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THE FUNCTIONAL RECOVERY OF STROKE: A COMPARISON BETWEEN NEURO-DEVELOPMENTAL TREATMENT AND THE BRUNNSTROM METHOD

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ABSTRACT. The relative efficacy of Neuro-Developmental Treatment (N.D.T.) versus the Brunnstrom method was studied from the perspective of the functional recovery of stroke patients. An alternating treatment design (B-C-B-C) was used. Each intervention phase lasted 5 weeks. The functional recovery of the patients was assessed every week by using the Barthel Index and the Action Research Arm test, by registering walking velocity, and by performing gait analysis. At the start and at the end of each intervention phase, neurological and neuropsychological assessments took place. Time series analysis indicated that for one patient only, walking speed progressed more during the Brunnstrom phases than the N.D.T. phases. This result did not generalize towards other parameters or patients studied. For upper extremity function and maximum walking speed, a high correlation was found between the week post stroke in which the patient showed the first signs of recovery and the end condition after 20 weeks.

Key words: exercise therapy, stroke, hemiplegia, single case experimental design.

INTRODUCTION

The many forms of 'neurological' exercise therapy in the rehabilitation of stroke patients, are mainly oriented towards treating the hemiplegic side of the body—e.g., neurodevelopmental treatment (N.D.T., being a modernized version of Bobath), proprioceptive neuromuscular facilitation (P.N.F.), Johnstone, Brunnstrom, Rood, Temple Fay, EMG feedback therapy, etc. Although these forms of physical therapy have been extensively described, in theory as well as in practice, relatively little has been published about their differential efficacy, especially when compared to functional recovery.

In the present study, functional recovery is used as the framework to establish the relative efficacy of N.D.T. versus Brunnstrom. Brunnstrom (4) understood the functional recovery of stroke patients as a 'natural and lawful' process in which several stages can be distinguished. First, no movement in the hemiplegic side of the body is possible, then, 'flexion and extension synergies' emerge, so that, finally, these 'basic synergy patterns' (and 'associated movements') develop into dissociated motor behaviour. According to Brunnstrom, the therapist should facilitate this natural process; in particular by encouraging the associated reactions in the acute phase after stroke.

Proponents of the N.D.T. approach, however, regard the emergence of basic synergies as pathological, unwanted manifestations of spasticity, which the therapy should suppress (5). In N.D.T., the patient learns to consciously exert control over his or her muscle tone during activities of daily life (A.D.L.) —mainly by using 'reflex-inhibiting patterns or positions' (R.I.P.).

Because of their strongly contrasting rationales for treatment, one would expect differences in relative efficacy between these two forms of physical therapy. To our knowledge, no articles have been published to date in which the relative efficacies of N.D.T. and Brunnstrom have been contrasted. However, in several studies each of these therapies has been contrasted with a third therapy form. In general, the latter intervention studies report no significant differences in efficacy between either Brunnstrom or N.D.T./Bobath on the one hand, and some other therapy form on the other (e.g., 2, 6, 16, 17, 22).

In the relevant literature mentioned, the only formal model of functional recovery to have been pre-

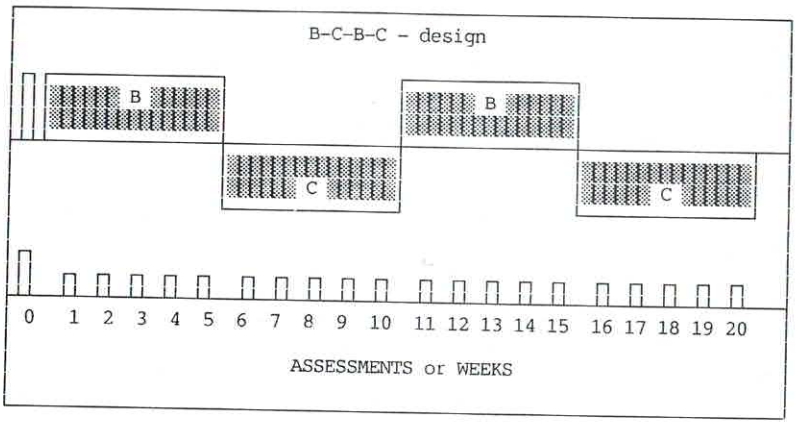

Fig. 1. The single subject design used, i.e., an alternating treatment (B-C-B-C) design. In the first B phase, either N.D.T. or Brunnstrom was applied while during the other intervention phases the two treatment forms were alternated. In the first week and at the end of each phase, a neurological and neuropsychological investigation was performed. Functional recovery was assessed weekly.

sented was that of Basmajian et al. (2) in their analysis of upper limb function.

