*Clinical Rehabilitation* 2010; **24:** 46–54

# Exercise on a treadmill or walking outdoors? A randomized controlled trial comparing effectiveness of two walking exercise programmes late after stroke

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Received 15th March 2009; returned for revisions 25th May 2009; revised manuscript accepted 29th June 2009.

**Objective**: To evaluate spatial and temporal gait characteristics and endurance late after stroke in people who had received two different walking exercises. A secondary aim was to compare the outcomes in relation to length of time exercising and number of exercise occasions between the two.
**Design**: A randomized controlled trial.
**Setting**: A private rehabilitation centre.
**Subjects**: Thirty-nine people with stroke entered the study, and five dropped out.
**Interventions**: Treadmill training versus walking outdoors.
**Main measures**: Six-Minute Walk Test, a 10-metre walk test and pulse rates at rest and in activity.
**Results**: There were significant differences in favour of the treadmill group in Six-Minute Walk Test distance ($P = 0.04$), Six-Minute Walk Test speed ($P = 0.03$), 10-m walking speed ($P = 0.03$), bilateral stride length (right leg; $P = 0.009$, left leg; $P = 0.003$) and step width ($P = 0.01$), indicating more symmetrical use of the legs in the treadmill group (1.02–1.10 m versus 0.97–0.92 m). There were no significant differences between groups in cadence ($P = 0.78$). All participants complied 100% with their respective programmes. Exercise frequency did not differ between the groups but significantly less time was spent exercising on the treadmill compared with walking exercise outdoors (107 versus 316 minutes, $P = 0.002$). There were no differences in use of assistive aids between the groups on arrival at the clinic or at departure.
**Conclusion**: The results indicate that treadmill walking improves spatial and temporal gait characteristics more effectively than walking outdoors.

## Introduction

Stroke care has changed over the last 20 years with the introduction of stroke units, and in recent years the promising use of thrombolysis.[1–3] Early coordinated treatment has led to increased survival among people with stroke and to a decrease in disability.[4,5] As a result, a large number of people with stroke are surviving with minimal to

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10.1177/0269215509343328

moderate reductions of function.[5,6] Many people who have had a stroke return to work,[7–10] live at home with their families, and maintain their social roles to a greater extent than they did a few years ago.[11]

Despite these promising developments, a number of people experience difficulties in physical and psychological functioning in the first year after stroke. Some are in need of a 'booster' dose of rehabilitation in order to maintain and improve functions vital for activities in daily life.[12–16] However, when more than six months have passed after stroke and the person has entered the chronic phase,[17] access to rehabilitation is limited. The acute hospitals with stroke and rehabilitation units are targeted to serve the acute patients with stroke. Post-stroke care is defined as a task for primary care, which has limited resources and competence for this purpose. Private rehabilitation centres and private physiotherapy practices, on the other hand, provide rehabilitation and treatment to people in the chronic phase.

Private rehabilitation centres in Norway specialize in different diagnostic disorders and have nurses, physiotherapists, social workers and doctors to help and treat people during a three- to six-week stay, and the community often subsidizes part of the treatment. Patients are referred by their family doctors, and such a referral can be made for physical, social or psychological reasons.

A vital part of the programme in private rehabilitation centres is physiotherapy, with a focus on exercise and coping. Other services that may be provided are social counselling, nursing and occupational therapy, with a doctor on call.

The physiotherapy programmes often include individual treatment, group sessions, outdoor walking and balance groups. Group sessions with different aspects of coping are offered by physiotherapists, occupational therapists and nurses. The walking groups are organized outdoors with the aim of improving the walking capacity in a functional environment. The climate, however, can be an obstacle, with snow and icy roads in the winter. Walking indoors is then a natural option, if not so challenging.

Treadmill walking has been shown to be a valuable therapeutic tool for improving walking patterns post stroke.[18] It is also effective in enhancing endurance.[19] Although treadmill training does not seem to be better than ordinary walking exercises in the acute stage for initiating walking,[20,21] it might be beneficial in improving gait in the chronic stage as an alternative to ordinary walking exercise.[18]

The present study was undertaken to evaluate the efficiency of treadmill training compared with walking outdoors and to evaluate spatial and temporal gait characteristics, namely bilateral stride length, step width, cadence and walking speed, measured with a 10-m walk test and Six-Minute Walk Test. A further aim was to determine whether walking on a treadmill had better effects than walking outdoors with regards to endurance, as measured by the Six-Minute Walk Test. Third, we wanted to find out whether there was any difference in therapy time between the two exercise forms and whether they were feasible for all patients in the private rehabilitation setting.

