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**Trunk balance in stroke:**  
**The effects of right and left cerebral lesions**  
**on the sensory and motor components of response to tilt**

Thesis submitted to the University of Ottawa  
in partial fulfillment of the requirements for the degree of  
Master of Science in Human Kinetics

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## Abstract

The purpose of the study was to evaluate motor and sensory components of trunk control in individuals with unilateral cerebral stroke and to identify differences in response between right and left sided lesions.

Eighteen subjects, who were unstable in standing or unable to stand were tested. There were 9 subjects with right hemiplegia and 9 subjects with left hemiplegia for the motor testing and 8 subjects in each group for the sensory testing.

Subjects were tested on a motorized seat that could be tilted approximately  $15^{\circ}$  to either side at a controlled velocity. Reflective markers were placed on the subject on the seat. The subjects' responses were videotaped and digitized to compute the segmental kinematics.

The motor response was tested by tilting the seat to each side and recording the response to maintain the upright position. Both the trunk movement relative to the starting position and the end position of the trunk relative to the vertical were calculated. The sensory response was tested by tilting the seat to the side and asking the subject to indicate when the seat felt level as it returned slowly to the horizontal. All trials were done three times to each side with eyes open and eyes closed. Clinical data was collected on motor function and sensation of the leg, lateral trunk strength, lateral pelvic alignment, neglect, spatial deficits and apraxia.

1) There is a greater deficit in the motor response of the subjects with right hemiplegia than in subjects with left hemiplegia on tilt to the normal side (using muscles on the hemiplegic side). This difference is seen in the end position of the trunk relative to the vertical and suggests a reduced motor

response in right hemiplegia, using the hemiplegic trunk muscles, compared to subjects with left hemiplegia.

2) The deficit in the motor response of the subjects with right hemiplegia is greater on tilt to the normal side (using muscles on the hemiplegic side) than on tilt to the hemiplegic side (using muscles on the normal side). This difference is seen in the end position of the trunk relative to the vertical and suggests a reduced motor response on the hemiplegic side compared to the normal side in right hemiplegia.

3) The deficit in the motor response of the subjects with left hemiplegia is greater on tilt to the hemiplegic side (using muscles on the normal side) than on tilt to the normal side using muscles on the hemiplegic side). This difference cannot be explained on the basis of trunk strength as the lesser reaction is with the hemiplegic trunk.

4) The deficit in perception of the seat as horizontal is greater in subjects with left hemiplegia than in subjects with right hemiplegia from tilt to the hemiplegic side. Perception of the seat as horizontal for subjects with left hemiplegia is displaced to the hemiplegic side. This may explain the lesser motor response of the trunk when tilted to the hemiplegic side (even though the normal side of the trunk is active). The subject may sense the vertical to be displaced to the hemiplegic side and does not respond appropriately to the true vertical.

5) Eye closure was expected to result in a greater deficit in both the motor and sensory response in subjects with left hemiplegia than in subjects with right hemiplegia but this was not a significant interaction.

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## Chapter I

### Introduction

Disruption in balance control is often overlooked as a distinct and critical element in the stability of gait after cerebrovascular accident (Keenan, Perry & Jordan, 1984; Perry, 1974). The effects of lesions in the brainstem or cerebellum on balance are well known (Brodal, 1981, chap. 4 & 5; Patton, 1976, chap. 20 & 21), but the effects on balance of lesions in the cerebral hemispheres are less well recognized perhaps because the balance deficit is overshadowed by the more visible hemiparesis.

The majority of surviving stroke patients have lesions in the cerebral hemispheres in the distribution of the internal carotid artery and contralateral hemiplegia is characteristically the dominant finding (Bobath, 1978). The hemiplegia is often assumed to be the cause of the instability and treatment therefore frequently focuses on improving motor function. In addition, the level of motor control correlates highly with static standing performance (Bohannon, 1989) and with balance and ambulation (Keenan et al, 1984). However, many stroke patients with cerebral lesions learn to walk independently, despite severe motor and sensory deficits (Davies, 1985). On the other hand, others are unsteady, even with good return of motor control. They fail to shift their center of gravity over the unaffected leg in stance as would, for example, an amputee and have a tendency to fall to the hemiplegic side ((Perry, 1969. Shumway-Cook & Woollacott, 1995: pp. 191, 200). Thus while balance deficits often occur in conjunction with sensory motor deficits in cerebral lesions, this is not always the case, and balance appears to be a separate and distinct problem.

The erect human body is a very unstable structure (Horak, 1996) and the maintenance of balance is a complex activity. Martin (1967) observed that the human body is a tall form on a narrow base. Its center of gravity is more than half its height above the base and it has a jointed skeletal system that requires continuous muscular activity to resist folding under the forces of gravity. Martin also noted that despite its physical instability, the body is very stable physiologically i.e., in terms of balance reactions, and a normal person cannot easily be unbalanced from the upright position.

Perhaps, because of its complexity, balance is a rather nebulous and ill-defined term that is used in various ways by different authors. In reference to stroke patients, balance includes symmetry of body alignment (Bobath, 1978), maintenance of a static sitting or standing position (Bohannon, 1987), and the withstanding of external forces (Hill, Vandervoort, & Kramer, 1990; Lee, Deming, & Sahgal, 1988) or internal forces generated by limb movement (Horak, 1987; Goldie, Matyas, Spencer, & McGinley, 1990).

Several studies have considered the relationship between balance and ambulation. The balance assessment is often a composite of scores on various activities in which the ability to right the body becomes blended with other functions that can be affected to varying degrees. For example, the motor variable of control of movement of the leg (Bohannon, 1987; Keenan et al., 1984; Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) and sensory variables of vision and spatial orientation (Berg, Wood-Dauphinee, Williams, & Gayton, 1989) are often an inherent part of the balance score. The attempt to see relationships is further confounded if a particular function is an element of both the test and outcome variable. If, for example, the effect of balance on the level of ambulation achieved is being examined and the balance score includes ankle and stepping responses in standing (Keenan et

al., 1984), motor control of the leg is a critical element of both the balance score and the ambulation score and would influence both in the same direction.

There have been some studies that have examined the different components of balance. Horak (1987) suggested that the basic functional components are biomechanical factors, motor coordination and sensory organization.

There is evidence that some aspects of sensory organization are lateralized to the right hemisphere and several studies link posture and balance with lateralized perceptual deficits. Perceptual deficits in judgment of the visual vertical (Birch, Procter, Bortner, & Lowerthal, 1962; DeCencio, Leshner, & Varon, 1970) and postural vertical (Bowen, 1976; Teuber, 1976) are greater in lesions of the right hemisphere and are related to deficits in body alignment (Low Choy, 1980) and ambulation (DeCencio et al. 1970).

There does not seem to be literature that is directly concerned with asymmetry of hemispheric influence on the motor aspect of balance control. However, it is worth noting that most studies on laterality do not show a significant correlation between side of lesion and outcome on ambulation (DeCencio et al. 1970; Mayo, Korner-Bitensky, & Becker, 1990) or functional activities in which balance is involved (Cassvan, Ross, & Dyer, 1976; Kinsella & Frod, 1980). One might expect the perceptual problems associated with right hemispheric lesions to result in a poorer outcome for that group, and therefore the general lack of a significant difference in activities involving balance suggests that left hemispheric lesions may also be associated with deficits that affect balance control.

There is considerable evidence that the higher level control, e.g., motor learning, coordination of complex movements, timing etc., of voluntary

motor activities produced on either side of the body, is lateralized to the left hemisphere (Kimura, 1977; De Renzi, Faglioni, Ladesani, & Vecchi, 1983; Roy, 1983). There have been no published accounts reported in the literature of a significant difference between the hemispheres concerning this motor aspect as it relates to balance, that is, the possibility that a greater deficit in the motor component of balance exists in left CVA (Cerebrovascular Accident) as a counterpart to the sensory (perceptual) deficits seen in right CVA. This may be due in part to the type of observations that are commonly made on stroke patients. Tilting on an unstable surface is used by physiotherapists in balance training but the feet are usually on the floor. The response is then not limited to the head and trunk and the protective reactions of the feet pushing on the floor give counter pressures that make the trunk asymmetries less obvious. Another factor may be that assessment of the accepted lateralized functions is not traditionally the realm of physiotherapists, and the disciplines which have been more concerned with assessing lateralized functions do not usually test trunk responses to tilt.

Balance or postural control can be defined as the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987). Several studies have shown balance to be the single most important factor in independent ambulation of stroke patients (Keenan et al. 1984; Dettman, Linder & Sepic, 1987; Bohannon & Leary, 1995). However, the relative importance of the many factors contributing to the perception and control of balance remains obscure (Keenan et al. 1984). Horak (1987) stated that, "postural control is complex and cannot be evaluated with any global measure of balance. For rehabilitation of postural disorders to be specific and effective, measurements must separate the postural problem into its basic functional components." This study

proposes to isolate one element of balance, i.e., trunk balance or postural control, and investigate the motor and sensory components as they are affected by lesions in either hemisphere.

Trunk balance is a useful aspect to study because it appears to be the essential element in maintaining the centre of body mass over the base of support and, as such, is a part of many procedures for assessment of balance (Berg, et al. 1989; Keenan, et al. 1984; Mayo, et al. 1990). Furthermore, Collin and Wade (1990) found trunk control to be predictive of eventual independence in ambulation. Response of the trunk to tilt of the base of support is one way to gain a measure of dynamic balance and is part of several assessments (Keenan, et al. 1984; Fugl-Myer, et al. 1975). Shumway-Cook and Horak (1986) designed a sensory organization test to assess the influence of somatosensory, visual and inputs on postural stability. Di Fabio and Badke (1990), in evaluating the sensory organization test (Shumway-Cook & Horak 1986), advocated that other measures including a tilt test be used as well if a more complete understanding of balance is to be obtained. Martin (1967) stated that protective limb reactions stimulated by tilt were inadequate to maintain equilibrium and *the only effective response to tilt is the reaction of the trunk..* A better understanding of the mechanisms of trunk balance and evidence of a lateralizing influence would aid in recognition and analysis of a balance deficit and give direction for more specific treatment techniques towards either the sensory or motor component.

### Purpose

The purpose of the study was to compare patients with right and left cerebral lesions in the motor and sensory components of trunk responses to tilt.

## Hypotheses

The relative importance of the motor and sensory components of trunk control depends on the side of the lesion, specifically, deficits in the motor response required to maintain the vertical position when seated on a tilting base will be more severe in subjects with left CVA whereas deficits in the perception of the vertical position will be more severe in subjects with right CVA.

The specific hypotheses to be tested are;

- 1) The deficit in the motor response of the hemiplegic trunk (on tilt to the normal side) will be greater in subjects with right hemiplegia than in subjects with left hemiplegia.
- 2) The deficit in perception of position will be greater in subjects with left hemiplegia than in subjects with right hemiplegia.
- 3) The deficit in perception of position will be greater from tilt to the hemiplegic side than to the normal side in subjects with left hemiplegia..
- 4) Eye closure will result in a greater deficit in the motor and sensory response in subjects with left hemiplegia than in right hemiplegia

## Limitations

Subjects were filmed in two dimensions and movement was assumed to be restricted to the coronal plane. Any rotation in the trunk response was not captured. The rotation was, however, towards the vertical, i.e., in the opposite direction to the tilt and would tend to reduce the range of the angles measured.

The range and velocity of the tilt of the seat varied somewhat with the weight and alignment of the subject because of limitations of the capacity of the motor of the seat. The range of displacement of the seat varied from 12 to

16 degrees and the velocity from about 7 to 10 degrees per second. Subjects for whom the velocity and range were unequal to each side were generally severely involved and aligned their body towards one side or made a poor response to maintaining the vertical when tilted. This shift of the centre of mass toward the side of the poorer response caused the seat to move with a greater range and velocity and possibly to magnify the difference between the two sides. Therefore, because the inequality of range and velocity was caused by the poorer response on tilt to that side, an equal tilt to each side would still have shown a difference, although perhaps not as great, and more importantly, would not have changed which side of tilt resulted in a greater deficit of response.

Subject groups would have been more homogeneous if the selection criteria had included alignment of the trunk toward the hemiplegic side. This could have been determined in sitting by assessing the level of the pelvic crests or, if the pelvis was level in sitting, by the alignment of the trunk in standing.

### Delimitations

The number of subjects was small and the results cannot be generalized to the stroke population.

Subjects were older than 56 years and the findings may not apply to younger subjects.

Trunk balance was assessed using only response to tilt and cannot be generalized to trunk balance under other conditions.

Sensory awareness of body position was assessed by position of the seat and may be distinct from other aspects of awareness of body position in space.

## Definition of terms

Cerebrovascular Accident (CVA): rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death with no apparent cause other than of vascular origin. (WHO definition).

Hemiplegia: loss of voluntary motor function on the side of the body contralateral to a lesioned cerebral hemisphere.

Paresis: partial or incomplete loss of voluntary function.

Apraxia: a disorder of the execution of learned movement that cannot be accounted for by weakness, incoordination or sensory loss, or by incomprehension of, or inattention to, commands.

Aphasia: loss of the ability to comprehend or express spoken or written language.

Balance or postural control: the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support (Horak, 1987).

Automatic postural control: the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support without conscious planning.

Motor response: 1) Trunk movement relative to the seat: change in angle formed by the marker at the sternal notch, the center of the seat (calculated as the mid point between the markers on either side of the seat) and a marker at the side of the seat (on the downward side of tilt). (See angle diagram, Figure 2 ).

2) Trunk position relative to the vertical: the angle formed by the marker at the sternal notch, the center of the seat (as described

above) and the vertical (calculated from the calibration matrix). (See angle diagram, Figure 2).

**Sensory response:** Perception of seat position: the position of the seat which the subject perceived to be the horizontal or level position. This was the angle made by the 2 markers on the seat with the horizontal (calculated from the calibration matrix). (See angle diagram, Figure 2).

**Outcome:** the final recovery level of the ability being tested.

## Chapter II

### Review of Literature

This review of the literature will first describe a model of balance control which is relevant to the study, and then examine some of the evidence for the lateralization of function in the cerebral hemispheres. Studies of functional outcome will be described in relation to the effect of balance on outcome and the influence of right CVA on balance. There does not seem to be literature relating to the influence of the left hemisphere on balance responses specifically, but there is considerable literature linking the left hemisphere with motor programming in general. This literature will be reviewed in detail as background for consideration of the hypothesis that motor control of dynamic balance resides in the left hemisphere.

#### Model of postural control

The model of postural control that appears to be most relevant to this study is the systems model described by Shumway-Cook and Wollacott (1995, chap.6). In this model, the task of postural control involves controlling the body's position in space for the purpose of 1) postural orientation, defined as the ability to maintain an appropriate relationship between the body segments, and between the body and the environment and 2) postural stability, defined as the ability to maintain the centre of body mass within stability limits, i.e., boundaries of an area of space in which the body can maintain its position without changing the base of support. These boundaries can vary with the task, the individual's biomechanics, and the environment.

**Systems needed for postural control must a) integrate sensory information to assess the position and motion of the body in space, and b) generate forces to control body position. This requires complex integration of musculoskeletal systems including muscle properties and biomechanical relationships among linked body segments, with neural systems. Neural systems include a) sensory systems including vestibular, somatosensory and visual systems b) sensory strategies that organize the multiple inputs c) internal representations for the mapping of sensation to action d) motor systems including neuromuscular strategies of response e) adaptive mechanisms to modify the sensory and motor systems to adapt to changing task and environmental demands and f) anticipatory mechanisms to pretune the sensory and motor systems based on previous experience.**

**The motor aspect of postural control requires the generation, scaling and coordination of forces to control the body's position in space. Motor control of quiet stance is dependent on background muscle tone to keep the body from collapsing. Neural and non-neural mechanisms contribute to this tone as well as an increase in activity of antigravity muscles referred to as postural tone. EMG studies have shown that muscles throughout the body are tonically active to maintain upright stance. If the body is within an ideal alignment range there is little muscular effort required, but if the body moves outside this range, compensatory postural strategies are used to regain stability. Three of these postural movement strategies have been described in the sagittal plane. If the perturbation to balance stability is small, an ankle strategy in which movement takes place around the ankle joints to restore stability. There is a synergic pattern of muscle activation from distal to proximal which maintains body alignment. If the perturbation is larger, a hip strategy is used, with activity mainly around the hip, in which the activation**

of the muscle synergy pattern is proximal to distal. A postural perturbation large enough to displace the center of mass outside the base of support elicits a step or hop in a stepping strategy. Motor control of posture in the seated position has not been as extensively studied, however forward translations and legs up rotation of the platform elicited similar patterns of response in a sequence from legs to neck. Since these movements cause similar backward rotation of the pelvis but different head movements the authors concluded that the trigger for postural responses was the movement of the pelvis not vestibular stimulation from head movements (Forsberg & Hirschfield, 1994).

