'Stance Symmetry and Sway After Stroke'

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CONTENTS

ABSTRACT

The aim of the study was to investigate the assessment and treatment of stance symmetry and sway after stroke and was divided into 3 parts.

Stage 1;
Sway and stance symmetry were surveyed with the Nottingham Balance Platform (NBP), a computerised limb load monitor. Over 400 volunteers of both sexes and a wide age range were recruited. There were significant differences between the sexes for both sway ($p<0.05$) and stance symmetry ($p<0.01$) and significant correlations between age and sway ($p<0.001$) and stance symmetry ($p<0.001$). Thus, normative data was provided.

Stage 2;
Patients were surveyed to examine these variables after stroke and their relationships with age, falls and motor and ADL function. A consecutive sample of 92 patients underwent 2 assessments, 4 months apart, between 2 and 9 months post-stroke. Abnormal stance symmetry was seen, which improved with time ($p<0.01$) and correlated with functional measures ($p<.001$), length of stay and age. Abnormal sway values also present, improved with time ($p<0.01$). A significant relationship existed between sway values and falls frequency ($p<0.01$), but there was no significant association with functional abilities, age or sex.

Stage 3;
A single-blind randomised-controlled trial was conducted with 26 stroke patients to assess the value of visual feedback training. Patients demonstrating asymmetry were randomly allocated to two groups. Group A received visual feedback and Group B a placebo program, incorporated into

12 physiotherapy sessions. Independent assessments of motor and ADL function were completed at the start (0 weeks) and end of treatment (4 weeks) and at 8 weeks. Initially, there were no significant differences between the groups. At 4 weeks, stance symmetry and measures of function were significantly better for the treatment group than controls ($p<0.05$), but not at the final assessment. The improvement, although maintained, did not continue after treatment. The results support the further use of feedback techniques to improve standing posture after stroke.

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CHAPTER 1
INTRODUCTION

1.1 Definition of stroke

The World Health Organisation defines stroke as;

'Rapidly developing clinical signs of focal (or global) disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than of vascular origin.' (Aho et al 1980)

The resulting impairment depends on the site and extent of the damage. The patient can experience motor loss (commonly down one side; hemiplegia), complete or partial loss of speech, disorders of sensory and cognitive functions and emotional disturbance. Singularly or in combination these impairments can result in severe loss of functional abilities, ranging from simple self-care activities such as feeding and toileting to the more complex tasks of driving and working.

1.2 Incidence and prevalence

Cerebrovascular disease is the third commonest cause of death in Britain. The national average of stroke mortality is 100 per 100,000 per year (Fratiglioi et al 1983). Although the trends suggest that the incidence of stroke in the Western World is decreasing (Whisnant 1984), recent estimates are still as high as 250 per 100,000 per year (Aho et al 1980). The incidence increases dramatically with age, with rates as high as 2,000 per 100,000 in those over 85 years (Bamford et al 1988).

Prevalence is more difficult to estimate and results differ depending on the inclusion criteria and survey design. The most recent survey in Britain (Weddell 1980) estimates a rate of 549 per 100,000, (800 age 55-64, 2,800 age 65-74).

1.3 Cost and burden of care

Calculating the number who have permanent handicap resulting from their stroke is difficult because of the effects of age. Many elderly stroke survivors may have been handicapped before their stroke. An estimated 30% of stroke survivors remain dependant in self-care activities at 6 months post-stroke. This proportion increases with age with as many as 75% of those over 85 years becoming dependant (Bamford 1990).

The proportion of patients with residual motor impairment is unclear. Again, problems with the accuracy of assessment and the complicating factors of age result in a wide range of estimates ranging from 50-80% (Wade 1985). Whichever is the most accurate, it indicates that there is a large number of stroke patients requiring care for a long time. This brings with it a financial burden not only for in-patient care, but also for out-patient therapy and community services. It has been estimated (Harris 1971) that stroke survivors account for onequarter of all severely disabled people in the community. The chronic nature of the disease is reflected in the work load of district nurses, a recent survey in Nottingham demonstrated that 50% of the stroke patients they care for are more than 2 years post-stroke (Barer 1988).

The cost to the National Health Service is estimated to be nearly 5% of the total budget (Wade et al 1985) and it is the fourth most expensive disease in the United States (Hartunian et al 1980). The cost is thought to be related to physical disability and length of hospital stay rather than medical treatment and investigations (Wade and Langton Hewer 1987)

At present no estimates of the cost of physiotherapy, either nation-wide or in the Nottingham Health District exist. It is difficult to generalise as the amount of physiotherapy contact varies greatly between districts and units and is related to the severity of the stroke. Intense and individual therapy is the usual method of treatment, patients rarely attend group sessions. In the specialist stroke unit in Nottingham, fifteen patients share three full-time physiotherapists and the average length of stay is sixteen weeks, obviously an expensive approach to care.

1.4 Patterns of Recovery and Disability

The natural history of the recovery of stroke is not well documented. A commonly held view point is that the majority of recovery is complete by three months and continues more slowly up to six months (Wade et al 1983, Andrews et al 1981), the speed and degree of recovery is very variable. Other authors have suggested that recovery is possible for a much longer period of time (Bach-y-Rita 1987, Fugl-Meyer 1975), but it appears to be those most seriously affected that demonstrate later improvement (Lindmark 1988) and this may be adaptive improvement rather than true recovery.

The initial density of limb paresis has prognostic value when applied to a group of patients. Poor motor function is related to an increase in fatality, independence and subsequent placement (Feigensen et al 1977, Andrews et al 1981, Logigian et al 1983). Urinary incontinence, age, IQ and arm function are other prognostic indicators (Wade 1987). Therefore it would appear that the severity of the lesion and existing level of neuromuscular function combine to dictate the outcome.

The most frequently noted sequela of motor impairment after stroke is hemiplegia (Gautier and Pullicino 1985), which produces asymmetry of both gait and posture. Patients tend to exhibit abnormal patterns of stance and gait and these are described extensively in physiotherapy texts (Bobath 1978, Davies 1985). Such texts also claim a propensity for patients to follow the same abnormal weight bearing pattern and favour their unaffected leg. It is perhaps because these abnormalities are so obvious and have been acknowledged and documented for decades, that research evidence substantiating clinical observation has only come in recent years.

There is now research evidence to substantiate the clinical observation that some stroke patients stand with less of their body-weight through their affected leg. Dickstein et al (1984) in a survey of foot-ground pressure of 23 hemiplegic patients (mean age 71 years), found that 20 (87%) favoured their unaffected leg to carry their body weight. The degree of asymmetry differed significantly from a group of elderly controls. Caldwell et al (1986) and Bohannon and Larkin (1985) obtained similar results using digital weighing scales with younger patients (mean ages 57 and 55 years respectively), but again with very small samples (10 and 25). As yet, no large scale cross-sectional studies of consecutive stroke admissions have been completed and so we are still not able to realistically estimate the magnitude of the problem.

Two studies have calculated the percentage of body-weight on the unaffected leg. Shumway-Cook et al (1988) in a survey of 16 stroke patients (mean age 66 years, mean time since onset of 5.3 weeks) calculated that the unaffected leg carried 70%. Mizrahi et al (1989) examined 16 stroke patients (mean age 61 years, mean time since onset of 11.8 weeks) and calculated an asymmetry of 24%, ie carrying 74% on the unaffected leg. There is little difference between the results, which is unexpected considering the mean times since onset. One explanation is that the patients in Mizrahi's study had recovered further (therefore not a directly comparable sample), another is that stance asymmetry does not follow a pattern of recovery. These unexpected results may be due to the small numbers involved or the selection procedure.

Studies of weight distribution in normal adults have found that a small degree of asymmetry is usually present. Caldwell et al (1986) examined two groups, one of young women aged 19-25 (mean 21) and one of elderly women aged 61-83 (mean 70) and found the difference in weight distribution to be up to 12% in young women and 16% in the elderly group. However only small numbers were used, ten in each group. Murray and Peterson (1973) reported a difference of up to 15% from a sample of 40 men (age range 20-60, mean 38). In the only study looking at both sexes together Dickstein et al (1984) calculated from a group of 11 normal elderly (mean age 71) a 90% confidence interval of the mean of up to a 8% difference.

It is presumed that abnormal weight bearing through the affected limb is linked with impaired motor function and in turn decreased functional ability. However little work has been done on the the relationship between these three factors and the existing work has only examined the relationship between motor function and functional abilities, not abnormal stance symmetry. Smith et al (1985) in a short report, found a strong relationship between motor function and independence in self-care activities at the time of discharge from hospital, but the results have to be interpreted with caution as both the measures of motor power and independence were made subjectively and the assessments had not been standardised. Hamrin et al (1982) examined 37 stroke patients and found a relationship between knee strength and locomotion (as measured on an ordinal scale) and elbow strength and ADL performance. Bohannon (1989) also found a relationship between muscle strength in seven lower limb muscle groups and standing capacity (measured on an ordinal scale), in a group of 33 stroke patients.

1.5 Falls and Sway.

In clinical practice falls are recognised as a serious and common complication of stroke (Wade et al 1985, Wayne Massey 1987). However, although the consequences of a fall and the subsequent fear of falling can be an obstacle to successful rehabilitation, there is little data on the incidence of falls in a stroke population. Moskowitz (et al 1972) followed a group of 518 stroke patients for ten years and found that during this time 3.1% had sustained a fractured hip.

By comparison, falls in the elderly, in both community and institutionalized settings, have been extensively investigated. Unfortunately methodological differences in subject selection and the units used to express rates hinder comparison. In a review article Downton (1987) concluded that these difficulties make it impossible to estimate the rate of falls in hospital, sheltered accommodation or in residential care. The rate in the community for those over 65 years is approximately 30% per year, with women falling more than men and an increase in rate with increasing age. Blake et al (1988) conducted a survey of 1042 elderly people in the Nottinghamshire Health District and reported a falls rate of one or more per year for 35% of the sample and again found an increased rate with age and in women. Fallers had significantly weaker hand grips and reduced mobility.

In another community survey, Campbell et al (1981) found that fallers were more likely to have decreased mobility levels and use a walking aid. Prudham et al (1981) reported from a study of 2,793 elderly people living at home in the North East of England that those with a stroke were more likely to be in the group who had fallen in the previous year.

Postural sway is the term used to describe the movement of the body during standing. It is thought to be the result of muscular activity in the 'anti-gravity' muscles, reflecting the dynamic nature of posture and balance. Sheldon (1963) first suggested that there may be a relationship between postural sway and falls in the elderly. Since then there have been several studies with somewhat conflicting results. Comparison is difficult because of the different methods of measuring sway, of recording and classifying falls and because of differences in subject group and selection.

Most of the investigators have measured sway and then gathered information on falls retrospectively. In two of the earlier studies the 'Wright's Ataxiameter' (Wright 1971) was used to measure sway. Overstall et al (1977) found a relationship between a reported history of falls (excepting trips) and an increase in sway. The majority (88%) of the sample of 243 elderly people (mean age 76) lived at home. In a study of 151 institutionalized elderly, Brocklehurst et al (1982) found that 62 (41%) reported one or more falls in the past year. The subjects were divided into three age bands for analysis. Only the middle age band, 75-84 years, showed a statistically significant relationship between reported falls and an increase in sway.

Since then more sophisticated methods of measurement have been employed, namely a computerised biomechanics platform measuring ground reaction forces. In a survey of 50 single women living in an apartment block, Lichtenstein et al (1988) compared the reported history of falls in the previous year with sway and found a positive relationship between the number of falls and increased sway area. In another study Ring et al (1988) examined three groups, two groups of fallers either with a recent wrist fracture or a reported history of falling in the last few months and a group of elderly non-fallers. All were subjected to an artificial visual stimulus while standing on a force platform. Both groups of fallers had significantly higher levels of sway than the controls.

In the only prospective study, Fernie et al (1982) recorded sway at the pelvis with displacement transducers and then followed a cohort of 205 institutionalized elderly for a year. Falls were recorded if they were observed by staff or reported by the subjects. There was a significant difference in the speed of sway with non-fallers being slower than fallers, but although the sway measurement indicated a tendency to fall it was not possible to predict those who fell.

There have also been conflicting results, in one study of 71 hospital in patients and elderly members of the community (Imms et al 1981), no association was found between sway and a reported history of falls. However, other measures of gait abnormality such as step length and walking speed were found in those with a history of falling.

Studies examining the relationship between sway values (as measured by a force platform) for stroke and non-stroke controls are in agreement that stroke patients have significantly higher levels of sway. In the first of these Seliktar et al (1978) examined 18 stroke patients but do not provide details of the ages or the time since onset. Shumway-Cook et al (1988) included 16 stroke patients (mean age 82 years) with a mean time since stroke onset of 5.4 weeks. Mizrahi et al (1989) found similar results with a very different group of 16 stroke patients (mean age 60 years, mean time since onset of 11.8 weeks). Although these studies show similar results they have all used very small numbers of strokes and perhaps more importantly set the normal limits with even smaller numbers of controls. As yet, the recovery of postural sway values after stroke has not been reported.

1.6 Physical Therapy

Before the successful introduction of the Salk vaccine in the 1950s the main focus of neurological physiotherapy was to treat the large numbers of adults and children suffering from poliomyelitis. As this disease resulted in lower motor neuron damage the main emphasis of treatment was the reeducation of the affected or weakened muscles. Gradually physiotherapists turned their attention to those with lesions of the central nervous system (CNS), resulting from strokes, cerebral palsy and head injury. This led to the development of neurophysiological approaches to treatment. Therapists concentrated their efforts on pathological movement patterns rather than specific muscle weakness, training the whole body including the affected side rather than trying to achieve compensation by the unaffected side . A number of different concepts and approaches to 'neuromuscular' treatment were born (Rood 1956, Knott and Voss 1968, Brunnstrom 1970, Bobath 1978).

Unfortunately they all share one similarity, they have not been adequately formally evaluated. Comparative studies of different approaches to treatment have yet to show any statistical differences in functional outcome between groups (Stern et al 1970, Basmajian 1971, Dickstein et al 1986, Lord et al 1986, Basmajian 1987, Wagenaar et al 1990). Methodological inadequacies are present in the selection of patients, size of the sample, lack of randomisation and absence of standardised outcome measures. The only significant result was the increased length of hospital admission for those receiving the 'neuromuscular' training (Lord and Hall 1986).

In rehabilitation, more so than other areas of medicine, the results of animal studies are not directly applicable to humans. In one animal study (using monkeys) (Black et al 1975) the cortical pre-central forelimb control are was surgically removed from one side of the brain. The subjects received active training for either the contralateral forelimb, the ipsilateral forelimb or both forelimbs and the training started immediately or after 4 months and lasted for 6 months for both groups.

Functional recovery was better in those receiving training to the week hand or both hands and enhanced if training was initiated early

More generalised studies of therapy after stroke have not attempted to examine the content or quality of therapy, but have looked at gross measures such as the amount, frequency and timing of therapy received. This brings other complicating factors, it has been demonstrated that patients with severe stroke receive more physiotherapy, as do patients with shoulder pain. Thus physiotherapy correlates with severity and shoulder pain (Brockelhurst et al 1978). Wade et al (1984) failed to find any specific beneficial effects of therapy, but identified similar associations between the severity of the stroke and the amount of therapy received.

Two randomised controlled (Smith et al 1981, Stevens et al 1984) trials have compared specialised units with more generalised care (ie, medical wards) and demonstrated a slight, dose-related improvement in function for the patients in the stroke units. Two other trials (Smith et al 1982, Hamrin 1982) have produced evidence of an increased rate of recovery for patients receiving therapy early, but it did not affect the long term outcome. The most recent study (Sivenius et al 1985) concluded that both early and intensive physiotherapy improved functional outcome at 3 months and although this difference persisted at 6 and 12 months, it was no longer statistically significant at the later assessments.

The most common 'neuromuscular' training method is that developed by Bobath (1978) and this treatment approach is routinely used in Nottingham (Crow 1988). A recent review of the latest textbook of this theory criticised it as '..grossly unscientific, ...replete with erroneous statements and ...compromised by the inclusion of numerous suppositions and many nostrums'(Bohannon 1990).

The paucity of evidence of the effects of physiotherapy contrast greatly with the amount of therapeutic time and expense allocated to these patients. To some extent it would be difficult to claim that physiotherapy has no effect and thus ethical approval for studies in which patients have no access to a physiotherapist has been denied (Smith 1982, Gresham 1986). It is the heterogeneous nature of stroke and the complexity of physiotherapy intervention that has hindered evaluation. Not only do therapists provide physical maintenance and training, but also psychological support for the patient and family. Maintaining optimism and motivation must play a part in successful rehabilitation. However, prolonged intervention aimed at impossible goals may concentrate the patient on their impairments and prolong their reliance on the 'sick role' (Armstrong 1983), ultimately restricting their independence.

Another reason for the lack of evaluation is that, until recently, appropriate assessments of motor function did not exist. Standardised scales that can be used in both clinical practice and research have been developed but remain unused in the majority of physiotherapy departments. The root of therapists reluctance to evaluate their intervention in a formal way lies in their initial training. Therapists are not taught the basic skills of critically evaluating written work.

It would now be very difficult to formally evaluate these different approaches to treatment as physiotherapists tend to generalise their treatments, picking and choosing different techniques from various concepts. The integration of the neurophysiological approach into other forms of therapy and nursing care would also hinder comparison. To some extent it could be seen as a pointless exercise as randomised controlled trials indicate that it is the amount of therapeutic time (not necessarily the technique) that is important, but it would have wider implications such as justifying the cost of postgraduate training.

However, new forms of treatment are being developed as more information becomes available through the biomechanical and behavioural analysis of motor impairment. One of these is the incorporation of external feedback into therapeutic treatments.

1.7 Feedback

In the normal adult the control of motor tasks depends on accurate sensory feedback. The concept of augmenting that feedback to allow the person to control physiological actions developed from the field of psychology. Feedback has been defined as

'.. a process by which man might gain control over his physiology, using available instruments to transduce biological information into appropriate sensory cues.' (Wolf 1979).

During the 1970s and 1980s external methods of feedback have been used to enhance skill acquisition after stroke. The advantage of using equipment to enhance the verbal and tactile feedback from the therapist is that it is quantifiable and precise (Wolf 1979). It can also provide more sensitive measures than the visual and tactile subjective evaluation of the therapist (Basmajian and De Luca 1985).

Electromyographic biofeedback (EMG) for stroke has been widely used and investigated over the last 25 years in North America and parts of Europe. It is seldom used by physiotherapists in Great Britain (De Weerdt and Harrison 1985). In a recent review of EMG treatment for the upper limb Ince (et al 1985) explained that the majority of the published work contained design flaws, preventing any conclusion. However, six papers had sufficiently sound methodology and the results suggest that EMG biofeedback is at least comparable with exercise therapy. Since that review two papers have indicated that EMG biofeedback compares favourably with neuromuscular approaches to treatment (Crow et al 1990, Basmajian et al 1987), but failed to find any long term carry-over of treatment effects.

The effects of augmented feedback on postural control have been less extensively studied. Yet, research from North America, utilizing postural feedback devices have demonstrated some improvements in standing posture. The first of these was by Wannstedt and Herman (1978) who used augmented sensory feedback via an auditory signal provided by the information from a limb load monitor. Of the 30 ambulatory stroke patients included, 27 (77%) corrected their symmetry of weight bearing by enhancing their limb loading on the paretic limb, when introduced to the feedback signal. Unfortunately there was no control group and the paper does not report any physiotherapy input to monitor standing posture.

More recently, Shumway-Cook et al (1988) used force plate information to provide centre of pressure feedback to 16 hemiplegic patients and to provide an accurate assessment of stance symmetry and sway characteristics. They compared this with conventional therapy in 8 control group patients. The experimental group received twenty sessions of a two minute duration of feedback over two weeks, a physiotherapist also provided postural correction. The control group received twenty sessions of standing practice with a physiotherapist. The experimental group were found to significantly increase their symmetry of limb loading but no change was found in overall sway patterns. Subjects were not randomly allocated to either the control or treatment group and it is questionable wether conventional therapy (to which the patients would be very familiar) is an adequate control to the exposure to new and interesting equipment.

The above studies made the assumption that postural symmetry was linked to functional ability and that patients would automatically be able to transfer their newly learned skills to functional, task-orientated movement. Two studies have examined the transfer of skills learned from postural training to gait, with conflicting results.

In the most recent study, Winstein et al (1989) provided visual feedback from force plate information to an experimental group of 17 hemiplegic patients. These subjects were trained an average of 30 to 45 minutes per day, five days a week, for three to four weeks. Both the experimental group and a control group of 21 matched subjects received conventional physiotherapy during the trial period. At the end of the study the experimental group achieved a more symmetrical standing posture than the control group, but this difference did not persist for measures of gait performance. Again it is possible to question the adequacy of the control, especially as the experimental group received more therapy treatment time in total and in the light of work discussed above, it would seem that the amount of therapy received can affect outcome.