Some studies do reveal significant differences in efficacy between neurological exercise therapies but, generally, these differences have to do with rather specific treatment effects with minimal functional impact. Mulder (21), for example, found EMG feedback therapy to be more effective than N.D.T. in terms of EMG activity of the trained muscles (i.e., the dorsal flexors of the foot), but not in terms of either range of motion (i.e., dorsal and plantar flexion of the foot) or walking speed.

It has been argued repeatedly (e.g., 1, 2) that the heterogeneity of the stroke population is the major confounding factor in intervention studies. In general, detailed knowledge of stroke patient characteristics and their individual recovery patterns, is scanty indeed. A number of authors (e.g., 9) have pleaded for single case experimental designs in which (cf. 14) measurements are taken frequently and treatments are alternated within one patient. In this way, it is argued, a better perspective can be obtained on both the relative efficacy of treatment forms and the importance of patient characteristics as major determinants of functional recovery patterns. The present study uses a single case experimental design to compare the relative efficacies of N.D.T. and Brunnstrom in the context of functional recovery.

METHODS

Design

Seven stroke patients were treated according to a B-C-B-C design in which the methods N.D.T. and Brunnstrom were alternated (Fig. 1). The first treatment phase started five to nine days after the onset of the stroke. The rehabilitation method that was applied in the first treatment phase, was randomly assigned to the first patient. For the other six patients, N.D.T. and Brunnstrom were alternately used as the first treatment. Each intervention phase lasted five weeks, so that the total duration of the study was twenty-one weeks per patient.

Before initiating the first intervention condition, the patients were assessed by both a neurologist and a neuropsychologist in order to decide whether or not they fulfilled the admission criteria (see *Subjects*). The neurologist diagnosed the pathological condition of the patient, recorded relevant parameters (e.g., reflex activity, muscle tone, sensibility, etc.) and, on this basis, selected patients for the study. The neuropsychologist evaluated perceptual deficits (e.g., visual inattention), alertness, recognition-deficits and comprehension deficits of the patients so selected. These assessments were repeated at the end of each treatment phase in order to obtain a broad perspective on individual recovery patterns. Every week, walking disability, upper limb function, A.D.L., and depressive mood and feelings were measured.

After a period of four to eight weeks in the Neurology Ward of the Free University Hospital, patients were either admitted to a rehabilitation clinic ($N=4$) or returned home ($N=3$) to be treated three to four times per week in the outpatients' department of the hospital. While in the hospital or the rehabilitation clinic, patients were treated each week-day. Each treatment session lasted thirty minutes.

Subjects

The seven patients participating in this study, met the following admission criteria: 1) 40 to 80 years of age; 2) suffered a stroke involving an ischaemic infarct in the territory of the middle cerebral artery—as revealed by CT scanning; 3) no Transient Ischaemic Attacks (T.I.A.), Recurrent Ischaemic Neurological Deficit (R.I.N.D.), or progressive stroke, i.e., the patients suffered from complete rather than progressive stroke; 4) no severe deficits in memory or understanding; 5) no complicating medical history such as cardiac or pulmonal disorders; 6) informed consent and sufficient motivation to participate.

During the period in which this intervention-study took place (i.e.,eight months), seven stroke patients were included in the study—about 3% of the total stroke population admitted to the Neurology Ward of the Free University Hospital. Thus, the study was restricted to a small and relatively homogeneous subpopulation of the total population of stroke patients. Even the seven patients admitted, however, differed on relevant parameters. Their age ranged from 40 to 77 years. Five of them had suffered a stroke in the right hemisphere and two in the left.