The sensory aspect of postural control requires the organization of an accurate picture of where the body is in space and whether it is stationary or in motion. Peripheral inputs from visual, somatosensory and vestibular systems, each provide a different frame of reference for postural control. Visual input provides information about the position and motion of the head with respect to surrounding objects. This gives a reference for verticality from objects in the environment. Somatosensory input gives information about the body's position in space with reference to supporting surfaces and about the relationship of body segments to one another. The vestibular system provides information about the position and movement of the head with respect to gravity and inertial forces and is important in distinguishing between self movement and movement of the environment. All three inputs are important in control of quiet stance but in surface perturbations to stance somatosensory input appear to diminish in adults. Adapting how we use the senses is important in maintaining stability in a variety of environments. This has been examined under six conditions in which 1) stance has normal sensory inputs 2) vision is eliminated 3) visual information is inaccurate 4) somatosensory input is inaccurate 5)

somatosensory input is inaccurate and vision is eliminated and 6) somatosensory input and visual information are inaccurate. Adults could easily maintain balance in all conditions but there was progressive increase in sway with the greatest difficulty in conditions 5 and 6 where only vestibular information is accurate.

### Lateralization of the brain

The human brain is a parallel organ in which basic functions are represented on both sides of the brain in corresponding areas, however, there also exists a complementary specialization in which the performance of a function is qualitatively different in the two hemispheres (Milner, 1972). The left hemisphere appears to be dominant for handedness and verbal functions and the right hemisphere dominant for spatial and non-verbal functions (Sperry, 1972; Heilman & Valenstein, 1979). Memory deficits for example, occur from lesions in either temporal lobe, but a left sided lesion affects memory of verbal material whereas a right sided lesion affects memory for spatial location, faces and melodies (Milner, 1972).

Milner (1972) investigated the prevalence of localization of speech in the left hemisphere. Sodium amytal was injected into a carotid artery to disrupt the function of that hemisphere so that the affect on speech could be assessed prior to surgery on epileptic foci. Speech was found to be controlled from the left hemisphere in almost all right handed subjects and in 70% of natural left handers as well. This also suggested that cerebral dominance for speech and handedness are somewhat separate entities.

Cerebral dominance has further been shown to vary depending on the function involved. In studies of split brain subjects in whom the corpus callosum was severed, leaving each cerebral hemisphere intact but separated

from the other, it was found that only the left hemisphere could communicate by speech or writing. For example, when images were flashed to each visual field separately, the subject could describe the image in the right visual field but not in the left, even though he was able to identify the image in the left visual field by non-verbal means. The right hemisphere has been shown to be dominant in spatial skills however, e.g., a left hand superiority in copying complex block designs (Gazzaniga, 1980).

Other studies have demonstrated asymmetries in anatomical and chemical characteristics that may underlie some of the observed lateralization of function. In a study of the gross anatomy of human brains, Geschwind (1974) showed that the speech area was larger on the left side in 65% of human brains suggesting that the linguistic function of the left hemisphere could result from an anatomical bias. The speech area was equal or larger on the right side in 35% of the brains studied. This figure approaches the incidence of natural left handers, 10%, plus the incidence of anomalous dominance, 30% which suggests that left handedness and anomalous dominance may also have an anatomical explanation (Geschwind, 1984). Microscopic studies add support to an anatomical basis for greater development of the left hemispheric speech area. A region of distinctive cellular architecture, designated Tpt, was found to be larger in the plenum temporale on the left side (Galburda, 1984) and the left operculum was shown to have a more complex, higher order dendritic pattern than the right that may be a more suitable matrix for speech development (Scheibel, 1984). Motor function also showed an anatomical bias to the left hemisphere in that the pyramidal decussation was asymmetric with a greater number of fibers crossing from left to right, i.e. a greater projection of fibers from the left motor area (Galburda, 1984).

Chemical asymmetry has been demonstrated in unequal concentrations of neurotransmitters in each thalamus (Galburda 1984), and immune, hormonal, and other disorders have been correlated with cerebral dominance (Geschwind, 1984). Asymmetries have also been demonstrated in human skulls, in the fossil skulls of early man and some other primates, and in the brains and skulls of fetuses (LeMay, 1984). This last finding suggests that asymmetry is innate and not a response to functional demands.

### Studies of gross motor function

In the last few years there has emerged in the literature a recognition of the importance of balance, and of trunk balance in particular, as a predictor of outcomes of physical function in stroke patients. However, most studies evaluating outcomes of physical function have not found a difference between left CVA and right CVA despite the distinct patterns of deficits associated with each hemisphere. This is generally the case even for subcategories of function such as balance or ambulation.

One common finding is a higher incidence of perceptual problems in right CVA and some studies have linked this deficit to poor functional or poor ambulation outcome in that specific group of patients. Several studies show right CVA to be correlated with poor function at the level of static sitting or supported standing activities, but this relationship is not apparent when activities involving dynamic control, for example, independent ambulation, are included in the assessment score. It might be expected that perceptual/spatial problems, particularly deficits in perception of the body relative to the vertical, would exaggerate the less favorable outcome of right CVA at the level of ambulation compared to the left CVA but this does not seem to be the case. This suggests the possibility that left CVA may also be

associated with deficits that affect dynamic balance and offset the effect of perceptual deficits so that there is no measurable difference in the level of ambulation outcome.

### Balance and motor function

Several studies have shown balance to be correlated with function but show no difference in final outcome of activities of daily living and ambulation between right and left CVA. Keenan et al (1984) found the level of independence of ambulation to be highly correlated with balance reactions in 90 stroke patients but found no relationship to the side of CVA. Balance was tested by tilting the patient in sitting on a stable surface with feet on the floor and observing trunk response and limb protective reactions, and by observing stepping reactions in standing. Not surprisingly, balance, also, was found to be dependent on motor control of the leg as this was an essential element of the manner in which balance responses were scored. Similarly, Bohannon (1987) found standing balance to be correlated with several measures of ambulation (particularly independence in ambulation), and lower limb muscle strength to be significantly related to static standing balance (Bohannon, 1989). These studies also showed no difference with side of CVA.

Measures of balance that do not require motor control of the leg in standing also show balance to be correlated with functional motor outcome and may be better able to differentiate the effect of balance from the effect of motor control of the limbs. Collin and Wade (1990) found the ability to roll, sit up and maintain static sitting at 6 weeks post stroke to be a better predictor of independent ambulation at 18 weeks than was motor function of the leg. Although the maintenance of sitting balance was static, there was a dynamic

element required in the activity of sitting up. Sandin and Smith (1990) also reported a strong positive correlation between intact or early recovery of dynamic sitting balance and functional motor outcome.

### Right CVA and balance

There are several studies in which there was an initial association of poor sitting balance with right CVA but again, there was no difference between right and left CVA in overall outcome. Wade, Langton-Hewer and Wood (1984) also found that poor sitting balance was related to right CVA on initial assessment in a study of 162 stroke patients. However this was not reflected as a difference between patients with right and left CVA in overall function or ambulation at any point in assessments done at 6 month intervals over 36 months. In a chart review of 102 stroke patients, Bohannon, Smith & Larkin (1986) found that 81% of patients could maintain static sitting at initial assessment but in those who could not, there was a significant relationship with right CVA, however, functional outcomes were not reported. In a large study of all stroke patients of 976 patients admitted over a period of 28 months to hospitals within a specific geographical area, Wade and Langdon-Hewer (1986) found that despite different patterns of deficits on initial assessment, e.g., greater sensory and perceptual loss in right CVA, there was no difference between right and left CVA in overall functioning at 6 months post stroke.

### Perceptual deficits in right CVA and function

DeCencio, Leshner and Varon (1970) assessed perception of the visual vertical and its relationship to ambulation in right CVA, left CVA and normals. Subjects were seated in a dark room in front of a luminescent rod

The rod was rotated by the examiner and the subject was asked to indicate when the rod was in the vertical position. Errors in the frontal plane were greater in right CVA than in left CVA and both were greater than in normals. In right CVA errors were in the counterclockwise direction, i.e., towards the patients' left. In contrast, in left CVA the errors showed a starting position effect in the direction towards which the rod was set for each trial and not a bias toward one direction. In the sagittal plane errors were anterior to the vertical in right CVA and did not differ from normals in left CVA. Deficits in perception of the vertical correlated with poor ambulation in right CVA but not in left CVA. However, there was no significant difference in ambulation ratings between right and left CVA which suggests that although disturbance of verticality perception does not seem to be a significant factor in left CVA, there must be another deficit affecting the ambulation in left CVA.

In a large study of 236 stroke patients (Cassvan, Ross, & Dyer, 1976), patients with right CVA were significantly slower to achieve standing and walking in the parallel bars; however, the overall time to achieve independent ambulation outside the parallel bars was not significantly different. The authors attributed the earlier difference to the negative effect of perceptual deficits known to be associated with right CVA and the positive incentive to use the dominant limbs. One might question, however, why the perceptual problems would not be expected to accentuate the instability in independent walking where there are no longer parallel bars to supply balance support and a spatial reference point, or why incentive to use the dominant limbs would diminish at the level of independent ambulation.

In a more recent and prospective study of 93 stroke patients, Mayo, Korner-Bitensky and Becker (1991) reported on the influence of cognitive, perceptual and language variables on the time to achieve independence of

sitting, ambulation and stair climbing. Longer times to achieve sitting and stair climbing were associated with perceptual deficits; however, longer times to achieve ambulation were associated only with depression and comprehension deficits, and not with perceptual deficits. The authors postulate that motivation may have been affected by depression and the understanding of treatment instructions limited by poor comprehension but surely this would be equally true of the other functional levels. The authors also suggest that poor comprehension (aphasia) is often associated with apraxia which may be an influence. Although right and left CVA were not reported on separately, one might note that aphasia, apraxia and depression are more highly associated with left hemisphere deficits and suggest that the longer time to achieve ambulation is associated with left CVA. However, it could be equally argued that the seemingly anomalous results of these and other outcome studies might be explained by the presence of a dynamic balance deficit associated with left CVA that offsets the effect of the perceptual deficits associated with right CVA. Independent ambulation would seem to be the level at which one might expect this deficit would be apparent, as static sitting or activities done while holding parallel bars or a stair railing do not require the dynamic balance of independent ambulation.

Finally, Mills and Digenio (1983) reviewed 102 charts of stroke patients to examine possible differences in functional abilities of patients with CVA on the right or left side. They found no significant difference for any functional outcome category except language. The authors suggest that it may be more useful to examine the patterns of deficits associated with each hemisphere to identify possible prognostic indicators of functional rehabilitation rather than comparing right and left CVA groups on functional outcomes. This study advocates studying the differences in patients with right

and left hemispheric lesions at the more detailed level of the specific deficits associated with each hemisphere. This is in agreement with the premise of this thesis that it is important to identify the components which contribute to a functional problem in order to analyze the problem and improve treatment planning for the particular patient.

### Motor functions of the left hemisphere

The following discussion of the literature relating to specialization of motor performance in the left hemisphere applies only to voluntary movements as there does not appear to be literature on hemispheric specialization of automatic postural reactions. The discussion of voluntary movement lends support for the possibility that there may be some specialization of motor control of automatic postural movements as well.

The dominance of the left hemisphere in the control of certain aspects of motor function has long been recognized. The most obvious evidence of this dominance in the intact brain is the superiority of right hand function. Preference for use of the right hand appears to be of biological origin rather than the result of cultural shaping by a "right handed world" although the idea that handedness is culturally imposed has recurred in history. Advocates of the training of ambidexterity were prominent at the turn of the century, and the Boy Scout handshake, which deliberately uses the left hand, is a remnant of this view of the brain as a duplicate organ that can be symmetrically developed (Corballis, 1983).

Right handedness predominates in all human cultures, including those that have been geographically isolated from one another for centuries. The direction of reading or of script does not appear to influence or reflect handedness, as illustrated by Israelis who read from right to left and yet are

predominately right handed. Evidence from art and folklore of many cultures attests to the universal and historical dominance of the right hand (Bryden, 1984; Corballis, 1983).

In addition to the observations made on normals in society, motor functions of the left hemisphere have been investigated by examining the disorders of aphasia and apraxia that follow lesions of the left hemisphere. While the traditional interpretation of aphasia and apraxia has been as symbolic or representational disorders, evidence has accumulated in recent years that suggests that it may be the specialization for motor abilities in the left hemisphere which provides the basis for speech and praxis.

Geschwind (1975) defined apraxia as a disorder of the execution of learned movement that cannot be accounted for by weakness, incoordination or sensory loss, or by incomprehension of or inattention to commands. Heilman (1979) also excludes cases that involve akinesia, abnormality of tone and posture, abnormal movements such as tremor and chorea, intellectual deterioration and uncooperativeness. A key element of both definitions is the disruption of learned or skilled movements. This is also the case with Liepmann's (1908) description of apraxia, i.e., having to do with control of "purposive movements, that is, those learned connexions of elementary muscle actions" (cited by Kimura, 1974, p. 338). However, Kimura (1974) found deficits not only in familiar, learned movements, but also in unfamiliar, meaningless movements, and has proposed that apraxia is a purely motor disorder. The literature concerned with the nature of the motor deficits seen in apraxia will be discussed in three categories: performance of simple and multiple movements, temporal control, and motor learning.

### Performance of simple and multiple movements

Kimura and Archibald (1974) studied several kinds of manual activity in right and left CVA patients to define the nature of the motor deficit in apraxia. Most of the left CVA patients were aphasic. Unfamiliar, meaningless sequences that would have little or no verbal association were chosen for testing to minimize the effect of verbal mediation. Subjects with left CVA had more difficulty than the right CVA group in producing a series of different movements that were demonstrated by the examiner. This was bilateral and unrelated to the presence of hemiplegia. There were no differences, however, between the groups in copying static postures or in finger flexion movements at a single joint.

A further study (Kimura, 1977) compared right and left CVA subjects in acquisition and performance time on a learned sequence of manual movements and on finger tapping speed. The left CVA patients were subdivided into aphasic and non aphasic groups. The non aphasic group was impaired only on the acquisition time required to learn the sequence of manual movements whereas the aphasic group was impaired relative to the right CVA group on performance of the learned manual sequence but not on the finger tapping test i.e. on multiple but not on simple movements.

Other investigators have not found this dichotomy between simple and multiple movements. Wycke (1967, as reported by Kimura, 1977) found a general decrease in finger tapping speed in left CVA patients as compared to right CVA patients. Heilman (1979) concurred with this finding and further noted that the degree of deficit correlated with the degree of severity of apraxia. Kimura (1977) did note that the majority of the left CVA patients in the 1977 study would not be considered apraxic by the criterion of demonstrating how to perform familiar movements to command, and the few who fell into this category did in fact show reduced finger tapping speed.

She suggested that in severe apraxia all manual activity may be impaired. This would seem to undermine the assumption of a dichotomy between control of simple versus complex movements and to suggest that perhaps the subjects who showed no impairment on simple movements i.e. finger tapping, were simply not as severely involved.

Another consideration that lends support to the interpretation of a continuum of severity is that the differences in the Kimura (1977) study between right and left CVA groups in the manual sequence task reached statistical significance only with those left CVA patients in whom aphasia was also present. Kimura interprets this close association between speech and hand movements as evidence of a functional relationship, with apraxia and aphasia being different manifestations of the same problem (Kimura, 1977, 1979, 1981, 1982). An alternative interpretation depends only on a close anatomical contiguity of control areas (De Renzi, 1980) so that the larger the lesion of, for example, the speech area, the more likely it is to encroach on adjacent areas and result in apraxia as well.