A report of two single case 'ABAB' designs (De Weerdt 1989) described the effects of visual feedback on weight distribution and gait. Patients received EMG biofeedback to the arm in week A and visual feedback training in week B. An immediate and substantial improvement in the symmetry of weight distribution was demonstrated and this was sustained over time. Some carry over to the gait pattern was seen but there was no measurable improvement in gross motor function. The paper does not give the frequency or duration of treatment, so the total treatment time is unclear, therefore it may be unrealistic to expect large behavioural changes. It is also difficult to generalise the results of two patients to a larger stroke population.

It would seem that the question of patients ability to transfer training has not been closely examined with postural skills. This aspect has been examined for cognitive abilities, but a poor carry over to functional tasks was found (Wood and Fussey 1987, Towle et al 1988). Further work in this area is needed.

1.8 Skill acquisition theory

Therapy after stroke is essentially directed at teaching the patient new skills, helping the patient regain the ability to perform everyday tasks. Learning new skill involves the complex interaction of many systems. The process is a dynamic one and involves both conscious and automatic motor control, the proportion of which changes as the task becomes more familiar. Firstly, it is helpful to consider this process in the normal, non-neurologically impaired adult.

Gentile (1987) classifies behaviour in everyday tasks on three levels;

1. Action, the gross, goal orientated change

2. Movement, the means by which the action is achieved. Movement consists of components that are sequenced into a pattern, eg gait.
3. Neuromotor processes, organizational mechanisms within the CNS

The relationship between these levels is not a constant one. It depends on the task to be completed and is influenced by biomechanical components (such as weight and height), as well as environmental demands. There is debate as to the influence of the persons prior knowledge of the results (Lee et al 1990) and the processes of ordering planned movement (Ulrich 1990). The exact influence of the demands of the task on different components of sensory-motor functioning in the normal adult has yet to be identified and lies outside the topic of this thesis. However, without knowledge of this relationship it is still possible to describe the general process of skill acquisition.

Initially the person uses sensory modalities to appreciate the purpose or goal of the action, the next stage involves the integration of neural processes and finally the motor, goal-orientated action. The person then judges the feedback from their action and modifies the process. Practise continues until the process becomes more efficient and the action more accurate. During this learning process the action becomes increasingly automatic, it requires less conscious effort.

In the neurologically impaired, skill acquisition and motor learning are impeded by difficulties in sensory input, neuronal organization, motor output or any combination of these. The interruption of the action, movement or neuromotor process will result in reduced functional ability. Physiotherapists retrain normal movement by providing information to their patients via tactile, visual or verbal clues. They base their treatment on the resulting changes in their patients performance, monitored by their experience, feeling and watching for changes. Apart from recently published work from Australia (Carr et al 1987), physiotherapy theory claims that therapists actually enhance the process of neuronal recovery. It would seem more likely that, unintentionally, therapists were improving sensory input by providing feedback.

1.9 Physiological Recovery

As was discussed above, the majority of patients exhibit some degree of spontaneous recovery. There are several theories as to the mechanisms involved. Wade (1985), reviewing the work of Laurence and Stein (1978) describes recovery as;

1. Intrinsic-a return of neurological control.
2. Adaptive-the use of new tactics to achieve functional goals.

These definitions are not mutually exclusive, as both depend on changes within the central nervous system (CNS).

Intrinsic

Von Monakow (1914) first identified a process he called 'diaschisis' in which he claimed that focal neural damage not only destroyed some tissue, but interfered with the functioning of neural areas related to the damaged area. This concurs with the present concept of neural shock in which cerebral oedema and biochemical changes inhibit neural functioning in areas not directly damaged and gradually revert over time. Innoue et al (1980) used CT scans to examine this process and found that it may occur for up to 8 weeks post-stroke. This theory has support from pharmaceutical studies demonstrating improvements in function after the administration of amphetamines (Meyer 1972, Crisostomo et al 1988) and anticholinesterase drugs (Luria et al 1969).

Other investigators have proposed that damaged axons regenerate (Nieto-Sampedro 1985) or that unaffected axons sprout into denervated areas (Johnson and Almli 1978). Although animal studies have demonstrated both these processes, it is thought to be unlikely that behavioural changes in humans can result (Laurence and Stein 1978, Braun 1978).

Adaptive

A more popular concept is that of functional substitution. Undamaged areas are thought to take over the function of those affected. This ability is thought to decline with age and it has been demonstrated that functional recovery from the same lesion is better in the very young (Hicks and D'Amato 1970, Kinsbourne 1974) who exhibit greater neural plasticity.

Experiments examining the role of environmental changes have demonstrated improvements in function brought about by enriched environmental stimulus in both animals (Einon et al 1980) and neurologically damaged patients (Gazzaniga 1978). One explanation is that environmental stimulus may encourage the patient to use adaptive behaviours, therefore encouraging the use of existing neural circuitry. This model has most relevance to the effects of physical therapy.

Therefore, the mode of action of therapy may be to increase environmental stimulus and at the same time provide additional feedback, improving motor learning. This model also fits the results of clinical trials, in as much as the amount and timing of therapy appears more important than the choice of specific techniques. There is a need to evaluate therapeutic intervention using this model. To examine the effects of accurate and precise feedback of the components of movement when incorporated into functional goals.

1.10 Summary and aims of study

From this review it is possible to identify several gaps in existing knowledge and this study will attempt to answer some of the questions raised. The research was conducted in three separate stages and the aims for each stage are stated below.

Stage 1
To define normal ranges of weight distribution and postural sway in standing and to show the effects of age and sex on these variables. The data will be used as a base line for the studies on stroke patients.

Stage 2
1. To compare stance symmetry and sway after stroke with the normal values, allowing for age and sex differences present in the normal population and to determine whether these differences are still present after a stroke.
2. To examine the recovery of these variables and their relationship with motor function and activities of daily living (ADL) performance.
3. To monitor falls following stroke and to examine the relationship of falls to other variables, such as sway, stance symmetry, motor function, ADL, length of admission and age.

Stage 3
To assess the efficacy of visual feedback as a method of improving stance symmetry and functional ability after stroke.

CHAPTER 2
DESIGN OF STUDY

Individual studies will be discussed in detail in the next three chapters. However, they share some design considerations and methodological similarities and these will be outlined in this chapter.

2.1 Ethical Considerations
2.2 Stroke Register
2.3 Selection of Assessments
  Motor Function
  Activities of Daily Living (ADL)
  Recording Falls;
2.4 Instrumentation
2.5 Data Analysis
2.6 Summary

2.1 Ethical Considerations

All three sections of the research project were approved by the ethical committee and all of the consultant physicians and geriatricians caring for stroke patients in the Nottingham Health District. Following the guidelines published by the Royal College of Physicians of London (1990); each subject was asked for their verbal, informed consent. No risk to the health of these subjects was anticipated. All records were confidential, including computer records, where code numbers replaced the subject's names.

2.2 Stroke Register

Since 1983, a register has been kept of all new incident cases of stroke admitted to the medical and health care of the elderly wards throughout the Nottingham Health District. Stroke was diagnosed by a medical registrar compiling the list according to the WHO definition (Aho et al 1980) and following the WHO (1978) classification. This was made on clinical signs and symptoms as scanning facilities are scarce for these patients. Sandercock (et al 1985) demonstrated that clinical diagnosis was reliable and sufficiently consistent with the results of computerised tomography to be of value in surveys or epidemiological studies.

Demographic details; date of birth, sex, marital status and stroke details; date, side and admission destination, were recorded.

2.3 Selection of Assessments

Motor Function
Physiotherapists recognise the need to monitor the recovery of stroke patients and assessments of motor function are used routinely in most departments. Unfortunately, although many assessments have been designed to measure the physical recovery after stroke, the majority remain unpublished. Few have been standardised and even less have been examined for their reliability (both inter-rater and intra-rater) and validity. Four published scales have been found to fit these criteria (Fugl-Meyer et al 1975, Lincoln and Leadbitter 1979, Carr et al 1985, Lindmark and Hamrin 1988).

The Fugl-Meyer Assessment of Sensorimotor Recovery (Fugl-Meyer et al 1975) consists of 9 sections, containing up to 15 items. It is a long complicated assessment which not only measures functional skills but also reflex activity, balance, co-ordination, sensation, passive joint motion and pain. The limitations of the assessment are;

1. The items are not ranked, so the whole assessment must be completed and is therefore very time consuming to use.
2. Parts of the assessment are not directly relevant to this study.
3. Intra-rater and inter-rater reliability is poor in some sections (Duncan et al 1983).

Lindmark and Hamrin (1988a) adapted the Fugl-Meyer assessment by including items measuring gross mobility and changing the scoring system and found the new assessment to be reliable and valid (Lindmark and Hamrin 1988a, Lindmark and Hamrin 1988b). However, the 'Motor Capacity Assessment' was published after the start of this study.

The Motor Assessment Scale (Carr et al 1985) consists of 9 sections each of 6 items, ranging from bed mobility to climbing stair and using a comb. A section measuring general tonus is included. The limitations of the assessment are;

1. The assessment is not ranked and is, therefore, very time consuming.
2. The scoring system is unclear. For example in the general tonus section, of the six categories flaccidity rates 1, normal tone rates 4 and hypertonus 6. Also, the reliability of this section has not been tested.

The assessment chosen for this study was the 'Rivermead Motor Assessment' (Lincoln and Leadbitter 1979). This scale was developed to provide a standardised, ranked assessment of physical recovery after stroke. The inter-rater and test-retest reliability have been found to be acceptable. It was designed as a tool for both routine clinical use and research purposes. The Rivermead Motor Assessment consists of three parts (outlined below), each part consists of between ten and fifteen items and items are arranged in order of difficulty.

1. Gross Function (13 items)- a measure of functional ability, which includes items ranging from sitting unsupported and independent transfers to climbing stairs and running.
2. Leg and Trunk Function (10 items)- includes items such as rolling, bridging and tests of leg control.
3. Arm Function (15 items)- includes test items that start as simple movements and increase in precision.

(For further details of the items included see Appendix A).

In the Gross Function section the patient is asked to perform each item and is simply judged as dependent/independent. The quality of movement does not influence the score. In the other two sections the assessor needs to observe the patient's performance as the patient may be able to manage the task by using abnormal or trick movements and so would fail the item. The assessment is often used in conjunction with other assessments for research purposes and in clinical use. The time needed to complete the assessment varies with the patient's abilities, but is usually less than thirty minutes.

As it is a Guttman scaled assessment (Williams et al 1976) there is no need to complete the section once a patient has failed three consecutive items. One of the advantages in using a ranked assessment is that it can save time, another is that the score gives an accurate indication of the patients functional ability. It was found to be the most appropriate for this study.

Activities of Daily Living (ADL)

Many assessments have been developed to measure functional ability or ADL after stroke, but few have been found to be reliable and valid. Some have only been tested on a very limited patient group and rarely have formal administration (observing patients behaviour) and informal administration (relying on self-reporting either as an interview or questionnaire) been compared.

Two assessments fulfil these conditions, the 'Nottingham Ten Point Activity of Daily Living (ADL) Scale' (Ebrahim et al 1985) and the 'Barthel Index' (Mahoney and Barthel 1965). The Barthel Index has been widely used but the scoring system contains some inconsistencies, as some items are allocated different scores. Although the assessment demonstrates a hierarchical tendency (Wade and Langton Hewer 1987), analysis of the strength and consistency of scaling is not available. To save time it was necessary to use a ranked assessment that could be used both formally and informally.

Therefore, only one assessment was suitable and so functional ability was measured with the 'Nottingham Ten Point Activity of Daily Living (ADL) Scale'. It is a Guttman scaled assessment and is reliable if administered formally or informally. It consists of a scale of ten items, ranging from drinking and eating to dressing and bathing. (Further details in Appendix B). Patients are scored as independent or dependent on each item, the test is stopped after three consecutive fails and the score (which summarises their level of ability) is equal to the number of the most difficult item successfully completed.

As with the majority of ADL scales the 'Ten Point Activity of Daily Living Scale' is primarily concerned with self-care functions, but is of limited use in assessing the patient's independence in their home where as more complex ADL tasks are needed. The Frenchay Activity Index (Wade et al 1985) has been developed to include social and domestic tasks but unfortunately reliability data has not been published and the scoring system is somewhat cumbersome. Another such scale is the Extended Activities of Daily Living Scale (Nouri and Lincoln 1987) which is Guttman scaled, reliable and easy to score.

Consequently, the Extended Activities of Daily Living Scale was used. (For further details see Appendix C). Again, it is Guttman scaled, reliable and easy to score. Four sections are included, mobility, kitchen activities, domestic tasks and leisure activities. Two sections contain five items and two six items. The questionnaire is designed to be completed by the patient or carer and there are four response categories, on my own, on my own with difficulty (which both score 1), with help and no (which score 0). Although the original article reported difficulties with the scalability of the first section on mobility more recent work has confirmed that it is indeed a ranked assessment (Lincoln and Gladman 1991).

Recording Falls

The majority of studies of falls in the elderly or after stroke have depended on retrospective data (Moskowitz et al 1972, Prudham et al 1981, Blake et al 1988). The only prospective information comes from a population of institutionalised elderly (Fernie et al 1982), where falls were recorded if they were observed by staff, visitors or reported by the subjects.

For the purposes of this study a fall was defined as;

> 'An unexpected loss of balance resulting in a person coming to rest on the floor or another lower level.'

Initially, a diary was designed to be used for monitoring the frequency of falls. It was sent by post to forty stroke patients, living at home, whose names were taken from the Stroke Register. Subjects (or their carers) were asked to complete it every day for two weeks. Thirty five were returned and had been correctly completed (of the five that were missing, three had subsequently moved and two refused to complete the diaries). However, only one patient had experienced a fall in that time. As the study required a record of falls for four months, it seemed unlikely that compliance would be sufficient to maintain a daily diary, especially if the frequency of falls was so small. The low frequency also suggested that random sampling using the diaries would not supply enough detail.

Therefore, information about the frequency of falls was gathered using a variety of methods. At the initial assessment patients were asked if they had fallen in hospital, ward accident reports were examined and staff were asked to report any falls. Patients were asked to report any subsequent falls that occurred over the next four months. At the half way stage between the first and final assessments, patients were checked by phone or visited and their carers were also asked to report any falls. At the final assessment both patients and carers (where appropriate) were asked to report any falls in the study period.

Where possible details of the circumstances and consequences of the the fall were recorded from structured interviews. A form was designed for this purpose, the 'After Fall Interview'. Included were details such as, time of day, place, length of time on the floor, the use of professional consultations or hospital admissions. (see Appendix D)

Before commencing the study, patients were asked to report any mobility or balance problems or falls in the year before their stroke. Again a form was developed to record the data, the 'Initial Interview'. Patients were also asked questions about their attitude to falls since their stroke and if they had provision for getting help once they were at home. (See Appendix E)

Structured interviews were chosen instead of questionnaires because the method of administration was more flexible. It is not possible to assess the reliability of the interviews or to corroborate the data, as it was retrospective and possibly contained subjective bias from the patient, carer or hospital staff.

1.4 Instrumentation

The Nottingham Balance Platform (NBP) (De Weerdt et al 1988) is a purpose-built computerised limb load monitor and was developed for two purposes;

1. To measure body weight distribution between the left and right feet.
2. To provide a visual feedback training program.

Its constituents are described below (see Figure 2.1)

Load platforms

There are two limb load platforms which are similar in size to bathroom scales. They are constructed of metal with a ribbed rubber upper surface. Each contains a 'Wheatsone Bridge' arrangement of strain gauges which are situated in all four corners. The output consists of the total of all four measurements. The load platforms are embedded in a wooden base to improve stability and safety. The plinth is large enough to accommodate a chair and has a ramp for wheelchair access.

Amplifiers

The two amplifiers, two disc drives and the BBC microcomputer are housed in a purpose built unit. The output from the load platforms is amplified before it is processed by the computer.

High resolution monitor

A twenty four inch colour monitor provides a clear visual image. It stands on a trolley about 120cms high.

BBC Micro-Computer and disc drives

This allows the input from the load platforms to be analysed and presented in both graphic and numerical forms. There are two disc drives, one for the program disc and one to record the data. The soft ware was produced by the medical physics department at the Queen's Medical Centre, Nottingham. It has two main functions, firstly to analyse the postural information from the platforms and secondly to provide visual feedback training (see Figure 2.2). Every day, before the NBP was used it was necessary to calibrate the input from the load platforms by equalising the arbitrary numerical

FIGURE 2.1

The Nottingham Balance Platform

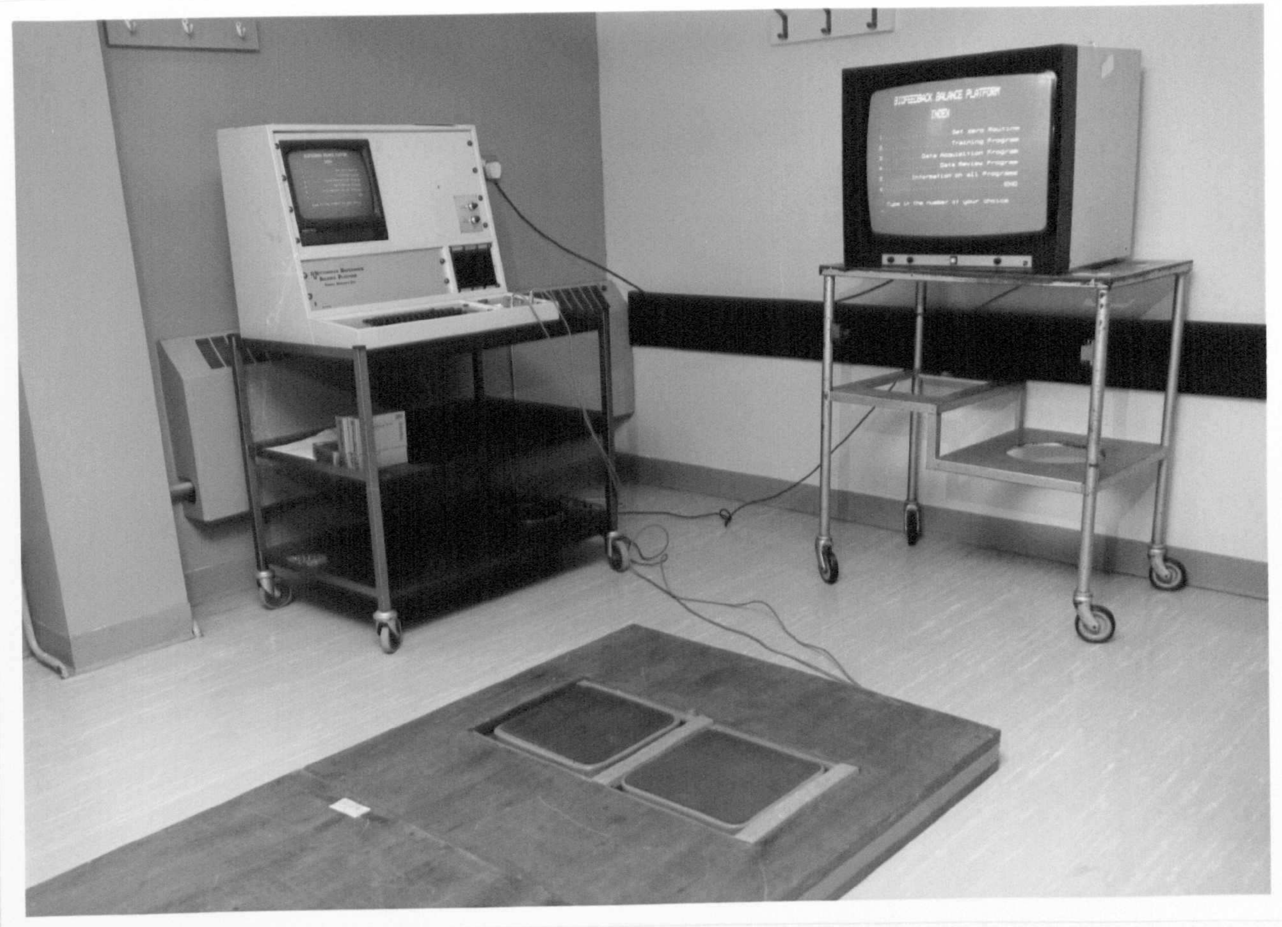

FIGURE 2.2

The Nottingham Balance Platform (Software)

values corresponding to the linear output from the summation of the strain gauge readings.

Data-Acquisition Program

At the start of the test the subject's name, age and the date are recorded. The subject stands with one foot on each of the platforms and the subject's body weight distribution is recorded for thirty seconds at a sampling rate of ten per second. Therefore, 300 measurements are made in the test period. This information is presented graphically, with the x-axis denoting time and the y-axis arbitrarily divided from 1 to 0 representing the subject's weight (see Figure 3.2). The pattern of weight-shift activity throughout the test is drawn and from this the 'Balance Coefficient' (BC) is calculated. If all the body weight is on the left leg the BC would equal 1, if on the right the BC would be 0 and if equally divided it would be 0.5. It also provides a measurement of postural sway. The 'Sway Coefficient' (SC) is calculated from the weight shift activity during the test period. It is represented by the standard deviation of the weight distribution. The graph of the weight shift activity can be either presented on the monitor or printed on paper and is stored on the data disc.