Treatment conditions

Both N.D.T. and the Brunnstrom method are commonly applied forms of physical therapy in the rehabilitation of stroke patients and have been described in detail in the literature. In this study, the approach used in the N.D.T. condition adhered strictly to the principles presented by Davies (5) and the approach used in the Brunnstrom condition to the principles formulated by Brunnstrom (4). Facilitation, or inhibition techniques and instructions for motor behaviour were specified accordingly, as well as the positioning and moving of the patient in bed and in the chair, e.g., lying and sitting positions, sitting up, transfers, etc. Every member of the team of physical therapists, occupational therapists and nurses, acted in accordance with a detailed written protocol based on the aforementioned principles of the therapies involved. Both methods were applied by specially trained therapists.

Assessment

The relative efficacy of the two contrasting forms of physical therapy was evaluated in terms of disability (functional recovery) using ecologically valid assessment instruments. Each week, upper limb function, walking disability, and ADL were measured. In addition, occurrence of depressive mood and feelings was assessed.

Upper limb function. After reviewing twenty-seven tests for upper limb function, the Action Research Arm Test (ARA test, see 18) was chosen because of its high reliability, high validity, and practical applicability. It measures a range of motor actions involving several hand grips and arm movements. Hand grips (i.e., grasp, grip, lateral prehension, finger-thumb opposition) are evaluated by asking the patient to move objects with different shapes, sizes and weights to various places on a specially designed wooden table (12). In addition, the hand has to be moved to the mouth and to the top and the back of the head. In this study, two tasks were included in the fourth subtest without changing the total score, i.e.: an object on the table had to be pushed forward and the arm had to be stretched above the head. In this way, the ARA test is made more sensitive for those stroke patients who hardly show any functional recovery.

The movement tasks are evaluated on a four-point scale: 0=no movement is possible; 1=the movement is 'partially' performed; 2=the movement task is completed, but 'abnormally' so; 3=the movement is 'normally' performed. In this study, a 'partial' performance implied that the patient could not reach the end goal of the task, but was able to either lift the hand with the object off the table (subtests 1, 2 and 3), or to push the object forwards/lift the hand off the table (subtest 4). A 'normal' performance implied that the patient completed the task both within a certain time-limit and without losing contact with the back of the chair. The time-limit was calculated for each movement-task separately by testing twenty healthy subjects of comparable age, i.e., their mean score 'plus' twice the standard deviation.

The ARA test consists of nineteen movement tasks which are divided into four domains (i.e., grasp, grip, pinch and gross movement). The maximum score is fifty-seven points. In each domain the items are arranged in order of difficulty, according to the Guttman scale (see 18). This last feature makes this assessment instrument particularly easy and quick to apply. The high inter-rater and test–retest reliability (0.98 and 0.99) found by Lyle (18), was reproduced here and the intra-rater reliability (0.99) as well as the validity (0.94) were ascertained. In these evaluations, Spearman Rank Correlation Coefficients were used. The validity was established by correlating the ARA-test with the Sollerman-test (12).

Walking disability. Walking disability was assessed by measuring walking velocity and by performing gait-analysis (e.g., 3, 20). The patients walked (if possible) a distance of eight metres. Video-recordings were made in the sagittal plane by a video-camera moving on a trolley. If necessary, the patients were guided by a physiotherapist. The walking disability was recorded in two conditions, i.e., the patient was asked first 'to walk as fast as possible', and then to 'walk as comfortably as possible'.

Measurement of walking velocity and gait-analysis were performed in both conditions on a trajectory of five metres. Gait-analysis focused on time parameters such as step-time, swing-time, stance-time, and time-symmetry (i.e., ratio between the swing times of both legs). Furthermore, step frequency, cadence, and stride-length were measured. The video-tapes were analysed by counting the individual frames using a Panasonic AG-6200 video recorder and converting the results into seconds. Before the intervention study started, the inter and intra-rater reliability as well as the test–retest reliability were assessed. The reliability coefficients were 0.97 or higher for speed of walking and 0.78 or higher for the time parameters studied (Spearman Rank Correlation Coefficients).

Activities of daily living. The modified Barthel Index was used for the evaluation of ADL (e.g., 7, 11). This index includes feeding, bathing, personal toilet, dressing, bowel and bladder control, toilet transfers, chair/bed transfers, ambulation and stair climbing. In the literature, this assessment instrument has been described as a reliable test (11). No special tests to evaluate the reliability and validity of the Barthel Index were invoked during the research reported.

