in stroke, along the lines suggested by Edwards *et al.* [19]. During treadmill treatment we simply instructed patients to continue walking for as long as they felt comfortable. They were allowed rest breaks whenever required. Similar instructions and advice were given to all patients, specifically avoiding giving any advice about home exercises.

Outcome measures

We assessed the impact of treatment on ambulatory function weekly during the 12-week study period and at 6 weeks after the final treatment, using the outcome measures listed in Table 2 [24–33].

Statistical analysis

Statistical analysis was by repeated measures analysis of variance, with logarithmic transformations of the data where appropriate, using data for each individual week of the study. Assessment points were considered in chronological order, with the order of treatment specified as a grouping factor in the model. We performed the analysis on an intention-to-treat basis, using imputation methods on patients with incomplete data. Two patients from the treadmill-first group

Table 2. Outcome measures

Sit-to-stand test [25]	To assess initiation of movement in an everyday activity
Timed 10 m walk [26]	For time to complete, velocity and number of steps
Inked footprints—5 m walk [27]	Mean values for the central three strides were used to calculate right and left step lengths and width of base
One-leg stance test [28, 29]	The mean of three attempts was recorded
'S' test [30]	To assesses more complex aspects of ambulation. The mean time taken to complete three runs was recorded
ADL-oriented assessment of mobility [31]	Subjects completed sections B (standing balance) and C (gait)
The Nottingham extended ADL scale [32]	To determine whether any changes in gait parameters translated into improvements in the wider aspects of daily living
Nine-hole peg test of manual dexterity [33]	As it was not expected that treatment would have any effect on upper limb function, this test acted as a control

ADL, activities of daily living.

Table 3. Breakdown of therapy received

Patient	First treatment	Distance on treadmill (m)	Conventional physiotherapy, time in module[c] (h) [18] 1	2	3
1	Treadmill	11 396	3.13	3.83	2.07
2	Physiotherapy	13 343	0.10	6.80	2.08
3	Physiotherapy	10 608	0.80	5.23	2.98
4[a]	Treadmill	97	–	–	–
5	Treadmill	4 942	0.16	0.15	0.20
6	Physiotherapy	15 497	2.21	3.96	2.48
7	Treadmill	16 124	0.64	2.68	2.66
8	Physiotherapy	9 272	0.89	3.91	3.43
9	Treadmill	4 683	1.95	2.56	3.47
10	Physiotherapy	15 643	2.03	4.16	2.95
11	Treadmill	9 562	0.47	4.29	4.03
12	Physiotherapy	2 656	0.48	2.36	2.11
13	Physiotherapy	2 189	1.59	3.22	2.43
14	Treadmill	4 024	2.13	2.18	3.20
15	Physiotherapy	5 713	1.25	2.89	4.02
16[a]	Treadmill	2 463	–	–	–
17	Treadmill	13 372	0.13	4.10	4.39
18[b]	Treadmill	16	3.50	1.83	2.38

[a]Not included in the formal statistical analysis as they did not cross over to the conventional physiotherapy limb of the trial.
[b]Received a small amount of treadmill treatment but felt unsafe and frightened on the treadmill. Because some treatment had been given the patient was included in the formal statistical analysis.
[c]Module interventions: 1, for gait ignition failure and turning; 2, to improve postural alignment and enhance balance reactions; 3, for other components of cerebral multi-infarct state disordered gait.

Table 4. Scores on outcome measures for treadmill re-training followed by conventional physiotherapy