In a refinement of the 1974 study on simple vs. complex movements in right vs. left CVA, Kimura (1982) investigated the interaction of lesion location, (anterior vs. posterior) and type of task (oral vs. manual). As in the earlier study, subjects were asked to copy meaningless static hand postures, or sequences of movements which were demonstrated by the examiner. In general, deficits were significantly greater in subjects with left CVA. Within the left CVA group, multiple movements were more affected than single movements and were impaired in both anterior and posterior lesions. Single movements were also affected, but the loss was more specific to location, with single oral movements lost only in anterior lesions and single manual movements affected mainly by posterior lesions. Therefore, for example, an

anterior lesion in the left hemisphere would impair multiple movements but leave single hand movements relatively intact. This interpretation could explain the findings of the earlier study showing a dichotomy between single and multiple movements in a subject with an anterior lesion.

In a similar study of manual tasks in patients with left CVA compared to controls (rather than the comparison with patients with right CVA in Kimura, 1982), DeRenzi (1983) looked at the effect of anterior and parietal lesions on single movements and on sequences. In contrast to Kimura, this study did not find sequences to be more impaired than single movements, nor were multiple manual movements found to be dependent on the frontal lobe. Patients with parietal, but not frontal lesions were found to be more impaired than normals on both single and multiple movements. There was agreement with Kimura, however, on the paramount role of the parietal lobe in motor control. Kolb and Milner (1981) also found the parietal lobe to be important in the control of manual movements. In a study of the effect of surgical lesions on multiple movements of the arm and face, facial movements were more affected in frontal lesion on either side and the arm, or manual task showed the greatest deficit in parietal lesions.

In summary, there is some doubt about a dichotomy in the control of single versus multiple movements and it appears probable that, in left CVA, there is a general disruption of motor performance that is graded in severity. There also seems to be agreement that the left parietal lobe plays an important role in this control.

### Temporal considerations

The left hemisphere appears to be specialized for sequencing and for fine temporal programming. The right hand is more proficient at tapping

rhythms, not only in right handed people, but also in 60% of left handers as well. Given that language is associated with the left hemisphere, this suggests that dominance for rhythm is associated with language dominance rather than handedness per se (Corballis, 1983).

The left hemisphere has been described as being specialized for serial processing, e.g., movements one at a time in sequence, as opposed to the parallel processing of the right hemisphere e.g. the processing of simultaneous inputs in spatial judgments, (Todor, Kyprie & Price, 1982). It appears to be specialized for programming the order of oral and manual movements (Mateer, 1983) and for making transitions i.e. stopping one movement before going on to the next (Kimura, 1977). All of these functions have a timing or initiation component.

Mateer (1983) discussed the perceptual counterpart of this timing function, i.e., left hemisphere is superior for processing rapidly changing temporal cues without regard for verbal versus nonverbal content. For example, Tallal (as reported by Mateer, 1983) presented similar sounds in a syllable (CV) to each ear separately and altered the rate of change of the two sounds. The right ear was superior in detecting the separate sounds at a high rate of change but this advantage was decreased when the rate of change of the sounds was decreased. Tallal suggested that it is this function that underlies the comprehension deficits of some aphasics, in that rapidly changing acoustic events characterize much of speech stimuli. This author questions that this is the essence of the comprehension deficit however, given that aphasic patients with speech comprehension problems frequently have difficulty in comprehension of the written word as well.

The supplementary motor area (SMA) appears to be important in these timing functions. The cortical potential (BP) preceding voluntary movement

has been found to be maximal over the SMA for all movements regardless of the location of the movement control in the brain (Deecke, Kornhuber, Lang, & Schreiber, 1985). Regional blood flow studies (Roland, 1985) show the SMA to be especially active during complicated sequences of voluntary movements, e.g., maze test.

Deecke et al. (1985) considers the SMA to be the key structure for all motor acts in that it determines the timing for all movements. The SMA has an abundance of afferents from many parts of the brain, and is the only centralized structure for otherwise decentralized motor acts, e.g., eye fields, speech area, motor cortex, etc. (Deecke et al, 1985). Afferent input to the SMA from joint movement has a long latency and is therefore probably polysynaptic implying multiple inputs from other structures. Connections from the cortical sensory areas are mainly from S1 and S2 where input from joints predominate, from Area 5 which receives complex inputs from more than one limb, and from cells in the Secondary Sensory area which generally have bilateral receptive fields (Brinkman, 1979). Stimulation of the SMA results in bilateral movements as described by Deecke et al, (1985) and Brodal (1980), and cerebral blood flow studies show that unilateral movements of the extremities activate the SMA bilaterally (Roland, 1985).

Bilaterality is present in the SMA presumably to coordinate actions on both sides of the body in timing of complex motor acts. Despite the bilateral nature of the SMA, a dominance effect has been described. The SMA of the left hemisphere showed a larger increase in metabolism during fluent, descriptive speech (Roland, 1985) and larger cerebral potentials during a writing task (Deecke et al. 1985).

In summary, clinical studies indicate that timing and sequencing of motor actions is more disrupted in lesions of the left hemisphere. The

supplementary motor area bilaterally is thought to be the critical structure and shows some evidence of lateralization of function.

### Motor learning

A deficit in motor learning has been correlated with both aphasia (Kimura, 1977) and apraxia (Heilman, 1979). Kimura (1977) found that the time required to learn a manual skill requiring several hand movements with each hand separately, was longer in patients with left CVA than in those with right CVA. However, the difference was significant only in the left CVA patients who also showed aphasia. A study by Heilman (1975), reported in Heilman, 1979) on aphasic patients showed a lack of significant improvement on a task using the non paretic hand only in those aphasics who were also apraxic.

Kimura (1977) noted that the types of errors made during acquisition of the skill were related to the severity of the apraxia. That study found that the patient with severe apraxia cannot approximate the desired movement and makes errors that are unrelated to the movement being attempted. The patient with moderate apraxia runs off the previous movement again as perseverative errors, and the patient with mild apraxia shows only a longer than normal decision time between movements (Kimura, 1977).

Heilman (1979) found a deficit in retention as well as acquisition but Jason (1984) found retention to be unimpaired. This may be explained by the type of subjects used in each study. Many authors consider the parietal lobe to be the site of storage of motor engrams (Heilman, 1979; Kolb & Milner, 1981; Kimura, 1982; DeRenzi et al. 1983), and as Jason's subjects had surgical removal of frontal or temporal areas, they may have been more likely to

have had the parietal lobe selectively spared compared to the group of subjects with cerebral vascular lesions studied by DeRenzi.

In addition to being the site of storage of motor engrams, some authors consider the parietal lobe to be critical to motor learning. Janda (personal communication, 1986) stated that the learning of a motor sequence occurs from peripheral sensory input, via the cerebellum, to the sensory cortex in the parietal lobes, where engrams are formed. Janda stressed that normal learned programs are performed on an automatic level which does not require attention to the movement.

Some authors have found areas other than the parietal lobe to be active in motor learning. Cortical potentials (Deecke et al. 1985) and blood flow (Roland, 1985) were found to be increased over the frontolateral cortex in a motor learning task and, in a clinical study, Jason (1984) found left frontal and left temporal lesioned subjects to be impaired in learning a sequence of hand positions compared to controls.

In summary, motor learning deficits are greater in lesions of the left hemisphere and are associated with apraxia. The site of motor learning is controversial but the left parietal lobe is considered to be important at least for retention.

### Summary

The literature was reviewed in relation to the following points:

i) There is abundant evidence, both physical and clinical, of lateralization of functions in the cerebral hemispheres. The right hemisphere appears specialized for spatial and perceptual functions and the left hemisphere for language and motor functions.

ii) Despite this lateralization of function, most studies do not find a difference between right CVA and left CVA in overall physical functional outcome, including ADL and ambulation.

iii) Balance is difficult to isolate and in testing is often blended with other functions, particularly motor function of the leg. Trunk balance, particularly dynamic balance, is a better predictor of outcome than motor function.

iv) Deficits in perception of orientation to the vertical in right CVA are associated with poor balance and poor functional outcome. The association of poor balance and function with right CVA is seen in static activities but is not evident when dynamic activities are included. This suggests the possibility that a deficit in dynamic balance is associated with left CVA that offsets the effect of the perceptual deficits associated with right CVA.

v) The literature does not address the influence of left CVA on balance specifically, however, left CVA is associated with a general disruption of motor function affecting performance, timing and motor learning.

## Chapter III

### Method

#### Subjects

Eighteen subjects, 11 male and 7 female, were tested in the Gait Laboratory of the Rehabilitation Centre in Ottawa. All were inpatients on the Stroke Program at the Rehabilitation Centre or on the Neurological unit at the adjacent Ottawa General Hospital. There were 9 subjects with left hemiplegia (mean age =70 years, SD=5) and 9 subjects with right hemiplegia (mean age 72 years, SD=6). Patients who were medically stable and satisfied the inclusion criteria were accepted into the study in order of admission to the hospital. Inclusion criteria were 1) a cerebrovascular accident within the previous 6 months, 2) unilateral brain damage based on CT scan in 16 subjects and on clinical evidence in 2 subjects for whom a CT scan was not available, 3) over 50 years of age, 4) right handedness except subject R7 (subject with right hemiplegia number 7) who was a natural left hander but showed severe aphasia and apraxia and was therefore assumed to have "normal" lateralization, 5) sitting balance sufficient to sit on a flat surface without hand or foot support for at least 10 seconds, 6) dynamic standing balance deficit such that they were unable to stand with feet together and rotate the arms and shoulders 30 degrees to each side, 7) no musculoskeletal problems which would influence alignment in sitting, e.g. scoliosis, or above knee amputation, 8) sufficient vision to see doors and walls (to orient to verticals in the room), 9) able to pass a simple aphasia screen, 10) body weight less than 250 lbs. (thought to be a limit for the equipment). Individual patient characteristics are presented in Table 1. The study was approved by the

Research Committee of the Rehabilitation Centre and the Research and Ethics Board of the Ottawa General Hospital.

### Apparatus

A tilting seat was designed and constructed by the Rehabilitation Engineering Department at the Rehabilitation Centre. The features were developed from clinical assessment and training of trunk reactions on the stroke program at the Rehabilitation Centre in which a seat attached to a barrel is used to tilt the patient to each side.

The seat for the study consisted of a platform, 18" wide and 24" deep, which pivoted at its attachment to a centre post so that it could be tilted to each side (Figure 1). The range and velocity of tilt were controlled by a motor with the start and stop controls on a foot switch so that the examiner's hands were free to handle the subject. The seat had a stop position at the horizontal and a carpenter's level attached to the back of the seat to confirm that the starting position for each trial was horizontal. The limit of excursion of tilt was approximately 15 degrees to each side but could be stopped during the excursion by the examiner releasing pressure from the foot pedal or pushing a stop button. The velocity of tilt was in the range of 7 to 10 degrees per second and relative adjustments could be made on a dial. An appropriate excursion of tilt and velocity were determined by pilot testing on 3 normal subjects and 2 subjects with hemiplegia. The seat was 27" from the floor so that the subjects' feet did not touch the floor but assisted transfers onto the seat were still fairly easy. The surface of the seat was covered with rug for comfort and to ensure that the subject did not slide off the seat. Parallel lines were drawn on the surface of the seat from front to back to facilitate centering the subject

on the seat and horizontal bars 20 cm long were attached laterally to the front of the seat to make the angle of tilt more easily visible.

The subjects' responses were recorded from the front using a single camera at 60 frames per second. A 2D calibration matrix with 9 markers at 50 cm intervals was used to calibrate the image space and each trial was digitized using the Ariel Performance Analysis System. The BIOMECH (University of Ottawa) package was used to analyze the digitized information and compute segmental kinematics.

### Procedure

All procedures were explained and demonstrated to the subjects before testing. The subjects from the Rehabilitation Centre had experienced similar testing as part of the routine assessment in physiotherapy and photographs of the equipment were shown to subjects at the Ottawa General Hospital. All subjects received an information sheet describing the purpose of the study and procedures involved and signed a consent form.

Markers were placed on the centre of the forehead, on the sternum just below the sternal notch and at the ends of the bars extending horizontally on either side of the front of the seat. Markers were also placed on a horizontal bar below the seat but digitized information from these or from the forehead were not used in this study.

### Testing the motor response - reaction to tilt

The subject was centered on the seat with the thighs fully supported. The feet were off the floor and the arms folded across the chest to eliminate effective limb reactions so that the observed reaction was primarily a trunk response. The subject wore a hospital gown, open at the back, to facilitate observation or palpation of the spine and iliac crests by the examiner. A

"walking" belt with handles at the sides and at the back, was placed around the subject's waist. The examiner stood behind the subject and held the handles of the belt to ensure the subject's safety.

The examiner adjusted the subject's position on the seat so that the iliac crests were level and the spine as straight as possible. The seat was tilted 3 times to each side first with eyes open and then with the eyes closed. This allowed the subject to become familiar with the testing procedure with eyes open first to reduce anxiety. A blindfold was used for subjects unable to reliably sustain eye closure and the procedure was simplified by completing the eyes open and eyes closed conditions in separate blocks. The sequence of direction of tilt was: right / left / left / right / right / left, or the reverse, with half of each group (subjects with left hemiplegia and subjects with right hemiplegia) starting with tilt to the right and half with tilt to the left. This was to control for any bias in reaction which might be dependent on the direction of the previous tilt in that there were equal numbers of trials following tilt to the same and opposite sides. In pilot studies this sequence of trials made the direction of tilt unpredictable for the subject as there were insufficient trials to determine a pattern so that the response was an automatic postural reaction rather than a preplanned compensatory movement. The trunk was supported by the examiner as needed to ensure safety.

The motor response to maintain the upright position was measured in two ways (figure 2);

- 1) The trunk movement relative to the starting position of the seat when the seat was tilted. This was measured by the change in angle formed by the marker at the sternal notch, the centre of the seat (calculated as the mid point between the markers on either side of the seat) and a marker at the side

of the seat (on the side of downward tilt). The largest change in the angle between the starting position and the end position of the trunk was taken as the measure of the active balance response with a larger angle indicating a better response, i.e., as the seat descended, the angle between the trunk and the seat decreased if the trunk tilted further than the seat (eccentric muscle activity) or increased as the subject moved the trunk toward the maintain the vertical position (concentric muscle activity). Therefore, the measured angle could be negative, zero, or positive on a continuum of scores.

2) The trunk position relative to the vertical at the end of tilt of the seat: This was measured by the angle formed by the marker at the sternal notch, the centre of the seat (as described above) and the vertical (calculated from the calibration matrix). This angle was taken as the measure of the ability to orient or maintain the body at the true vertical. The largest deviation of the trunk away from the vertical, after downward tilt of the seat, was used as the score for the trial. An angle towards the side of tilt was scored as negative and therefore the smaller the negative angle, the better the response. If the subject crossed midline, the angle was positive. Therefore, as in the measure above, the scores could be on a continuum from negative to positive.

On some trials the subjects lost control of balance and required support of the trunk to prevent a fall. This occurred mainly in subjects with left hemiplegia on tilt to the left. The actual angle of the trunk was used as the score and falls were not recorded as such.

### Testing the sensory response - perception of position

The sensory testing was done the same day as the motor testing in 13 subjects and following day in 3 subjects. In subject number 5 with right

hemiplegia, the sensory testing was done 2 weeks after the motor testing because of illness but there was no significant change in medical status in that time. The testing apparatus was the same as above. The seat was gently tilted approximately 15 degrees towards one side and then once the subject was stable in the tilted position, it was slowly returned towards the horizontal. The subject indicated verbally, or with a nod or hand signal, the point at which he/she felt the seat to be horizontal. Testing was done three times from each side with eyes open and eyes closed in the sequence described above, i.e., right / left / left / right / right / left. Data could not be collected from one subject with left hemiplegia (subject L1) because of language problems despite the assistance of an interpreter.