Feedback Program

This was designed to provide continuous visual feedback of the patient's stance symmetry and weight shift activity to re-train motor function after stroke. The visual stimulus was designed to be simple, bright and easy to understand, as well as being of enough interest to maintain the patients' attention.

At the start of the session the patient stands on the right platform and is weighed. Two yellow vertical columns are then displayed, the patient then stands with one foot on each of the platforms and a red trace fills the yellow column, the scale of which corresponds to the individuals weight. The signal varies with the patient's movement and gives the impression of a changing column of liquid in a tube. As the patient increases weight on the left foot the red trace moves up the left yellow column and down on the right (and visa versa). When the two columns are level within 5% a red triangle appears. Horizontal lines of different colours are drawn at intervals between the yellow columns, which can be used for targeting activities with patients (see treatment protocol).

Control Program

A static display can be selected for use with the control group. This consists of two yellow columns both constantly half filled with red, which do not move as the patient moves.

Accuracy of the NBP

De Weerdt (1988) reported on the accuracy of the NBP when tested with standard weights from the Trading Standards Department. Weights ranging from 5-60kg were used in combinations, progressing by 5kg steps from 45kg-80kg. The readings were made over 10 second periods with a sample rate of 12 per second. The tests were repeated two days later.

From these readings the Expected Balance Coefficient (EBC=weight on left/total weight) was calculated and compared with the Observed Balance Coefficient (OBC=computer readout), using the equations X(1)=EBC-OBC(1) and X(2)=EBC-OBC(2). Calculating the mean difference between the expected and observed readings gave the results; X(1)=0.0089, X(2)=0.0085, standard deviations (1)=0.0060, (2)=0.0066). He reported that the measurement was reliable and demonstrated no significant differences between the first and second readings ($p>0.005$) and no systematic errors ($p>0.005$). However, as a gradually higher amount of weight was shifted from the left to the right platform a small error did occur but this was then rectified by using a correction factor of 0.0087 in the data acquisition program.

Before commencing this study the above test was repeated using the correction factor of 0.0087. A wider range of weights was used, 10kg-80kg as this was thought to be more representative of the pattern of weight bearing exhibited by stroke patients. For each test the weights were adjusted from 80kg on the left platform to 10kg on the right and then gradually shifted, in 5kg steps, until there was 80kg on the right platform and 10kg on the left. This was then repeated in the opposite direction (ie, from right to left) and the whole experiment was repeated once more. Sixty readings were recorded and the observed data was compared with the expected readings using a Pearson product moment correlation ($n=60$, $r=.98$, $p<0.001$). This confirmed that the NBP was an accurate tool.

Reliability of Postural Measurements

Test-retest reliability of the parameters of standing weight-bearing symmetry and weight shift activity were examined with twenty normal subjects. The Balance Coefficients and Sway Coefficients of fourteen women and six men were recorded for thirty seconds (sample rate of ten per second). The test was conducted in the same manner as with the normal group (see Chapter 3) and similarly the subjects were unaware of the exact measurements being made and did not see the results. They were re-tested after a period of fifteen days. The results were compared with Pearson product moment correlations, which indicated that the Balance Coefficient and the Sway Coefficient are reproducible measures of habitual standing posture.

2.5 Data Analysis

The results were analysed using the computing facilities and advice of the Cripps Computer Centre, University of Nottingham. Parametric and non-parametric statistics were used as necessary, details of the individual tests used are given in the appropriate chapter.

2.6 Summary

This chapter outlines the methods that are common to the three parts of the study. It includes a comprehensive description of the Nottingham Balance Platform and its reliability as a measurement tool. Each assessment is described in detail and the rational for choosing each assessment is discussed.

CHAPTER 3

STANCE SYMMETRY AND SWAY IN HEALTHY ADULTS

3.1 Aims

The aims were to define normal ranges of weight distribution and postural sway in standing and to show the effects of age and sex on these variables. The data will be used as a base line for the studies on stroke patients.

3.2 Methods

Subjects

Volunteers were recruited in a number of ways. Posters advertising for subjects were displayed at the General Hospital and in the local 'Age Concern' office. From this mainly hospital staff and visitors under the age of sixty were identified. The Nottingham Balance Platform (NBP) was then taken to main corridor of the Sherwood wing of the City hospital one Sunday. The Sherwood wing, because of its function as an acute care unit for the elderly, has many elderly visitors, who were then recruited. The NBP was also taken to two meetings arranged for people over 50 years at a local community centre.

People were asked to participate in a study of balance but were not told exactly what measures were being recorded during the test period. Subjects were included if they were;

a) Independently mobile.
b) Had no reported history of vestibular, neurological or orthopaedic impairment (including congenital deformity)
c) No uncorrected visual handicap or blindness.

A total of 403 subjects out of a total of approximately 425 who were approached were included, 269 women and 134 men. Several refused to volunteer and a few were using walking aids and therefore excluded. (For age and sex details see Table 3.1).

Procedure
The date of the test and the persons age and sex were recorded.
The subject was asked to stand with one foot on each of the load platforms. They were instructed to stand with the feet a comfortable distance apart, as they would do normally, with their arms at their sides and to fix their gaze on a blue cross placed on the wall, in the midline, at eye level. Shoes were worn by most of the subjects, except those young women with high heels, who were asked to remove them.

The test lasted for thirty seconds using a sampling rate of ten per second, the weight shift activity was recorded in graphic form on a floppy disc.

Data Analysis
The SPSSX statistical package was used via the main-frame facilities of the Cripps Computer Centre. To estimate

the distribution of the data a graph was drawn of the frequency.

The relationships between variables were determined by calculating Pearson product moment correlation coefficients,for the Balance Coefficient it was necessary to calculate the difference from the midline and square the result to remove the negative values. This was labelled as the Balance Coefficient 2 (BC2);

$$BC2=\sqrt{(BC-0.5)^2}$$

The 'Student's' t Test was calculated to examine sex differences between variables. The interaction of the variables was compared with an analysis of variance.

3.3 Results

A total of 403 volunteers were included, 269 women and 134 men. Their ages ranged from 18 to 87 years, mean 50.0, standard deviation (sd) 16.5 (see Table 3.1).

The Balance Coefficient (BC) ranged from 0.278 - 0.658, mean 0.517, sd 0.051 and the Sway Coefficient (SC) (which is the standard deviation of the weight shift activity during the test) ranged from 0.0018 - 0.0491, mean 0.0117, sd 0.0076.

It can be seen from Figure 3.1 that the distribution of the BC variable approximated to a normal distribution. From the properties of a normal distribution, it would be expected that 95% of the sample would lie between 1.96 x sd (0.051) in both directions from the mean. For this variable it would therefore be expected that 382 samples would lie between 0.417 and 0.617. The number of samples

TABLE 3.1

Mean Balance Coefficient (BC) and Sway Coefficient (SC) for each Age Group.

	Age Groups (in years)							
	18-29	30-39	40-49	50-59	60-69	70-79	80-89	Total
Men								
n	18	15	20	31	36	11	3	134
Women								
n	49	33	40	64	53	27	3	269
Total								
n	67	47	60	96	89	38	6	403
BC								
x	0.518	0.506	0.516	0.519	0.526	0.502	0.538	0.517
sd	0.039	0.046	0.050	0.079	0.051	0.070	0.099	0.051
SC								
x	0.010	0.010	0.011	0.012	0.010	0.014	0.010	0.012
sd	0.006	0.007	0.006	0.008	0.007	0.010	0.010	0.008

(Abbreviations; x=mean, sd=standard deviation)

FIGURE 3.1

Frequency Distribution of the Balance Coefficient in Healthy Adults

```
                                                        n=403
  0.275 *
  0.285
  0.295
  0.305
  0.315
  0.325
  0.335 ****
  0.345 *
  0.355
  0.365
  0.375
  0.385 *
  0.395 **
  0.405 **
  0.415 ****
  0.425 ***
B 0.435 ****
A 0.445 ******
L 0.455 ********
A 0.465 *****************
N 0.475 *************************
C 0.485 *****************************
E 0.495 ***************************
  0.505 ***************************
C 0.515 **************************************
O 0.525 *****************************************
E 0.535 ************************************
F 0.545 **************************
F 0.555 *****************************
I 0.565 ********************
C 0.575 ********************
I 0.585 ***********
E 0.595 *******
N 0.605 ***
T 0.615 **
  0.625 ****
  0.635 ***
  0.645
  0.655 **
  0.665
  0.675
  0.685
  0.695
  0.705
  0.715

            FREQUENCY (one symbol= one occurrence)
```

in that area is 382. The highest difference between actual weight distribution and symmetrical (50:50) weight distribution was 12% for 95% of the sample. It ranged between 13% and 22% for the remainder.

Pearson product moment correlation coefficients indicated that an increase in age was significantly correlated with both an increase in postural sway ($r=0.19$, $p<0.001$) and asymmetry of weight distribution ($r=0.17$, $p<0.001$).

The 'Student's' t Test showed a significant difference between the sexes for weight distribution (balance coefficient) and for postural sway (sway coefficient). Women tended to be more asymmetrical to the left side and to sway more (Table 3.2). No statistically significant differences were demonstrated differences between the sexes for age distribution ($t=0.7$, $p>0.05$).

An analysis of variance of the Sway Coefficient and the Balance Coefficient by age and sex group was done to look at the interaction of these variables. For the Sway Coefficient there was a significant main effect of age ($F_{6,389}$ 4.31 $p<0.01$) and of sex ($F_{1,389}$ 4.26 $p<0.005$) and no significant interaction of age and sex ($F_{6,389}$ 0.41 $p>0.05$). Similarly, for the Balance Coefficient there was a significant main effect of age ($F_{6,389}$ 2.97 $p<0.01$) and of sex ($F_{1,389}$ 9.46 $p<0.001$) but no significant interaction of age and sex ($F_{6,389}$1.27 $p>0.05$).

Figure 3.2 illustrates a graph of a thirty second test for a healthy adult.

TABLE 3.2

Comparison of The Sexes For Balance Coefficient (BC) and Sway Coefficient (SC).

n=403

	Sex	n	Mean	Standard Deviation	t Value	2-Tailed Probability
BC	F	269	.522	.048	2.75	0.006
	M	134	.507	.054		
SC	F	269	.012	.008	2.21	0.028
	M	134	.010	.006		

FIGURE 3.2

Graph of Thirty Second Standing Test For a Healthy Adult

3.4 Discussion

The results from this study confirm earlier findings (Dickstein et al 1984, Caldwell et al 1986, Murray and Peterson 1973) that the majority of normal adults do not stand with exactly half their body weight on each foot. To a small degree they tend to favour either the left or right foot. The difference was up to 12% for the majority of the sample, which is of a similar magnitude to the 8-16% estimates reported from smaller (largest n=40) and more highly selected samples (Dickstein et al 1984, Caldwell et al 1986, Murray and Peterson 1973).

The degree of asymmetry increased with age. The cause is unclear, without radiological examination it is impossible to exclude occult or unspecific joint disease or musculoskeletal injury. Old injuries may not have resulted in any permanent damage, but the compensatory posture learnt during that time may never have been completely corrected. However, the subjects did not complain of pain or report any history of problems and those few who did were excluded.

Women were found to be more asymmetrical towards the left side than men. There is no obvious reason for this and it is unlikely that it occurred because of sample bias, as there are large numbers of both men and women in the study group. No relationship was found between age and sex, which supports the argument that it was not an artifact produced by a combined age and sex bias in the sample. The lack of time prevented a detailed analysis of the subjects hand and/or foot preference and this may be an area that warrants further investigation.

Postural sway in standing has been found to be dependent on visual, somatosensory and vestibular sensory input.

Therefore subjects exhibiting severe impairments in any of these systems were excluded (again, those with mild or occult impairments may have been unintentially included). The importance of visual input in maintaining a stable standing posture has been shown in healthy adults (Ring et al 1989, Weissman & Dzendololet 1972, Dornan 1978, Okubo et al 1979) and it can be used to compensate for deficiencies in other systems (Black et al 1983, Dornan et al 1978). There are indications that the compensatory mechanism can been improved by training (Dickinson and Leonard 1967).

Alterations in proprioceptive input from foot pressure sensory changes (Ring et al 1989) and impaired vibratory sensation (Brockelhurst et al 1982) have been associated with increased sway values. The role of vestibular input has become apparent from patients with vestibular disease (Nashner et al 1982). If the disease is severe, visual and somatosensory input cannot compensate (Black et al 1983).

A combination of the changes in any of these systems because of age may go some way to explain the significant increase in sway with age demonstrated in this study and in earlier work (Fernie and Holliday 1978, Overstall et al 1977, Sheldon 1963, Murray et al 1975, Era and Heikkinen 1985).

Women displayed the tendency reported by Overstall (1977) and Stribley (1974), to sway more than men. Again there is no clear explanation, but one hypothesis is that anthropometric variables such as muscle strength have some influence. The only example of this was demonstrated by the relationship of sway and grip strength (Era and Heikkinen 1985). Further investigation of this observation may have clinical implications as it is possible to train muscle strength even in the elderly (Aniansson and Gustafsson 1981).

From the results of this study it has been possible to calculate normal ranges for postural sway and weight distribution for each age decade up to 70 years, for use in the studies with stroke patients. To complete the information in the over 80 years category more subjects would be needed. However, as few stroke patients over 80 years fulfilled the inclusion criteria of the stroke studies in this thesis, it was not necessary for normal ranges to be calculated in that group.

The information provides base line data for the investigations into weight distribution and postural sway after stroke and also gives targets for the treatment of stroke patients.

3.5 Summary

This chapter describes an investigation of stance symmetry and sway. The aims were to provide normative data for the subsequent studies on stroke patients and to show the effect of age and sex on these variables.

Male and female volunteers were recruited from various sources. Weight distribution in standing was expressed as the balance coefficient (BC), the mean proportion of body weight on the left leg calculated over thirty seconds. Postural sway was calculated from the deviation from that mean and expressed as the sway coefficient (SC). These variables were recorded during a thirty second test for each subject

The 403 volunteers included 269 women and 134 men, age range 18-87 years (mean 50). There were significant differences between the sexes for both BC ($p<0.01$) and SC ($p<0.05$). Also significant correlations between age and postural sway ($p<0.001$) and age and weight distribution ($p<0.001$).

The results are discussed in the light of the existing literature. The results provided base-line data allowing for age and sex differences for the studies with stroke patients.

CHAPTER 4
STANCE SYMMETRY AND SWAY AFTER STROKE

4.1 Aims

The aims of the study were;
1. To compare stance symmetry and sway after stroke with the normal values, allowing for age and sex differences present in the normal population and to determine whether these differences are still present after a stroke.

2. To examine the recovery of these variables and their relationship with motor function and activities of daily living (ADL) performance.

3. To monitor falls following stroke and to examine the relationship of falls to other variables, such as sway, stance symmetry, motor function, ADL, length of admission, age, sex and side of stroke.

4.2 Methods

Subjects

Patients were identified from the stroke register. They were recruited between 6 and 9 weeks after stroke, or when capable of standing (up to 26 weeks). Patients who had been discharged were followed up at home. Patients were included if they were capable of independent standing for thirty seconds. It was acceptable if the patient needed initial assistance to get into a standing posture. They were excluded if they;

1. Were unable to understand instructions, ie if they were aphasic or had a history of dementia.
2. Had a history of major lower limb deformity (either neurological , congenital or traumatic).
3. Were blind.

Patients were undergoing rehabilitation as decided by the staff on each ward. Details of patient characteristics are given in Table 4.1.

Assessments

In addition to demographic details a record was kept of the past medical history and the social history. Details of the stroke included the date of the stroke , date of admission and side of stroke. Any speech, visual, continence or perceptual deficits were noted from the medical, paramedical or nursing notes. Perceptual deficits were identified by the occupational therapist with the Rivermead Perceptual Assessment Battery (Whiting et al 1985) and from the results the deficits were classified as absent, mild or severe.

Procedure

The patients were approached individually and asked for their permission to take part in a study of balance and mobility after stroke. Precise details were not given as to what measures were being taken as this may have influenced them. The patient details were recorded and the ward accident reports examined for any record of a fall during their time in hospital. The first assessment was completed once they had fulfilled the inclusion criteria and consisted of;

The Initial Interview
Measurements with the Nottingham Balance Platform (NBP)
The Rivermead Motor Function Assessment.
The Nottingham 10 point ADL Scale

(For details of the assessments see Chapter 2)

The second assessment was done approximately 4 months after the first, with a falls check at 2 months (see Chapter 2). At this stage the majority of the subjects had been discharged from hospital and so travelled to the hospital by taxi for the final assessment. Patients were encouraged to bring someone with them. The assessment included;

Measurements with the Nottingham Balance Platform
The Rivermead Motor Function Assessment.
The Nottingham 10 point ADL Scale
The Extended ADL Scale
A falls check and (if appropriate) completion of the After Falls Interview.

A flow diagram is presented in Figure 4.1 which summarises the study procedure

Figure 4.1

Flowchart of Study Procedure

6-9 weeks post-stroke	Patients identified from stroke register and given 30 second standing test
	↓ Pass ↓ Fail
	Fail: Re-assessed at later date ↙
	↓
	Inclusion criteria
	↓ Pass ↘ Fail → Excluded
	↓
	1st Assessment The Initial Interview Measurement with the NBP The Rivermead Motor Function Assessment. The Nottingham 10 point ADL Scale
	↓
2 months later	Falls check
	↓
4 months later	2nd Assessment Measurement with the NBP The Rivermead Motor Function Assessment. The Nottingham 10 point ADL Scale The Extended ADL Scale Falls check

If at any time a fall was reported the patient (or carer) was asked to complete the After Falls Interview.

Assessment Procedure

The patients were asked to stand on the NBP with one foot on each of the load platforms. Help was given to the patient (if needed) to position the foot, but their standing posture was not corrected. The subject was then asked to fix their gaze on the monitor screen in front of them. This was placed in the midline and displayed a message 'Test in Progress' which appeared on the screen to encourage them to maintain their concentration and to look straight ahead. The test ran for 30 seconds and three trials were done with a few minutes rest in between each.The 'Balance Coefficient' (BC) and the 'Sway Coefficient' (SC) were computed as the average of the three observations. The assessments of motor function, functional ability (ADL) and weight distribution were completed at the same time or within forty-eight hours.

Data Analysis

Parametric tests were used for interval data and non-parametric tests for ordinal data. Differences between groups were examined with t-tests, which can be applied to both ordinal and interval data. To examine the relationships between the BC and the other two measures it was necessary to calculate the Balance Coefficient 2 (see Chapter 3) which gave the difference from the mid point (0.5) as this represented 50:50 weight distribution.

To investigate the relationships between variables, Pearson product moment correlations were used for parametric data and Spearman Correlations for non-parametric data. To estimate changes over time between the first and second assessment paired t-tests are used for interval data and Wilcoxen matched pairs signed ranks test for ordinal data.

4.3 Results

Description of Study Group.

Ninety-two patients were recruited from 180 on the stroke register, 35 died, 29 were too severely affected either with communication or motor impairments, 15 had previous neurological disease, 5 had a history of dementia, 2 were amputees and 2 were transferred outside the Nottingham Health District.

The sex, age and time since stroke details for the 92 included are given in Table 4.1. Fifty two had a right-sided hemiparesis, 38 a left-sided hemiparesis and 2 had a brainstem stroke. Many of the patients had a past medical history predisposing them to stroke disease, 6 (6.5%) had diabetes, 14 (15.2%) ischaemic heart disease and 32 (34.8%) hypertension. Six patients (6.5%) had a history of both ischaemic heart disease and hypertension.

At the time of the first assessment 25 (27.2%) patients exhibited signs of aphasia and 32 (34.8%)dysarthria. Fifty seven patients (61.9%) had evidence of perceptual deficits, 20 of those were rated as severe. Only one patient was catheterised, but 5 had problems with 'occasional accidents'.

The majority of patients (58, 63%) lived in their own homes with a spouse. Eleven (12%) lived alone either in their own house or flat. The remainder lived either with other members of the family (19, 21%) or in sheltered accommodation.

Information on mobility and balance problems in the year before their stroke was available for 78 of the 92 patients. The remaining 14 had expressive communication problems resulting from their stroke and so could not

TABLE 4.1

Biographical Characteristics of subjects

n=92

Sex	Age (years)			Time From Onset of Stroke (weeks)		
	Range	Mean	SD	Range	Mean	SD
45 Men	41-86	64.7	9.1	6-32	15.4	8.1
47 Women	21-87	62.2	13.4	6-29	13.3	7.5
Total	21-87	63.5	11.5	6-26	11.3	5.0

complete the assessment. Fifteen patients reported at least one fall and 17 reported balance problems in the year before their stroke. Eight subjects had regularly used a walking stick and one had used two sticks. Patients were often included in more than one of these groups, thus in total 22 patients (28%) reported problems.

