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Functional recovery of gait after stroke.

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CHAPTER 4

IS SYMMETRY OF GAIT A REQUIREMENT FOR FUNCTIONAL RECOVERY AFTER STROKE?

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ABSTRACT

Achieving symmetry in gait is one of the specific goals in stroke rehabilitation. The purpose of the present study was to determine whether symmetry in step length and single support duration is a requirement for functional recovery of walking ability after stroke. Thirteen stroke patients, admitted for inpatient rehabilitation three weeks post stroke, and 16 healthy control subjects were included to the study. At 3, 6, 12, 24, and 48 weeks post stroke functional recovery of walking ability was assessed by means of the Rivermead Mobility Index and the Functional Ambulation Categories. Patients required a minimum score of 8 on the RMI and 4 on the FAC to be classified as functionally recovered. Step length and single support duration were assessed by means of gait analysis while subjects walked at a self-selected comfortable speed. Patients whose step length symmetry and single support duration symmetry had recovered to values within the range of the control group, all showed functional recovery. However, several patients whose gait symmetry had not recovered to normal values did show functional recovery of walking ability. Therefore, it is concluded that symmetry in step length and single support duration is not a requirement for functional recovery of walking ability after stroke. Gait symmetry should be considered a rather questionable goal in stroke rehabilitation.

INTRODUCTION

Several studies have demonstrated that hemiparetic stroke patients often show an asymmetric gait pattern in contrast to healthy subjects.¹⁻⁴ Both spatio-temporal and kinematic gait characteristics may be affected and achieving symmetry in these characteristics is one of the specific aims in rehabilitation approaches for stroke patients.⁵⁻⁷

Much is still unknown, however, about the relation between gait symmetry and functional recovery of walking ability in stroke patients or how changes in gait symmetry across time interact with the recovery of walking ability. Certainly, the better and faster walkers show a higher degree of symmetry in general.^{8,9} Still, several studies show contradicting results concerning the relation between gait symmetry and walking ability. For example, a study of Brandstater et al. showed that patients with a greater degree of motor recovery walked faster and more symmetrically than those with less motor recovery.¹⁰ However, Hesse et al. concluded that although a 4-week NDT rehabilitation program improved several gait parameters, among which stance-duration symmetry, the functional performance of these patients did not improve considerably.¹¹

A possible limitation in several studies that might account for the apparent contradictions are the applied measures for recovery. Clinical measures like the Fugl Meyer¹² or the Motricity Index¹³ are often applied to assess motor recovery in stroke patients. However, these assessments rather focus on body functions than on activities and participation. They do not take into account that patients are able to develop compensations, which may enable them to establish walking ability at the level of activities even though the recovery of body (motor-) functions is less profound. Walking speed is quite often used to assess motor recovery as well^{14,15} but is still rather limited in quantifying walking ability at the activity level.

Furthermore, the research in which the relation between gait parameters and motor recovery is studied focuses mainly on correlations between the measured

variables. It would be more interesting to establish if the recovery of gait parameters towards normal values, which is a goal in many stroke rehabilitation programs, is a *requirement* for functional recovery of walking ability. The aim of this study is, therefore, to gain more insight into the relation between gait symmetry and functional recovery of walking ability. The study addresses the changes that take place in spatio-temporal kinematics during the first year post-stroke and how they relate to the functional recovery of walking ability. Functional recovery of walking ability will be defined as the ability to independently perform common activities in daily living such as being able to walk outside without help. It will be quantified by means of the Rivermead Mobility Index (RMI)¹⁶ and the Functional Ambulation Categories (FAC).¹⁷

METHODS

Subjects

The present study was part of a larger study in which the effects of hemi-neglect in right hemisphere stroke patients on gait was researched. The present group of patients formed a control group in this larger study and consisted therefore only of right hemisphere stroke patients. Patients were included by screening all stroke patients at the neurological wards of two local hospitals. If patients met the inclusion criteria they were asked to participate in the study. Patients had to (1) be within 20 to 80 years of age, (2) have suffered a first time single right hemisphere cerebrovascular accident, (3) have no severe cognitive disorders that might interfere with the aims of the present study, (4) have no other pre-morbid disorders that might interfere with the aims of the present study and (5) be admitted for inpatient rehabilitation three weeks post stroke.