Depressive mood and feelings. Occurrence of depressive mood and feelings was measured with the VROPSOM list, a Dutch version of the Depression Adjective Checklist (23). The test includes thirty-four adjectives that connote dysphoric or euphoric states of mood, such as 'sad' or 'fine'. Van Rooyen & Vlaander (23) have shown that the VROPSOM reliably registers transient states of mood.

Neuropsychological factors. At the end of each intervention phase, neuropsychological deficits were assessed using the following, reliable (15), tests: 1) Categoric Verbal Fluency test; 2) Auditory Visual Comprehension test; 3) the Dutch version of the Rey Auditory-Verbal Learning test; 4) Facial Recognition test; 5) Line Bisection test; 6) Judgement of Line Orientation; 7) Simple Auditory Reaction Time test.

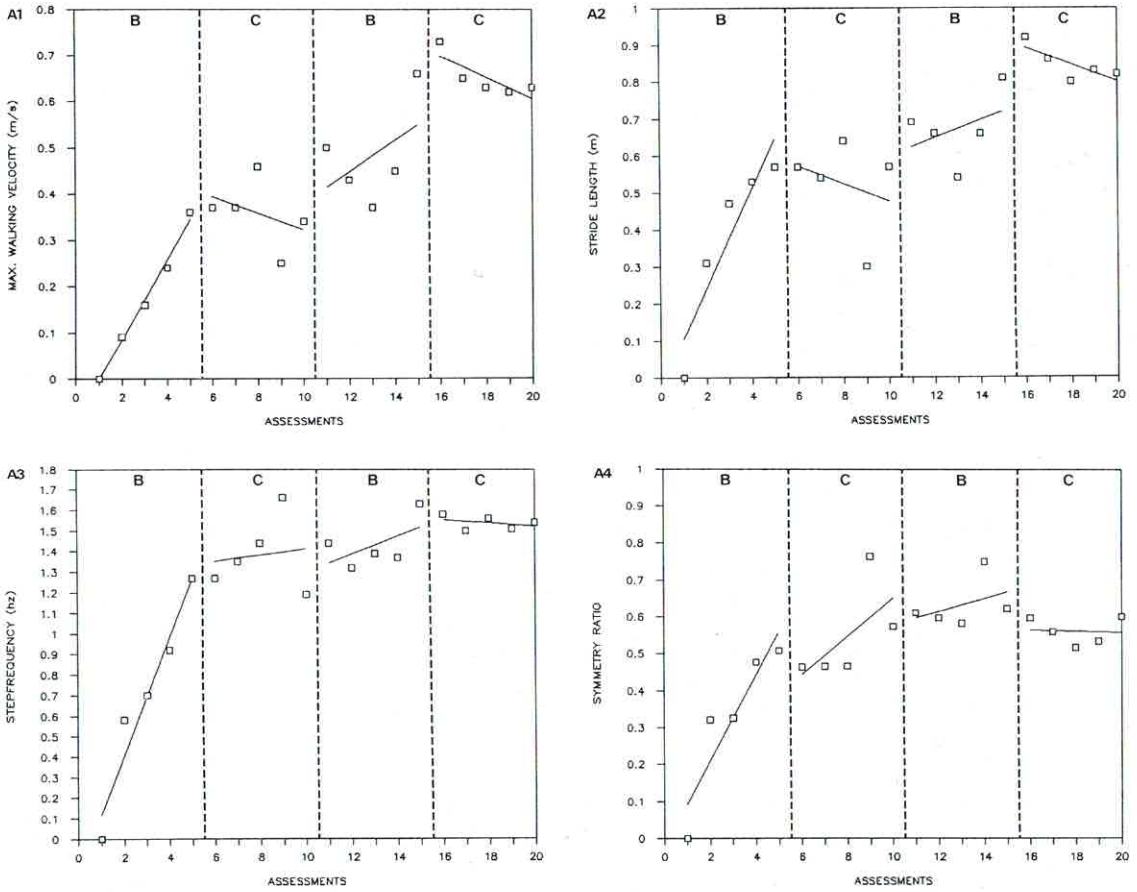

Fig. 2A. The results of one patient on a number of gait parameters under the instruction 'WALK AS FAST AS POSSIBLE'. Results are displayed with respect to walking speed (1), stride length (2), step frequency (3) and symmetry ratio (4). During the B-phases the Brunnstrom method was applied, during the C-phases the N.D.T. method. Linear regression analysis was applied to each phase separately.