Outcome measure		Mean score (95% confidence interval) Baseline	After treadmill	After conventional	At follow-up
Sit-to-stand test	Time to complete[a] (s)	4.39 (2.81, 6.86)	3.79 (2.43, 5.93)	3.49 (2.23, 5.46)	3.87 (2.48, 6.06)
10 m walk	No. of steps[a]	40.07 (24.93, 64.42)	36.67 (22.81, 58.95)	27.75 (17.26, 44.62)	31.73 (19.74, 51.02)
	Mean velocity (m/s)	0.50 (0.23, 0.77)	0.60 (0.33, 0.87)	0.79 (0.52, 1.06)	0.66 (0.39, 0.93)
5 m walk	Right step length (cm)	27.95 (15.41, 40.49)	31.06 (18.52, 43.6)	37.51 (24.97, 50.05)	37.52 (24.97, 50.06)
	Left step length (cm)	30.68 (19.23, 42.12)	35.08 (23.64, 46.53)	40.00 (28.55, 51.44)	39.34 (27.9, 50.78)
	Width of base (cm)	19.18 (15.09, 23.28)	17.53 (13.44, 21.63)	19.38 (15.29, 23.47)	17.65 (13.56, 21.74)
One-leg stand (scored 0–4)[b]	Right	2.38 (1.4, 3.35)	2.63 (1.65, 3.6)	3.21 (2.24, 4.19)	2.93 (1.95, 3.91)
	Left	3.00 (1.96, 4.04)	3.00 (1.96, 4.04)	3.02 (1.97, 4.06)	3.02 (1.97, 4.06)
'S' test	Time to complete[a] (s)	32.70 (15.87, 67.37)	30.19 (14.66, 62.2)	25.29 (12.27, 52.09)	26.98 (13.1, 55.58)
Activities of daily living	Balance (scored out of 6)	5.5 (4.92, 6.08)	5.38 (4.8, 5.96)	5.73 (5.15, 6.31)	5.73 (5.15, 6.31)
	Gait (scored out of 4)	4 (3.64, 4.36)	4 (3.64, 4.36)	3.85 (3.49, 4.21)	3.85 (3.49, 4.21)
	Nottingham (scored out of 14)	10.88 (8.19, 13.57)	10.63 (7.94, 13.32)	11.8 (9.11, 14.49)	11.37 (8.68, 14.06)
Time to complete NHPT[a] (s)	Right	36.65 (30.84, 43.55)	35.44 (29.83, 42.12)	37.12 (31.23, 44.11)	35.25 (29.66, 41.89)
	Left	38.04 (31.55, 45.86)	39.04 (32.38, 47.06)	37.13 (30.8, 44.76)	36.73 (30.46, 44.27)

[a]Geometric mean.
[b]Berg categorical scale: 0, unable; 1, stands for <3 s; 2, stands for between 3 and 5 s; 3, stands for between 5 and 10 s; 4, stands for >10 s.
NHPT, nine-hole peg test of manual dexterity.

Table 5. Scores on outcome measures for conventional physiotherapy followed by treadmill re-training

Outcome measure		Mean score (95% confidence interval) Baseline	After treadmill	After conventional	At follow-up
Sit-to-stand test	Time to complete[a] (s)	4.72 (3.02, 7.37)	3.25 (2.08, 5.08)	4.03 (2.58, 6.3)	3.95 (2.53, 6.18)
10 m walk	No. of steps[a]	39.87 (24.8, 64.1)	31.90 (19.84, 51.28)	32.14 (19.99, 51.67)	33.70 (20.97, 54.18)
	Mean velocity (m/s)	0.52 (0.25, 0.79)	0.70 (0.42, 0.97)	0.64 (0.37, 0.91)	0.67 (0.4, 0.94)
5 m walk	Right step length (cm)	28.62 (16.08, 41.16)	38.94 (26.4, 51.48)	33.45 (20.91, 45.99)	38.01 (25.47, 50.55)
	Left step length (cm)	30.97 (19.52, 42.41)	39.58 (28.14, 51.03)	36.67 (25.23, 48.12)	38.62 (27.18, 50.07)
	Width of base (cm)	18.90 (14.81, 23)	18.84 (14.75, 22.94)	19.88 (15.79, 23.97)	19.85 (15.76, 23.95)
One-leg stand (scored 0–4)[b]	Right	2.00 (1.02, 2.98)	2.38 (1.4, 3.35)	1.88 (0.9, 2.85)	2.30 (1.32, 3.28)
	Left	2.00 (0.96, 3.04)	2.50 (1.46, 3.54)	2.00 (0.96, 3.04)	2.17 (1.12, 3.21)
'S' test	Time to complete[a] (s)	46.30 (22.48, 95.38)	35.68 (17.32, 73.5)	41.91 (20.35, 86.35)	39.97 (19.4, 82.35)
Activities of daily living	Balance (scored out of 6)	5.38 (4.8, 5.96)	5.63 (5.05, 6.21)	5.63 (5.05, 6.21)	5.65 (5.07, 6.23)
	Gait (scored out of 4)	3.88 (3.51, 4.24)	3.88 (3.51, 4.24)	3.88 (3.51, 4.24)	3.68 (3.31, 4.04)
	Nottingham (scored out of 14)	13.63 (10.93, 16.32)	14.63 (11.93, 17.32)	13.88 (11.18, 16.57)	14.73 (12.04, 17.42)
Time to complete NHPT[a] (s)	Right	36.2 (30.46, 43.02)	35.54 (29.91, 42.24)	36.3 (30.54, 43.14)	33.55 (28.23, 39.87)
	Left	35.54 (29.48, 42.85)	37.01 (30.7, 44.61)	36.9 (30.61, 44.49)	34.3 (28.45, 41.35)