The response was measured by the position of the seat which the subject perceived to be the horizontal or level position (figure 3). This was the angle made by the marker at the side of the seat (on the side of downward tilt), the centre of the seat and the horizontal (calculated from the calibration matrix). An angle below the horizontal on the side of tilt was scored as negative. If the position of the seat was beyond the horizontal, i.e., tilted to the opposite side, then the angle was above the horizontal and was scored as positive. There was, therefore a continuum of scores.

### Clinical Data

Lateral trunk strength was measured with a hand held dynamometer (Nicholas Manual Muscle Tester) using the method described by Bohannon (1995). The subject sat on a flat surface with the feet unsupported and pushed against the dynamometer held just below the tip of the acromion.

Position of the pelvis in the frontal plane was recorded with the subject sitting on a flat surface and feet on the floor. The position of the pelvis was

scored as (1) laterally tilted to the hemiplegic side (2) level or (3) laterally tilted to the normal side.

Data were also collected from the clinical assessment by the treating physiotherapist. Stage of motor recovery of the leg was scored using a modified Brunnstrom scale from Chedoke Stroke assessment (Gowland, 1995). Sensation of light touch of the leg and standing balance were scored on an ordinal scale developed at the Rehabilitation Centre for the assessment of patients on the Stroke Program. Sitting balance and level of ambulation were scored using the Clinical Outcome Variables Scale (Seaby & Torrence, 1989). These scales are in appendix A. The severity (mild, moderate or severe) of neglect, visuospatial problems and apraxia was noted from the assessment done by the occupational therapist or the psychologist.

### Analysis

Three measures 1) trunk movement relative to the starting position, 2) trunk movement relative the vertical, and 3) perception of a the seat position as horizontal, were tested under four conditions, i.e., direction of tilt (toward the hemiplegic or non hemiplegic side) and vision (eyes open or closed). Scores for individuals were averaged over three trials of each condition. The data were analyzed with three 3 way analyses of variance (ANOVA) with a between groups factor of right versus left hemiplegia and 2 repeated measures of a) direction of tilt (toward the hemiplegic and nonhemiplegic side) and b) vision (eyes open and eyes closed) (Huberty and Morris, 1989). These analyses were done on 1) movement of the trunk relative to the starting position 2) response of the trunk relative to vertical and 3) position of the seat perceived to be horizontal. There were nine subjects in each group for the analyses of the motor response and eight subjects in each group for the sensory analysis.

**The subject with left hemiplegia who could not be tested for the sensory response was severely involved and therefore a subject with right hemiplegia (subject number 7) who was also severely involved was dropped from the analysis of variance to maintain equal numbers.**

## Chapter IV

### Results and Discussion

Results will be presented and discussed first for the two measurements of the motor response 1) movement relative to the starting position and 2) end position of the trunk relative to the vertical, followed by the sensory response, i.e., perception of the seat position as horizontal. A 3 way ANOVA was performed on each of the 3 sets of data. The assumptions of normality and homogeneity of variance were not met by the motor data, i.e.,  $F_{\max} = 17.9$  for the movement relative to the starting position and  $F_{\max} = 7.8$  for the end position of the trunk relative to the vertical. This exceeds the  $F_{\max} = 5$  which is an acceptable level (Howell, 1982). However, Howell (1982, pp. 258-259) states that the analysis of variance is a very robust statistical procedure, and the assumptions can frequently be violated with relatively minor effects. He also states that it is important to have equal sample sizes if there is heterogeneity of variance and all groups had equal sample sizes. The sensory data had an acceptable homogeneity of variance at  $F_{\max} = 2.8$ . For all variables there was a significant interaction between the side of hemiplegia (left and right) and the direction of tilt of the seat (toward the hemiplegic side and toward the normal side). The main effects are not of clinical interest and therefore will not be discussed. Post hoc analysis, to determine which means were significantly different, will be reported. For all 3 variables, vision (eyes open or eyes closed) was not significant and these data were combined for the post hoc analysis. Finally, results of clinical testing will be presented and discussed.

### Motor response to tilt

There was a significant interaction between side of hemiplegia and direction of tilt for trunk movement relative to the starting position,  $F(1, 16) = 8.72$ ,  $p < .05$  (Table 2). The interaction diagram for trunk movement relative to the starting position (Figure 4) shows that when tilted to the hemiplegic side (using muscles on the normal side) the range of movement of the subjects with left hemiplegia is less than the subjects with right hemiplegia. This difference was marginally significant,  $t = -1.77$ ,  $p = 0.055$ . On tilt to the normal side (using muscles on the hemiplegic side), the response of subjects with left hemiplegia was not significantly different from subjects with right hemiplegia,  $t = 1.0$ ,  $p = 0.17$ .

The data for individual subjects for trunk movement relative to the starting position is presented in Figure 5. Figure 5A shows movement relative to the starting position for subjects with left hemiplegia. The data for each subject represents the average of six trials for each side of tilt. The starting position is represented by 0 on the chart scale. A negative angle indicates that the subject moved beyond the starting position in the same direction as tilt of the seat (eccentric movement). This is seen in subjects L3, L4, L6 and L7 (all of whom were severely involved) on tilt to the hemiplegic side. Subjects L3 and L4 moved a smaller amount beyond the starting position on tilt to the normal side as well. A positive angle indicates that the subject moved toward the vertical, i.e., opposite to the side of tilt (concentric movement). This is seen on tilt to both sides in subjects L1, L2, L5, L8 and L9 and on tilt to the normal side in subjects L6 and L7. As illustrated in the chart, the range of trunk movement of all subjects with left hemiplegia is less on tilt to the hemiplegic side than on tilt to the normal side (except for subject L8, who made a larger response on tilt to the hemiplegic side).

Figure 5B shows movement relative to the starting position for subjects with right hemiplegia. The magnitude of the response on tilt to each side was more similar than in subjects with left hemiplegia. On tilt to the normal side the response was smaller than in subjects with left hemiplegia and on tilt to the hemiplegic side the response was larger except for subject R8.

Figure 5C shows the mean of angles of movement of the trunk presented in charts A and B. When subjects with left hemiplegia were tilted to the hemiplegic side the mean range of movement towards the upright position was  $-1.68^\circ$  ( $SD = 8.81$ ) indicating that the trunk tilted slightly further than the seat. On tilt to the normal side the mean range was  $7.14^\circ$  ( $SD = 6.71$ ) opposite to the direction of tilt, i.e., towards the upright position,  $t = -2.27$ ,  $p = 0.02$ . This illustrates the tendency for subjects with left hemiplegia to make a lesser response on tilt to the hemiplegic side than on tilt to the normal side. In subjects with right hemiplegia there was little difference between the two sides of tilt,  $t = -0.33$ ,  $p = 0.37$ , with a mean range of  $3.92^\circ$  ( $SD = 2.08$ ) on tilt to the hemiplegic side and  $4.43^\circ$  ( $SD = 4.49$ ) on tilt to the normal side. Note the greater variability of response in subjects with left hemiplegia. Figure 5D shows the mean of angles of movement of the trunk without the data for subject L8. This accentuates the difference on tilt to the two sides in subjects with left hemiplegia. Post hoc testing for interaction of subjects with right and left hemiplegia on tilt to the hemiplegic side was significant,  $t = -2.5$ ,  $p = 0.02$ , when subject L8 was removed from the data pool.

It is useful to evaluate the data without subject L8 because had the criteria for subject selection been more specific, he would not have been included. The primary subject selection criterion for this study was a deficit in dynamic balance as defined by the inability to stand with feet together and

rotate the trunk 30 degrees to either direction. Many of these patients do align their center of gravity toward the hemiplegic side, but there are some who align to the normal side but have other problems that may impair performance on the above criterion, e.g., high tone or a premorbid instability in standing on one leg. Most patients align to the normal side (Shumway-Cook, 1995) but a significant group with both left and right hemiplegia align to the hemiplegic side (about 10% in the study by Pedersen et al, 1996). As this was the target group for this study, subject selection based on alignment of the trunk would probably have been a better criterion. Subject L8 was aligned to the normal side even in sitting and results of both motor and sensory testing for that subject are opposite to the results for the other subjects with left hemiplegia all of whom oriented, in varying degrees, to the hemiplegic side. If data from subject L8 is not included the differences found between subjects with right and left hemiplegia, and between sides of tilt in left hemiplegia, are somewhat larger.

There was also a significant interaction between side of hemiplegia and direction of tilt, for trunk position relative to the vertical,  $F(1, 16) = 17.06, p < .05$  (Table 3). The interaction diagram for trunk movement relative to the vertical (Figure 6) shows an even greater difference in the response of the subjects with left versus right hemiplegia than was seen in the measurement from the starting position. When tilted to the hemiplegic side (using muscles on the normal side), the distance of the end position from the vertical of the trunk was significantly greater in subjects with left hemiplegia than in subjects with right hemiplegia,  $t = -2.8, p = 0.009$ . Whereas, when tilted to the normal side (using muscles on the hemiplegic side), the distance of the end position of the trunk from the vertical was significantly greater in subjects with right hemiplegia than in subjects with left hemiplegia,  $t = 1.79, p = 0.008$ .

The data for individual subjects for trunk position relative to the vertical is presented in Figure 7. Figure 7A shows movement relative to the vertical for subjects with left hemiplegia. As illustrated, the end position of the trunk of subjects with left hemiplegia is further from the vertical on tilt to the *hemiplegic* side than on tilt to the normal side (except subject L8). On tilt to the normal side, four subjects (L1, L2, L7 and L9) crossed midline to the hemiplegic side. Figure 7B shows the data for subjects with right hemiplegia and illustrates that the end position of the trunk of subjects with right hemiplegia is further from the vertical on tilt to the *normal* side than the hemiplegic side in 5 subjects (R3, R5, R6, R7 and R9), almost equal in 3 subjects (R1, R2 and R8) and further on tilt to the hemiplegic side than the normal side in one subject (R4). Also, none of the subjects with right hemiplegia maintained the trunk at, or past, the vertical on tilt to either side.

Figure 7C shows the mean of angles of end position of the trunk from the vertical presented in charts A and B. All subjects showed a mean angle from the vertical toward the side of tilt in both directions. In subjects with left hemiplegia, the mean angle of the trunk from the vertical was  $-19.44^\circ$  ( $SD = 10.3$ ) on tilt to the hemiplegic side and  $-3.95^\circ$  ( $SD = 7.86$ ) on tilt to the normal side  $t = -3.43$ ,  $p = 0.002$ . This illustrates the tendency for subjects with left hemiplegia to lean more toward the *hemiplegic* side than to the normal side. In subjects with right hemiplegia the mean angle of the trunk from the vertical was  $-8.60^\circ$  ( $SD = 4.11$ ) on tilt to the hemiplegic side and  $-12.42$  ( $SD = 3.69$ ) on tilt to the normal side,  $t = 2.07$ ,  $p = 0.03$ . The difference between the two sides of tilt is not as large in subjects with right hemiplegia but, in contrast to subjects with left hemiplegia, they showed a tendency to lean more to the *normal* side than to the hemiplegic side. Note the greater variability of response in subjects with left hemiplegia. Figure 7D shows the mean of angles

of the trunk from the vertical without the data for subject L8. This accentuates the difference on tilt to the two sides in subjects with left hemiplegia.

As described above, in the interaction diagram of the end position of the trunk from the vertical (Figure 6), the subjects with right hemiplegia were significantly further from the vertical than subjects with left hemiplegia, on tilt to the normal side (using muscles on the hemiplegic side). This suggests a reduced motor response in right hemiplegia, using the hemiplegic trunk muscles, compared to subjects with left hemiplegia. In Figure 6, subjects with right hemiplegia were also significantly further from the vertical on tilt to the normal side (using muscles on the hemiplegic side) than on tilt to the hemiplegic side (using muscles on the normal side) suggesting a smaller response on tilt to the normal side. This contrasts with the results seen in Figure 6 on tilt to the hemiplegic side (using muscles on the normal side), where the subjects with left hemiplegia were significantly further from the vertical than subjects with right hemiplegia. Subjects with left hemiplegia were also significantly further from the vertical on tilt to the hemiplegic side (using muscles on the normal side) than on tilt to the normal side (using muscles on the hemiplegic side). The average starting position of the subjects with left hemiplegia was approximately  $5^{\circ}$  to the left of vertical, i.e., towards the hemiplegic side, and the end position was an average of almost  $20^{\circ}$  on tilt to the left as compared to an average of less than  $4^{\circ}$  from vertical on tilt to the right. This difference cannot be explained on the basis of trunk strength as the lesser reaction is with the hemiplegic trunk. A possible explanation will be discussed in conjunction with the sensory response.

It was expected that the interaction diagram for movement from the starting position, Figure 4, would show similar relationships, i.e., that subjects with right hemiplegia would have a significantly smaller angle of movement

than subjects with left hemiplegia on tilt to the normal side (using muscles on the hemiplegic side) and that subjects with right hemiplegia would have a significantly smaller angle of movement on tilt to the normal side (using muscles on the hemiplegic side) than on tilt to the hemiplegic side (using muscles on the normal side). These differences, however, were not significant. A possible explanation is that in several subjects there was some counter rotation of the trunk opposite to the side of tilt when they felt unstable on tilt to the normal side. This rotation may have moved the markers at the sternal notch closer to the vertical and obscured an actual difference. This counter rotation response to tilt was noted in a study of children tilted on a rocker board (Millette & Rine, 1987). Also, the average starting position was approximately 2° to the left of vertical so that slightly less range of movement was needed to maintain a stable upright position on tilt to the hemiplegic side. This may be reflected in the greater deviation from vertical on tilt to the normal side seen in the subjects with right hemiplegia in Figure 6.

Trunk strength on the hemiplegic side was 0.9 of the strength of the normal side and one would expect this to be adequate strength to complete an unresisted righting reaction against gravity. The response to tilt may be explained in terms of a deficit in motor response of the trunk in an automatic postural reaction rather than a deficit in voluntary movement. The counter rotation referred to above (Millette & Rine, 1987) was found to be greater on externally induced tilt than on self induced tilt, leading the authors to suggest that there may be different motor programs for automatic and willed balance responses. Martin (1977) also postulated from observations on patients with Parkinson's disease, that postural activity and voluntary movement are separate functions and that in some lesions postural mechanisms can be lost

without impairment of voluntary movement. Shumway-Cook and Wollacott (1995) also report a different pattern of movement in patients with Parkinson's disease on postural movements.

The ratio of strength of the hemiplegic trunk to the normal trunk in the present study at 0.9 is similar to that reported by Bohannon (1995) at 0.85. Bohannon found that trunk muscle strength *was* correlated with sitting balance which was measured as the ability to maintain sitting balance against gravity or graded displacement forces while sitting on a firm base. Therefore this may have involved primarily voluntary activity as opposed to the automatic postural reactions required following an unpredictable tilt of the base of support and therefore perhaps not reflecting the same motor programs.

#### Sensory response

There was a significant interaction between side of hemiplegia and direction of tilt for the angle of the seat perceived as horizontal  $F(1, 14) = 11.54, p < .05$  (Table 4). The interaction diagram for the sensory response (Figure 8) shows that from tilt to the hemiplegic side, the angle of the seat perceived as horizontal is in the same direction as the starting position of the seat and the angle is greater in subjects with left hemiplegia than in subjects with right hemiplegia,  $t = -2.89, p = 0.01$ . From tilt to the normal side, the response of subjects with left hemiplegia was not significantly different from subjects with right hemiplegia,  $t = -1.34, p = 0.10$ .

The data for individual subjects is presented in Figure 9. Figure 9A shows the angle of the seat from the horizontal for subjects with left hemiplegia. The horizontal is represented by 0 on the chart. A negative angle indicates that the subject perceived the seat to be horizontal while still tilted

in the direction of the starting position of the seat, before reaching the horizontal. This is seen in all subjects from tilt to the hemiplegic side. A positive angle indicates that the seat was perceived as horizontal only after the seat moved beyond the horizontal opposite to the direction of the starting position of the seat. This is seen in subjects L3, L4, L5 and L9 from tilt to the normal side. All subjects with left hemiplegia show a larger angle of the seat toward the hemiplegic (left) side whether from tilt to the hemiplegic side or the normal side except subject L8. Figure 9B shows the angle of the seat from the horizontal for subjects with right hemiplegia. The direction of tilt of the seat that is perceived as horizontal is less consistent in subjects with right hemiplegia than in subjects with left hemiplegia. Subjects R3, R4 and R6 show a greater angle from the horizontal on tilt to the normal side and subjects R7 and R9 show a greater angle from the horizontal on tilt to the normal side. In almost half of the data points, perception of the horizontal is within a degree of the true horizontal. Thus perception of the horizontal appears to be more accurate in subjects with right hemiplegia than in subjects with left hemiplegia.