Fifteen patients were included during a period of 20 months. Two patients dropped out: one patient suffered a second stroke one month after the first stroke and one patient never reached any walking ability within the duration of the study. The remaining group of 13 patients consisted of 7 men and 6 women. The average age was 59.4 years (sd: 12.7 years, range: 35-79 years). For comparison 16

healthy control subjects (8 men, 8 women) volunteered. The average age of the control group was 61.3 years (sd: 11.1 years, range: 33-77 years). None of the control subjects had a history of motor, vestibular or neurological disorders that may have interfered with the aims of the present study. The study was approved by the hospital's ethics committee and an informed consent was obtained from each subject.

Procedure and materials

At 3, 6, 12, 24 and 48 weeks post stroke (T₁ up to T₅) patient's functional walking ability was assessed by means of the RMI and the FAC. Gait characteristics were assessed by means of gait analysis, however, gait analysis did not start until a patient was able to walk independently for several meters. The use of an assistive device was allowed. Gait analysis was conducted while patients walked at a self-selected comfortable speed on the floor of an 8x4m gait lab. Patients were asked to walk from one side to the other side of the lab and back, resulting in two walking cycles.

Spatial (step length) and temporal (single support duration, heel-strike, toe-off, mid-stance, mid-swing) parameters were recorded by means of an ultrasonic motion analysis system.¹⁸ Data were sampled at 200 Hz and further processed on a personal computer using Matlab 5.3.

Data analysis and statistical analysis

Kinematics were calculated for each separate stride of both walking cycles and then averaged. The first and last stride of each walking cycle were omitted from analysis. The average walking speed was calculated only for these analysed cycles. The single support difference, SSDiff = (mean single support hemiplegic side) - (mean single support non hemiplegic side), was used to reveal asymmetries in the duration of single support phases between the hemiplegic and non-hemiplegic side. SSDiff is about zero for a symmetrical gait pattern. It is negative when the single support phase on the hemiplegic side is shorter than on the non-hemiplegic side, which is characteristic in a hemiplegic gait.

A similar parameter was used to reveal asymmetries in step length: $SLDiff = (\text{mean step length hemiplegic side}) - (\text{mean step length non hemiplegic side})$. Again, for a symmetrical gait pattern this parameter is about zero. A longer step length on the hemiplegic side results in a positive value, a shorter step length on the hemiplegic side results in a negative value.

The FAC and RMI were used to classify whether a patient's gait had functionally recovered or not. A patient required a minimum 4 on the FAC (patient is able to walk independently outside on a flat surface, but requires assistance with stairs, slopes or uneven grounds) and 8 on the RMI (patient is able to walk outside on pavements without help; a score of 8 allows 1 item to be scored 0 preceding this item) to be classified as functionally recovered.

To determine whether the patients group improved in time on the FAC and RMI, a repeated measures analysis of variance (ANOVA) with one within-subjects factor [measurement] with 5 levels [$T_1..T_5$] was performed. If justified, post hoc median tests on SSDiff and SLDiff were performed between patients (sub-) groups and healthy controls.

RESULTS

In Table 1 data from the control group is presented. It shows the mean, standard deviation, minimum and maximum of Speed, SSDiff and SLDiff.

Table 1. Comfortable walking speed (Speed), the difference between single support duration left and right (SSDiff) and the difference between step length left and right (SLDiff) for 16 healthy control subjects.

Variable	mean	sd	min.	max.
Speed (m/s)	1.24	0.0954	1.08	1.42
SSDiff (s)	-0.0058	0.0078	-0.0206	0.0092
SLDiff (cm)	0.05	2.32	-5.02	4.69

The mean group scores on both the RMI and the FAC are presented for each measurement in Figure 1. To make the scores of the two assessments comparable, scores were converted to a percentage of the maximum test score. Both tests showed a significant main linear effect for measurement [$F_{RMI}(1,12)=34.4, P<0.001$; $F_{FAC}(1,12)=29.3, P<0.001$].