We hypothesized that treadmill walking would be more beneficial than regular walking exercise to improve qualities of gait and endurance. We based this hypothesis on the fact that treadmill walking is continuous and triggered from an outside source in contrast to self-paced walking. The strategy to maintain balance and stay on the treadmill was hypothesized to be increased step length as shown in earlier studies,[18] and a continuous individualized speed rate on the treadmill would result in a higher pulse rate than walking outdoors, thus influencing endurance.

## Methods

This pilot study was a single-blind randomized controlled trial. The assessor was blinded, but the participants and physiotherapists in charge of the exercise programme were not. The assessor was experienced, and well qualified in the use of the Six-Minute Walk Test and 10-m walk test. Patients were tested within one day after arriving at a private rehabilitation centre, and were randomized into two groups directly after the test, by a person not involved in the study: one group for treadmill exercises and the other for outdoor walking. The randomization was performed by selection of an opaque closed envelope from envelopes

in which the group assignment was written. Treatment started on the day after the randomization. Participation in the study was voluntary. All participants were informed about the tests and the use of the test results, and were asked to sign a written statement in which they formally consented to inclusion in the study. The study was approved by the Regional Committee of Medical Research Ethics of Norway, S-04036.

**Subjects**

Patients with stroke were recruited to the study consecutively as they arrived at the private rehabilitation centre. Inclusion criteria were neurological impairment and age above 50 years. Exclusion criteria were barriers to taking part in a physical rehabilitation programme, insufficient language, an unstable cardiac status, neurosurgery and a premorbid history of orthopaedic problems or any problems that would prevent a patient from walking.

**Outcome measures**

The Motor Assessment Scale was used to test motor function. This scale was developed by Carr and Shepherd[22] and each item scores from 0 to 6, the total scores ranging between 0 and 48. Item 3 in the Motor Assessment Scale was chosen to evaluate balance as the people entered the programme.

The Six-Minute Walk Test was used as an endurance test,[23] and length and gait speed were recorded. The participants were asked to walk as fast as they could for 6 minutes. They were told that they would be informed of the length of time at 2, 4 and 5 minutes of the Six-Minute Walk Test. Walking capacity was monitored using a standardized protocol.[23,24] Distance walked (m) and gait velocity (m/s) were measured by the investigator. The test was performed in an 85-m-long corridor. The Six-Minute Walk Test is also used to assess exercise tolerance,[25] thus measuring functional exercise capacity. Gait velocity has been tested among elderly individuals for validity and reliability, with satisfactory results,[26] and it has also been used in several stroke studies.

Pulse was recorded at rest and during the Six-Minute Walk Test. The resting pulse was recorded after a 10-minute rest before starting the walk test. The three highest pulse recordings during activity were noted and a mean of the three recordings was presented as pulse in activity during walking. Pulse rate was measured with a pulse monitor (Sport testerTM PE 3000; Polar Electro, Finland). The pulse monitor consists of a belt placed around the patient's thorax and a wrist pulse monitor, which was in the hands of the examiner during the test.

A 10-m walk test was performed by walking 10 m, with markers on the heels on both the affected and the intact foot, to measure quality of walking. The walk-way was 14 m long, with 2 m for warming up and 2 m for slowing down, as also used in other studies.[24] The participants were instructed to walk as fast and as safely as they could. The markers made it possible to measure step length, stride length and step width, and with these recordings cadence was also calculated. Gait speed was measured with a stopwatch. Cadence, or steps per minute, was calculated as $120 \times$ speed (m/s) divided by stride length (m).[27–29] The test subjects were asked to walk as fast as they could, and they were instructed that time was the main issue within a frame of safety.

The patients underwent the tests on arrival at the private rehabilitation centre (test 1) and at the end of the intervention period (test 2). The test procedure was performed in approximately 45 minutes, starting with the Motor Assessment Scale item 3, then the 10-m walk test followed by a short break before the final Six-Minute Walk Test. The participants could use assistive devices and take a rest during the tests. This information was recorded in the test protocol. An experienced investigator, well known with the tests, and blinded to group allocation, performed all tests in a separate section of the centre.