Figure 9C shows the mean of angles of end position of the trunk from the vertical presented in charts A and B. In subjects with left hemiplegia the mean angle of the seat from the horizontal was  $-3.29^\circ$  ( $SD = 2.27$ ) from tilt to the hemiplegic side and  $0.19$  ( $SD = 3.13$ ) from tilt to the normal side  $t = 2.88$ ,  $p = 0.007$ . This illustrates the tendency for subjects with left hemiplegia to perceive the seat as horizontal when it was tilted toward the hemiplegic side, from a starting position of the seat tilted to either side. In subjects with right hemiplegia the mean angle of the seat from the horizontal was  $-0.99$  ( $SD = 1.85$ ) from tilt to the hemiplegic side, and  $-1.22$  ( $SD = 1.75$ ) from tilt to the normal side  $t = 0.26$ ,  $p = 0.4$ . Thus, subjects with right hemiplegia do not show

a bias to one side in perception of the position of the seat to perceive the position of the seat more accurately than subjects with left hemiplegia. In subjects with left hemiplegia, the bias of perception of the seat as horizontal when it was tilted toward the hemiplegic side may explain the lesser motor response of the trunk when tilted to the hemiplegic side. The subject senses the vertical to be displaced to the hemiplegic side and does not respond appropriately to the true vertical.

Several authors have noted that some patients with hemiplegia align the body towards the hemiplegic side in sitting or standing. This is usually associated with left hemiplegia. Davies (1985) described a "pusher" syndrome found mainly in patients with left hemiplegia in which the patient pushes strongly to the hemiplegic side, has associated neglect and symptoms of spatial disturbance. Bohannon (1996) refers to studies and clinical observations that support pushing to the hemiplegic side to be associated with left hemiplegia. Taylor, Ashburn and Ward (1994) also found that alignment of the trunk toward the hemiplegic side was associated with left hemiplegia.

They noted however that the study was somewhat biased toward subjects with left hemiplegia in that subjects who could not communicate clearly at 1 week post stroke were excluded thereby possibly excluding some of the more severely involved patients. Other authors have not found this association with left hemiplegia. Pedersen et al, (1996) investigated this "pushing" phenomenon in a large study of all stroke patients from a well defined catchment area who were treated in physiotherapy (327 subjects from a total of 647 admissions). The study reported the incidence of subjects pushing to the hemiplegic side to be 10% of the treated group but found no relationship to side of hemiplegia. Shumway-Cook and Wollacott (1995) and Perry (1974) describe instability to the hemiplegic side but do not identify a

specific side of hemiplegia. The present study agrees with the findings of lateral weight shift toward the side of hemiplegia in both right and left hemiplegia. A lateral tilt of the pelvis toward the hemiplegic side was found in subjects with both left and right hemiplegia in the clinical assessment data.

Neglect of the hemiplegic side has been thought to be the significant factor in this shift to the hemiplegic side (Davies, 1985; Taylor et al. 1994) but Pedersen et al. (1996) did not find an association with neglect. Shumway-Cook and Wollacott (1995) explained this shift to the hemiplegic side as a discrepancy between actual and internal models of stability limits. Bohannon (1996) in response to the article by Pedersen et al (1996) suggested that the pushing to the hemiplegic side in patients with left hemiplegia was consistent with the patient believing that his appropriate position in space was somewhere to the left of true center.

The studies referred to above describe the pushing behavior but do not identify why or how it occurs and advocate further investigation into that aspect. The present study suggests that the shift toward the hemiplegic side in left hemiplegia results from the perception of horizontal (or vertical) as tilted to the left and that the neglect frequently found in left hemiplegia may be just a concomitant but not critical factor.

#### Clinical data

The clinical assessment data are presented in Table 4. Trunk strength was not tested on two subjects with left hemiplegia and two subjects with right hemiplegia and data were not recorded in the chart for some patients for pelvic level, neglect, spatial deficits and apraxia as indicated in Table 4. The data were not analyzed statistically because of the small number of subjects but on inspection of the data there is no obvious relationship of the balance

deficit, which was a criterion of subject selection (Table 1), with severity of motor function of the leg, sensation of the leg, trunk strength or hemispatial neglect. Similarly, spatial deficits recorded in subjects with left hemiplegia and apraxia in subjects with right hemiplegia do not show consistency in level of severity. For example, all subjects with right hemiplegia and a standing balance deficit do not show severe apraxia. There does, however, seem to be a pattern of lateral tilt of the pelvis toward the hemiplegic side especially in the group of subjects with left hemiplegia. It is also worth noting that the two groups of subjects with right and left hemiplegia appear to be well matched in patient characteristics (Table 1) and in clinical assessment data (Table 4). In agreement with other authors (Davies, 1985; Pedersen et al. 1996; & Taylor et al. 1994) there was no indication that peripheral sensation or motor recovery level influenced the balance problem nor did aphasia or apraxia. Pedersen et al (1996) also did not find a relationship with aphasia or apraxia or a specific lesion location to be either necessary or sufficient for the pushing behavior. Similarly, in this study there is no obvious relationship with apraxia or lesion location.

### Vision

An interaction was expected between vision and side of hemiplegia but this was not significant. One would expect that vision would be a more important compensation in the subjects with left hemiplegia who have a displaced sense of space than in subjects with right hemiplegia whose perception of space is more accurate. Several authors have discussed the importance of vision in balance control and as a compensatory strategy for deficient vestibular or somatosensory information (Horak, 1996; Shumway-Cook & Wollacott, 1995). This difference has also been seen frequently in

personal clinical observations. It may be that the number of subjects was too small to demonstrate this with a three-way analysis of variance. Another possibility noted in viewing the videotapes is that in several trials with eyes open, the subjects were looking down rather than at the verticals of the room and therefore not using vision for orientation. Also, the wall in front of the subjects was approximately 12 feet from the subject and Paulus, Straube & Brandt (1987) state that visual stabilization is less effective in eye target distances beyond 1 m because the retinal image shift due to normal head sway falls short of the motion discrimination threshold. A visual target closer to the subject might have been more effective, however, the author was not familiar with this information at the time of subject testing.

## Chapter V

### Conclusions and Recommendations

#### Conclusions

Based on analysis of the data the following conclusions are warranted;

1) The deficit in the motor response of the subjects with right hemiplegia is greater on tilt to the normal side than in subjects with left hemiplegia on tilt to the normal side (using the hemiplegic trunk). This difference is seen in the position of the trunk relative to the vertical.

2) The deficit in the motor response of the subjects with left hemiplegia is greater on tilt to the hemiplegic side, i.e., when using the normal side for the response, than on tilt to the normal side. This difference in response is much greater when examined relative to the vertical.

3) The deficit in the motor response of the subjects with right hemiplegia is greater on tilt to the normal side, i.e., when using the hemiplegic side for the response than on tilt to the hemiplegic side. This difference in response is much greater when examined relative to the vertical.

4) The deficit in perception of the seat as horizontal is greater in subjects with left hemiplegia than in subjects with right hemiplegia from tilt to the hemiplegic side. Perception of the seat as horizontal for subjects with left hemiplegia is displaced to the hemiplegic side. This may explain the deficient motor response of the subjects with left hemiplegia on tilt to the hemiplegic side (even though the normal side of the trunk is active).

5) Eye closure was expected to result in a greater deficit in both the motor and sensory response in subjects with left hemiplegia than in subjects with right hemiplegia but this was not a significant interaction.

### Recommendations

1) A control group was not part of this study because the purpose of the study was to investigate a difference between the effect of left and right hemiplegia on trunk responses. It would be useful to compare these results to an age matched control group of normals.

2) Investigate related aspects of the automatic motor responses in right hemiplegia by comparing subjects with right hemiplegia who align the center of gravity toward the hemiplegic side with subjects who align to the normal side in sitting or in standing (if the pelvis is level in sitting). It would be interesting to relate the range of trunk movement in response to tilt and the voluntary movements of strength testing in order to compare automatic and voluntary movements. The comparison could also be made with the response to displacement on a stable surface to determine if strength measures relate to level of balance control under the same surface conditions.

3) Investigate related aspects of the sensory deficit in the awareness of the position of the seat in subjects with left hemiplegia in relation to

- a) awareness of the visual vertical with the subject seated on both flat and tilted surfaces to examine the relationship of the visual vertical to the sense of postural position,
- b) spatial deficits as measured in paper and pencil tasks to examine the relationship of constructional problems to the sense of postural position,

**c) the relationship between awareness of the position of the supporting surface and position of the body relative to the vertical to examine the relationship between perception of the horizontal and the vertical.**

**4) Establish subject selection criteria to include only subjects who align their centre of gravity to the hemiplegic side in sitting or standing rather than subjects with simply dynamic balance instability.**

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Table 1

Characteristics of Subjects

Subjects	Sex	Age	Weeks post stroke	Standing balance	Brain lesion location
Left hemiplegia					
L1	M	67	10	2	frontal, parietal
L2	M	73	10	3	internal capsule
L3	F	65	8	1	frontal, parietal
L4	F	75	6	1	internal capsule
L5	F	54	2	2	internal capsule
L6	F	86	11	1	temporal, parietal
L7	M	56	5	1	basal ganglia, thalamus
L8	M	76	17	3	internal capsule
L9	M	78	3	1	frontal, temp, parietal
Mean		70	8	2	
SD		10	5	1	
Right hemiplegia					
R1	F	78	13	3	basal ganglia
R2	F	78	5	1	middle cerebral artery
R3	M	69	3	3	posterior, occipital
R4	M	74	22	3	Internal carotid
R5	F	71	9	1	temporal, parietal
R6	M	63	11	3	ant, middle cerebral artery
R7	M	65	12	1	frontal
R8	M	73	2	2	internal capsule
R9	M	80	2	3	middle cerebral artery
Mean		72	9	2	
SD		6	7	1	

Table 2

Summary of the Analysis of Variance

Motor response: movement of trunk from starting position

Source	df	SS	Obtained F ratio	P
<b>Between groups</b>				
Side of hemiparesis	1	37.6	0.31	>.05
<b>Within groups</b>				
Direction of tilt	1	391.4	10.97	<.05
Vision	1	0.1	0.0	>.05
Side x tilt	1	311.0	8.72	<.05
Side x vision	1	0.1	0.02	>.05
Tilt x vision	1	9.4	1.64	>.05
Side x tilt x vision	1	0.0	0.01	>.05
Total	71	3393.1		

Note: critical value of  $F(1,16) = 4.49$  ( $\alpha = .05$ )

Table 3

Summary of the Analysis of Variance

Motor response: position of trunk from vertical

Source	df	SS	Obtained F ratio	P
Between groups				
Side of hemiparesis	1	25.5	0.22	>.05
Within groups				
Direction of tilt	1	612.5	6.23	<.05
Vision	1	1.6	0.02	>.05
Side x tilt	1	1676.0	17.06	<.05
Side x vision	1	0.4	0.09	>.05
Tilt x vision	1	13.4	2.75	>.05
Side x tilt x vision	1	1.9	0.33	>.05
Total	71	5919.6		

Note: critical value of  $F(1,16) = 4.49$  ( $\alpha = .05$ )

Table 4

Summary of the Analysis of VarianceSensory response: perception of seat as horizontal

Source	df	SS	Obtained F ratio	P
<b>Between groups</b>				
Side of hemiparesis	1	4.2	0.45	>.05
<b>Within groups</b>				
Direction of tilt	1	30.5	3.60	>.05
Vision	1	8.8	1.04	>.05
Side x tilt	1	70.2	8.29	<.05
Side x vision	1	4.0	0.87	>.05
Tilt x vision	1	9.4	1.64	>.05
Side x tilt x vision	1	6.6	2.39	>.05
Total	63	478.2		

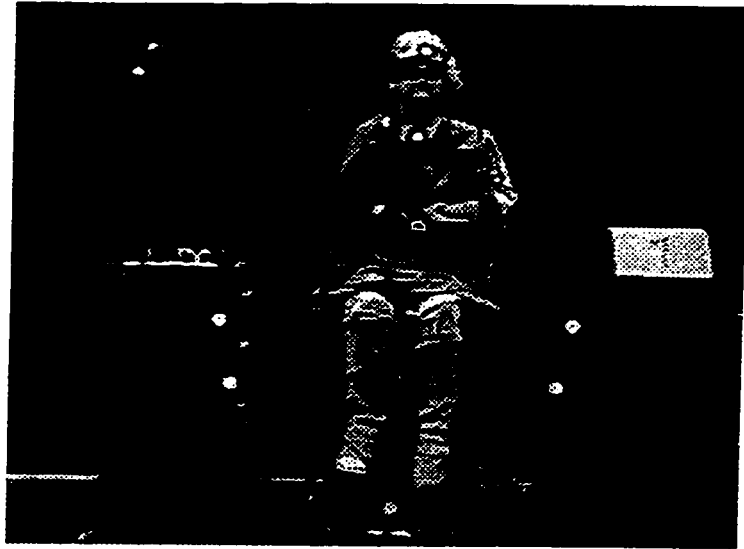
Note: critical value of  $F(1,14) = 4.60$  ( $\alpha = .05$ )

Table 5

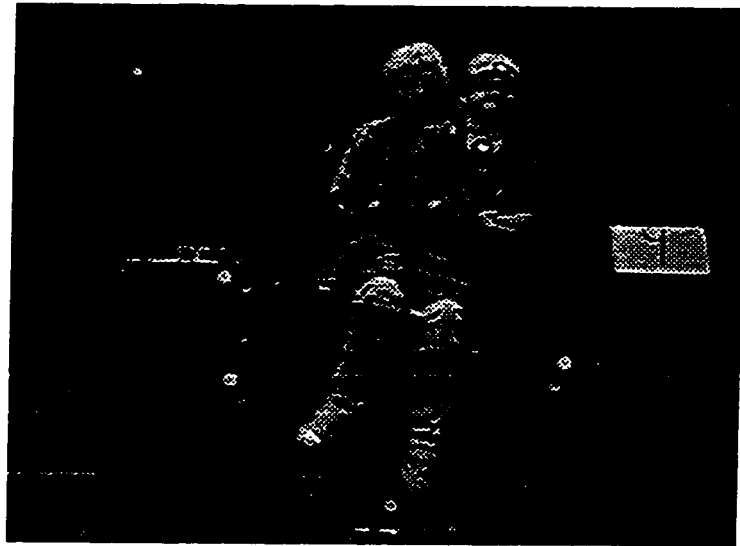
Clinical assesment data

Subjects	Motor Function of Leg	Sensation of Leg	Sitting Balance	Trunk Strength hemiplegic / normal side	Lateral Pelvic tilt (low side)	Neglect	Spatial Deficits
Left hemiplegia							
L1	3	3	4	0.9	L	mod	mod
L2	4	5	4	0.9	L	mild	mild
L3	3	2	3	0.7	L	mod	mod
L4	3	5	3	1.0	L	mild	mild
L5	5	2	4	1.0		mild	
L6	2	5	3		L	mod	mod
L7	4	5	2	1.1	L	none	mild
L8	5	5	4		R	none	none
L9	3	5	2	0.9	L	mod	
Mean	4	4	3	0.9			
SD	1	1	1	0.1			
Right hemiplegia							
R1	5	3	3	0.9	level	mild	none
R2	5	2	4	1.0	level	mild	mild
R3	6	5	5	1.1			
R4	3	5	4	0.8	R	mild	mild
R5	3	4	3	0.8	R	mild	none
R6	2	3	3		R	mild	severe
R7	4	5	3	1.0	level	mod	severe
R8	6	5	4	0.9	R	none	none
R9	6	5	5			none	mild
Mean	4	4	4	0.9			
SD	2	1	1	0.1			

A.