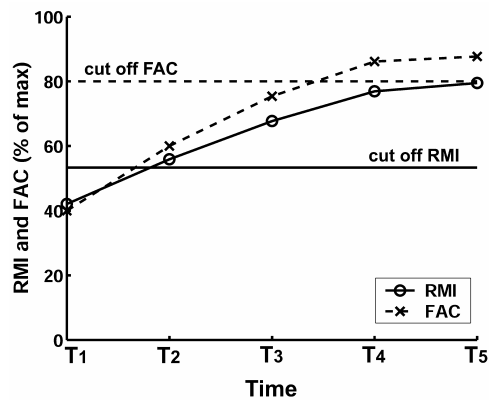


Figure 1. Mean relative group score on Rivermead Mobility Index and Functional Ambulation Categories for each measurement.

Figure 2 shows the average comfortable walking speed for each patient and for each measurement. The figure reveals that the walking speed at T₅ of five patients had recovered to values close to the control group. Eight patients' walking speed had not recovered to normal values, however only three of these patients did not show functional recovery.

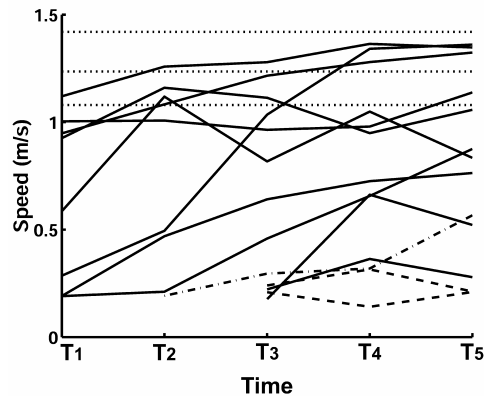


Figure 2. Average comfortable walking speed presented for each patient and each measurement. Solid lines represent patients whose gait had functionally recovered at T_5 according to the FAC (score ≥ 4) and RMI (score ≥ 8). Non-solid lines represent patients whose gait had not functionally recovered at T_5 ; dashed lines = FAC < 4 , RMI ≥ 8 ; dash-dotted line = FAC < 4 , RMI < 8 . The dotted, straight horizontal lines represent the mean, minimum and maximum comfortable speed of the control group.

SSDiff is presented for each patient and each measurement in Figure 3. Visual assessment of Figure 3 appeared to reveal two subgroups. In a subgroup of seven patients in the upper part of the figure, SSDiff had recovered to values at T_5 close to the control group. In a subgroup of six patients in the lower part of the figure SSDiff had not recovered. A median test at T_5 showed a significant difference between the subgroups ($P=0.003$; single sided). Furthermore, median tests showed that the subgroup in which SSDiff had recovered did not significantly differ from the control group ($P=0.500$; single sided); the subgroup that had not recovered did significantly differ from the control group ($P=0.006$; single sided).

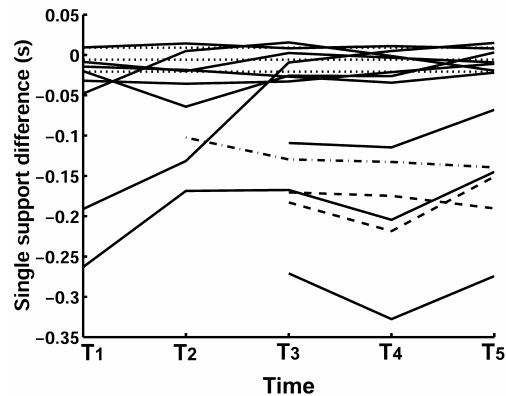


Figure 3. Single support difference (SSDiff) for each patient and each measurement. Legend: see Figure 2. The dotted, straight horizontal lines represent the mean, minimum and maximum SSDiff of the control group.

Figure 4 shows SLDiff for each patient and each measurement. Visual assessment of Figure 4 did not reveal different subgroups at T₅ as clearly as it did in Figure 3. However, at least four cases could be identified, three with large positive SLDiff values and one with large negative SLDiff values, whose gait had functionally recovered but whose SSDiff values did not fall into the range of healthy controls. One patient, who had not functionally recovered at T₅, showed an extreme shift in step length asymmetry. This patient had a large positive value of SSDiff at T₃, which means that the step length of the hemiparetic side was larger than the non-hemiparetic side at T₃. At T₅, however, SSDiff was extremely negative, indicating that at T₅ the patterns had reversed: the step length of the non-hemiparetic side was larger than the step length of the paretic side.