**Intervention**

The group randomized to the treadmill exercises were supposed to do walking exercises for up to 30 minutes five days a week while they attended the private rehabilitation centre. The treadmill had hand railings to hold on to, otherwise there

were no safety precautions or body support. The participants walked on the treadmill, and the exercises were carried out with the treadmill in a flat position. The speed was started on the lowest level and was increased within the first minutes to the working level. The working load was increased in cooperation with the participants to a level they felt comfortable with and they felt no insecurity in balance or discomfort otherwise.

The group randomized to outdoor walking also exercised five days a week at a comfortable speed and with the use of ordinary assistive devices when necessary. The walk was performed regardless of weather conditions. The length of the walk was dependent on time rather than distance, and the intention was a 30-minute continuous walk.

The other activities in the physiotherapy department were the same in the two groups. Each patient had a programme consisting of 30 minutes with individual therapy, with the main focus on balance, strength and coordination, 60 minutes of circle training, with the main focus on endurance, strength, flexibility and balance, and 30 minutes of group exercise training in a sitting position with a therapist. A group therapy session with the main focus on coping for patients with stroke was also offered. This group was led by a nurse. All participants were encouraged to do 30 minutes of exercise on their own every afternoon with an individually tailored programme. In addition, a relaxation group of 20 minutes was offered twice a week. The total amount of physiotherapy during a day was 3 hours with an additional 20 minutes relaxation and 30 minutes of education, giving a total of approximately 21 hours of therapy per week.

### Statistical analysis

Descriptive and analytical statistics are presented. An independent *t*-test was used to assess baseline differences. A general linear model for repeated measure (a mixed between-within analysis of variance) was used to evaluate treatment effects with time, using changes in performance as the within subjects factor, the treatment as the between subjects factor and total time exercising as a covariate.[30] Data are presented as mean and standard deviation (SD). Effect sizes are also given. The analyses were performed on an intention-to-treat basis. Statistical significance was set at $P < 0.05$.

## Results

A total of 39 people were initially included in the study with baseline tests. Five people dropped out, three in the treadmill group and two in the walking outdoor group. Four participants, two in each group, were returned to the hospital because of acute symptoms, and one in the treadmill group, discontinued the stay for personal reasons (Figure 1). There were no baseline differences between the groups, and the length of stay was approximately 2.5 weeks in each group (Table 1). Group activities and exercises were carried out five days a week, and during weekends only self-training was performed.

The intensity of the walking exercises on a treadmill and of the exercise walks outside was determined by the patient, with a minimum of 0.1 m/s on the treadmill and a moderate tempo and a time limit of 30 minutes when walking outdoors. The therapists encouraged the patients to increase or maintain the load daily. The mean treadmill speed during exercise was 0.5 m/s, with a range of 0.4–1.1 m/s and a flat surface. The mean time per session for treadmill walking was 12 minutes, and the total exercising time was 107 minutes (Table 2). The outdoor walks were carried out at a comfortable walking speed. The time spent exercising depended on the weather conditions, but was on average 29 minutes per session. The total mean time for outdoor walking was 316 minutes (Table 2). Thus, significantly less time was spent on the treadmill than on walking exercise outdoors (Table 2). The groups were supervised by physiotherapists and the participants were active, and compliance to their respective programme was 100%.

There were significant differences in favour of the treadmill group in Six-Minute Walk Test distance, 6-minute walking speed, 10-m walking speed, bilateral stride length and step width. There were no significant differences between groups in cadence (Table 3). The results regarding speed, distance walked, stride length, step width

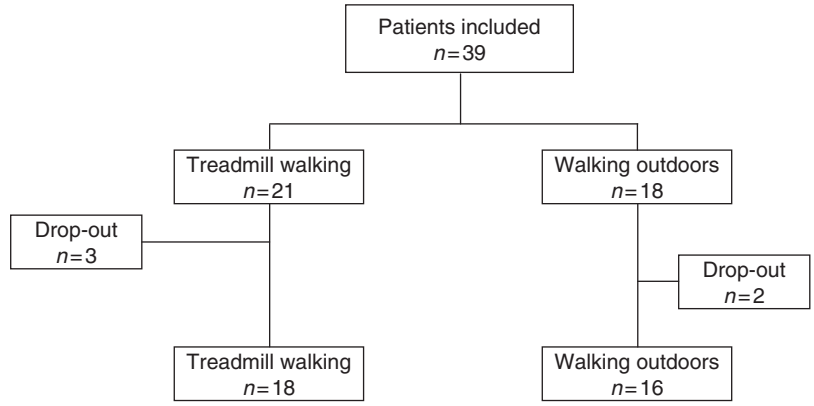


**Figure 1.** Flow diagram of the study.

**Table 1** Baseline demographic data for patients included in the two different groups and significance levels at $P<0.05$ for differences between the groups