Results of Initial Assessment.

The Balance Coefficients ranged from 0.016-0.892 (mean 0.521, sd 0.188). The mean of the three tests was calculated and called the Balance Coefficient 1 (BC1) range 0.050-0.853, mean 0.521, sd 0.184

The Sway Coefficients ranged from 0.0052-0.1310 (mean 0.0302, sd 0.0205) The mean of the three tests was calculated and called the Sway Coefficient 1 (SC1) range 0.0073-0.0845, mean 0.0297, sd 0.0169.

The 'Rivermead Motor Function' and the 'Ten Point ADL' scores at the first assessment are summarised in Table 4.2

Differences between groups.

Patients with left and right-sided hemiplegia were compared and t-tests indicated a statistically significant difference between the groups for BC1 values as shown in Table 4.3, but no significant difference in SC1 values. Of the 52 patients with a right-sided hemiplegia, 44 (85%) favoured their left leg and 8 (15%) their right leg. Of the 38 with left-sided hemiplegia 27 (72%) favoured their right

TABLE 4.2

Rivermead Motor Function and Ten Point ADL Scores.

n=92

	Range	Mean	Standard Deviation
Gross Function	1-13	5.6	2.6
Leg and Trunk Function	0-10	5.1	2.9
Arm Function	0-15	3.9	4.5
Total Score	1-38	14.6	8.7
ADL score	3-10	5.0	2.7

TABLE 4.3

Comparison of Variables for Patient with Right and Left-Sided Hemiplegia at the Initial Assessment

Variable	Left-Sided Hemiplegia (n=52)			Right-Sided Hemiplegia (n=38)			Comparison	
	mean	sd	range	mean	sd	range	t	p
BC1	0.62	0.12	0.31-0.85	0.38	0.16	0.05-0.64	8.18	<0.001
SC1	0.030	0.015	0.008-0.073	0.029	0.019	0.007-0.084	0.09	ns
BC2	0.15	0.09	0.01-0.35	0.16	0.12	0.00-0.45	0.54	ns
Age	63.4	11.5	21-87	63.2	11.8	33-87	0.07	ns
Time Since Onset	11.5	5.1	6-25	11.2	5.0	4-26	0.33	ns

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TABLE 4.3 (Continued)

Comparison of Variables for Patient with Right and Left-Sided Hemiplegia at the Initial Assessment

Variable	Left-Sided Hemiplegia			Right-Sided Hemiplegia			Comparison	
	mean	sd	range	mean	sd	range	t	p
ADL	5.3	2.6	3-10	5.3	2.7	3-10	0.08	ns
Leg and Trunk	5.1	2.7	0-10	5.3	3.4	0-10	0.45	ns
Arm Function	3.3	4.3	0-15	4.6	4.9	0-15	1.31	ns
Gross Function	5.3	2.2	1-10	5.9	3.1	1-13	1.16	ns
Total Motor Function	13.6	7.7	2-34	15.8	9.9	1-38	1.12	ns

TABLE 4.4

Comparison of Variables for Men and Women at the Initial Assessment

Variable	Men (n=47)			Women (n=45)			Comparison	
	mean	sd	range	mean	sd	range	t	p
BC1	0.52	0.22	0.05-0.85	0.52	0.15	0.08-0.81	0.23	ns
SC	0.032	0.016	0.009-0.084	0.027	0.017	0.007-0.080	1.27	ns
BC2	0.18	0.11	0.01-0.45	0.13	0.09	0.00-0.42	1.19	ns
Age	64.7	9.1	41-86	62.2	13.4	21-87	1.0	ns
Time Since Onset	12.2	5.2	7-26	10.7	4.3	3-20	1.26	ns

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TABLE 4.4 (Continued)

Comparison of Variables for Men and Women at the Initial Assessment

Variable	Men (n=47)			Women (n=45)			Comparison	
	mean	sd	range	mean	sd	range	t	p
ADL	4.9	2.5	3-10	5.7	2.8	3-10	1.43	ns
Leg and Trunk	5.0	2.6	1-10	5.3	3.3	0-10	0.41	ns
Arm Function	3.2	4.2	0-15	4.6	4.8	0-15	1.43	ns
Gross Function	5.7	1.7	1-10	5.5	3.3	1-13	0.36	ns
Total Motor Function	13.9	7.5	4-34	15.3	9.7	1-38	0.79	ns

leg, 10 (26%) favoured their left leg and one had a BC1 of 0.5 and so was dividing her weight equally. The mean proportion of individual body weight on the unaffected leg was 66%. The magnitude of the degree of asymmetry was compared between left and right sided stroke patients (BC2) and no significant difference was found (Table 4.3). The ADL and motor function scores of patients with left and right-sided hemiplegia were also compared and no significant differences were found. No significant differences were demonstrated between men and women for any of the variables (Table 4.4).

Correlations between variables.
Spearman's rho was used to evaluate the relationship between the BC2, ADL score and each part of the Rivermead Motor Assessment Scale. The results are given in Table 4.5. Correlations between sway coefficients, motor function scores and ADL scores were not significant. Age was significantly related to the BC2 ($r=-.269$, $p<0.005$) and ADL ($r=.175$, $p<0.05$) and total motor function scores ($r=.378$, $p<.0.001$).

Final Assessment

Description of study group.
Seventy-one completed the whole study, 36 with right-sided and 33 with left-sided hemiplegia and two with brainstem strokes. Eight patients died (including 2 in hospital), 2 had further strokes, 3 moved outside the area, 3 were admitted to hospital with fractures resulting from falls and 6 refused to return for the final assessment.

TABLE 4.5

The Relationship Between Measures of Weight Distribution (BC2), Motor Function and Activities of Daily Living (ADL) at the Initial Assessment.

n=92

	BC2	ADL	Arm Function	Leg Function
ADL	r_s=-.35 p<.001			
Arm Function	r_s=-.45 p<.001	r_s=.51 p<.001		
Leg Function	r_s=-.30 p<.001	r_s=.58 p<.001	r_s=.47 p<.001	
Gross Function	r_s=-.27 p<.001	r_s=.68 p<.001	r_s=.45 p<.001	r_s=.69 p<.001

r_s= Spearman correlation coefficient

p= probability

Those who had moved away were sent the ADL and falls questionnaires by post and all three completed them. Of the 6 who had refused 2 agreed to a home visit, consequently the only assessments missing for those two are the NBP measures. The remaining 4 were sent postal questionnaires and only one refused again. Details of the falls that resulted in hospital admission were included in the results, therefore information on falls in hospital before the 1st assessment and during the study period (between the 1st and 2nd assessments) was available for 81 patients (88% of the original sample).

Results of Final Assessment.

The second assessment was made between 16 and 24 weeks after the first (mean 20.2). At this stage the patients were between 24 and 48 weeks (mean 31.3) weeks post stroke. Their length of stay in hospital ranged from 2 to 32 weeks (mean 14.4, standard deviation 7.8), 2 died in hospital.

The Balance Coefficients ranged from 0.098-0.828 (mean 0.514, sd 0.153). The mean of the three tests was calculated and called the Balance Coefficient 1 (BC1) range 0.110-0.810, mean 0.517, sd 0.146, n=71.

The Sway Coefficients ranged from 0.0042-0.0933 (mean 0.0231, sd 0.0163) The mean of the three tests was calculated and called the Sway Coefficient 1 (SC1) range 0.0062-0.0923, mean 0.0237, sd 0.0157, n=71.

The 'Rivermead Motor Function' and the 'Ten Point ADL' scores at the second assessment are summarised in Table 4.6

TABLE 4.6

Rivermead Motor Function and ADL Scores at the Final Assessment

	n	Range	Mean	s d
Gross Function	73	1-13	8.4	2.8
Leg and Trunk Function	73	0-10	6.9	3.0
Arm Function	73	0-15	6.0	5.5
Total Score	73	2-38	21.5	9.5
ADL score	78	3-10	8.0	2.3
Extended ADL	77	1-22	9.6	6.3

In the study period, between the first and second assessment, 47 (58%) patients had a total of 92 falls. The frequency ranged from 1 to 6 (mean 1.14, standard deviation 1.45). Including both falls in hospital prior to the 1st assessment and falls in the study period, 59 patients (73%) experienced 153 falls (range 1-8, mean 1.89, standard deviation 1.94).

Differences between groups at the final assessment

The Student's t-test indicated a significant difference between left and right-sided hemiplegia (brain stem strokes excluded), $t=6.4$, $p<0.001$. for BC1 values as shown in Table 4.7, but no significant difference in SC1 values ($t=-1.69$ $p>0.5$).

Using the BC2, t-tests revealed no significant differences in the magnitude of asymmetry between right and left-sided strokes ($t=0.61$, $p>0.05$).

There were no significant differences between right and left-sided strokes for the number of falls either in hospital or in the study period, sex, age, length of stay, motor function or either of the ADL measures.

There were no significant differences between men and women for any of the variables. However, the sway coefficient showed a tendency to be higher in women ($t=1.85$, $p=0.07$). See Table 4.8.

Correlations between variables at the final assessment

The relationships between BC2, SC, motor function and ADL scores are given in Table 4.9. Correlations between sway coefficients, falls, motor function and both

TABLE 4.7

Comparison of Variables for Patient with Right and Left-Sided Hemiplegia at the Final Assessment

Variable	Left-Sided Hemiplegia (n=38)			Right-Sided Hemiplegia (n=34)			Comparison	
	mean	sd	range	mean	sd	range	t	p
BC1	0.60	0.11	0.34-0.81	0.42	0.13	0.11-0.64	6.34	<.001
SC1	0.021	0.015	0.007-0.092	0.027	0.016	0.006-0.089	1.69	ns
BC2	0.12	0.09	0.01-0.31	0.10	0.11	0.00-0.39	0.61	ns
Length of Stay	14.5	7.8	2-32	13.7	7.7	2-29	0.47	ns
Falls in Hospital	0.91	1.14	0-4	0.75	1.05	0-3	0.65	ns
Total Falls	2.02	2.04	0-8	1.67	1.84	0-6	0.81	ns

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TABLE 4.7 (Continued)

Comparison of Variables for Patient with Right and Left-Sided Hemiplegia at the Final Assessment.

Variable	Left-Sided Hemiplegia			Right-Sided Hemiplegia			Comparison	
	mean	sd	range	mean	sd	range	t	p
ADL	8.5	2.0	3-10	7.7	2.4	3-10	1.51	ns
Leg and Trunk	7.1	2.8	0-10	6.7	3.2	0-10	0.60	ns
Arm Function	6.1	5.6	0-15	5.9	5.5	0-15	0.17	ns
Gross Function	8.4	2.8	1-11	8.5	3.0	2-13	0.15	ns
Total Motor Function	21.7	9.6	2-37	21.18	9.7	5-38	0.26	ns
Extended ADL	9.3	5.6	1-21	10.3	7.0	1-22	0.69	ns

TABLE 4.8

Comparison of Variables for Men and Women at Final Assessment

Variable	Men n=36			Women n=34			Comparison	
	mean	sd	range	mean	sd	range	t	p
BC1	0.51	0.17	0.11-0.81	0.53	0.11	0.20-0.77	0.48	ns
SC1	0.027	0.019	0.009-0.092	0.020	0.10	0.060-0.047	1.82	0.07
BC2	0.13	0.11	0.00-0.39	0.80	0.07	0.01-0.30	1.77	0.08
Length of Stay	15.4	8.0	2-32	13.3	7.5	2-29	1.27	ns
Falls in Hospital	0.8	1.0	0-4	0.9	1.2	2-29	0.16	ns
Total Falls	2.1	2.0	0-8	1.7	1.9	0-8	0.96	ns

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TABLE 4.8 (Continued)

Comparison of Variables for Men and Women at Final Assessment

Variable	Men n=37			Women n=36			Comparison	
	mean	sd	range	mean	sd	range	t	p
ADL	7.7	2.5	3-10	8.3	2.2	3-10	1.27	ns
Leg and Trunk	6.8	3.2	0-10	7.1	2.7	2-10	0.51	ns
Arm Function	5.9	5.7	0-15	6.1	5.4	0-15	0.17	ns
Gross Function	8.2	2.6	1-12	8.5	3.1	1-13	0.51	ns
Total Motor Function	21.0	10.1	2-37	21.9	9.0	4-38	0.38	ns
Extended ADL	8.3	6.0	1-21	10.9	6.5	1-22	1.86	0.06

TABLE 4.9

The Relationship Between Measures of Weight Distribution (BC2), Motor Function and Activities of Daily Living (ADL) at the Final Assessment

n=73	BC2	Extended ADL	10 Point ADL	Gross Function	Arm Function
Extended ADL	$r_s=-.35$ $p<.001$				
10 Point ADL	$r_s=-.45$ $p<.001$	$r_s=.69$ $p<.001$			
Gross Function	$r_s=-.35$ $p<.001$	$r_s=.58$ $p<.001$	$r_s=.77$ $p<.001$		
Arm Function	$r_s=-.40$ $p<.001$	$r_s=.42$ $p<.001$	$r_s=.42$ $p<.001$	$r_s=.51$ $p<.001$	
Leg Function	$r_s=-.35$ $p<.001$	$r_s=.59$ $p<.001$	$r_s=.60$ $p<.001$	$r_s=.82$ $p<.001$	$r_s=.58$ $p<0.001$

r_s = Spearman Correlation Coefficient
p = probability

measures of ADL were not significant. Age was significantly related to the total motor function score ($r=.188$, $p<0.05$), but not the BC2 or the ADL scores.

Pearson product moment correlations were used to assess the relationships between the BC2 and the SC (at the initial assessment), the number of falls in hospital and in the study period, age and length of admission. (See Table 4.10). The SC correlated significantly with the number of falls and the BC2 with age and length of admission.

Relationships Between the Initial and Final Assessments

Balance coefficients (BC1) and SC values improved significantly in the period between the first and second assessment , BC ($t=7.89$, two-tailed $p<0.01$) SC ($t=6.97$, two-tailed $p<0.01$)

Wilcoxen matched pairs signed ranks test indicated that both motor function and ADL performance had improved significantly by the second assessment (see Table 4.11).

Description of Falls Data.

Of the seventy eight patients completed the Initial Interview, only 27 (35%) had discussed the possibility of a fall at home and 25 (32%) had practised getting up from the floor after a fall. The majority of patients (72, 92%) had means of getting help if they fell at home. Most commonly this was by phone (59, 76%) and/or the help of someone they lived with (55, 70%). Five had alarms and four arranged regular checks by relatives or neighbours.

TABLE 4.10

The Relationships between the Balance Coefficients, Sway Coefficients, Age, Number of Falls in the Study Period and in Hospital and the Length of Hospital Admission.

	BC2	SC1	Age	Falls in Hospital	Falls in Study Period
Age	r=-.30 p<.001 n=71	ns			
Falls in Hospital	ns	ns	ns		
Falls in Study Period	ns	r=.27 p<0.01 n=81	ns	r=.33 p<0.01 n=81	
Length of Hospital Admission	r=.28 p<.01 n=71	ns	ns	ns	ns

ns= Not significant
r= Pearson product moment correlation coefficient
p= probability

TABLE 4.11

Comparison of Motor Function and Scores between the Initial and Final Assessment.

	n	ties	z	2-tailed p
Gross Function	73	12	-6.40	< 0.001
Leg and trunk Function	73	18	-5.66	< 0.001
Arm Function	73	35	-5.21	< 0.001
Total Score	73	3	-6.62	< 0.001
Ten Point ADL	78	12	-6.52	< 0.001

z= Wilcoxen matched pairs signed ranks test.

Only 20 (26%) described being often or constantly frightened of falling, yet 55 (70%) thought that they were more likely to fall after their stroke than before. Thirty-two patients (41%) reported that concerns about falls prevented them from attempting certain activities including, climbing stairs, opening doors, doing things alone, bending over and carrying hot drinks.

Communication problems meant that the details and consequences of only 72 of the 92 falls in the study period were recorded. The time post-stroke ranged from 6-30 weeks (mean 18, sd 6.54). The majority had occurred in the morning or during the day (62, 79%), most frequently in the living room (30, 38%) or the bedroom (21, 27%). Half the patients (51%) claimed to have fallen towards their affected side, the others having fallen backwards (21%), forwards (17%) or to their unaffected side (11%). Only one person reported feeling dizzy at the time of the fall. The commonest explanations were that they either tripped, slipped or 'over balanced'.

Ten patients (14%) were left on the floor for over an hour, most managed to summon help by calling to someone in the house and consequently either got up on their own or with the help of that person. Ten patients suffered either lacerations or fractures and of those six consulted their General Practitioner and four went to Accident and Emergency. Nearly half (35, 49%) reported lasting affects from their experience and these included loss of confidence and (less frequently) pain.

DISCUSSION

Stance Symmetry

Asymmetrical stance is a common feature of the change in standing posture after stroke. In a clinical setting the therapist will make a subjective judgment of the patient's symmetry of weight bearing often concluding that it is abnormal without measuring it. Perhaps it is because this is so obvious that research evidence substantiating clinical observation has only come in recent years. The results of this study confirm the findings of others (Dickstein et al 1984, Bohannon and Larkin 1985, Caldwell et al 1986), that stroke patients stand asymmetrically with an uneven and abnormal distribution of body weight between the affected and unaffected legs. Significant differences were apparent in the weight bearing patterns of patients with left-sided compared with right-sided hemiplegia. There was a tendency for the patients to follow the same pattern and favour their unaffected leg, which confirms clinical observations.

Two studies have calculated the percentage of body-weight on the unaffected leg. Shumway-Cook et al (1988) Mizrahi et al (1989) both estimated that patients carried approximately 70% of their body weight on the unaffected leg. The degree of asymmetry (66%), exhibited in this study was less than that found previously. This difference is probably due to the larger and less selected sample. The magnitude of the weight bearing asymmetry was similar for left and right- sided strokes.

Studies of weight distribution in normal adults (Caldwell et al 1986, Murray and Peterson 1973, Dickstein et al 1984) give some indication of normal ranges but the age groups are not exactly comparable with the sample in this study. From the study of stance symmetry with healthy adults (Chapter 3), of 403 men and women between the ages of 18 and 87, it was calculated that 95% of the normal population would have a balance coefficient of between 0.417 and 0.617. It is therefore possible to identify the number of subjects in the sample who were abnormally weight bearing, 61% had an abnormally large amount of weight on their unaffected leg at the first assessment and 44% at the second. This is less than the 87% found by Dickstein et al (1984) and the 80% found by Caldwell et al (1986). This difference may have occurred because of the small number of stroke patients in their studies (23 and 10 respectively), differences in selection and time post stroke or because the small number of subjects in their control groups gave a distorted normal range. The subjects demonstrated a significant improvement in stance symmetry between the first and second assessment.

Age and sex variability in stance symmetry after stroke has not previously been reported. In the normal population woman are more asymmetrical than men (Chapter 3). This survey indicated that this sex difference disappeared after stroke. Asymmetry was significantly related to age at the initial assessment, as were other measures of severity, the ADL and total motor function scores. It may be that elderly patients recover at a slower rate, perhaps because their pre-stroke level of fitness is not as good.

In this study 5 patients (5.5%) demonstrated abnormal weight bearing favouring their affected side, none of the patients in the three studies mentioned above demonstrated this abnormality. Clinical examination of these patients revealed that they were displaying the 'pusher syndrome' (Davies 1985). These patients constantly push towards their hemiplegic side and actively resist any attempts to move them towards the unaffected side or even the midline. They are thought to have an abnormal perception of the midline which results in them constantly leaning to their affected side, even in sitting.

Sway

The results are in agreement with the findings of studies examining the relationship between sway values (as measured by a force platform) for stroke and non-stroke controls, that stroke patients have significantly higher levels of sway (Seliktar et al 1978, Shumway-Cook et al 1988, Mizrahi et al 1989). Although these previous studies show similar results they have all used very small numbers of strokes and perhaps more importantly set the normal limits with even smaller numbers of controls. It is difficult to compare actual sway values because, as in this study, arbitrary values are used.

Using the normal ranges calculated from Chapter 3, it is possible to identify the number of subjects lying outside the 95% confidence limits. At the first assessment 50% had abnormally high sway levels and at the second assessment 31%. As yet, the recovery of postural sway values after stroke has not been reported, but in this study sway values improved significantly between the first and second assessment.

As with stance symmetry, sex and age differences present in the normal population have not been previously investigated after stroke. In this survey both age and sex differences in sway values were no longer significant. Neither were there any significant differences between left and right-sided strokes.

Motor Function and ADL

The stroke patients in this study represented quite a large range of motor and functional abilities, as can be seen by the ranges of scores on the 'Rivermead Motor Assessment Scale' and the 'Ten Point ADL Scale'. The high scores at the initial assessment are from patients with less severe strokes who made a good recovery in the six weeks before the initial assessment.