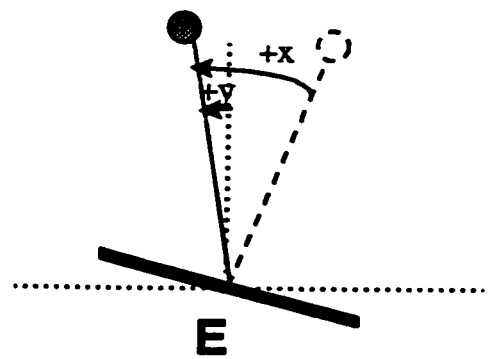
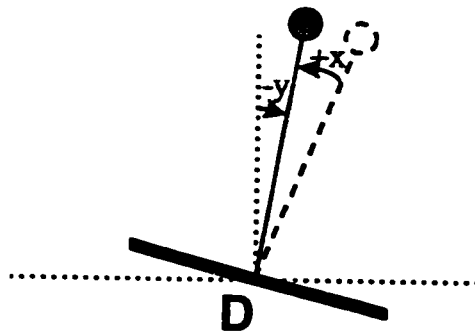
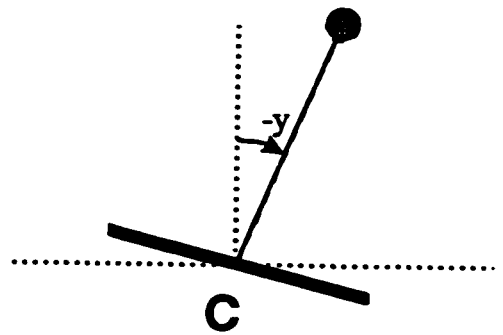
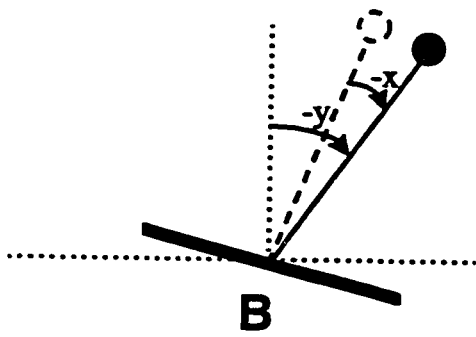
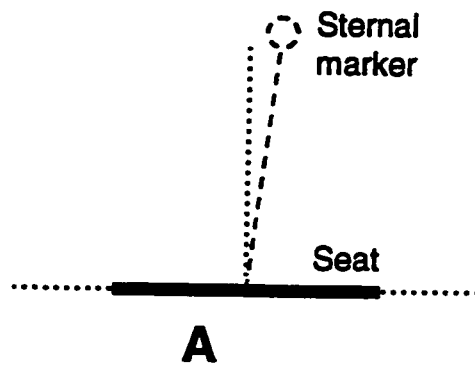


B.

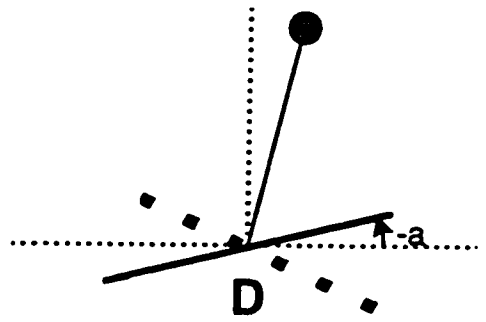
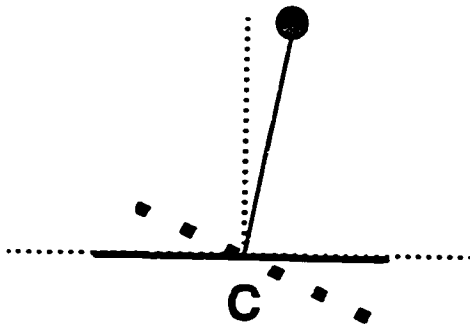
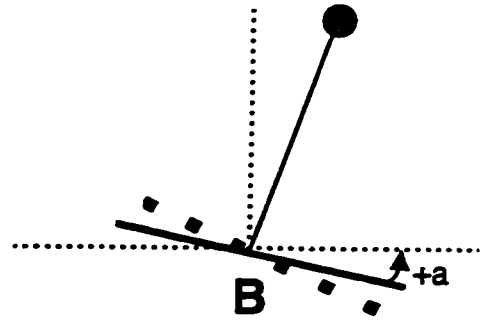
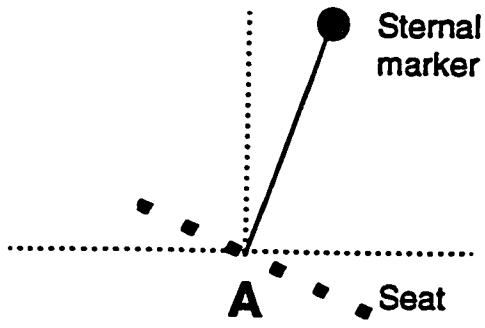


**Figure 1. Images grabbed from video in testing session for subject with left hemiplegia. A illustrates the seat in the horizontal position. B illustrates the seat in the tilted position towards the subject's hemiplegic side. Note the lack of correction of the trunk towards the vertical.**

**Figure 2.** Measures of motor response of the subject's trunk following tilt of the seat to the left. The dashed line (- - -) represents the starting position relative to the seat. The solid line (----) represents the position of the subject's trunk at the end of tilt of the seat. The dotted lines (.....) represent the true vertical and horizontal.  $x$  is the angle of movement of the trunk relative to the starting position. Angles measured from the starting position to an end position of the trunk further in the direction of tilt of the seat are negative. Angles measured from the starting position to an end position opposite to the direction of tilt are positive.  $y$  is the angle of the trunk from the vertical at the end of tilt of the seat. Angles measured from the vertical to an end position of the trunk in the direction of tilt of the seat are negative. Angles measured from the vertical to an end position opposite to the direction of tilt are positive. A is the starting position and B C D and E illustrate possible end positions of the trunk after tilt of the seat. In B, the trunk does not maintain the starting position but moves further away from the vertical in the direction of tilt of the seat. In C, the trunk just maintains the starting position. In D, the trunk moves in the opposite direction to the tilt of the seat but does not return to vertical. In E, the trunk moves in the opposite direction to the tilt of the seat and continues across the vertical.



**Figure 3.** Measures of sensory response of the subject's perception to the seat position as horizontal, following tilt of the seat to the left. The dashed line (- - -) represents the starting position of the seat in the tilted position. The solid line (-----) represents the position of the seat which was perceived as horizontal by the subject. The dotted lines (.....) represent the true vertical and horizontal.  $\alpha$  is the angle of the seat from the horizontal. An angle below the horizontal, in the direction of tilt of the starting position of the seat, is negative. An angle above the horizontal, opposite to the direction of the starting position of the seat, is positive. A is the starting position and B C D and E illustrate possible end positions of the seat which were perceived as horizontal by the subject. In B, the seat is perceived to be horizontal before reaching the horizontal position. In C, the seat is perceived correctly in the horizontal position. In D, the seat is perceived as horizontal after the seat moves beyond the horizontal opposite to the direction of tilt of the starting position of the seat.



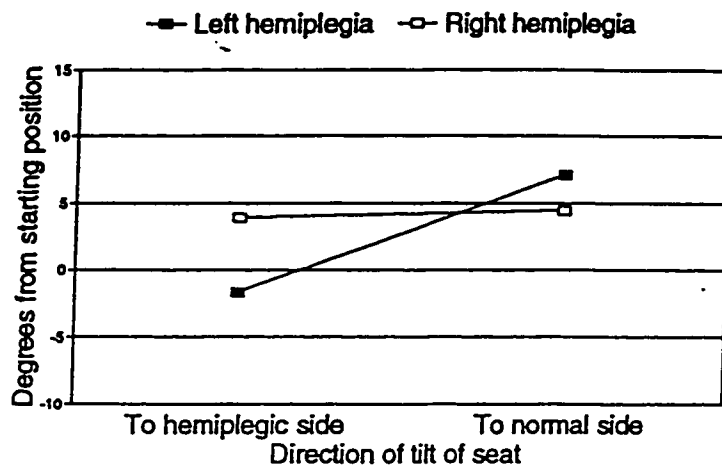


Figure 4. Motor response: interaction diagram of mean values of the angle of movement of the trunk from the starting position. Subjects with right and left hemiplegia were tilted to hemiplegic and normal sides.

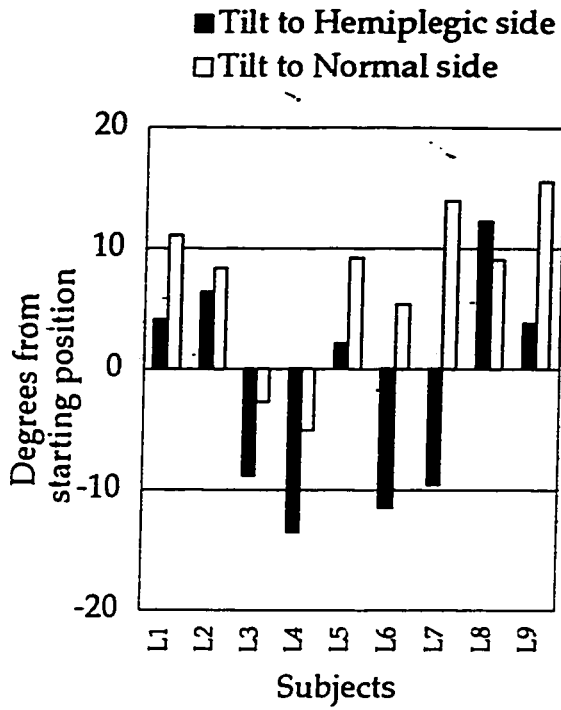
**Figure 5. Motor response: trunk movement relative to the starting position.** The starting position is represented by 0 on the chart scale. A negative angle indicates that the subject moved beyond the starting position in the same direction as tilt of the seat. A positive angle indicates that the subject moved toward the vertical, i.e., opposite to side of tilt.

**A. Subjects with left hemiplegia:** angle of movement of the trunk from the starting position on tilt to the hemiplegic and normal side. Note the larger response of the trunk toward the vertical on tilt to the *normal* side than on tilt to the hemiplegic side in all subjects except for subject L8, who made a larger response on tilt to the hemiplegic side.

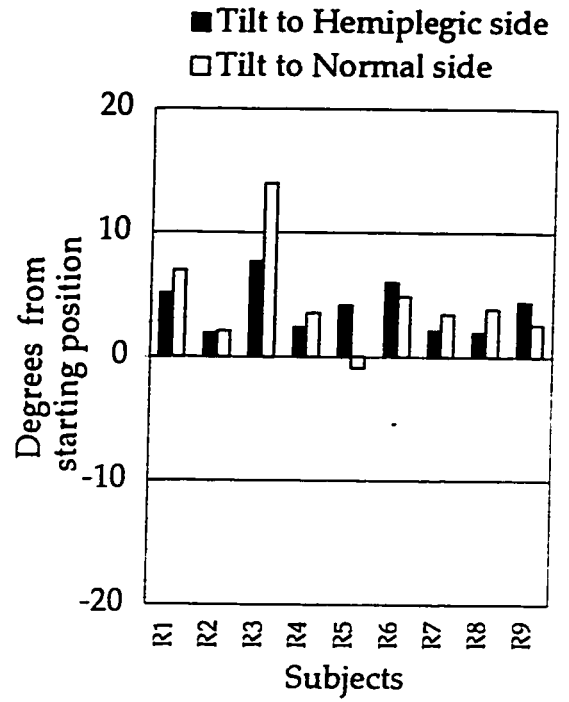
**B. Subjects with right hemiplegia:** angle of movement of the trunk from the starting position on tilt to the hemiplegic and normal side. Note the magnitude of the response on tilt to each side was more similar than in subjects with left hemiplegia.

**C. Mean of angles of movement of the trunk presented in charts A and B, for subjects with right and left hemiplegia, on tilt to hemiplegic and normal sides.** This illustrates the tendency for subjects with left hemiplegia to make a lesser response on tilt to the hemiplegic side than on tilt to the normal side. In subjects with right hemiplegia there is little difference between the two sides of tilt. Note the greater variability of response in subjects with left hemiplegia.

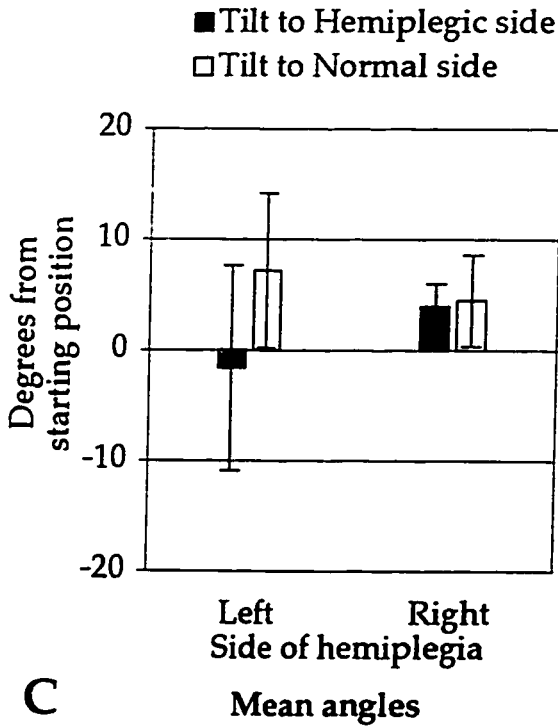
**D. Mean of angles from the vertical without the data for subject L8.** This accentuates the difference on tilt to the two sides in subjects with left hemiplegia.



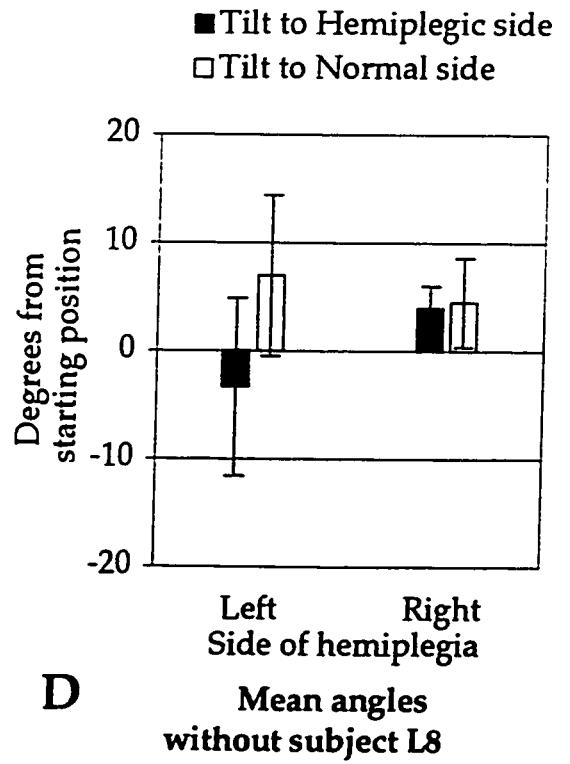
**A** Left hemiplegia



**B** Right hemiplegia



**C** Mean angles



**D** Mean angles without subject L8

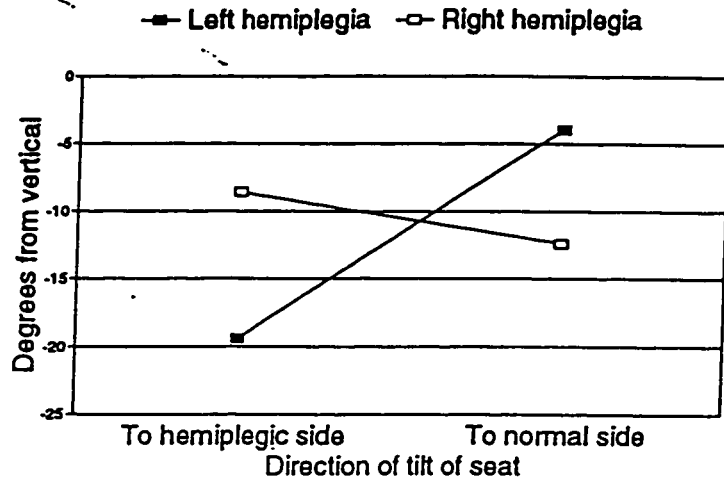


Figure 6. Motor response: interaction diagram of mean values of the angle of the position of the trunk from the vertical. Subjects with right and left hemiplegia were tilted to hemiplegic and normal sides.