| | Treadmill $n=21$ | Walking outdoors $n=18$ | *P*-value |
|---|---|---|---|
| Men (*n*) | 10 | 6 | 0.4 |
| Women (*n*) | 11 | 12 | |
| Age (years), mean (SD) | 74 (13.3) | 75 (10.4) | 0.8 |
| First time ever stroke (*n*) | 17 | 16 | 0.5 |
| Right/left hemisphere (*n*) | 15/6 | 13/5 | 0.9 |
| Time after stroke (days) | 419 (1034) | 349 (820) | 0.8 |
| Height (cm), mean (SD) | 172 (9.2) | 167 (11.6) | 0.2 |
| Weight (kg), mean (SD) | 75 (15.0) | 67 (17.3) | 0.1 |
| Neglect (*n*) | 2 | 2 | 0.9 |
| MAS 3 score | 5.4 | 5.3 | 0.7 |
| Spasticity (*n*) | 2 | 2 | 0.4 |
| Reduced sensation (*n*) | 7 | 6 | 0.9 |
| Length of stay in the private rehabilitation facility (days), mean (SD) | 15.9 (5.3) | 16.9 (5.4) | 0.6 |

**Table 2** Total time exercising in the groups, frequency of exercise classes, use of support when exercising and assistive devices on arrival and at departure from private rehabilitation setting

| | Treadmill $n=21$ | Walking outdoors $n=18$ | *P*-values |
|---|---|---|---|
| Total time walking exercise (min), mean (SD) | 106.9 (136.4) | 315.5 (210.7) | 0.002 |
| Number of exercise classes in walking (*n*), mean (SD) | 9.9 (3.4) | 10.9 (3.7) | 0.44 |
| Support, yes/no | 13/8 | 5/13 | 0.003 |
| Assistive device arrival (*n*) | 7 | 9 | 0.73 |
| Assistive device departure (*n*) | 5 | 6 | 0.53 |

and cadence were lower in both groups than in healthy older people of the same age.[24,31] Both groups increased their walking distance and walking speed. However, the change was greater in the treadmill group than in the walking outdoor group (Table 4).

There was a significant difference in the use of support during the exercises in favour of the group walking outdoors, but there was no significant difference in the number of exercise classes or in the number of rests during the exercises (Table 2). There was no difference in the use of assistive aids between the groups either on arrival at the clinic or at departure (Table 2). The pulse rates at rest and during activity did not differ significantly between the two groups on either test occasion (Table 3).

There were no significant differences in rests during tests occasions ($P=0.19$). One person in the treadmill group needed a rest when performing the Six-Minute Walk Test during the first test. The other participants rested between the tests.

**Table 3** Descriptive measurements

| | Treadmill ($n=21$) | | Walking outdoors ($n=18$) | | Between groups | Effect size[a] | Time | Effect size[a] |
|---|---|---|---|---|---|---|---|---|
| | Test 1 | Test 2 | Test 1 | Test 2 | *P*-values | | *P*-values | |
| 10-m (m/s) | 0.8 (0.5) | 1.0 (0.4) | 0.8 (0.4) | 0.9 (0.4) | 0.03 | 0.16 | 0.001 | 0.3 |
| 6MWT (m) | 277.7 (139.9) | 320.6 (153.8) | 299.4 (159.3) | 310.1 (164.4) | 0.04 | 0.14 | 0.002 | 0.28 |
| 6MWT (m/s) | 0.8 (0.4) | 0.9 (0.4) | 0.8 (0.4) | 0.9 (0.5) | 0.03 | 0.15 | 0.002 | 0.29 |
| Stride length right leg (m) | 1.1 (0.2) | 1.1 (0.3) | 0.97 (0.4) | 1.0 (0.4) | 0.009 | 0.21 | 0.001 | 0.23 |
| Stride length left leg (m) | 1.0 (0.2) | 1.1 (0.4) | 0.97 (0.4) | 0.92 (0.3) | 0.003 | 0.27 | 0.007 | 0.23 |
| Step width (cm) | 7.2 (5.2) | 7.9 (5.3) | 11.3 (5.6) | 12.3 (5.3) | 0.01 | 0.2 | 0.25 | 0.05 |
| Cadence (number of steps) | 81.6 (45.3) | 97.6 (24.4) | 99.3 (30.1) | 108.1 (35.1) | 0.78 | 0.003 | 0.02 | 0.17 |
| Pulse at rest | 77 (15.1) | 79 (9.8) | 77 (14.7) | 72 (11.9) | 0.5 | 0.02 | 0.94 | 0.01 |
| Pulse in activity | 99 (16) | 101 (14.4) | 90.6 (14.2) | 99 (16.7) | 0.37 | 0.03 | 0.87 | 0.001 |