[a]Geometric mean.
[b]Berg categorical scale: 0, unable; 1, stands for <3 s; 2, stands for between 3 and 5 s; 3, stands for between 5 and 10 s; 4, stands for >10 s.
NHPT, nine-hole peg test of manual dexterity.

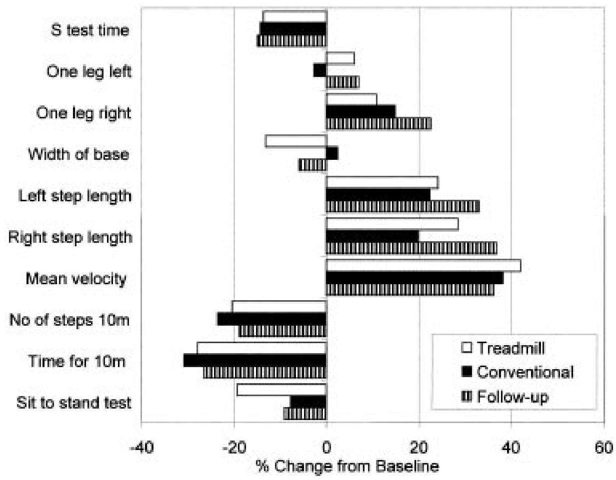

Figure 1. Percentage change from baseline after treadmill re-training, after conventional physiotherapy and at follow-up for patients who received treadmill-gait re-training followed by conventional physiotherapy. Percentage change = (mean value at end of baseline − mean value at end of treatment)/mean value at end of baseline × 100.

withdrew from the study before receiving any physiotherapy treatment. Their data were not included in the formal statistical analysis. The significance level was set at $P \leq 0.05$.

Results

During the 8 weeks of active treatment, patients walked an average of 7.9 (5.5) km on the treadmill

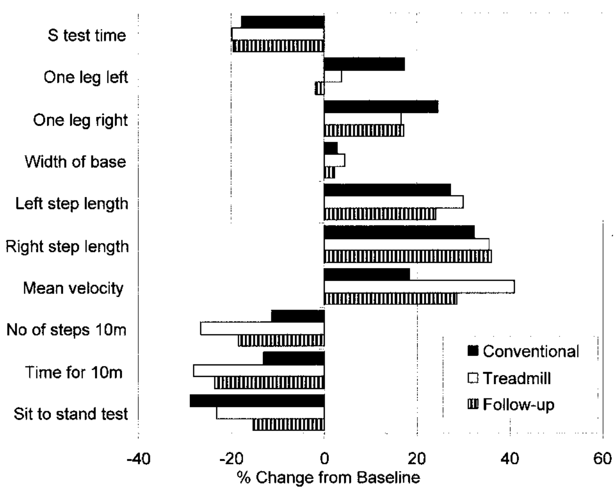

Figure 2. Percentage change from baseline after conventional physiotherapy, after treadmill re-training and at follow-up for patients who received conventional physiotherapy re-training followed by treadmill gait re-training. Percentage change = (mean value at end of baseline − mean value at end of treatment)/mean value at end of baseline × 100.

and had an average of 6.7 (3.2) h of physiotherapy. A breakdown of the therapy each patient received is shown in Table 3. Although data were collected weekly, and all data were used in the analysis, only the values recorded at the end of baseline and each treatment phase are reported here (Tables 4 and 5).