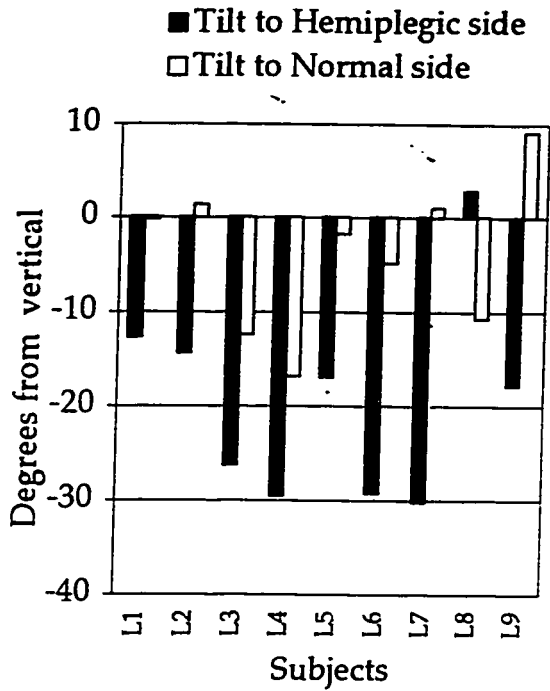
**Figure 7. Motor response: trunk position relative to the vertical at the end of tilt of the seat.** The vertical is represented by 0 on the chart scale. A negative angle indicates that the subject remained leaning toward the side of tilt. A positive angle indicates that the subject crossed midline and was leaning toward the side opposite to the tilt.

**A. Subjects with left hemiplegia:** angle of the trunk from the vertical on tilt to the hemiplegic and normal sides. Note the greater distance of the trunk from the vertical on tilt to the *hemiplegic* side, except for subject L8 who crossed midline to the normal side. On tilt to the normal side, four subjects crossed midline to the hemiplegic side.

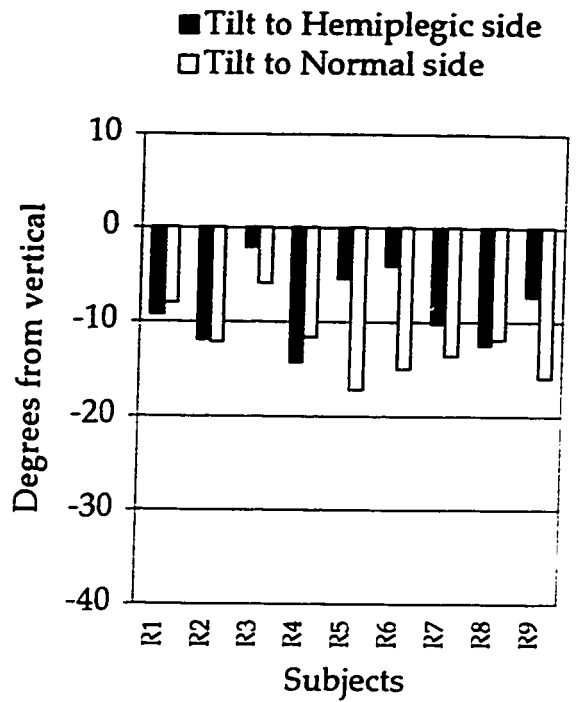
**B. Subjects with right hemiplegia:** angle of the trunk from the vertical on tilt to the hemiplegic and normal sides. Note the greater distance of the trunk from the vertical on tilt to the *normal* side in five of the nine subjects. Also, none of the subjects maintained the trunk at, or past, the vertical on tilt to either side.

**C. Mean of angles from the vertical presented in charts A and B, for subjects with right and left hemiplegia, on tilt to hemiplegic and normal sides.** This illustrates the tendency for subjects with left hemiplegia to lean more toward the hemiplegic side than to the normal side. In subjects with right hemiplegia the difference between the two sides of tilt is not as large but, in contrast to subjects with left hemiplegia, they showed a greater tendency to lean to the normal side than to the hemiplegic side. Note the greater variability of response in subjects with left hemiplegia.

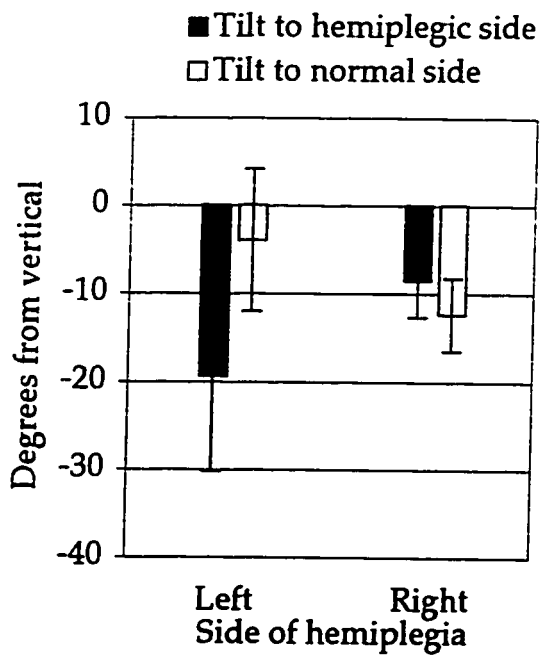
**D. Mean of angles from the vertical without the data for subject L8.** This accentuates the difference in subjects with left hemiplegia on tilt to the two sides.



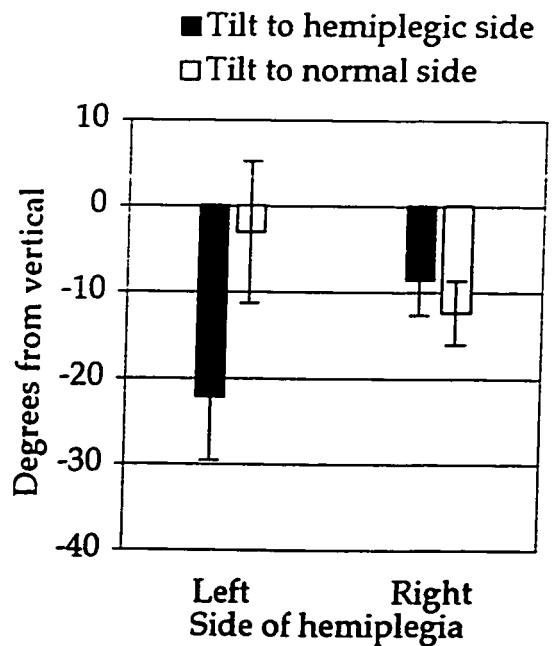
**A** Left hemiplegia



**B** Right hemiplegia



**C** Mean angles



**D** Mean angles without subject L8

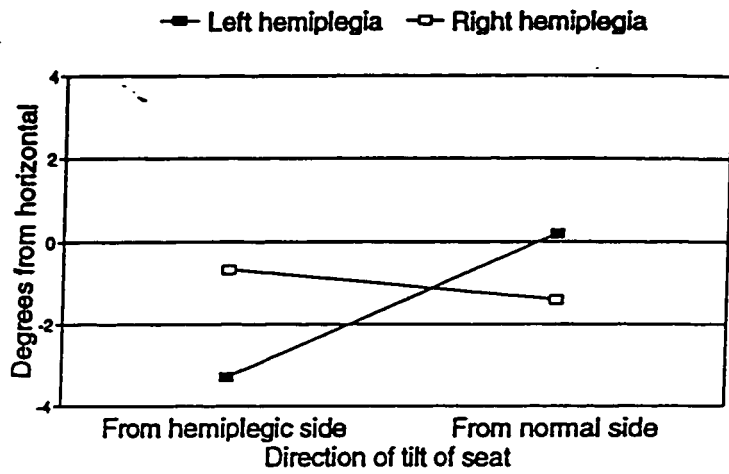


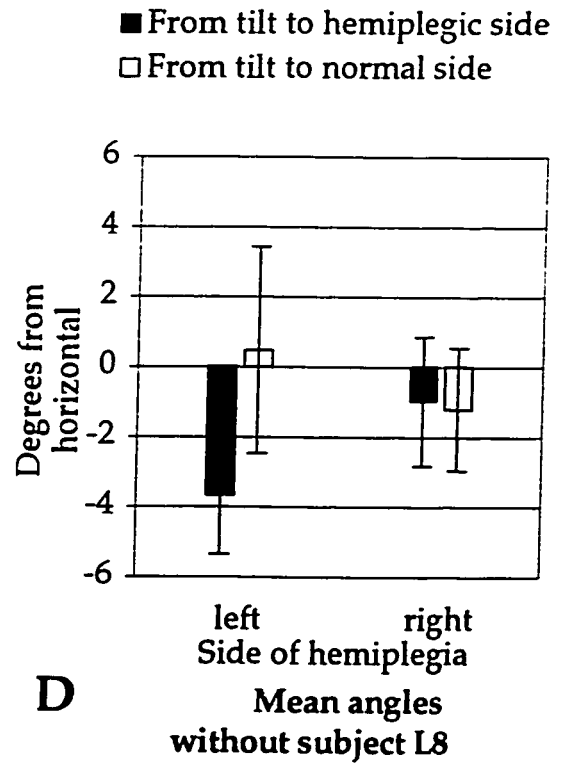
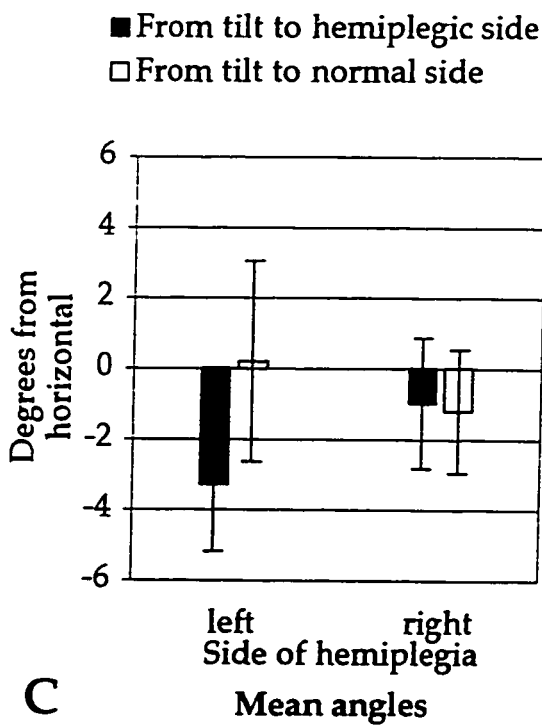
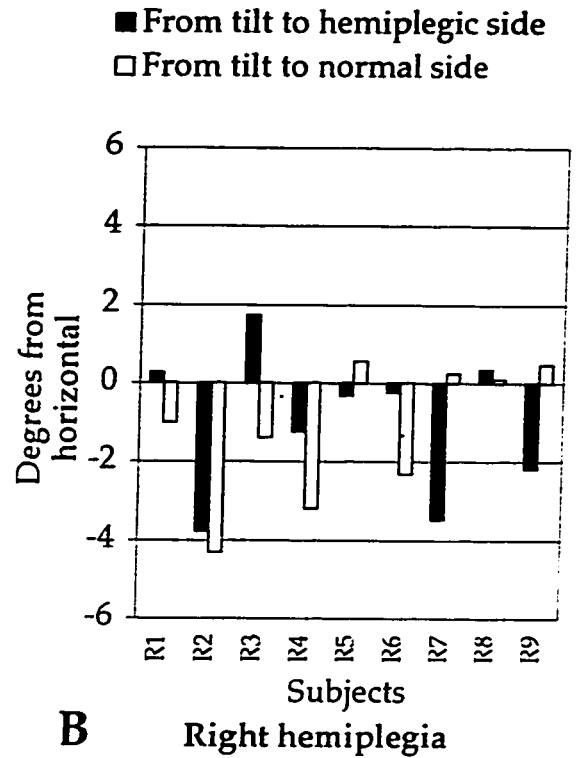
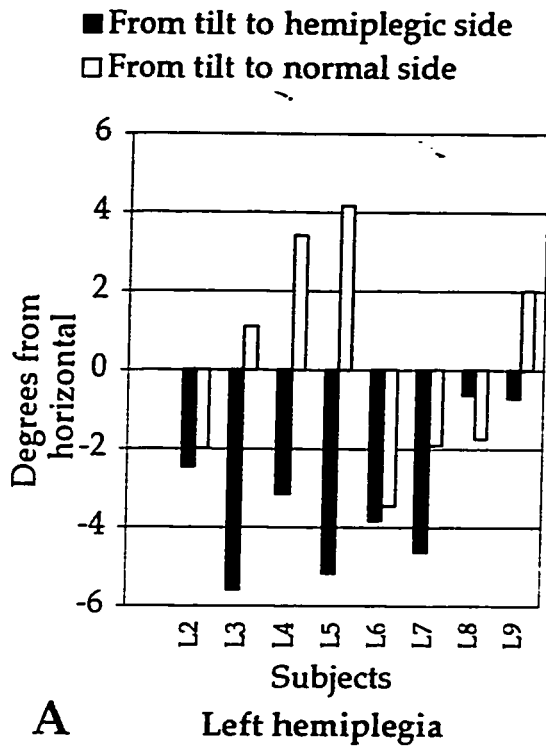
Figure 8. Sensory response: interaction diagram of mean values of the angle of the seat from the horizontal. Subjects with right and left hemiplegia were tilted to hemiplegic and normal sides.

**Figure 9. Sensory response: position of the seat perceived to be horizontal.** The horizontal is represented by 0 on the chart. A negative angle indicates that the subject perceived the seat to be horizontal while still tilted in the direction of the starting position of the seat, before reaching the horizontal. A positive angle indicates that the seat was perceived as horizontal after the seat moves beyond the horizontal opposite to the direction of the starting position of the seat.

**A. Subjects with left hemiplegia:** angle of the seat from the horizontal from a starting position of the seat to the hemiplegic and normal sides. Note the greater angle from the horizontal toward the side of tilt of the seat from a starting position to the hemiplegic side, than from the normal side. Even from a starting position to the normal side, four subjects perceived the seat as horizontal after the seat moved beyond the horizontal toward the hemiplegic side. Subject L8 was the exception and showed a larger angle from the horizontal from a starting position to the normal side.

**B. Subjects with right hemiplegia:** angle of the seat from the horizontal from a starting position to the hemiplegic and normal sides. Note that the direction of tilt of the seat that is perceived as horizontal is less consistent than in subjects with left hemiplegia and in almost half of the data points, perception of the horizontal is within a degree of the true horizontal.

**C. Mean of angles of the seat from the horizontal presented in charts A and B,** for subjects with right and left hemiplegia, from a starting position to hemiplegic and normal sides. This illustrates the tendency for subjects with left hemiplegia to perceive the the seat as horizontal when it was tilted toward the hemiplegic side, from a starting position of the seat to either side. In subjects with right hemiplegia the difference between the two sides of starting position is not as large. **D. Mean of angles from the horizontal without the data for subject L8.** This accentuates the difference in perception of the horizontal from the two sides.



## Appendix A

### Communication Screen

## **COMMUNICATION SCREEN**

for research project

### **The Effect of a Stroke on Balance**

The part of the study that requires the highest level of comprehension is the test of perception of body position. The seat is tilted to one side and then slowly brought back to horizontal. The subject is asked to indicate when the seat feels level.

#### **Instructions for Screening:**

1. Establish the particular response required from the subject.

Example: yes, now, raise hand, etc.

2. Test the response.

Example: "Can you say Yes?"

3. Check the ability to respond.

Hold a book in front of the subject. Tilt it to the side and slowly bring it back to the horizontal. Ask the subject to give the response established above.

Example: "Say yes when the book is level."