Data analysis

Data analysis in single case experimental design requires several steps (19). Before differential effects between two treatment forms can be analysed statistically, one has to ascertain that no general trends are inherent in the data. Whenever there is such a trend within the data, later data points can be predicted on the basis of former ones, i.e., the data points are 'serially dependent'. Since traditional statistical tests rely on the assumption that (the residuals of) the data points are independent, trends must be either removed before proceeding with further analysis (e.g., by using first order differences), or modelled and controlled for (e.g., by time series analysis).

In this study, lag sequential analysis was used in order to detect serial dependency within the data points. If a secular trend was manifest within the data derived from a specific patient, linear and non linear regression analysis was performed in order to construct a model for this trend leaving a minimum of unexplained variance. Differences in efficacy were calculated by applying the Mann-Whitney U test to the residuals.

Statistical relations between variables were estimated with the Spearman Rank Correlation test. For all tests 0.05 was chosen as the level of significance.

RESULTS

Differences in efficacy

After applying lag sequential analysis to the data derived from each individual patient, a 'lag 1' trend was found for all parameters studied. In most cases, it was a logistic function (producing sigmoidal patterns or S-shaped curves), but in some cases, an exponential function, that fitted the individual recovery patterns adequately.

In addition to this secular trend, visual inspection of the data revealed, for one patient only, a possible