Although studies have indicated that motor function and ADL are related (Smith et al 1985, Hamrin et al 1982, Bohannon 1989) they have not investigated the relationship between these variables and weight bearing symmetry. Both motor function and ADL improved significantly between the first and second assessment, which agrees with the tendencies shown by the results of the work referenced above. It is impossible to compare these studies directly as different assessments were used and strength was used as the measure of motor function in the latter two.

The degree of asymmetry was related to motor function and to the level of self-care independence, as measured by an ADL scale. This supports the treatment approaches commonly used by physiotherapists of practising weight transference and encouraging weight bearing through the affected leg. However, although the correlations were significant they did not account for a very high proportion of the variance and so other factors need to be considered, such as sensory deficits. The possibility remains that the significant correlation may reflect a third variable, the severity of the stroke. Sway values were not significantly related to either motor function or ADL performance.

Although physiotherapy and occupational therapy techniques are intended to improve the symmetry of weight bearing, further work is needed to be able to say if they are successful and whether or not the level of independence improves as a consequence.

Falls

In this sample of stroke patients falls were a common occurrence. Nearly three quarters of the subjects experienced at least one fall in the period between admission and the second assessment (approximately six-months post stroke). Although the number of fractures and re-admissions were small, there is a need to look at other consequences, such as delays in discharge and the reduction of independence.

The number of fallers was much higher than the 30% per year that would be expected for a community population of elderly people. This is in agreement with the results of Prudham and Grimely-Evans (1981) who found that elderly people with stroke were more likely to fall than others. It would be expected that the consequences of falls in elderly strokes are more serious because of the multiple problems often present in this patient group, but further investigation with a larger sample may be needed to show this.

The information given retrospectively about the subjects' incidence of falls in the year before their stroke (only 19%) suggests that the sample is not directly comparable with a sample of elderly in the community. Indeed their age range indicates that many would not be classified as elderly. This implies that an incidence of less than 30% per year may be expected for this group and may explain why sex and age differences present in studies of the elderly were not found.

The number of falls in the study period correlated significantly with the sway values at the first assessment. The results suggest that there is a link between falls and sway which was also found in elderly populations (Overstall et al 1977, Lichtenstein et al 1988, Ring et al 1988). Unlike the subjects in these studies, sway values for stroke patients improve as they recover, which may be why the second sway measurement was not related to the number of falls. The number of falls in hospital (before the study period) correlated with the number of falls in the study period, during which the majority of patients were at home. Although correlations were significant they did not account for a large proportion of the variance, which suggests that other factors were involved. Other factors which may be relevant (which were not recorded in this study) are impairments of a perceptual or sensory nature caused by a stroke. Other non-neurological factors may be involved such as pre-existing rheumatological or cardiac disease. It seems unlikely that sway values alone could be used to predict those at risk of falling. Differences in sway values, falls or length of admission were not observed between right and left-sided hemiplegia.

The degree of asymmetry correlated with the length of admission and improved with recovery. As stated earlier asymmetry was relate to other measures of severity such as motor function and activity of daily living performance. This suggests that symmetry of stance is another indication of the severity of the stroke.

No relationship was found between asymmetry of weight-bearing and the number of falls or between the number of falls and length of admission. This implies that it is not just severity of stroke that increases patients risk of falling, as those most severely affected would be likely to have longer stays in hospital and a more asymmetrical posture. This mirrors clinical observation, as those with poor levels of mobility are less likely to fall as they do not attempt tasks or ensure that they have help before they do, whereas patients with better motor function may fall attempting more difficult tasks, such as climbing stairs or walking on uneven ground.

4.5 Summary

A survey of stroke patients was undertaken to examine the recovery of stance symmetry and sway after stroke. The relationships with other variables, motor function, ADL, falls, age and length of hospital admission were examined. Any side of stroke or sex differences were noted.

A consecutive sample of 92 stroke patients underwent 2 assessments, four months apart, at between 2 and 9 months post-stroke.

Significant differences were seen in the weight distribution of right and left sided hemiplegias, which improved over time with recovery. Asymmetry correlated with motor function and ADL. Stance symmetry was significantly related to length of stay and age, but not to falls. No sex differences were apparent.

A significant relationship was found between sway values and the number of falls. Sway values also improved over time with recovery.

This suggests that stance symmetry may be yet another index of stroke severity, but that sway and falls frequency are not. However, an important relationship between sway and falls was revealed.

CHAPTER 5

SINGLE BLIND RANDOMISED CONTROLLED TRIAL OF VISUAL FEEDBACK

5.1 Aims

To assess the effectiveness of visual feedback as a method of improving stance symmetry and functional ability after stroke.

5.2 Methods

Subjects

Stroke patients were identified from the stroke register and patients from the Stoke Unit and Health Care of the Elderly wards at Sherwood Hospital were included.

Exclusion criteria;

Inability to stand for one minute
Severe receptive aphasia and/or a history of dementia.
Blindness or severe unilateral neglect.
Normal stance symmetry (within 2 standard deviations, allowing for age and sex).

Procedure

In addition to demographic details a record was kept of the past medical and social history, the date and side of the stroke ,and the date of admission. Any speech, visual, perceptual or continence problems were noted as in Chapter 4.

Details of the assessments used are given in Chapter 2. These include;

1. An assessment of pre-stroke mobility and balance function- the Initial Interview
2. A measure of stance symmetry and sway with the Nottingham Balance Platform (see Chapter 2).
3. The Rivermead Motor Function Assessment.
4. Two measures of ADL performance; The Nottingham 10 Point ADL Scale and the Extended ADL Scale.

The assessment with the Nottingham Balance Platform (NBP) (Chapter 4), was undertaken without any postural correction. At the first and last session the mean of three measures of stance symmetry and sway were used. Single measurements were also made at the start and end of each treatment session. The patient did not receive any postural feedback during the tests, nor were they made aware of the results.

Before treatment began, fully informed consent was obtained and ward accident reports were examined for any record of a fall. Patients were also assessed as for conventional Bobath based therapy (Davies 1985). This is not a standardised assessment, but it gives the therapist a subjective impression of the patients muscle tone and posture as well as motor impairment.

Subjects were randomly allocated to either the feedback treatment or control group, using random number tables

(Bourke et al 1985). The results were placed in sealed envolopes and numbered in order. Restricted randomisation was used so that out of every block of ten consecutive patients 5 were randomly allocated to the treatment group A and 5 to the control group B (Bourke et al 1985).

Group A received training from a physiotherapist using the feedback program of the (NBP). Treatment was given three times a week for four weeks. Group B received training from a physiotherapist, but using the placebo program. This was of the same frequency and duration as Group A. (The study plan is outlined in Figure 5.1). Assessments were undertaken at the following intervals;

0 weeks;
The Initial Interview
Measurements with the NBP
The Rivermead Motor Function Assessment.
The Nottingham 10 point ADL Scale

4 weeks (patients were assessed by the independent assessor, who was blind to the group allocation);
Measurements with the NBP
The Rivermead Motor Function Assessment.
The Nottingham 10 point ADL Scale
The Extended ADL Scale (when appropriate)

12 weeks (at this stage the majority of the subjects had been discharged from hospital and so the independent assessor visited them at home);
The Rivermead Motor Function Assessment.
The Nottingham 10 point ADL Scale
The Extended ADL Scale

FIGURE 5.1

Plan of Investigation

Patients identified from stroke register

↓

Inclusion Criteria

↓

Randomisation

Treatment group (A)	Control group (B)
↓	↓
1st assessment (week 0)	1st assessment (week 0)
↓	↓
2nd assessment (week 4)	2nd assessment (week 4)
↓	↓
3rd assessment (week 12)	3rd assessment (week 12)

2nd and 3rd assessments carried out by an independent assessor

DATA ANALYSIS

As in Chapter 3, it was necessary to calculate the Balance Coefficient 2 to investigate the relationships between variables. Pearson product moment correlations were used for parametric data and Spearman Correlations for non-parametric data.

To identify differences between treatment and control groups, t-tests are used for parametric data and Mann-Whitney 'U' tests for non-parametric data.

To estimate changes over time, paired t-tests are used for interval data and Wilcoxen matched pairs signed ranks test for ordinal data.

Physiotherapy Treatment Protocol

Patients in Group A and B received twelve treatment sessions, over four weeks, each of approximately one hours duration. This was dependent on the patients tolerance and medical status. The treatment was divided into three stages. Both the treatment and control group underwent the first and third stages, only the second stage differed and that is described separately for each group.

Stage 1 Preparation for standing.

This varies with the patients' degree of recovery and motor ability and allowances were made for the individual differences in postural tone and motor control produced by the stroke. However, the majority of patients adopt a starting position of sitting on a 'perching stool'(a 4 legged stool with the seat slopping down from the back to the front at approximately 30 degrees) with their feet on the ground. The sitting posture is observed and the postural tone assessed.

Trunk mobilisations are carried out in this position with the aim of normalizing tone and facilitating normal movement (Davies 1990). Once the patient appears to be sitting with weight bearing symmetry and has no obvious postural abnormalities caused by an imbalance of tone on either side of their body the patient is asked to stand with one foot on each of the load cells. The position of the feet is carefully checked as internal rotation of the ankle may affect the base of support and in turn increase the amount of postural sway (Okubo et al 1979). Some patients need help to get into standing, for example, by pressing on the patient's knee to increase weight bearing on the affected foot while encouraging patients to bring their trunk forward as they stand. The therapist may encourage or assist the patient to stretch their unaffected arm above the shoulder to prevent compensation on the unaffected side of the trunk.

Stage 2 Treatment with visual feedback (Treatment Group)
Feedback displaying weight distribution and weight shift activity are continously presented to the patient in the form of two vertical red columns. Each column moves upwards with an increase in weight on the corresponding foot. When the columns are within 5% of each other a red triangle appears confirming that stance symmetry has been achieved. The importance of visual input in maintaining a stable standing posture has been shown in healthy adults (Ring et al 1989, Weissman & Dzendololet 1972, Dornan 1978) and stroke patients (Ashburn 1981).

The patients practised a number of activities on the NBP with the constant supervision of at least one physiotherapist. These included;

Sitting to standing
The NBP provides constant visual feedback to the patient throughout the activity. This is useful as it helps the patient divide their weight symmetrically from the moment they take weight through their feet until they are fully upright. This preventing a 'trick' movement technique which patients frequently use of propelling themselves with the unaffected leg to achieve standing (encouraging the extensor pattern in the affected side Davies 1990) and then adjusting their weight bearing symmetry.

Standing, balancing the columns
Once upright standing has been achieved the patient can use the visual feedback to practise symmetrical weight bearing by altering their posture until the columns are level (within 5%). The patients are then encouraged to mentally register the feeling of symmetry and to try to

remember it. The visual feedback is only given intermittently to assess patient's ability to maintain stance symmetry without the feedback signal.

Targeting practice

The columns have horizontal lines of different lengths drawn along them. The patients are asked to use the lines as a target and adjust their weight distribution until the target is reached. The therapist monitors the activity to prevent compensatory postures being used to achieve the same result.

Reaching

The tasks gradually become more dynamic. The next task the patients practise is to reach to the affected side (usually with the unaffected arm as few have enough recovery at an early stage in their affected arm) and then return to symmetrical weight bearing. There are numerous variations of this task and goal orientated activities are included, such as reaching across to lift an object.

Stride standing and stepping.

The tasks can then be incorporated into activities that constitute part of the gait pattern such as weight adjustments in stride standing, preparing to take a step and finally stepping forwards or occasionally backwards.

Co-ordination Practice

Difficult tasks requiring a high level of co-ordination were practised such as bending the affected leg while weight-bearing through it.

Stage 2 Placebo Program (Control Group)

The 'Placebo Program' is used which displays two static yellow columns each half filled with red. The display does not move when there is a change in weight distribution. The patients practise similar activities to the treatment group, but without the visual feedback. Again, they had the constant supervision and feedback of at least one physiotherapist. Therefore the targeting and balancing the columns exercises are performed using the subjective impressions of the patient and therapist.

Stage 3 Practising New Skills

It is important that the patient can transfer the skills learned on the NBP to more functional activities. After the feedback or placebo treatment the physiotherapist works with the patient to incorporate the new skills into goal orientated tasks, such as walking to a chair or climbing stairs.

FIGURE 5.2

Preparation for Standing

FIGURE 5.3
Sitting to Standing (1)

FIGURE 5.4

Sitting to Standing (2)

FIGURE 5.5

Standing, Balancing the Columns

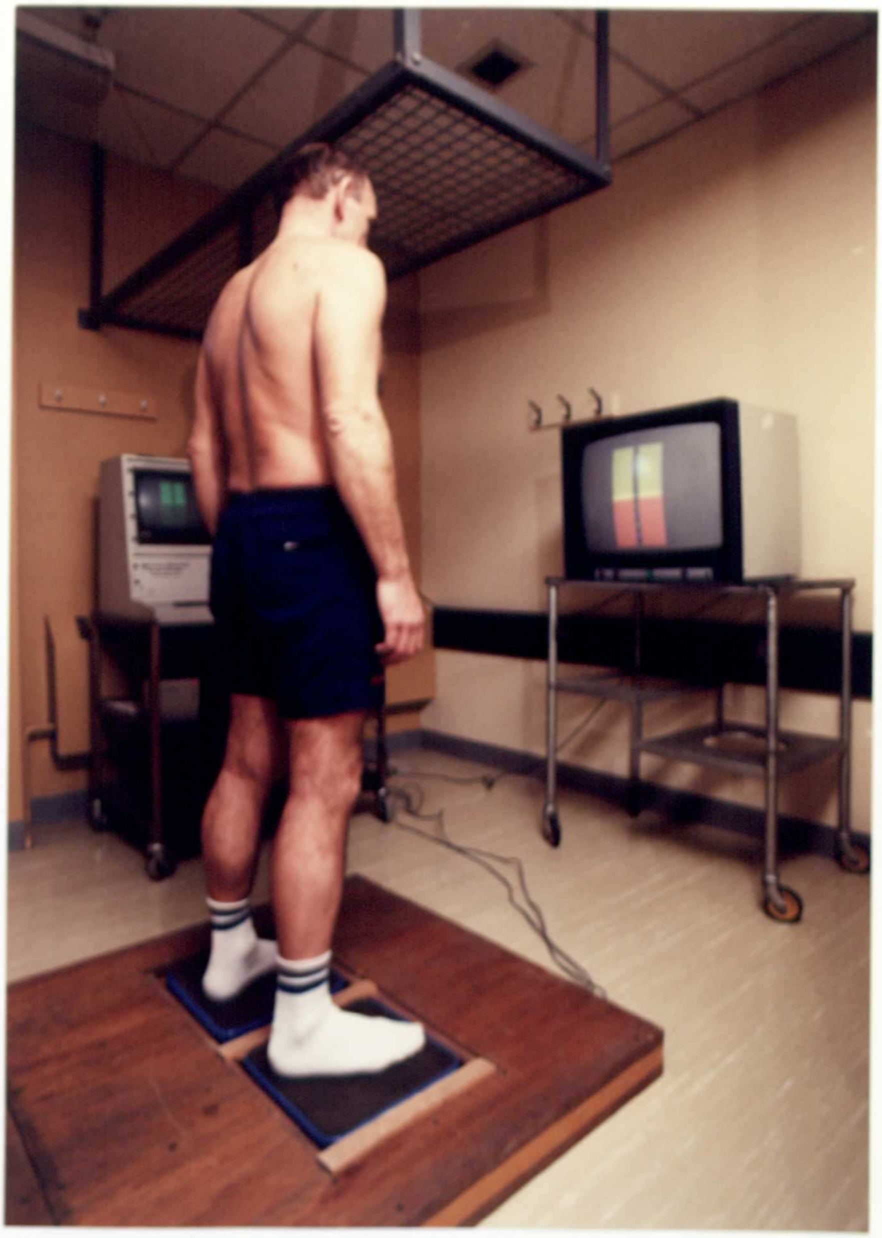

FIGURE 5.6

Targeting Practice

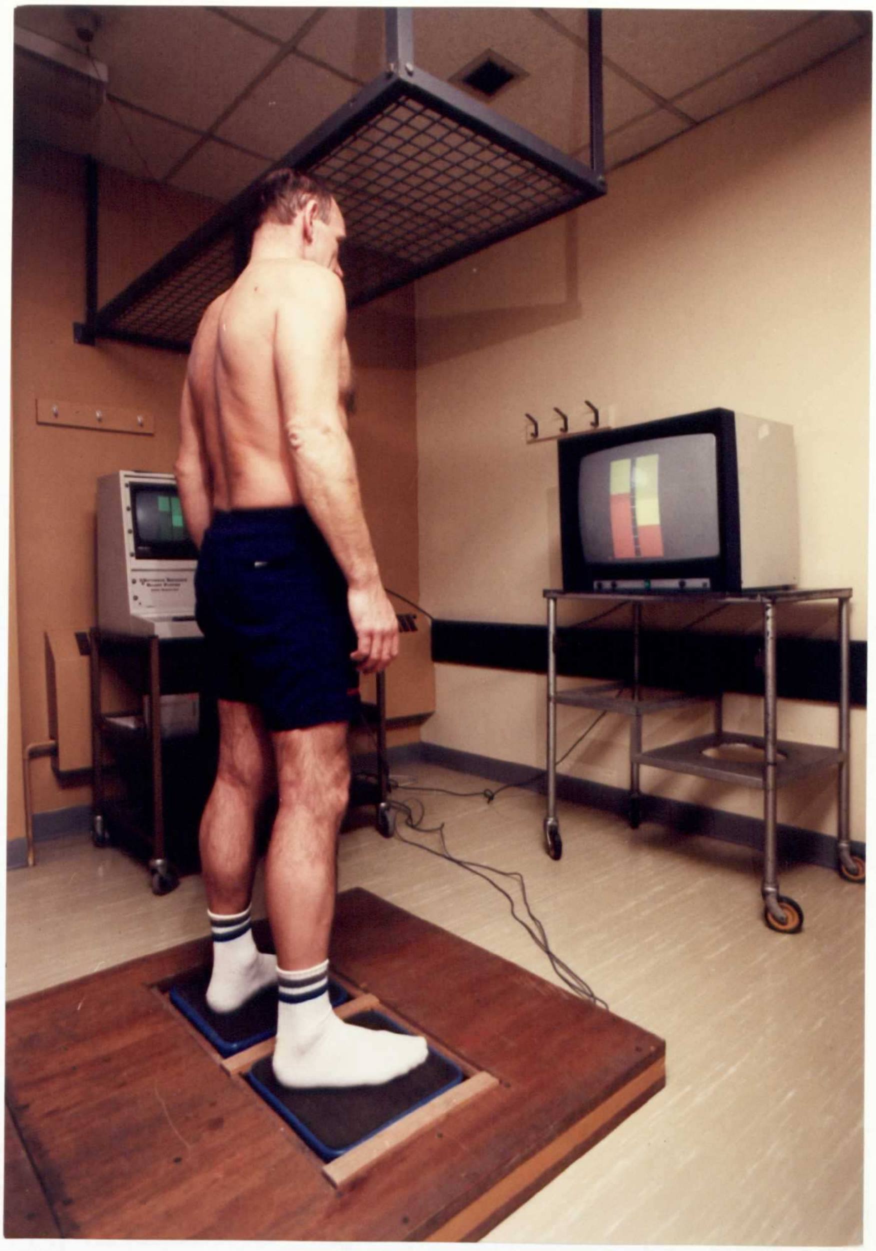

FIGURE 5.7

Reaching

FIGURE 5.8

Stride Standing and Stepping.