Values are means (SD).
6MWT, Six-Minute Walk Test.
The tests were performed on arrival at the private rehabilitation centre (test 1) and at the end of the intervention period (test 2).
The significance levels were set at $P<0.05$ for differences between the groups with time as covariate.
[a]Guidelines from Cohen[38]: 0.01 = small effects; 0.06 = medium effect; 14 = large effect.

**Table 4** Outcome data at departure from the private rehabilitation centre, within-groups changes

| Group | Treadmill | | Walking outdoors | |
|---|---|---|---|---|
| | At departure $N=21$ | Change $N=21$ | At departure $N=18$ | Change $N=18$ |
| 10-m (m/s) | 1.0 (0.4) | 0.07 (0.3) | 0.9 (0.4) | 0.08 (0.1) |
| 6MWT (m) | 320 (153.8) | 31.1 (104.1) | 310.1 (124.4) | 24.1(40.1) |
| 6MWT (m/s) | 0.9 (0.4) | 0.09 (0.3) | 0.9 (0.5) | 0.06 (0.1) |
| Stride length right leg (m) | 1.1 (0.3) | 0.06 (0.2) | 1.0 (0.4) | 0.04 (0.2) |
| Stride length left leg (m) | 1.1 (0.4) | 0.7 (0.2) | 0.92 (0.3) | −0.02 (0.2) |
| Step width (cm) | 7.9 (5.3) | 0.16 (4.1) | 12.3 (5.3) | 1.1 (4.4) |
| Cadence (*n*) | 97.6 (24.4) | 18.9 (26.9) | 108.1 (35.1) | 9.1 (31.9) |

Values are means (SD).
6MWT, Six-Minute Walk Test.

## Discussion

The main results of this study are twofold. First, the treadmill group gained an increase in walking speed and distance. This group obtained an equally long or longer step length bilaterally in less time than the outdoor walking class, indicating that treadmill walking was an effective and important tool in rehabilitation. Similar results have been reported by others.[18,29]

Second, the exercise on the treadmill also improved walking on a flat surface, as tested by the Six-Minute Walk Test and 10-m walk test. These results indicate that this type of exercise will be an excellent tool in regions of the world where the climate often hinders outdoor activities. Also, it can be more motivating to walk on a treadmill than to walk in corridors, which often is the alternative to outdoor walking in a clinic or rehabilitation unit. In a patient group with moderate deficits in motor function, the therapists can increase the intensity of the treadmill in order to improve walking and can be assured that this gain will be transferred into the ordinary walking pattern.

Another important aspect is that all our patients were well past the acute period after their stroke, a mean of 480 and 300 days post stroke,

respectively. This fact stresses the importance of 'booster doses' of rehabilitation in order to maintain physical function levels in stroke patients.[12,13]

The stay in this private rehabilitation centre incorporated several activities, all very beneficial for improving physical function and supporting an empowering process. The results of this study must therefore be seen in the light of the participants' total amount of activity, which was equal in the two groups. However, the difference in the exercise protocols was in the methods of walking exercise. We believe, therefore, that this difference must probably be the main explanatory factor for the improvement in the treadmill exercise group. The benefit of treadmill walking as an addition to rehabilitation programmes has also been shown in other studies.[18,29,32]

Our study indicates that step width is increased in relation to increased speed and step length. This is an important finding since increased step width seems to be the strategy used for maintaining balance when increasing speed in people with stroke in comparison to healthy subjects.[33]