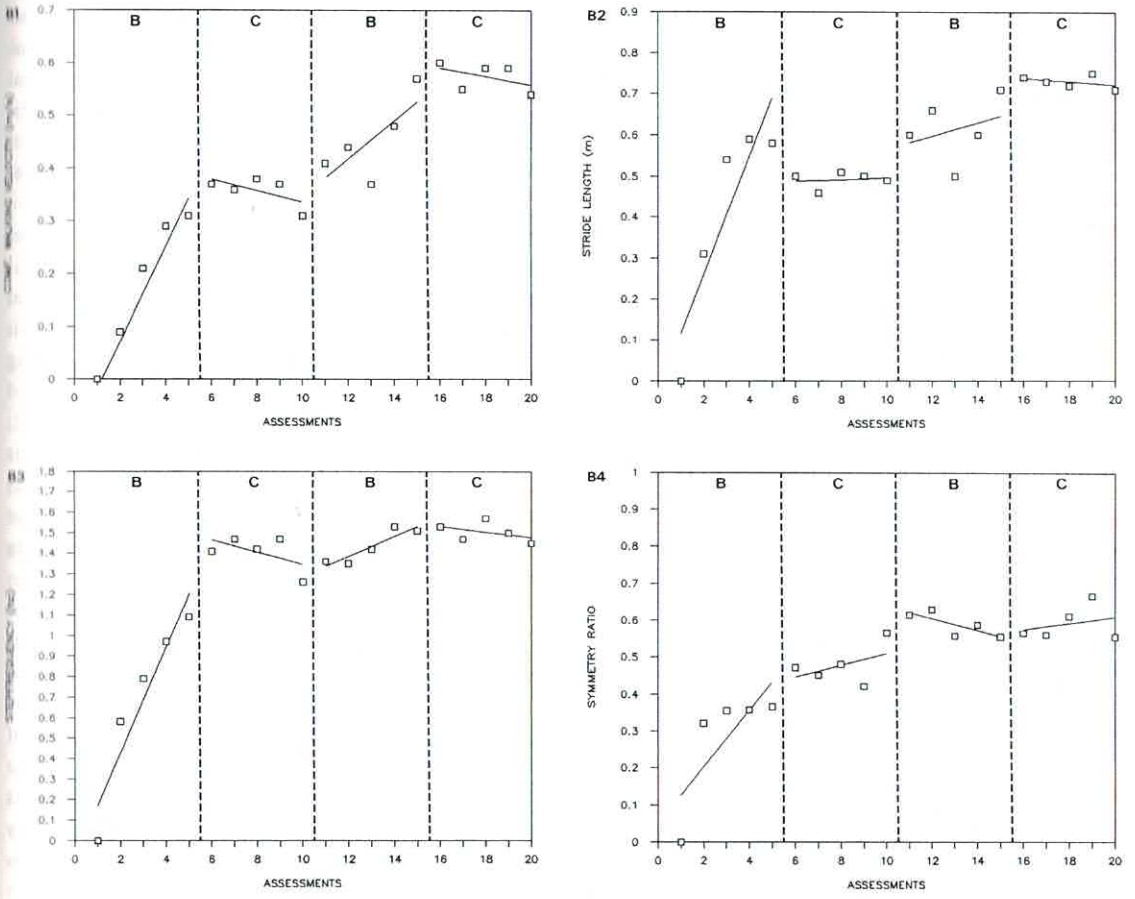

Fig. 2B. The results of one patient on a number of gail parameters under the instruction 'WALK AS COMFORTABLY AS POSSIBLE'. (See Fig. 2A for additional information.)

intervention effect on a few gait parameters (see Figs. 2A1–4 and B1–4): during the Brunnstrom intervention phases, more progress in 'recovery' occurred in comparison with the N.D.T. intervention phases. For this patient, the logistic function fitted the data most adequately. After analysing the residuals of this patient with the Mann-Whitney U test, more progress in speed of walking was demonstrated during the Brunnstrom intervention phases in comparison to the N.D.T. intervention phases. This result, however, was only found for comfortable speed of walking (see Fig. 2B1). Although fast walking speed, stride length during fast walking speed, and step frequency also showed a comparable recovery pattern (see Fig. 2A1, Fig. 2A2 and B3), no significant differences in efficacy were found for these parameters. The other gait parameters, upper extremity function and ADL showed no significant differences either.

Recovery patterns

The individual recovery patterns of the seven stroke patients are presented for maximum walking speed (Fig. 3), and upper extremity function (Fig. 4). For both of these variables, statistically significant correlations were found between, on the one hand, the week post stroke in which patients showed first signs of functional recovery (T) and, on the other, the amount of recovery after twenty weeks (A). The Spearman Rank Correlation Coefficients were $r=0.80$ for maximum walking speed and $r=0.95$ for upper extremity function. Parameter T was defined for walking velocity as the first week the patient was able to walk independently, and for upper extremity function as the first week in which the patient was able to partially perform at least one motor task. The results indicate that T is an important predictor for

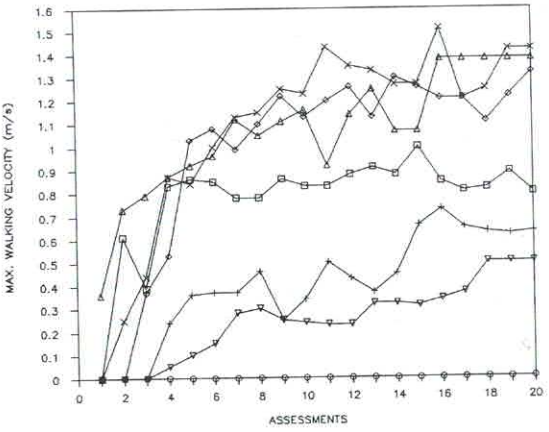

Fig. 3. The recovery of maximum walking speed for 7 patients during the first 21 weeks post stroke.

the end condition of the stroke patient after twenty weeks.

Neither within the individual patients, nor in the (rather small) sample of the seven patients taken together, could statistically significant correlations be found between the neuropsychological factors studied and functional recovery.

DISCUSSION

The results of this intervention study showed no clear differences in efficacy between the methods N.D.T. and Brunnstrom within the framework of functional recovery. For only one stroke patient, were significant differences (in favour of Brunnstrom) found, that is, in terms of one parameter only, i.e., comfortable speed of walking. It should be noticed that walking speed is specifically trained in the Brunnstrom method; it may be therefore, that we are here confronted with just another example of a therapy producing its own intrinsic effects. In this respect, the findings of this study correspond to the results of previous studies involving either N.D.T. or Brunnstrom which generally showed no differences in efficacy between 'neurological' exercise therapies (cf., 2, 6, 16, 17, 22), or, at best, specific treatment effects (e.g., 21).