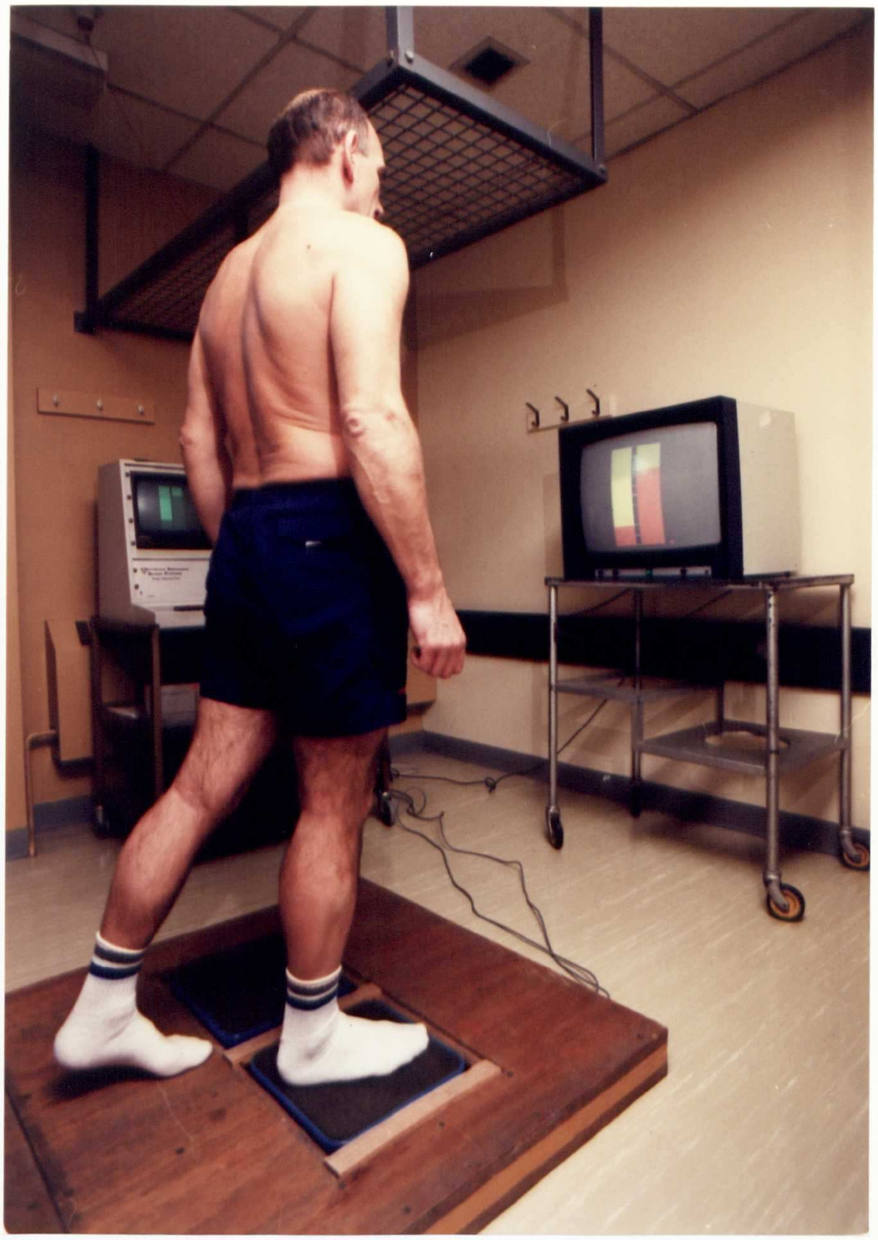

FIGURE 5.9

Placebo Program (Control Group)

Results

Description of study group

Twenty-six patients were recruited (20 men and 6 women), mean age 65.7 years (range 41-85, sd 11.4). Twelve had a right-side hemiplegia and 14 had a left-sided hemiplegia. The mean number of weeks since the onset of their stroke was 19.5 (range 4-63, sd 17.4). Two patients dropped out, one in Group A during the treatment stage due to medical complications and one in Group B, sustained a fractured hip during the follow-up period.

Six patients (23%) had some degree of expressive aphasia and 9 (35%) were dysarthric. Ten (38%) patients exhibited signs of perceptual deficits, one had severe problems.

Their length of stay in hospital ranged from 6-31 weeks, (mean 15.8, sd 6.4). Fourteen received their treatment as in-patients, eight as out-patients and four as both in and out-patients. Most of the patients were discharged to their own home, one went to stay temporarily with his daughter.

Two patients reported falls in the year prior to their stroke and one other complained of balance problems. Two of these used a walking stick as an aid to their pre-stroke mobility.

Initial Assessment

The range, mean and standard deviation (sd) of all the variables are given separately for both the treatment (group A) and control (group B) patients, in Table 5.1. The groups were compared with Mann Whitney U for non-parametric data, χ^2 for nominal data and t-tests for parametric data. There were no significant differences between the groups before the study.

There were no significant differences in the sample between men and women for any of the variables, nor were there any age related differences. The only side of stroke differences were the balance coefficient values, as in Chapter 4, (see Table 5.2). There were no differences in magnitude between right and left-sided strokes.

The sample demonstrated similar characteristics to the sample of patients in Chapter 4, Spearman Correlations demonstrated significant associations between motor function and ADL scores, ($r_s=0.71$, $p<0.001$) and Pearson product moment correlations demonstrated significant associations between the BC1 and motor ($r=-0.56$ $p<0.01$)and ADL function scores ($r=-.50$ $p<0.05$).

2nd Assessment

Twenty-five patients completed this assessment, twelve in group A and 13 in group B. Table 5.3 demonstrates the

TABLE 5.1

Comparison of Treatment Group (A) and Control Group (B) at the 1st Assessment.

n=26

		Group A n=13	Group B n=13	Difference
Sex	Men	10	10	ns
	Women	3	3	
Side of Stroke	Left	9	5	ns
	Right	4	8	
Age	range	41-85	50-83	
	mean	60.8	67.9	ns
	sd	12.3	9.2	
Length of Admission (weeks)	range	6-31	8-22	
	mean	15.9	15.7	ns
	sd	6.9	5.4	
Time Post Stroke (weeks)	range	4-48	4-63	
	mean	20.1	18.8	ns
	sd	15.8	19.3	
Gross Function	range	3-9	2-10	
	mean	5.7	5.2	ns
	sd	1.9	2.3	
Leg and Trunk	range	2-8	2-9	
	mean	4.7	5.0	ns
	sd	1.9	2.7	
Total Motor Function	range	5-15	4-19	
	mean	10.4	10.2	ns
	sd	3.5	4.1	
10 Point ADL	range	3-9	3-9	
	mean	5.2	6.5	ns
	sd	2.1	2.3	
BC2	range	0.099-0.284	0.071-0.254	
	mean	0.168	0.142	ns
	sd	0.065	0.054	
SC	range	0.0154-0.0555	0.0127-0.1132	
	mean	0.0310	0.0494	ns
	sd	0.0124	0.0364	

ns= not significant

TABLE 5.2

Difference in Balance Coefficient (1st Assessment) Values for Right and Left-Sided Hemiplegia for Treatment and Control Groups

Group A

Side of Hemi-Plegia	n	Mean	sd	t	p
Right	4	0.704	0.030		
				6.1	<0.001
Left	9	0.348	0.021		

Group B

Right	8	0.636	0.051		
				6.1	<0.001
Left	5	0.369	0.091		

TABLE 5.3

Comparison of Treatment Group (A) and Control Group (B) at the 2nd Assessment.

n=25

		Group A n=12	Group B n=13	Significance of Difference	
Gross Function	range	7-11	3-11		
	mean	9.7	6.9	U=20.5	p<0.001
	sd	1.2	2.2		
Leg and Trunk	range	5-10	2-10		
	mean	7.4	5.9	U=47.0	ns
	sd	2.0	2.4		
Total Motor Function	range	13-21	6-21		
	mean	17.0	12.7	U=32.0	p<0.05
	sd	2.9	4.5		
10 Point ADL	range	8-10	4-10		
	mean	9.0	7.8	U=42.0	p<0.05
	sd	0.8	2.0		
BC2	range	0.006-0.101	0.013-0.147		
	mean	0.039	0.055	t=2.6	p<0.05
	sd	0.028	0.044		
SC	range	0.0110-0.0380	0.0067-0.0662		
	mean	0.0193	0.0288	t=1.9	p=0.06
	sd	0.0078	0.0163		

differences between groups,(again Mann Whitney U was used for non-parametric data and t-tests for parametric data). The results demonstate significant improvements in motor function and ADL performance. The difference for sway values indicates a tendency for improvemnt in the treatment group, but does not reach a significant level.

3rd Assessment

Data from 24 patients was available, 12 from each group. Table 5.4 demonstrates no significant differences between the groups at this stage.

Differences between Assessments

Table 5.5 gives the differences between the 1st and 2nd assessments for the BC1 and SC, using paired t-tests. This shows significant improvements in both groups.Table 5.6 compares non-parametric data at the 1st, 2nd and 3rd assessments using Wilcoxen matched pairs signed ranks test. This demonstrates a significant improvement between the 1st and 2nd, between the 1st and 3rd but not between the 2nd and 3rd.

The before and after treatment effects on the BC1 at each session were compared using t-tests. There were no significant differences, but the treatment group showed a tendency to improved symmetry in the first few treatments (t=2.0, p=0.06), but not after the first six treatments. The SC was examined in the same way and the treatment group showed a tendency to increased sway values after intervention which reached statistical significance at a number of sessions (1,2,8,11,12), but did not follow the same pattern as the BC1.

TABLE 5.4

Comparison of Treatment Group (A) and Control Group (B) at the 3rd Assessment.

n=24

		Group A n=12	Group B n=12	Difference
Gross	range	5-11	2-11	
Function	mean	8.5	8.5	ns
	sd	2.0	2.6	
Leg and	range	1-10	4-10	
Trunk	mean	5.3	7.1	ns
	sd	3.2	2.6	
Total	range	6-21	7-21	
Motor	mean	13.8	15.5	ns
Function	sd	4.4	4.7	
10 Point	range	5-10	2-10	
ADL	mean	8.3	8.4	ns
	sd	1.4	2.3	
Extended	range	1-17	2-19	
ADL	mean	7.9	9.1	ns
	sd	5.3	5.5	

TABLE 5.5

Changes in Stance Symmetry and Sway With Treatment.

Group A n=12

	mean	sd	t	p
BC2 1st Assessment	0.173	0.065	9.78	<0.001
BC2 2nd Assessment	0.039	0.028		
SC 1st Assessment	0.0263	0.0098	2.76	<0.05
SC 2nd Assessment	0.0193	0.0078		

Group B n=13

	mean	sd	t	p
BC2 1st Assessment	0.141	0.054	7.90	<0.001
BC2 2nd Assessment	0.054	0.044		
SC 1st Assessment	0.0494	0.0364	2.79	<0.05
SC 2nd Assessment	0.0288	0.0163		

TABLE 5.6

Comparison of Functional Variables at Each Assessment

Group A

Variable	assessment	n	-ranks	+ranks	ties	z	p
Gross	1-2	12	0	12	0	-3.06	<0.01
Function	1-3	12	2	10	0	-2.67	<0.01
	2-3	12	7	4	1	-1.38	ns
Leg	1-2	12	0	12	0	-3.06	<0.01
and	1-3	12	6	6	0	-0.71	ns
Trunk	2-3	12	8	0	4	-1.81	ns
Total	1-2	12	0	12	0	-3.06	<0.01
Motor	1-3	12	4	8	0	-2.40	<0.05
Function	2-3	12	8	3	1	-1.80	ns
10	1-2	12	0	12	0	-3.05	<0.01
Point	1-3	12	0	12	0	-3.06	<0.01
ADL	2-3	12	6	2	4	-1.82	ns

Group B

Variable	assessment	n	-ranks	+ranks	ties	z	p
Gross	1-2	13	3	9	1	-2.47	<0.05
Function	1-3	12	1	11	0	-2.98	<0.01
	2-3	12	1	8	3	-2.03	ns
Leg	1-2	13	1	9	0	-2.65	<0.01
and	1-3	12	2	6	4	-0.71	ns
Trunk	2-3	12	8	0	4	-1.81	ns
Total	1-2	13	0	9	4	-2.66	<0.01
Motor	1-3	12	0	10	2	-2.80	<0.01
Function	2-3	12	1	7	4	-2.31	<0.05
10	1-2	13	0	9	4	-2.66	<0.01
Point	1-3	12	1	9	2	-2.56	<0.01
ADL	2-3	12	4	5	3	-0.82	ns

Multivariate analysis of variance was used to compare the before and after treatment BC1 and SC values at each individual treatment between groups A and B. The treatment group demonstrated a significant improvement in BC1 values ($F_{62,271}$ 8.63, $p<0.01$). Sway values demonstrated a tendency to increase in the treatment group ($F_{563,910}$ 3.87, $p=0.061$).

Discussion

As reviewed in the Introduction (Chapter 1), research studies from North America, utilizing postural feedback devices have demonstrated improvements in standing posture (Wannstedt and Herman 1978, Shumway-Cook et al 1988, Winstein et al 1989). Only one study examined the transfer of training to gait variables (Winstein et al 1989), and concluded that there was no automatic carry over. However, single case studies using the NBP (De Weerdt 1989) with patients late after stroke, demonstrated some improvement in weight transference during the gait cycle, but failed to show any improvement in motor function scores.

In this study the treatment group demonstrated a significantly better performance when compared with controls for stance symmetry and for functional performance (Ten point ADL and Gross Function Section of the motor assessment), sway values showed a tendency to greater improvent ($p=0.06$). The improvement in stance symmetry is consistant with the earlier studies discussed above, but the ability to transfer these skills to functional tasks is an interesting development. This effect is important as it would be pointless for the patient to learn new skills on the balance platform if they were unable to use them afterwards. It may have occurred because the feedback training was not done in isolation, but as part of a therapy treatment, which was orientated to gross motor skills. The ability to transfer weight, as learned on the NBP, was part of a functional skill such as, sitting to standing, reaching and stepping. This was immediately practised without feedback as part of a normal goal -orientated movement.

Improvements in the postural variables of stance symmetry and sway were seen for both treatment and control groups. This may have occurred because the patients were receiving more therapy, as all the treatments were done in addition to the established rehabilitation routines. This confirms the results of existing work, that the amount of therapy is important in achieving functional gains (Smith et al 1981, Stevens et al 1984). It also demonstrates the importance of including placebo treatment of the same duration for control groups. It is clearly not enough to have a 'no treatment' group, when the experimental group are receiving extra treatment of whatever type. This was omitted in the studies by Wannstedt and Herman (1978), Shumway-Cook et al (1988) and Winstein et al (1989).

The observation that functional ability improved , but specific leg and trunk motor skills did not supports the model of the mode of action of physiotherapy, as outlined in the Introduction. It suggests that physiotherapy may provide little more than an adaptation to impairment by encouraging motor learning and that accurate feedback enhances this. There is a need for further work examining physiotherapy using this model, using specific feedback and considering the duration and timing of therapy.

This has important implications for the concepts presently used, especially Bobath, as it would indicate a shift in the emphasis of treatment from rather passive abstract movements to goal-orientated functional tasks. If the primary aim is to enable the patient to be independent in self-care activities, it would seem reasonable to concentrate on the retraining of functional tasks. An added advantage would be that the patient would be able to understand the goals of treatment and be able to measure their own success in achieving them. Patients in the experimental group of this trial commented that they enjoyed the NBP treatment for that reason, they knew exactly what they were required to achieve and could judge the results for themselves. Knowledge of the results of their efforts appeared to improve motivation.

The NBP has the advantage of also providing the therapist with accurate feedback. This aspect of feedback has not been examined, but may be important as it enables the therapist to encourage the patients towards the limits of their ability. As with any treatment technique, there are limitations to the application of visual feedback with the NBP. The most obvious being the cost of the equipment and the space it occupies. Therapeutically, the major limiting factor is the static nature of the measuring platforms and future developments must look at methods of providing feedback during walking. Another consideration is that in its present form, the patient needs constant supervision by a physiotherapist to prevent the use of abnormal postures to produce symmetrical weight distribution. This does not cut down on the input of staff, but patients may need fewer treatment sessions to achieve the same results.

Multivariate analysis indicated a tendency for treatment patients to differ from controls in that their sway values increased after individual treatment sessions, although they decreased over the treatment period. In the light of the relationship between sway values and falls shown in Chapter 4, this may be a disadvantage of using this system. However the small number of patients in this study prevents the analysis of this relationship and a much larger trial is indicated. The increase in sway values had disappeared by the next treatment and may be a sign of treatment fatigue. As a precaution when using NBP feedback, patients could be advised to rest for an hour after treatment. Clinically, it is normal practice to allow the patients a rest period after therapy and it would be interesting to assess the patients after this period.

The relationship between sway and physiological efficiency has not been examined, even in healthy adults. Yet, it is possible to suggest that sway values may have increased because the physiological cost of the treatment was higher. The patient and therapist had accurate feedback of the results and therefore could safely estimate the threshold of the patient's abilities and work closer to those limits. Another explanation is that stance asymmetry is an adaptive change that increases the patients postural stability and because the treatment group demonstrated a greater increase in symmetry, it compromised their stability.

Some of the difficulties which were expected did not materialise, both staff and patients enjoyed the feedback and found it easy to use. Even elderly patients were not frightened by the exposure to new, 'high-tech' equipment. Communication impairments did not inhibit the use of the NBP, surprisingly, many patients with quite severe communication problems found the visual information easy to understand and grasped the concept of weight transference more effectively than with conventional treatment.

In conclusion, although all of the studies using postural feedback can be criticised for having small groups of specially selected and ill defined patient groups (including this one), the overall tendency shown seems to support the further use of feedback techniques to improve standing posture after stroke. Especially in the light of the paucity of research evidence to support other treatment regimens. Larger and or more tightly controlled studies in this area are needed. If this approach to treatment is adopted by more physiotherapy departments a multi-centre collaborative study is more feasible.

Summary

At the start of treatment there were no significant differences between the groups. Performance was significantly better for the treatment group than controls for stance symmetry and ADL and motor function after treatment, but not at the final assessment. There were and no sex or side of stroke differences.

The results indicate that feedback training incorporated into functional physiotherapy treatment can improve stance symmetry. Transfer of training was indicated by improvements in ADL and gross motor function. Although this improvement is maintained, it does not automatically continue after treatment.

CHAPTER 6
DISCUSSION

The relevance of the results to existing work has been discussed at the end of each chapter, as have the problems in the design and running of the study. This chapter will address the results in a wider context, examining the implications for clinical practice, further research and the theoretical model of physiotherapy for stroke.

Implications of findings and suggestions for further research.

6.1 Sway and stance symmetry

In the normal adult an upright posture, counteracting the effects of gravity, is achieved by using visual, vestibular or proprioceptive inputs. The rank order of these systems is changeable and dependent on its availability (Droulez et al 1985), but proprioceptive information is the first line of defence after an unexpected perturbation (Nashner 1977). If one of these inputs is reduced or altered the normal adult can compensate and still remain upright. However, if one system is damaged and then another altered the task becomes more difficult and the person may fall. This is the basis of the Romberg test (Romberg 1851, Njokiktjien and de Rijke 1972) and has been recognised clinically since the last century.

The process of ageing may bring about not only a deterioration in any of the three systems, but also a change in the hierarchy of postural control. There is some debate but it appears that the elderly become more dependent on visual input in quiet standing (Pyykko et al 1990) and proprioceptive input after a perturbation is delayed (Stelmach and Worringham 1985, Woolacott et al 1986). The reliance on visual clues further delays the response to displacement and increases susceptibility to falls, which more commonly occur during movement (Pyykko et al 1990).

Postural sway provides an accurate measure of the integrity of the system (Jansen et al 1990). Higher sway values have been noted in those presenting with vestibular, visual and proprioceptive impairment (Bles et al 1977, Dichgans et al 1976, Hadj-Dijilani 1986, de Jong 1981, McGee 1986). Sway values have also been noted to increase with ageing, without any obvious disease and this has been linked to the risk of falling (Sheldon 1963, Overstall et al 1977, Brockelhurst et al 1982, Lichtenstein et al 1988, Ring et al 1988, Fernie et al 1982). After further investigation those with abnormally high sway values are also more likely to show deterioration in temporal measures of gait and functional balance scores (Imms and Edholm 1981, Lichtenstein et al 1990).

Stroke patients can experience sensory and motor impairment and changes in their integration. Thus, not surprisingly, sway values have been found to increase after stroke (Seliktar et al 1978, Shumway-Cook et al

1988, Mizrahi et al 1989). In this study the increase was associated with an increased risk of falls, which has not been previously investigated. From this background it would appear that sway values, although limited by the more static nature of the test, provide an accurate and sensitive measure of sensory-motor integration and postural control.

No association was found in this study between sway values and motor and ADL function, yet Dettman (et al 1987) noted associations with gait variables, such as walking speed and stride length. At first this appears to be a contradictory result, but is more likely to be due to the insensitivities of the functional scales. Both the scales consisted of gross functions, many of which were performed in sitting. For example, ADL function was measured with a 10 point scale and at the first assessment the majority of patients could only manage very basic skills, such as eating, transferring from the bed to the chair and walking a short distance in a ward setting. The sway values provide more sensitive measures of dynamic postural control, but ideally a similar measure made during the gait cycle would give more information.

The effects of training on sway values after stroke are not clear. Previous work has shown that specific sway feedback can reduce sway values (Shumway Cook et al 1988, Hocherman et al 1984), but the effects of strength training have not been investigated. In this study, stroke patients showed an overall improvement in postural control allied to recovery and in the treatment group sway values improved significantly between the start and end of treatment. Yet, examining pre and post treatment scores at individual treatment sessions it would appear that sway values were increased after each session.

A number of factors may be responsible for this and further investigation would be needed to clarify the situation. It could be argued that it is the effect of fatigue, but then it would be expected in both treatment and control groups, unless the feedback helped the therapist to push the patient to the threshold of their abilities

Another explanation is that the treatment group increased their stance symmetry to a greater degree, which compromised their postural stability. Abnormal stance symmetry may be a compensatory change, counteracting the lack of proprioceptive input from the affected leg. Again, it is difficult to assess this relationship as a valid and reliable scale of sensory and proprioceptive impairment has not been developed. From the gross sensory assessment made in this study it is possible to say that this group did exhibit sensory impairment, but the measure is not sensitive enough to be able to examine correlations.