In the present study symmetry in the single support phase implied functional recovery of walking ability. All patients whose SSDiff recovered to values close to those of the control group functionally recovered. Symmetry, however, was not a requirement for functional recovery, because the subgroup that had SSDiff values at T₅ significantly lower than the control group included three patients whose walking ability showed functional recovery. Similar effects were present for the step length symmetry. If SLDiff recovered to normal values, walking ability recovered to a functional level. However, recovery of SLDiff to normal values was not a requirement for functional recovery.

Symmetry is often used to measure success of treatment in stroke rehabilitation.^{2,5-7} Based on the fact that all patients in the present study showed functional recovery of walking ability if their step length and single support phase were symmetrical, this use appears to be justified at first sight. Several studies^{1,7,14} question the usage of symmetry as an outcome measure, however, and they argue that it is difficult to offer theoretical defence for it. Olney et al. wrote: 'One would not expect a bilateral machine with motors of unequal power on each of its sides to produce an optimal solution by using equal outputs from those motors.'¹ Furthermore it is doubted whether training of gait symmetry will increase a patient's walking ability and whether symmetry in gait should be a goal in stroke rehabilitation at all. The data in the present study support this point of view, because, even though all patients with a symmetrical gait pattern showed functional recovery, an asymmetrical gait pattern did not impede functional recovery. Symmetry in gait is not a requirement for functional recovery of walking ability.

One might even raise the question whether these patients' walking ability would have recovered to a functional level at all if this asymmetry had not been present. It is argued here that the asymmetrical gait pattern may reflect compensations or strategies indeed required by the patient to be able to walk. For example, when a paretic leg lacks the strength to fully support the body weight for the duration of a normal single support phase, is it not sensible to try to reduce the duration of this phase? In a study in which 34 gait variables in hemiparetic gait were examined, Griffin et al. already showed that symmetry hardly influenced gait

speed and that asymmetric variables were in fact more important.¹⁴ Regarding asymmetrical timing in foot contact, the authors argue that 'the unequal timings may be a compromise between providing sufficient balance without greatly increasing the energy-absorbing double-support time'.

If a compensatory gait pattern can facilitate functional recovery in some cases then this should have implications for physical therapy. For these patients training to use compensatory strategies may be preferred instead of trying to change the gait towards the normal, uncompensated gait. The changed motor behaviour of these patients should not be considered pathological but adaptive.

From the present data it was not possible to predict at an early stage which patients would eventually show an asymmetrical gait pattern. Neither was it possible to predict from the data whether patients who showed an asymmetrical gait pattern and who did not functionally recover would have recovered functionally had they been trained to use compensatory strategies. Therefore, any recommendation regarding compensatory trainings based on the current experiment should be done with necessary modesty. For this further research that evaluates the effects of such training is needed. Research in which changes in kinematic variables are investigated that relate more to the cause of asymmetries in gait, such as reduced knee flexion during swing, may help in designing these trainings. The data in the present study do show, however, that gait symmetry is a rather questionable goal in stroke rehabilitation.

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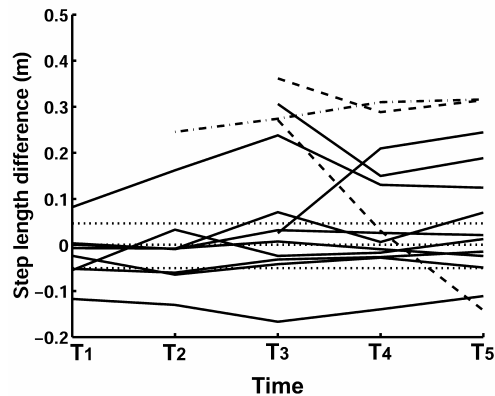


Figure 4. Step length difference (SLDiff) for each patient and each measurement. Legend: see Figure 2. The dotted, straight horizontal lines represent the mean, minimum and maximum SLDiff of the control group.

DISCUSSION

All patients whose walking speed had recovered to values close to the speed of healthy controls showed functional recovery of walking ability. However, several patients, although their speed increased during the period of one year post stroke, never reached a normal walking speed but did show functional recovery of walking ability at one year post stroke. In other words, walking at a speed within the range of healthy controls was not a requirement for functional recovery. This finding, to some extent, argues against the use of walking speed alone as a measure for functional recovery. Certainly, correlations between walking speed and measures like the FAC and RMI will be high and a normal walking speed also implies that walking has functionally recovered. However, using merely walking speed as a measure for functional recovery will yield several 'false negatives'.