The general lack of differences in efficacy between N.D.T. and the Brunnstrom method could, of course, have been due to the fact that our B-C-B-C design did not allow for the application of one treatment form during a longer period: longer treatment phases may still induce differences in efficacy to become visible. However, the general recovery process which became apparent, renders, in our opinion, the confounding influence of this factor highly improbable. Firstly, a high correlation was found between the number of the week in which a patient showed first signs of functional recovery (T), and the final amount of functional recovery after twenty weeks (A). Secondly, the individual recovery patterns display a general sigmoidal or exponential trend with hardly any systematic treatment-induced changes in the residuals.

In a number of studies (cf., 13, 24), several factors have been proposed as being predictive of the rehabilitation outcome of stroke patients, e.g., perceptual deficits, poor motivation, urinary/faecal incontinence, etc. Moreover, linear functions, incorporating one, or several, of these factors have been formulated in order to render long term prognosis feasible (e.g., 2, 25). The present study reveals the fact that the later post stroke functional recovery starts, the less functional recovery will occur. This result confirms other studies on the recovery process of stroke patients (e.g., 8, 24, 25).

The high correlations found, suggest that a prognostic relation (e.g., an exponential or linear function) exists between T and A, on the basis of which the end condition after twenty weeks (A) can be adequately predicted as soon as the patient starts to show signs of functional recovery (T). So far, we have been unable to find significant relationships between symptoms immediately after stroke and final outcome—possibly due to lack of sensitivity of the assessment instruments used.

In a number of studies, recovery patterns over time have been displayed graphically (e.g., 8, 24, 25). Only Mizrahi et al. (20) have analysed the individual recovery patterns for walking speed over time as an exponential function. Our study suggests that an S-

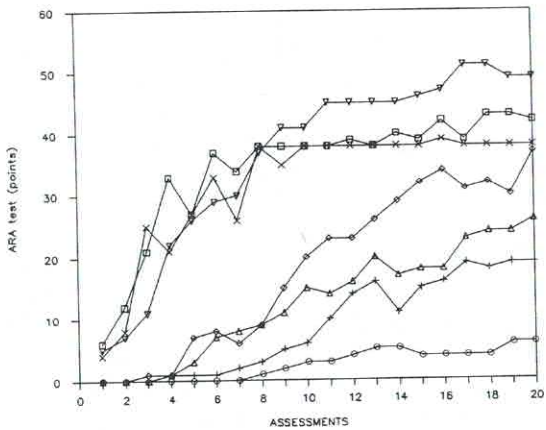

Fig. 4. The recovery of upper extremity function for 7 patients during the first 21 weeks post stroke.

shaped, or a sigmoidal curve, may fit the individual data better than a linear or an exponential trend. The sigmoidal trend is more striking for upper extremity function than for speed of walking (see Figs. 3 and 4). It remains to be seen whether or not a logistic function, producing sigmoidal curves, will do better in predicting the pattern of recovery and the final outcome, than a linear or an exponential one.

So far, both the week post stroke in which the patient shows first signs of functional recovery and the mathematical function used to model recovery patterns, appear to depend very much on the assessment instrument used. The equations presented in the literature have prognostic or descriptive rather than explanatory power. The advantage of even a prognostic or descriptive model is, however, that a better perspective on the heterogeneity of the stroke population can be obtained, so that relevant subpopulations can be distiguished, on the basis of which further intervention studies can be optimized.

Single case experimental methodology is frequently used in the evaluation of intervention strategies in the rehabilitation of stroke patients. By locating experimental control within one patient, rather than between groups of patients, one tries to cope with the heterogeneity of the stroke population. Of course, single subject designs do not solve all the problems arising from heterogeneity. In particular, generalizing treatment effects requires replication, and the methodological framework to establish generalizability is still in its infancy.

It is true that an alternating single case experimental design may create a major problem, i.e., not allowing for long term cumulative effects of a treatment. Nevertheless, an advantage of single case experimental methodology is that the patient is repeatedly measured over time, i.e., at least three times in each phase. In this way, it is not only possible to record differences in efficacy of treatments, but also to obtain more insight into the general recovery patterns of stroke patients.

A still better insight on recovery patterns would be obtained by providing no intervention at all. For ethical reasons, however, this would, in our opinion, be very difficult to implement.

Registering inter and intra-subject variability by means of longitudinal studies enables one to distinguish relevant subpopulations of stroke patients and to pinpoint patterns of functional recovery, a possibility which is important to rehabilitation practice as well to designing intervention studies.

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