6.2 **Falls**

The majority of patients in this study experienced one or more falls in the first six months after their stroke. This has not been previously reported and so it is impossible to compare this result directly with other work, but a number of studies of the elderly have compared the incidence of falls after stroke with other community (Wild et al 1980, Prudham and Evans 1981) or hospital populations (Diller and Weinberg 1970) and discovered a higher rate in both settings.

Relatively few of the falls recorded (in this study) resulted in fractures, but it is difficult to accurately assess any associated loss of function as the proportion of non-fallers is so small. This also hinders comparisons of age, sex, pre-admission mobility and recent falls history, all of which have been found to be significant in predicting falls in non-stroke elderly fallers (Wickham et al 1989, Mossey 1985, Prudham and Evans 1981, Tinetti et al 1988, Tinetti et al 1986). The only other positive association found in this study was that those who fell in hospital were more likely to fall at home.

The effect of the stroke may negate these demographic trends, but it would need a much larger number of subjects to be able to draw this conclusion. Many of the falls occurred during simple day-to-day activities, such as using the toilet and the majority of patients required help to get up again. It must be a frightening experience, especially when it happens at home, alone or with an elderly carer. Loss of confidence is recognised clinically as a cause of loss of function, but has not been formally examined.

More work is needed to ascertain the frequency and consequences of falls after stroke. It could lead to the development of a rating system for the individual to attempt to calculate and minimalize the risk of falling. Research with elderly non-stroke populations have indicated that sensory impairment, either visual or proprioceptive increases the risk of falling (Tobis et al 1985, Tobis et al 1990), as does an increase in sway values (Fernie et al 1982, Overstall et al 1977, Lichtenstein et al 1988). The lack of valid and reliable assessments of sensory impairment after stroke have prevented this relationship being examined in this population. The results of this study would suggest a link between the frequncy of falls and increased sway values, but not functional abilities. This may be because sway values gives a much more sensitive measure of sensory-motor integration.

Other factors that have been found to be important in the elderly (non-stroke) are age, sex, medication and falls history. The influence of medication was not examined in this study, but hypnotics and antidepressants have found to increase the risk of falling in the elderly (Blake et al 1988, Tinetti et al 1988). This has not been studied after stroke, despite the high proportion of depressed patients (approximately one third, Robinson and Price 1982, Wade et al 1985).

The role of environmental factors is not clear cut, although work with the elderly has indicated that unsuitable footwear (Gabell et al 1989, Kinsman 1983) and irregular ground surfaces (Waller 1978a) do have an influence, it appears to be the persons perception of the environmental hazard that leads to accidents. Archea (1985) defined this as ' architecturally triggered human error' and it has been demonstrated on stairs (Archea 1985) and escalators (Cohn and Lasley 1985). Visual impairment can enhance these effects. This highlights other areas that may have an influence on falls after stroke, perceptual impairment and visual inattention. Although an association between perceptual impairment and falls was not found in this study, the measure of perceptual impairment was a very crude, three point scale.

Clinically, more attention could be paid to alleviating the effects of the seemingly inevitable. Therapists already practice standing up after a fall with some patients, but must go further and together with the main carer (if there is one) plan for a fall; decide how the patient will attract help, who will help them get up and identify a member of staff to check mobility and function afterwards, even if it is not serious enough to warrant re-admission.

From this study and from existing work with the elderly it is possible to derive a check list of factors that would constitute the basis of a falls risk calculation. Namely;

Age
Sex
Pre-stroke mobility and falls history
Falls while in hospital
Medication
Visual impairment
Sensory impairment
Environmental factors
Sway level
Perceptual problems

A large prospective survey of consecutive stroke admissions would be needed to examine this theory. Although it is impossible to pre-judge the results, thorough assessment of the risk factors and causes of falls in the elderly have been shown to reduce disability and costs (Rubenstein et al 1990). The same may be true for stroke, and considering the higher falls rate, would have a larger impact.

6.3 Physiotherapy

As stated in the introduction, much physiotherapy after stroke is aimed at re-educating abnormal weight-bearing symmetry. One of the first stages is to re-educate standing by helping the patient onto their feet. This is achieved with the help of up to three therapists, the use of walking aids or occasionally a tilt table (the patient is strapped on to a table and gradually stood upright). Once the patient is standing the therapist facilitates symmetrical weight bearing by encouraging weight shift on to the affected leg (Lane 1978, Bobath

1978) , which in turn is thought to be transferred to functional movement (Daleiden 1990). The underlying rationale is that early weight bearing speeds functional recovery and reduces abnormal muscle tone (Ashburn and Lynch 1988), but this has not been tested.

Bobath (1978) recommends that good standing balance and stance symmetry must be achieved before gait training commences. Stockmeyer (1967) in her interpretation of the Rood approach, suggests that weight shifting activity improves the base of stability, essential for the development of mobility. However, although this seems a logical process, as it would be impossible to take a step with the unaffected leg if the affected one was not capable of weight bearing, it is based on a number of questionable assumptions.

Firstly, that patients stood symmetrically prior to their stroke, but to date little data was available on normal values and age and sex trends had not been examined. The normal variation demonstrated in this study will help to set realistic goals as older people (especially women) demonstrate much wider ranges of stance asymmetry, without obvious functional impairment.

Which leads to the next assumption, that regaining symmetry automatically improves function. Stance symmetry improved between 2 and 6 months after the stroke, as did motor function and ADL performance. This could be seen to confirm the basic assumption that standing symmetry brings with it improvements in function, especially as in this study, asymmetry also had a significant association with poor function. Yet, this is not necessarily a causal relationship and just as likely to be the result of a third factor, the severity of the lesion. This would also explain the results of

Hamrin (et al 1982) and Dettmann (et al 1987) who both identified a positive association between measures of stance stability, gait and function.

Another is that standing is a simpler task and forms part of a progression to walking. This is based on neurodevelopmental theory devised by Bobath (1978). However, there is increasing evidence that walking and standing are not part of the same motor pattern. In (as yet) unpublished work Isaacs and colleagues found no relationship between stance stability and gait in healthy elderly people and Winstein (1989) reported no automatic improvement in gait, after successfully re-training stance symmetry. It may be that static stance symmetry and control is not automatically represented in more skilled movement requiring dynamic interlimb coordination and that the associations between stance stability, gait and function discussed above are indeed artifacts of the pattern of recovery.

The results of Chapter 5 show an association between improvements in stance stability and function for both groups, which cannot be interpreted as necessarily an automatic transfer of motor skills. It may have occurred because the training includes practice of both standing balance and functional movements. Yet, the improvement in the treatment group suggests that augmented feedback enhances physiotherapy. It has been argued that combining new techniques into existing treatments is more representative of the clinical situation. Patients are not just subjected to one stimulus, they receive a rehabilitation package from the therapist and new or existing treatments are best evaluated as part of that package (see next section). It is difficult to do this when inappropriate models of the effects of therapy on neural recovery are still commonly used.

This raises questions about another underlying assumption demonstrated in both treatment texts and research; that the therapist by using certain techniques can, in some way, enhance physiological recovery (Carr and Shepherd 1980, Jacobson 1969). This was discussed in the Introduction, to surmise the results of research on the effects of therapy;

1. More intensive therapy given early produces better results in the short term. The results of this study support this, as both treatment and control groups improved, but once treatment finished improvement plateaued. Both groups were receiving extra therapy, in addition to their rehabilitation routine.

2. Functional recovery is possible after six months. Again the results of the treatment trial support this, as some of the patients were more than six months post-stroke and showed improvement.

What is not clear is the method by which these improvements were attained. If therapy enhances neural recovery then no improvement would be seen late after stroke. The lack of evidence supporting any particular approach to treatment and the results of this study (functional ability improved , but specific leg and trunk motor skills did not) suggests that the therapeutic effects may be different at different times, which would explain why studies have highlighted the benefits of early intervention. If, for instance it is only possible to stimulate different neural pathways for a period of three to six months , then the effects of training late after stroke may be compensatory or adaptive. Any improvement would be due to muscle strengthening, endurance training and teaching new techniques or movement strategies.

This has important implications for rehabilitation, as much therapy time is spent in trying to reproduce 'normal' movement, often concentrating a large part of therapy time on non goal-orientated, somewhat passive, repetitive tasks. If the primary aim is to enable the patient to be independent in self-care activities, perhaps the focus of physiotherapy input should shift from trying to attain the impossible (with the obvious negative effects on the morale of both the therapist and patient) to the retraining of functional tasks.

However the timing of intervention may provide a clue to the effects, perhaps therapy can enhance the use of existing neural pathways during the first three to six months but after that it provides adaptive training. If this is true, then it may be appropriate for the therapist to choose different approaches depending on the time post-stroke. Practising purely functional skills with those more than 6 months post-stroke.

Methodological considerations

6.4 The evaluation of physiotherapy after stroke.

Evaluating the effects of therapy is not straightforward. The complex character of physiotherapy is further compounded by the heterogeneous nature of stroke. Another contributing factor is the inadequacies of the assessments of severity, pre-existing impairment and natural recovery. Researchers have used different approaches to try and overcome these problems.

A number of intervention studies have examined the effects of therapy late after stroke, once the patient's performance has reached a plateau (De Weerdt 1989, Wannstedt 1978). While this is intended to exclude the influence of natural recovery it does not reflect clinical practice, where patients commonly receive therapy only while they continue to recover. Nor can it automatically be presumed that the effects of physical training in this period are directly comparable to this during the recovery process (as was discussed in the last section).

It is difficult to assess any improvement in relation to the natural recovery process, because the only studies of the recovery of motor function that have been done in recent years, have been while the patients were undergoing rehabilitation (Partridge et al 1987, Gray et al 1990, Bonita and Beaglehole 1988). Hopefully, rehabilitation was having some influence and so the information can not provide true base-line data. Therefore, more tightly controlled studies examining one aspect of therapeutic intervention are becoming increasingly popular. However, these tend to involve small numbers of patients and lead to problems of sample selection.

The heterogeneous nature of the disease, the variability of recovery and the multitude of possible impairments hinders the recruitment of comparable patients. The task becomes more difficult when less common problems are to be studied. Often papers report the results of trials on highly selected samples and there is scant detail of the sample (Meadows et al 1985, Cozean et al 1988) and the intervention (Wannstedt and Herman 1978). Trials of therapy late after stroke do not counteract these problems as 3-7% of patients continue to recover after six months (Wade et al 1985) and such trials may unintentionally recruit a higher proportion of these individuals (Burnside et al 1982), thus undermining the original assumption.

The lack of suitable assessments of some variables such as spasticity, muscle tone and sensory function prevents comparison of these factors. Most measures of motor and ADL function are very simple scales, judging the patient as independent or dependent. Although valid and reliable they often involve large differences between items, for instance, in the Nottingham 10 point ADL; patients score 3 if they are able to wash their face and 4 if they can transfer from bed to chair independently. There are clinical milestones, such as being able to move to the edge of the bed, in between these scores. The insensitivity of these assessments, coupled with the use of different assessments by different researchers means that it is difficult to compare the results of existing work.

Other researchers have tried to avoid these difficulties by the use of single-case designs, with the subject acting as their own control (Hersen and Barlow 1976). This approach is becoming increasingly popular but has obvious limitations. The results cannot be automatically generalised to the stroke population and are therefore not as cost-effective.

It is surprising that the most commonly used approach to the treatment of stroke patients, the Bobath concept, has survived thirty years without being evaluated. The basic assumptions upon which it is based have only recently started to be questioned (Carr et al 1987, Bohannon 1990). There appear to be a number of reasons why this has not happened.

The difficulties in conducting trials of physiotherapy/ no physiotherapy were discussed in the introduction. Briefly the main problems were, other staff took on the role and ethical issues arose because of the risks of bed rest. Yet, it could be argued that it is unethical to submit patients to treatments that have not been evaluated, especially when it involves such costly and intensive treatment.

This lack of quantitative assessment, either with instrumentation or standardised scales appears to be limiting the development of physiotherapy for stroke. It is very difficult to assess the effectiveness of a service when there is no formal record of the physical abilities at the start of treatment, the change with treatment and the outcome. Therapists are not taught basic research skills and information is disseminated by word of mouth, mainly at postgraduate courses. The Bobath concept has been redefined and developed beyond the original text, yet these developments are not written down and not questioned. To progress physiotherapists must start to monitor their treatment and evaluate its effects.

Many therapists are now aware of this, but the methodology of trials is being debated (Parry 1990, Hurley 1990). The scientific model of double-blind randomised controlled trials is not appropriate as it is impossible for the therapist to remain blind, when providing 'hands on' treatment. Another problem is the multi-factorial nature of the intervention. Not only does the therapist provide physical training, but his/her interaction involves many variables, such as education, motivation, prevention of contractures, moral support and counselling for the patient and family. The relative importance of these factors are not known and probably varies between patients.

Some therapists argue that it is not representative of the clinical situation to break down this interaction and isolate treatments. This has led to the idea of evaluating treatment packages (Edwards et al 1990), as in this trial, where one aspect of treatment is changed but in the over-all context of routine physiotherapy intervention. This technique is still limited, as the therapist is fully aware of the treatment to be given, therefore influencing the outcome. There is no obvious answer to this, if different therapists are used it could be argued that their clinical skills, including their ability to form a relationship with the patient, are not comparable.

Another problem is the lack of agreement as to a successful outcome. Although it would appear that functional independence is the ultimate goal, therapists differ as to the constituents of this. The Bobath approach aims for the inhibition of spasticity, normalisation of muscle tone, facilitation of normal movement and improved quality of movement. All of which are rife with assumptions, but share one common factor, they are extremely difficult to measure. During a treatment session clinical observation suggests that spasticity can indeed be reduced, yet this has not been measured and more importantly the affects on spasticity while performing a functional skill have not been assessed.

The long term effects of treatment need to be assessed, such as the effects on spasticity. If the Bobath approach is effective in reducing spasticity, then large differences would be expected between patients admitted to specialist intensive rehabilitation centres (where all the staff are trained in this approach) compared with those treated on general medical wards, or in the community.

If physiotherapy is to be evaluated on a wider scale there first needs to be agreement as to the mode of action of the treatment. The behavioural model is at least based on current knowledge of physiological recovery and research work on the theory of motor learning. Using this model of intervention, based on movement science (Carr et al 1987) it would be appropriate to assess it in terms of functional independence. Physiotherapy trials to evaluate the approaches to treatment must include some uniform base line data, such as;

1. Details of the subjects; demographic information, details of the stroke, side of stroke, time post stroke, etc. Standardised assessment of motor and ADL function.

2. Details of therapy; Amount, timing, goals of treatment for patient and therapist.

3. Outcome measures; Independent assessment of variables (including motor and ADL function) and long term (1-2 years) follow-up.

6.5 Conclusions

The conclusions of the study are given in relation to the aims of the three different sections of the study, as stated in Chapter 1.

Stage 1

Normative stance symmetry and sway data is provided for the use of the Nottingham Balance Platform. Sex and age trends for sway values, previously described were confirmed and sex and age trends for stance symmetry were found.

Stage 2

1. Both stance symmetry and sway values increased significantly after stroke. Sex and age differences present in the normal population were no longer evident.

2. Both variables improve with recovery. Abnormal stance symmetry correlated with the length of admission, as well as poor motor and ADL function. Sway values did not.

3. Falls were a common occurrence after stroke and correlated with sway scores, but not age, stance symmetry, length of admission, ADL or motor function.

4. No differences were apparent between sexes and the only side of stroke difference demonstrated was in the choice of weight-bearing leg, the pattern and magnitude was similar (both groups preferred their unaffected leg).

Stage 3

The treatment group demonstrated significant improvements when compared with the controls in stance symmetry and functional activities and showed a tendency for lower sway values at the end of the treatment period. Although, this improvement had disappeared by the final assessment.

These results support the further use of feedback techniques to improve standing posture after stroke.

REFERENCES

Aho K, Harmensen P, Hatano S, Marquardson J, Smirnov VE and Strasser T 1980 Cerebrovascular disease in the community: results of a WHO collaborative study. Bulletin of the World Health Organisation 58, 113-130

Andrews K, Brockelhurst JC, Richards B, Laycock PJ 1981 The rate of recovery from stroke and its measurement. International Rehabilitation Medicine 3:155-161

Aniansson A Gustafsson E 1981 Physical training in elderly menwith special reference to quadriceps muscle strentgh and morphology. Clinical Physiology 1:87-98

Archea JC 1985 Environmental factors associated with stair accidents in the elderly. Clinics in Geriatric Medicine 1:555-569

Armstrong D 1983 An outline of sociology as applied to medicine. Wright PSG, Bristol

Ashburn A 1981 Instrumented assessment and therapy for hemiplegic patients. Physiotherapy 67:78

Ashburn A, Lynch M 1988 Disadvantages of the early use of wheelchairs in the treatment of hemiplegia. Clinical Rehabilitation 2:327-331

Bach-y-Rita P 1987 Processes of recovery from stroke. In Basmajian JV, Brandstater ME (Eds) Stroke rehabilitation Williams and Wilkins, Baltimore 80-108

Bamford J, Sandercock P, Dennis M et al 1988 A prospective study of acute cerebrovascular disease in the community: The Oxfordshire community stroke project 1981-

1986. 1. Methodology, demography and incident cases of first-ever stroke. Journal of Neurology, Neurosurgery and Psychiatry 51:1373-1380

Bamford J 1990 The incidence and natural history of stroke. Geriatric Medicine ???:52-59

Barer DH 1988 Acute stroke: Its natural history and response to treatment. Doctor of Medicine Thesis, University of Nottingham

Basmajian JV 1971 Neuromuscular facilitation techniques. Archives of Physical Medicine and Rehabilitation 52:40-42

Basmajian JV, DeLuca CJ 1985 Muscles alive-their functions revealed by EMG. (5th ed) Williams and Wilkins, Baltimore

Basmajian JV, Gowland CA, Finlayson AJ, Hall AL, Swanson LR, Stratford PW, Trotter JE, Brandstater ME 1987 Stroke treatment: Comparison of integrated behavioural physical therapy vs traditional physical therapy programs. Archives of Physical Medicine and Rehabilitation 68:267-272.

Belenki VY, Gurfinkel VS, Paltsev Y 1967 Elements of control of voluntary movements. Biofizica 12:135-141

Black FO, Wall C, Nashner LM 1983 Effects of visual and support surface orientation references upon postural control in vestibular deficient subjects. Acta Otolaryngol 95:199-210

Black p, Markowitz RS, Cianci SN 1975 Recovery of motor function after lesions in motor cortex of monkeys. CIBA Foundation Symposium 34:65-83

Blake AJ, Morgan K, Bendall MJ, Dallosso H, Ebrahim SBJ, Arie THD, Fentem PH, Bassey EJ 1988 Falls by elderly people at home: prevalence and associated factors. Age and Ageing 17: 365-372

Bles W, Kapteyn TS, de Wit G 1977 Effects of visual-vestibular interaction on human posture. Advances in Otolaryngology 94:61-72

Bobath B 1978 Adult hemiplegia: evaluation and treatment. 2nd edition. William Heinemann, London

Bohannon RW, Larkin PA 1985 Lower extremity weight bearing under various standing conditions in independently ambulatory patients with hemiparesis. Physical Therapy 65: 1323-1325

Bohannon RW 1989 Correlation of lower limb strengths and other variables with standing performance in stroke patients. Physiotherapy Canada 41: 198-202

Bohannon RW 1990 (Letter) Physiotherapy Theory and Practice 6:246

Bonita R, Beaglehole R 1988 Recovery of motor function after stroke. Stroke 19:1497-1500

Braun JJ 1978 Time and recovery from brain damage. In Finger S (ed) Recovery from brain damage, Plenum Press, New York

Brocklehurst JC, Andrews K, Richards B, Laycock PJ 1978 How much physical therapy for patients with stroke? British Medical Journal 1978;i:1307-1310

Brocklehurst JC, Robertson D, James-Groom P 1982 Clinical correlates of sway in old age - sensory modalities. Age and Ageing 11: 1-10

Brunnstrom S 1970 Movement therapy in hemiplegia: a neurophysiological approach. Harper and Row, New York

Burnside IG, Tobias HS, Bursill D 1982 Electromyographic feedback in the remobilization of stroke patients; a contolled trial. Archives of Physical and Medical Rehabilitation 63:217-222

Caldwell C, Macdonald D, Macneil K, McFarland K, Turnbull GI, Wall JC 1986 Symmetry of weight distribution in normals and stroke patients using digital weigh scales. Physiotherapy Practice 2: 109-116

Campbell AJ, Reinken J, Allan BC, Martinez GS 1981 Falls in old age: a study of frequency and related clinical factors. Age and Ageing 10: 264-270

Carr JH, Shepherd RB 1980 Physiotherapy in disorders of the brain. Heinemann, London.