There were no significant differences between the two treatment groups at the end of the baseline period ($P \leq 0.8$). Statistically, there were no differences between the groups over the study period (from the evaluation of the main group effect and interaction between group and assessment time in the analysis of variance model). Improvements appeared greatest in those patients who had treadmill re-training first. The interaction between group and assessment time approached statistical significance for two gait variables: a reduction in both the time taken to walk 10 m ($P = 0.06$) and in the number of steps taken over 10 m ($P = 0.07$).

From evaluation of the main time effect in the analysis of variance model, there were moderate but statistically significant improvements over the 12 weeks of the study, with $P < 0.001$ in the following variables: time to complete the sit-to-stand test; time to walk 10 m; number of steps over 10 m; velocity; right and left step lengths; and time to complete the 'S' test. There were less significant increases in patients' ability to stand on one leg—for both right ($P = 0.005$) and left ($P = 0.007$) legs. There were no changes in width of base ($P = 0.8$) or the standing balance ($P = 0.3$) or gait ($P = 0.1$) sections of the activities-of-daily-living-oriented assessment of mobility scale. There was a strong trend towards improvement in the Nottingham extended activities of daily living scale ($P = 0.06$). There was no significant change in the time taken to complete the nine-hole peg test for the right hand ($P = 0.1$) but results for the left hand did show significant improvement ($P = 0.03$). Figures 1 and 2 express outcomes as percentage changes from the end of baseline for each treatment group.

Discussion

The results did not support our hypothesis that treadmill re-training would be more effective. There was no difference between the two treatment programmes for this group of patients. Significant improvements were recorded for both treatments, with the benefits achieved being largely maintained at the 6-week follow-up visit. However, these improvements may have been due to other factors, such as an increase in muscle strength or cardiovascular fitness, or the placebo effect of being evaluated. A placebo group was not used in this study, as we were comparing a novel with a conventional treatment, and our hypothesis was that the novel treatment would be more effective.

There were trends to suggest that patients who started with treadmill re-training had better outcomes than those who started with conventional physiotherapy, but these were not conclusive. A possible reason for the lack of significance was the wide variation in the amount of treadmill re-training each patient received. Six patients included in the analysis had walked well under 5 km compared with four patients who had walked over 10 km and three who had walked over 15 km. These differences were due to the wide variability in presentation and severity of the higher-level gait disorders. It is attractive to speculate that treadmill re-training 'kick-starts' the rehabilitation process, with conventional physiotherapy maintaining any improvements. This will require further testing, with a larger or more homogeneous patient group.

There was much less variability in the amount of conventional physiotherapy received by the patients, most of whom received >5 h of treatment. This may partly explain the relative effectiveness of physiotherapy in comparison with treadmill re-training. Additionally, the 31 interventions used were designed specifically for patients with higher-level gait disorders and the treatments were tailored to patients' individual needs. Similar, although less well defined, schedules have previously been used to demonstrate that physiotherapy late after a stroke produces small but significant improvements in mobility [24]. Clearly it is difficult to deliver equivalent 'packages' of both treadmill re-training and conventional physiotherapy to these types of patients, and this is a potential source of bias in this study.

In summary, there was no difference between treatment with either physiotherapy or treadmill re-training of patients with higher-level gait disorders secondary to CMIS. In these patients several gait variables improved, and improvements were well maintained at 6-week follow-up. There was a trend for therapy to be most effective when treadmill re-training was the first modality used. While these effects may be due to other factors, there appears to be scope to improve the gait of this group of frail, elderly patients.

Key points

- Higher-level gait disorders associated with cerebral multi-infarct states are an important cause of morbidity in frail elderly patients.
- It is possible to customize physiotherapeutic schedules for specific conditions and test them in a scientific manner.
- There is a theoretical rationale why treadmill re-training might improve gait in patients with higher-level gait disorders.
- While there was no difference between treadmill re-training and conventional physiotherapy, both are associated with improvements.

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The protocol for this study was approved by the Salford and Trafford research ethics committee (project 94055) and the Bolton research ethics committee (ref. 9/95/73). Informed consent was obtained from each patient, as specified within the above ethics approvals.

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