There were more people with a right hemisphere lesion than with a left hemisphere lesion in our study. Thus, the majority of the participants had the paresis or weakness mainly on the left side. This was also reflected by a shorter step length on the left than on the right side at the first test. However, people exercising on the treadmill increased their step length so that they had a similar step length on the two sides after training, in contrast to the outdoor walking group, where the difference was maintained. Thus, it seemed as if the treadmill walking improved and equalized step length to a greater extent than did the ordinary walking outdoors (Table 3). Other studies have shown lower cadence, and longer step times of the non-hemiplegic and hemiplegic limbs in people with stroke exercising on a treadmill, supporting our findings.[34]

Pulse rates were recorded at rest and during activity and did not differ significantly between the groups (Table 3). The pulse rates during activity reached 65% of the maximum pulse rates as estimated by Tanaka,[35] indicating an endurance impact of the walking activity in both groups. This is supported by other studies that have indicated that the Six-Minute Walk Test does provide a clinical measure of fitness for adults with stroke.[36] Whether this improvement reflects cardiovascular changes or not in a stroke population has been debated. Improvement in stress tests in a stroke population is related to a higher degree to improvements in neuromuscular function than aerobic capacity.[36,37]

A weakness of this study is the relatively small groups and the limited period of follow-up. The results, therefore, must be interpreted with caution. However, we believe that the participants were representative of this category of people with stroke. The drop-outs were even in the two groups, and the main reason for dropping out was acute illness.

The outcomes analysed in this study were limited to walking performance and balance. Coping and empowerment mechanisms were not targeted.

The results indicate that treadmill exercise gives improvements in less time than walking outdoor in stroke patients, and treadmill exercise additionally improves the symmetry in step length. In order to prepare an exercise programme for a person with reduced function it is important to choose exercises appropriate for that person's needs and if possible to limit the time required to achieve the desired results. This study can be of valuable help in planning such exercises.

**Clinical messages**

- Treadmill walking improves spatial and temporal gait characteristics in stroke patients more effectively than walking outdoors.
- Treadmill walking results in a more symmetrical gait in stroke patients than outdoor walking in a significantly shorter time.
- Increase in the pulse rate during exercise indicates an endurance impact in stroke patients both by treadmill walking and by walking outdoors.

**Acknowledgements**

We thank our colleagues Anette Faber Hansen, Wenche Mortensen and Vigdis Fenes at FRAM recreational centre, Baerum for valuable assistance and help.