Carr JH, Shepherd RB, Nordholm L, et al 1985 Investigation of a new motor assessment scale for stroke patients. Physical Therapy 65; 175-180

Carr JH, Shepherd RB, Gordon J, Gentile AM, Held JM 1987 Movement science, foundation for physical therapy in rehabilitation. Aspen, Royal Tunbridge Wells

Cohn TE, Lasley DJ 1985 Visual depth illusion and falls in the elderly. Clinics in Geriatric Medicine 1:601-615

Cozean CD, Pease WS, Hubbell SL 1988 Biofeedback and functional electric stimulation in stroke rehabilitation. Archives of Physical and Medical Rehabilitation 69:401-405

Crisostomo EA, Duncan PW, Propst M, Dawson DV, Davies JN 1988 Evidence that amphetamine with physical therapy promotes recovery of motor function in stroke patients. American Neurological Association 23:94-97

Crow JL 1988 The efficacy of electromyographic (EMG) biofeedback incorporated in routine physiotherapy after stroke. MSc Thesis, University of Liverpool.

Crow JL, Lincoln NB, Nouri FM 1990 The effectiveness of EMG biofeedback in the treatment of arm function after stroke. International disability Studies 11:155-160

Daleiden S 1990 Weight shifting as a treatment for balance deficits: a literature review. Physiotherpay Canada 42:81-87

Davies PM 1985 Steps to follow. Springer-Verlag, Berlin. p266

Davies PM 1990 Right in the middle. Springer-Verlag, Berlin.

Dettmann MA, Linder MT, Sepic SB 1987 Relationships among walking performance, postural stability and functional assessments of the hemiplegic patient. American Journal of Physical Medicine 66:77-90

De Weerdt WG, Harrison MA 1985 The use of biofeedback in physiotherapy: a survey on the use of biofeedback in physiotherapy departments in GB. Physiotherapy 71:9-12

De Weerdt WG, Crossley SM, lincoln NB, Harrison MA 1989 Restoration of balance in stroke patients. A single case study design. Clinical Rehabilitation 3: 139-147

Dickinson J, Leonard JA 1967 The role of peripheral vision in static balance. Ergonomics 10:421-429

Dickstein R, Nissan M, Pillar T, Scheer D 1984 Foot-ground pressure patterns of standing hemiplegic patients. Physical Therapy 64: 19-23

Dickstein R, Hocherman S, Pillar T, Shaham R 1986 Stroke rehabilitation:Three exercise therapy approaches. Physical Therapy 66:1233-1238

Dichgans J, Mauritz KH, Allum JHJ, Brandt T 1976 Postural sway in normal and atactic patients: analysis of the stabilizing and destabilizing effects of vision. Agressologie 17:14-24

Diller L, Weinberg J 1970 Accident prone behaviour in hemiplegic patients. Archives of Physical and Medical Rehabilitation 51:358-363

Dornan J, Fernie GR, Holliday PJ 1978 Visual input: Its importance in the control of sway. Archives of Physical and Medical Rehabilitation 59:586-591

Downton J 1987 The problems of epidemiological studies of falls. Clinical Rehabilitation 1: 243-246

Droulez J, Berthoz AA, Vidal PP 1985 Use and limits of visual vestibular interaction in the control of posture. In; Igarashi, Black (eds) Vestibular and visual control on posture and locomotion equilibrium. 7th International

Symposium International Society of Posturography, Houston 1983. Basel Karger, Texas:14-21

Duncan PW, Propst M, Nelson SG 1983 Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular accident. Physical therapy 63; 1606-1610

Ebrahim S, Nouri F, Barer D 1985 Measuring disability after a stroke. Journal of Epidemiology and Community Health 39: 86-89

Edwards S, Partridge C, Mee R 1990 Treatment schedules for research; a model for physiotherapy. Physiotherapy 76:605-607

Einon DF, Morgan MJ, Will BE 1980 Effects of post-operative environment on recovery from dorsal hippocampal lesions in young rats. Tests of spatial memory and motor transfer. Quarterly Journal of Experimental Psychology 32:137-148

Era P, Heikkinen E 1985 Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages. Journal of Gerontology 40:287-295

Feigensen JS, Fletcher H, McDowell FH, Meese P,McCarthy ML, Greenberg SD 1977 Factors influencing outcome and length of stay in a stroke rehabilitation unit. Stroke 8:651-657

Fernie GR, Holliday PJ 1978 Postural sway in amputees and normal subjects. Journal of Bone and Joint Surgery 60: 895-898

Fernie GR, Gryfe CI, Holliday PJ, Llewellyn A 1982 The relationship of postural sway in standing to the incidence of falls in geriatric subjects. Age and Ageing 11: 11-16

Fratiglioi L, Massey EW, Schoenberg DG, Schoenberg BS 1983 Mortality from cerebrovascular disease. International comparisons and temporal trends. Neuroepidemiology 2:101-116

Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S 1975 The post-stroke hemiplegic patient; 1. A method for evaluation of physical performence. Scandinavian Journal of Rehabilitation Medicine 7:13-31

Fugl-Meyer AR, Jaasko L, Norlin V 1975 The post-stroke hemiplegic patient. II Incidence, mortality, and vocational return in Goteborg, Sweden. Scandinavian Journal of Rehabilitation Medicine 7:73-83

Gabell A, Nayak USL, Isaacs B 1989 Gait, balance and falls in healthy old people. Personal Communication.

Gautier JL, Pullicino P 1985 A clinical approach to cerebrovascular disease. Neuroradiology 27:452-459

Gazzaniga MS 1978 Is seeing believing: notes on clinical recovery.In Finger S (ed) Recovery from brain damage, Plenum Press, New York

Gentile AM; in Carr JH, Shepherd RB, Gordon J, Gentile AM, Held JM 1987 Movement science, foundation for physical therapy in rehabilitation. Aspen, Royal Tunbridge Wells pg 93.

Gray CS, French JM, Bates D, Cartlidge NEF, James OFW, Venables G 1990 Motor recovery following acute stroke. Age and Ageing 19:179-184

Gresham GE 1986 Stroke outcome research. Stroke 17:358-360

Hadj-Dijilani AMT 1986 Clinical approach of head and neck static postural reflexes using force platform in otoneurological examination: first results on normal subjects and on patients. Neurology and Orthopaedics 1:98-118

Hamrin E, Eklund G, Hillgrin A, Borges O, Hall J, Hellstrom O 1982 Muscle strength and balance in post-stroke patients. Upsala Journal of Medical Science 87: 11-26

Harris AI 1971 Handicapped and Impaired in Great Britain. Part 1. Office of Population Censuses and Surveys. London HMSO

Hartunian NS, Smart CN, Thompson MS 1980 The incidence and economic costs of cancer, motor vehicle injuries, coronary heart disease and stroke: a comparative analysis. American Journal of Public Health 70:1249-12660

Hersen M, Barlow DH 1976 Single case experimental designs. Pergamon Press, Oxford

Hicks SP, D'Amato CJ 1970 Motor-sensory and visual behavior after hemi-spherectomy in newborn and mature rats. Experimental Neurology 29:416-438

Hocherman S, Dickstein R, Pillar T 1984 Platform training and postural stability in hemiplegia. Archives of Physical Medicine and Rehabilitation 65:588-592

Holliday PJ, Fernie GR 1979 Changes in the measurement of postural sway resulting from repeated testing. Agressologie 20:225-228

Hurley MV 1990 How do you think about physiotherapy? Physiotherapy, Letters, 76:333

Ince LP, Leon MS, Christidis D 1985 EMG biofeedback for improvement of upper extremity function: a critical review of the literature. Physiotherapy Canada 28:260-264

Imms FJ, Edholm OG 1981 Studies of gait and mobility in the elderly. Age and Ageing 10:147-156

Jacobson M 1969 Development of specific neuronal connections. Science 163:543-547

Jansen RD, Nansel DD, Szlazak MJ 1990 Power spectral and microvector analysis of dynamic standing foot force patterns in a normal male subject. Journal of Manipulative and Physiological Therapeutics 13:361-369

Johnson D, Almli CR 1978 Age, brain damage and performance.In Finger S (ed) Recovery from brain damage, Plenum Press, New York

de Jong JMBV, Bles W, Bovenkerk G 1981 Nystagmus, gaze shift, and self-motion perception during sinusoidal head and neck rotation. Annals of the New York Academy of Sciences 81:590-599

Kinsbourne M 1974 Mechanisms of hemisphere interaction in man. In Kinsbourne M, Smith WL(Eds) Hemispheric Disconnection and Cerebral Function. CC Thomas, Illinois

Kinsman R 1983 BSc Dissertation. The Polytechnic of Central London.

Knott M, Voss DE 1968 Proprioceptive Neuromuscular Facilitation. (2nd Ed) Harper and Row, New York

Lane REJ 1978 Facilitation of weight transference in the stroke patient. Physiotherapy 65: 48-51

Lane REJ 1978 Facilitation of weight transference in the stroke patient. Physiotherapy 64:260-264

Laurence S, Stein DG 1978 Recovery from brain damage and the concept of localization of function.In Finger S (ed) Recovery from brain damage. Plenum Press, New York

Lee TD, White AW, Carnahan H 1990 On the knowledge of results in motor learning: exploring the guidance hypothesis. Journal of Motor Behavior 22:191-208

Lichtenstein MJ, Sheilds SL, Shiavi RG, Burger MC 1988 Clinical determinants of biomechanics platform measures of balance in aged women. Journal of the American Geriatric Society 36: 996-1002

Lichtenstein MJ, Burger MC, Shiavi RG, Sheilds SL 1990 Comparison of biomechanics platform measures of balance and videotaped measures of gait with a clinical mobility scale in elderly women. Journal of Gerontolgy 45:M49-54

Lincoln NB, Leadbitter D 1979 Assessment of motor function in stroke patients. Physiotherapy 65; 48-51

Lincoln NB, Gladman J 1991 Validity of measures of ADL. Submitted for publication

Lindmark B, Hamrin E 1988a Evaluation of functional capacity after stroke as a basis for active intervention; Presentation of a modified chart for motor capacity assessment and its reliability. Scandinavian Journal of Rehabilitation Medicine 20; 103-109

Lindmark B, Hamrin E 1988b Evaluation of functional capacity after stroke as a basis for active intervention; Validation of a modified chart for motor capacity assessment. Scandinavian Journal of Rehabilitation Medicine 20; 111-115

Logigian MK, Samuels MA, Falconer J et al 1983 Clinical exercise trial for stroke patients. Archives of Physical Medicine and Rehabilitation 64:364-367

Lord JP, Hall K 1986 Neuromuscular reeducation versus traditional programs for stroke rehabilitation. Archives of Physical Medicine and Rehabilitation 67:88-91

Luria AR, Naydin VL, Tsvetkova LS, Vinarskays EN 1969 Restoration of higher cortical function following local brain damage. In Vinken RJ, Bruyn GW (eds). Handbook of Clinical Neurology 3:368-433

Meadows PM, Winstein CJ, Bowman BR 1985 Weight transfer training using biofeedback and electrical stimulation. Rehabilitation Engineering Society of North America 8th annual conference, Memphis 117-119

Meyer DR 1972 Access to engrams. American Psychologist 27:124-133

Mizrahi J, Solzi P, Ring H, Nisell R 1989 Postural stability in stroke patients: Vectorial expression of asymmetry, sway activity and relative sequence of reactive forces. Medical and Biological Engineering and Computing 27: 181-190

Moskowitz E, Lightbody FEH, Freitag NS 1972 Long-term follow-up of the post-stroke patient. Archives of Physical and Medical Rehabilitation 53: 167-172

Mossey JM 1985 Social and psychological factors associated with falls in the elderly. Clinic in Geriatric Medicine 1:541-552

Murray PM, Peterson RM 1973 Weight distribution and weight-shift activity during normal standing posture. Physical Therapy 53: 741-748

Murray MP, Seireg AA, Sepic SB 1975 Normal postural stability and steadiness; Quantitative assessment. The Journal of Bone and Joint Surgery 57A:510-516

Nashner LM 1977 Fixed patterns of rapid postural response among leg muscles during stance. Experimental Brain Research 26:59-72

Nashner LM, Black FO, Wall C 1982 Adaptation to altered support and visual conditions during stance: patients with vestibular deficits. Journal of Neuroscience 2:536-544

Nieto-Sampedro M, Cotman CW 1985 Growth factor induction and temporal order in central nervous system rapir. In Cotman CW (Ed) Synaptic Plasticity. Guilford Press, New York pg407-455

Njokiktjien C, de Rijke W 1972 The recording of Rhomberg's test and its application in neurology. Agressologie 13:1-7

Nouri FM, Lincoln NB 1987 An extended activities of daily living scale for stroke patients. Clinical Rehabilitation 1:301-305

Okubo J, Watanabe I, Takeya T, Baron JB 1979 Influence of foot position and visual field condition in the examination for equilibrium function and sway of the center of gravity in normal persons. Agressologie 20:127-132

Overstall PW, Exton-Smith AN, et al 1977 Falls in the elderly related to postural imbalance. British Medical Journal 1:261-264

Parry A 1990 How do you think about physiotherapy? Physiotherapy 76:197

Partridge CJ, Edwards MS, Mee R 1987 Recovery from physical disability after stroke: normal patterns as a basis for evaluation. The Lancet 26:373-375

Prudham D, Grimely Evans J 1981 Factors associated with falls in the elderly: a community study. Age and Ageing 10: 141-146

Pyykko I, Jantti P, Aalto H 1990 postural control in elderly subjects. Age and Ageing 19:215-221

Ring C, Nayak USL, Isaacs B 1988 Balance function in elderly people who have and have not fallen. Archives of Physical and Medical Rehabilitation 69: 261-264

Ring C, Nayak USL, Isaacs B 1989 The effect of visual deprivation and proprioceptive change on postural sway in healthy adults. Journal of the American Geriatric Society 37:745-749

Robinson RG, Price TR 1982 Post-stroke depressive disorders:a follow-up study of 103 patients. Stroke 13:635-641

Romberg MH 1851 Lehrbucl der nerevnkrankeiten des gmenschen 2-e auflage. Hirschwald, Berlin

Rood MS 1956 Neurophysiological mechanisms utilized in the treatment of neuromuscular dysfunction. American Journal of Occupational Therapy 10:220-225

Royal College of Physicians of London 1990 Guidlines on the practice of ethics committees in medical research involving human subjects. 2nd edition. Royal College of Physicians of London, London.

Rubenstein LZ, Robbins AS, Josephson KR, Schulman BL, Osterweil D 1990 The value of assessing falls in an elderly population: a randomized clinical trial. Annals of Internal Medicine 113:308-316

Sandercock PAG, Allen CMC, Corston RN, Harrison MJG, Warlow CP 1985 Clinical diagnosis of intercranial haemorrhage using Guy's Hospital score. British Medical Journal 291:1675-1677

Seliktar R, Susak Z, Najenson T, Solzi P 1978 Dynamic features of standing and their correlation with neurological disorders. Scandinavian Journal of Rehabilitation Medicine 10: 59-64

Sheldon JH 1963 The effect of age on the control of sway. Gerontological Clinica 5:129-138

Shumway-Cook A, Anson D, Haller S 1988 Postural sway biofeedback: Its effect on re-establishing stance stability in hemiplegic patients. Archives of Physical Medicine and Rehabilitation 69: 395-400

Sivenius J, Pyorala K, Heinonen OP, Salonen JT, Riekkinen P 1985 The significance of intensity of rehabilitation of stroke: a controlled trial. Stroke 6:928-931

Smith DL, Akhtar AJ, Garraway WM 1985 Motor function after stroke. Age and Ageing 14: 46-48

Smith DS, Goldenberg E, Ashburn A, Kinsella G, Sheikh K et al 1981 Remedial therapy after stroke: a randomised controlled trial. British Medical Journal 282:517-520

Smith ME, Garraway WM, Smith DL, Akhtar AJ 1982 Therapy impact on functional outcaome in a controlled trial of stroke rehabilitation. Archives of Physical Medicine and Rehabilitation 63:21-24

Stelmach GE, Worringham CJ 1985 Sensorimotor deficits related to postural stability. Clinics in Geriatric Medicine 1:679-694

Stern PH, McDowell F, Miller JM, Robinson M 1970 Effects of facilitation exercise techniques in stroke rehabilitation. Archives of Physical Medicine and Rehabilitation 51:526-531

Stevens RS, Ambler NR, Warren MD 1984 A randomised controlled trial of a stroke rehabilitation ward. Age and Ageing 13:65-75

Stockmeyer SA 1967 An interpretation of Rood to the treatment of neuromuscular dysfunction. American Journal of Physical Medicine 46:900-956

Stribley RF, Albers JW, et al 1974 A quantitative study of stance in normal subjects. Archives of Physical Medicine and Rehabilitation 55:74-80

Tinetti ME, Williams TF, Mayewski R 1986 Fall risk index for elderly patients based on a number of chronic disabilities. The American Journal of Medicine 80:429-434

Tinetti ME, Speechley M, Ginter SF 1988 Risk factors for falls among elderly persons living in the community. New England Journal of Medicine 319:1701-1711

Tobis JS, Reinsch S, Swanson JM, Byrd M, Scharf T 1985 Visual perception dominance of fallers among community-dwelling older adults. Journal of the American Geriatrics Society 33:330-333

Tobis JS, Block M, Steinhaus-Donham C, Reinsch S, Taamaru K, Weil D 1990 Falling among the sensorially impaired elderly. Archives of Physical Medicine and Rehabilitation 71:144-147

Towle D, Edmans JA, Lincoln NB 1988 Use of computer-presented games with memory-impaired stroke patients. Clinical Rehabilitation 2:303-307

Ulrich R, Giray M, Schaffer R 1990 Is it possible to prepare the second component of a movement before the first one? Journal of Motor Behaviour 22:125-148

Von Monakow C 1914 Diaschisis. In Pribram KH (Ed) 1969: brain and behaviour 1. Mood states and minds. Penguin, Baltimore pg27-36

Wade DT, Langton Hewer R, Wood VA, Skilbeck CE, Ismail HM 1983 The hemiplegic arm after stroke: measurement and recovery. Journal of Neurology Neurosurgery and Psychiatry 46:521-524

Wade DT, Skilbeck CE, Langton Hewer R, Wood VA 1984 Therapy after stroke: amounts, determinants and effects. International Rehabilitation Medicine 6:105-110

Wade DT, Wood VA, Langton Hewer R 1985 Use of hospital resources by acute stroke patients. Journal of the Royal College of Physicians 19:48-52

Wade DT, Legh-Smith J, Langton Hewer R 1985 Social activities after stroke: measurement and natural history using the Frenchay Activities Index. International Rehabilitation Medicine 7:176-81

Wade DT, Langton Hewer R, Skilbeck CE, David RM 1985 Stroke, a critical approach to diagnosis, treatment and management. Chapman and Hall, London. p52-53

Wade DT, Langton Hewer R 1987 Functional abilities after stroke: measurement, natural history and prognosis. Journal of Neurology Neurosurgery and Psychiatry 50:177-182

Wagenaar RC, Meijer OG, van Wieringen PCW, Kuik DJ et al 1990 The functional recovery of stroke: a comparison between neuro-developmental treatment and the Brunnstrom method. Scandinavian Journal of Rehabilitation Medicine 22:1-8

Waller JA 1978 Falls among the elderly; human and environmental factors Accident Analysis and Prevention 10:31-33

Wannstedt GT, Herman RM 1978 Use of augmented sensory feedback to achieve symmetrical standing. Physical Therapy 58:553-559

Wayne-Massey E 1987 Diagnostic, medical and surgical approaches to stroke management. Physical Therapy in Health Care 1:1-19

Weddell JM 1980 Applications of a stroke register in planning.In Clifford Rose F (Ed) Clinical neuroepidemiology. Pitman, Tunbridge Wells pg112-130

Weissman S, Dzendololet E 1972 Effects of visual cues on the standing body sway of males and females. Perceptual and Motor Skills 34:951-959,

Whisant JP 1984 The decline of stroke. Stroke 15:160-168

Whiting S, Lincoln NB, Bhavnani G, Cockburn J. 1985 The Rivermead Perceptual Assessment Battery. NFER-Nelson, Windsor

Wickham C, Cooper C, Margetts BM, Barker DJP 1989 Muscle strength, activity, housing and the risk of falls in elderly people. Age and Ageing 18:47-51

Williams HGA, Johnston M, Willis LA, Bennett AE 1976 Disability: A model and measurement technique. British Journal of Preventive and Social Medicine 30: 71-78

Winstein CJ, Gardner ER, McNeal DR, Barto PS, Nicholson DE 1989 Standing balance training: Effect on balance and locomotion in hemiparetic adults. Archives of Physical Medicine and Rehabilitation 70:755-762

Wolf SL 1979 EMG biofeedback applications in physical rehabilitation: An overview. Physiotherapy Canada 31:65-72

Wood RLI, Fussey I 1987 Computer-based cognitive retraining: a controlled study. International Disability Studies 9:149-153

Woollacott MH, Shumway-Cook A, Nashner LM 1986 Aging and posture control: changes in sensory organization and muscular coordination. International Journal of Aging and Human Development 23:97-114

WHO 1978 Cerebrovascular disorders; A clinical and research classification. WHO offset publication 43

Wright BM 1971 A simple mechanical ataxia-meter. Journal of Physiology 218:27