**Competing interests**
None.

## References

1 Donnan GA, Fisher M, Macleod M, Davis SM. Stroke. *Lancet* 2008; **371**: 1612–23.
2 Hacke W, Lichy C. Thrombolysis for acute stroke under antiplatelet therapy: safe enough to be beneficial? *Nat Clin Pract Neurol* 2008; **4**: 474–75.
3 Hacke W, Kaste M, Bluhmki E *et al.* Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. *N Engl J Med* 2008; **359**: 1317–29.
4 Eriksson M, Norrving B, Terent A, Stegmayr B. Functional outcome 3 months after stroke predicts long-term survival. *Cerebrovasc Dis* 2008; **25**: 423–29.
5 Asplund K, Asberg KH, Norrving B, Stegmayr B, Terent A, Wester PO. Riks-Stroke – A Swedish national quality register for stroke care. *Cerebrovasc Dis* 2003; **15**: 5–7.
6 Quain DA, Parsons MW, Loudfoot AR *et al.* Improving access to acute stroke therapies: a controlled trial of organised pre-hospital and emergency care. *Med J Aust* 2008; **189**: 429–33.
7 Hofgren C, Bjorkdahl A, Esbjornsson E, Stibrant-Sunnerhagen K. Recovery after stroke: cognition, ADL function and return to work. *Acta Neurol Scand* 2007; **115**: 73–80.
8 Medin J, Barajas J, Ekberg K. Stroke patients' experiences of return to work. *Disabil Rehabil* 2006; **28**: 1051–60.
9 Treger I, Shames J, Giaquinto S, Ring H. Return to work in stroke patients. *Disabil Rehabil* 2007; **29**: 1397–403.
10 Vestling M, Tufvesson B, Iwarsson S. Indicators for return to work after stroke and the importance of work for subjective well-being and life satisfaction. *J Rehabil Med* 2003; **35**: 127–31.
11 Glader EL. A national quality registry shows differences when it comes to stroke care. *Lakartidningen* 2004; **101**: 370–75.
12 Langhammer B, Lindmark B, Stanghelle JK. Stroke patients and long-term training: is it worthwhile? A randomized comparison of two different training strategies after rehabilitation. *Clin Rehabil* 2007; **21**: 495–510.
13 Langhammer B, Lindmark B, Stanghelle JK. Living with stroke: exercising for life. *J Aging Phys Act* 2008; **16**: S80.
14 Macko RF, Benvenuti F, Stanhope S *et al.* Adaptive physical activity improves mobility function and quality of life in chronic hemiparesis. *J Rehabil Res Dev* 2008; **45**: 323–28.
15 Kay-Lyons MJ, Makrides L. Exercise capacity early after stroke. *Arch Phys Med Rehabil* 2002; **83**: 1697–702.
16 Kay-Lyons MJ, Makrides L. Longitudinal changes in exercise capacity after stroke. *Arch Phys Med Rehabil* 2004; **85**: 1608–12.
17 Stuart M, Chard S, Roettger S. Exercise for chronic stroke survivors: a policy perspective. *J Rehabil Res Dev* 2008; **45**: 329–35.
18 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**: 1486–91.
19 Macko RF, Ivey FM, Forrester LW *et al.* Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke – a randomized, controlled trial. *Stroke* 2005; **36**: 2206–11.
20 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.
21 Dickstein R. Rehabilitation of gait speed after stroke: a critical review of intervention approaches. *Neurorehabil Neural Repair* 2008; **22**: 649–60.
22 Carr J, Shepherd R. Modified Motor-Assessment Scale. *Phys Ther* 1985; **65**: 175–80.
23 Guyatt GH, Sullivan MJ, Thompson PJ *et al.* The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J* 1985; **132**: 919–23.
24 Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. *Phys Ther* 2002; **82**: 128–37.
25 Larsen AI, Aarsland T, Kristiansen M, Haugland A, Dickstein K. Assessing the effect of exercise training in men with heart failure – comparison of maximal, submaximal and endurance exercise protocols. *Eur Heart J* 2001; **22**: 684–92.
26 Finch E, Brooks D, Stratford PW, Mayo NE. MAS, 6-minute walk test. In: *Physical rehabilitation outcome measures*. Baltimore, Lippincott Williams & Wilkins, 2002, 169–72, 248–53.
27 Rosengren KS, McAuley E, Mihalko SL. Gait adjustments in older adults: activity and efficacy influences. *Psychol Aging* 1998; **13**: 375–86.

28 Ringsberg K, Gerdhem P, Johansson J, Obrant KJ. Is there a relationship between balance, gait performance and muscular strength in 75-year-old women? *Age Ageing* 1999; **28**: 289–93.
29 Kuys SS, Brauer SG, Ada L, Russell TG. Immediate effect of treadmill walking practice versus overground walking practice on overground walking pattern in ambulatory stroke patients: an experimental study. *Clin Rehabil* 2008; **22**: 931–39.
30 Tabachnick BG, Fidell LS. *Using multivariate statistics*., fourth edition. New York, Harper Collins, 2001.
31 Langhammer B, Lindmark B. Performance-related values for gait velocity, Timed Up-and-Go and Functional Reach in healthy older people and institutionalized geriatric patients. *Phys Occup Ther Geriatr* 2007; **25**: 55–69.
32 Chen G, Patten C, Kothari DH, Zajac FE. Gait deviations associated with post-stroke hemiparesis: improvement during treadmill walking using weight support, speed, support stiffness, and handrail hold. *Gait Posture* 2005; **22**: 57–62.
33 Montero-Odasso M, Schapira M, Varela C, Pitteri C, Camera L. Gait velocity as an easy test to detect mobility impairment in the elderly. *J Am Geriatr Soc* 2001; **49**: S105.
34 Puh U, Baer GD. A comparison of treadmill walking and overground walking in independently ambulant stroke patients: a pilot study. *Disabil Rehabil* 2009; **31**: 202–10.
35 Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol* 2001; **37**: 153–6.
36 Pohl PS, Duncan PW, Perera S *et al*. Influence of stroke-related impairments on performance in 6-minute walk test. *J Rehabil Res Dev* 2002; **39**: 439–44.
37 Potempa K, Lopez M, Braun LT, Szidon JP, Fogg L, Tincknell T. Physiological outcomes of aerobic exercise training in hemiparetic stroke patients. *Stroke* 1995; **26**: 101–105.
38 Cohen J. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ, Erlbaum, 1988.