4. Place the subject on the tilting seat used for assessments in physiotherapy and check ability to respond.

Example: "Say yes when you feel the seat is level."

## COMMUNICATION

pour le projet de recherche

### Les effets des accidents cérébrovasculaires sur l'équilibre

La partie du projet qui nécessite le plus haut niveau de compréhension est le test de perception de la position du corps. Le siège est incliné d'un côté puis lentement ramené à l'horizontale. La personne doit indiquer quand le siège lui semble horizontal.

#### Instructions pour le dépistage

1. Déterminez la réponse précise demandée du sujet.

Par exemple: oui, maintenant, main levée, etc.

2. Testez la réponse.

Par exemple: "Pouvez-vous dire oui?"

3. Vérifiez la capacité de la réponse.

Tenez un livre devant le sujet. Penchez-le d'un côté, puis ramenez-le lentement à la position droite. Demandez au sujet de donner la réponse déterminée ci-dessus.

Par exemple: "Dites oui quand le livre est droit."

4. Placez le sujet dans le siège inclinable utilisé pour les évaluations en physiothérapie et vérifiez la capacité de répondre.

Par exemple: "Dites oui quand vous pensez que le siège est droit."

## **Appendix B**

### **Clinical Assessment Scales**

# DATA SHEET

NAME: \_\_\_\_\_

## SENSORY TESTING - LIGHT TOUCH

Test with patient blindfolded using cotton ball  
Compare uninvolved to involved side

### SCALE

- 1 Absent
- 2 Severe - Displaced > 6"
- 3. Moderate - Intermittent
- 4 Mild - Subjective difference
- 5 Normal

Thigh \_\_\_\_\_  
 Mid - shin \_\_\_\_\_  
       - calf \_\_\_\_\_  
 Foot - dorsum \_\_\_\_\_  
       - sole \_\_\_\_\_

## SITTING BALANCE

Test in sitting with feet on floor and arms folded across chest. Circle highest number

- 1. Unable to sit unsupported
- 2. No displacement tolerated
- 3. Moves within base e.g. lifts arm or turns head and trunk
- 4. Leans sideways beyond base and return i.e. shoulder beyond hip
- 5. Tolerates quick push beyond base

## STANDING BALANCE

Test in standing without hand support. Circle highest number achieved.

- 1. Unable to stand
- 2. Stand with feet apart 6 inches > 5 sec
- 3. Stand with feet together > 5 sec
- 4. Stand with feet together. Clasp hands and rotate arms 30° > 5 sec.
- 5. Stand on unaffected leg > 5 sec

## STAGE OF MOTOR RECOVERY

Test in position indicated. Check (✓) if movement is able to be done.

Crk ly (hip and knee flexed at about 45°)

- |  | Stage |
|--|-------|
| 1. Bring knee up toward chest to 90° of hip flexion. _____   | 3     |
| 2. Start with knees apart. Bring weak knee to neutral upright position. _____  | 3     |
| 3. Bring knee up toward chest to 90° of hip flexion and then straighten leg down to bed. _____   | 4     |
| 4. Bridging of hips. Lift hips to neutral with equal weight on each leg. Therapist tries to move weak leg to check weight bearing. _____ | 4     |
| 5. Straighten leg down to bed and then bring knee up toward chest to 90° of hip flexion. _____   | 5     |

Sitting (hips and knees at 90° and feet flat on floor)

- |  |   |
|--|---|
| 1. Slide foot under chair so the knee is flexed beyond 90°. Do not allow hip or trunk flexion. _____   | 4 |
| 2. Raise thigh up from bed. Do not allow external rotation of leg or trunk extension. _____  | 5 |
| 3. Lift thigh up as above repeatedly 5 times in 5 seconds. _____   | 6 |
| 4. Lift the foot off the floor and out to the side to internally rotate the hip. Do not substitute trunk movement. Range equal to unaffected side. _____ | 6 |

**PHYSIOTHERAPY CLINICAL OUTCOME VARIABLES (COVS)  
MOBILITY**

**Item 5: Performance of Ambulation**

- 1 no functional ambulation
- 2 1 person continuous physical assistance
- 3 1 person intermittent physical assistance
- 4 supervision
- 5 independent, level surfaces only, assistance with environmental barriers
- 6 independent including environmental barriers
- 7 normal

**Item 6: Performance of Ambulation - Aids**

- 1 not walking
- 2 parallel bars/2 person continuous assistance
- 3 walker (rollator and walk-cane)
- 4 2 aids
- 5 1 aid (except straight cane)
- 6 straight cane
- 7 no aids

## **Appendix C**

**Information Sheets and Consent Forms**

**The Rehabilitation Centre**



THE REHABILITATION CENTRE  
LE CENTRE DE RÉADAPTATION

A division of the Royal Ottawa Health Care Group / Une division des services de santé Royal Ottawa

**INFORMATION SHEET**

The Effect of a Stroke on Balance

**Investigators:**

- M. Eckstrand, Physiotherapist, The Rehabilitation Centre  
Master of Science candidate in Human Kinetics, University of Ottawa  
D. Grinnell, Physiatrist, The Rehabilitation Centre  
G. Robertson, Professor of Biomechanics, University of Ottawa  
C. Hong, Physiotherapist, Ottawa General Hospital

The purpose of the study is to compare balance responses of people who have had a stroke on the right side with people who have had a stroke on the left side. The study is done in the Gait Laboratory at The Rehabilitation Centre. Taking part in the study will require 2 visits of about 1 hour each or 1 longer visit if you prefer. You will have rest periods during that time.

You will be assisted on to the seat in the photograph which was shown to you. Your movements on the seat will be recorded on video tape. Paper markers will be placed just below the front of your neck and on your forehead. You will be assisted to put on a hospital gown so the physiotherapist can see that your back is straight in the starting position. A belt with handles will be placed around your waist. There are 4 parts to the test.

1. The seat will be tilted about 15° to each side to test the response of your trunk.
2. The seat will be tilted a little to each side and slowly straightened. You will be asked to indicate when you feel that the seat is level.
3. You will be asked to sit on a chair or to stand for 20 seconds.

Each test will be done 3 times with eyes, open and closed.

4. A small instrument which registers pressure will be held on the side of your trunk. You will be asked to push against it to measure muscle strength. The test will be done 3 times to each side.

You may experience a feeling of instability during the testing. The risk of falling is controlled by the physiotherapist standing behind you and holding the belt. A second person is available if needed. The seat is controlled by a motor. It has a locked position when it is flat and a limited amount of tilt which can be stopped at any point.

The results of your balance testing will be given to your physiotherapist if you wish. Otherwise your name and any information which identifies you will be kept confidential. You will not be paid for participating in the study.

I have been told that I can withdraw my consent and stop my participation in the study at any time and for any reason and that such action will not affect the quality of my ongoing care.

If you have any questions, please contact.

Marlene Eckstrand at 737-7350 Ext. 5313. If you wish you may talk to the Chairperson of the Research Review Committee, Dr. D. DeForge at 737-7350, ext 5595.



**THE REHABILITATION CENTRE  
LE CENTRE DE RÉADAPTATION**

A division of the Royal Ottawa Health Care Group / Une division des services de santé Royal Ottawa

**FEUILLET D'INFORMATION**

**Les effets de l'accident cérébrovasculaire sur l'équilibre**

**Chercheurs:**

- M. Eckstrand, physiothérapeute, Centre de réadaptation  
candidat à la maîtrise, Ecole des sciences de l'activité physique  
G. Robertson, professeur de biomécanique, Université d'Ottawa  
D. Grinnell, physiatre, Centre de réadaptation  
C. Hong, physiothérapeute, Hôpital Général d'Ottawa

L'objectif de ce projet de recherche est de comparer les réactions d'équilibre des personnes ayant eu un accident cérébrovasculaire du côté droit à celles qui ont été atteintes du côté gauche.

Les tests du projet de recherche s'effectueront au Laboratoire de la démarche au Centre de Réadaptation. La participation à ce projet comporte soit deux visites d'environ une heure chacune au Laboratoire de la démarche ou une plus longue visite. Il y aura des pauses pendant les tests si vous le voulez.

Pour les tests, vous serez positionné, avec assistance d'une personne sur le siège illustré sur la photographie. Vos mouvements sur le siège seront enregistrés sur vidéo. Un marqueur en papier sera placé au dessous de votre cou et sur votre front. Nous vous aiderons à changer vos vêtements pour porter une chemise d'hôpital afin que la physiothérapeute puisse vérifier la position de votre dos. Une ceinture avec des poignées sera placée autour de votre taille pour plus de sécurité.

Les tests comportent 4 parties:

1. Le siège sera incliné 15 degrés vers chaque côté pour tester les réactions de votre tronc.
2. Le siège sera alors incliné légèrement vers chaque côté et redressé lentement. On vous demandera d'indiquer quand vous aurez l'impression que le siège est droit.
3. On vous demandera de rester debout/assis pendant 20 secondes.  
Chaque test sera répété trois fois, avec les yeux ouverts et les yeux fermés.
4. Les chercheurs vérifieront la force musculaire des muscles de votre dos grâce à un instrument de mesure à pression placé sur un des côtés de votre dos.  
Le test sera répété trois fois de chaque côté.

Il se peut que vous ayez une sensation de faiblesse pendant les tests. Le risque de tomber sera contrôlé par une physiothérapeute qui sera debout derrière vous, tenant la ceinture pour plus de sécurité. Une deuxième personne sera disponible au besoin. L'inclinaison du siège sera contrôlée par un moteur. Le siège, en position neutre, sera immobilisé. Le degré d'inclinaison est limité et peut être arrêté à tout moment.

On m'a dit que je pouvais retirer mon consentement et suspendre ma participation à l'étude à n'importe quel moment et pour quelque motif que ce soit et que cette action n'affectera pas la qualité de mes soins.

Une copie des résultats des tests sera donnée à votre physiothérapeute si vous le désirez. Votre nom et toute information vous concernant seront gardés confidentiels. Il y a un remboursement pour votre participation dans cette étude. Si vous avez des questions, s'il vous plaît contacter Marlene Eckstrand au 737-7350 ext 5313. Si vous le désirez, vous pourrez discuter du projet avec le président du Comité d'étude de la recherche, Dr. D. DeForge au 737-7350, ext 5595.



**THE REHABILITATION CENTRE  
LE CENTRE DE RÉADAPTATION**

A division of the Royal Ottawa Health Care Group / Une division des services de santé Royal Ottawa

**CONSENT FOR MEDICAL RESEARCH**

Name of research project The Effect of a Stroke on Balance

**Investigators:**

- M. Eckstrand, Physiotherapist, The Rehabilitation Centre  
Master of Science candidate in Human Kinetics, University of Ottawa
- D. Grinnell, Physiatrist, The Rehabilitation Centre
- G. Robertson, Professor of Biomechanics, University of Ottawa
- C. Hong, Physiotherapist, Ottawa General Hospital

I consent to the participation of:

In the above study and hereby authorize the physician(s) and investigator(s) to proceed with the following examinations and/or to administer these treatments:

- Test sitting balance on tilting seat.
- Test sitting or standing balance on stable surface.
- Test strength of trunk muscles.

I have had a detailed description of all the known side effects and risks related to the examinations and treatments. I have also received a description of any benefits that may be expected from these examinations and treatments.

I have been given an opportunity to ask questions concerning the examinations and treatments involved and the questions which I have asked have been adequately answered.

**CONSENT**

I agree to participate in this study with the understanding that information collected will be used for research purposes only and will be treated as confidential. I have been informed about the purpose of the study and realize that I am under no obligation to participate and may withdraw at any time. Refusal to participate or withdraw from the study will in no way affect my present and/or future treatment at The Rehabilitation Centre.

Name	Signature	Relationship
<b>PATIENT OR PERSON LEGALLY RESPONSIBLE</b>		
1. name	Witness	Signature
		Date:
2. name	Witness	Signature
		Date:



THE REHABILITATION CENTRE  
LE CENTRE DE RÉADAPTATION

A division of the Royal Ottawa Health Care Group / Une division des services de santé Royal Ottawa

**CONSENTEMENT À DES RECHERCHES MÉDICALES**

**Nom de l'étude:** Les effets de l'accident cérébrovasculaire sur l'équilibre.

**Chercheurs:** M. Eckstrand, physiothérapeute, Centre de réadaptation, candidat à la maîtrise, Ecole des sciences de l'activité physique  
G. Robertson, professeur de biomécanique, Université d'Ottawa  
D. Grinnell, physiatre, Centre de réadaptation  
C. Hong, physiothérapeute, Hôpital Général d'Ottawa

Je consens à la participation de:  
(nom du patient)

à l'étude précitée et j'autorise par la présente le(s) médecin(s) et chercheur(s) à procéder aux examens et/ou à dispenser les traitements suivants:

- Vérifier l'équilibre assis sur un siège pivotant.
- Vérifier l'équilibre debout ou assis.
- Vérifier la force musculaire du tronc.

J'ai reçu une explication détaillée de tous les effets secondaires et des risques connus ayant trait aux examens et aux traitements. J'ai également reçu une description de tous les avantages à attendre de ces examens et de ces traitements.

J'ai eu l'occasion de poser des questions au sujet de ces examens et de ces traitements et on y a bien répondu.

J'accepte de participer à ce projet de recherche en comprenant que les informations collectées seront utilisées seulement pour les besoins de la recherche et seront traitées comme étant confidentielles. On m'a expliqué l'objectif du projet de recherche et je comprends que je ne suis nullement obligé de participer. Je pourrai m'en retirer à n'importe quel moment. Si je refuse de participer à ce projet ou si je m'en retire, les soins qui me sont ou me seront donnés au Centre de Réadaptation n'en seront nullement affectés.

<b>Nom</b>	<b>Signature</b>	<b>Lien de parenté</b>
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**Patient ou personne légalement responsable**

<b>Témoin</b>	<b>Signature</b>	<b>Date</b>
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CONSENT

RE PHOTOGRAPHS, MOVING PICTURES  
SOUND RECORDINGS AND TELEVISION RECORDINGS  
IN THE ROYAL OTTAWA HOSPITAL

In the interests of medical science and education, I hereby authorize the Royal Ottawa Hospital, its staff members, employers and agents, to televise and to take and cause to be taken, and to exhibit and cause to be exhibited, for scientific and education purposes only, including publications in scientific and professional publications and exhibitions to scientific and medical audiences, such still photographs, moving pictures, television and sound recordings of my \_\_\_\_\_

(self, son, wife, etc.)

\_\_\_\_\_  
(print name of patient or other persons)

before, during and after treatment, as may be approved by my physician, Dr. \_\_\_\_\_. It is understood and agreed that there will be no remuneration or other consideration payable to me or to the patient, as the case may be. This consent is given upon the understanding and subject to the condition that there will be no disclosure of identification by way of reference to the name of the patient.

I hereby expressly waive any and all claims against the Royal Ottawa Hospital, its staff, employees and agents in any manner whatsoever, relating to the said photographs, moving pictures, television and sound recordings.

I understand that the photographs, moving pictures, television and sound recordings shall be and remain the property of the Royal Ottawa Hospital and that I will have no interest in same.

Signed at the Royal Ottawa Hospital this:

\_\_\_\_\_ 19 \_\_\_\_ .  
(date)

\_\_\_\_\_  
(signature of patient, parent or guardian  
if patient is under 16 years of age)

\_\_\_\_\_  
(relationship to patient)

\_\_\_\_\_  
(signature of witness)

\_\_\_\_\_  
(please print name,  
position or title of  
Hospital Staff Member)

Having witnessed the execution of this Consent, I am of the opinion that the person signing was capable of and appeared to fully understand the nature and effect of the giving of Consent.

## **Appendix D**

### **Information Sheets and Consent Forms**

#### **Ottawa General Hospital**

**HÔPITAL GÉNÉRAL D'OTTAWA      OTTAWA GENERAL HOSPITAL**

**INFORMATION SHEET**

**The Effect of a Stroke on Balance**

**Investigators:**

- M. Eckstrand, Physiotherapist, The Rehabilitation Centre  
 Master of Science candidate in Human Kinetics, University of Ottawa
- D. Grinnell, Physiatrist, The Rehabilitation Centre
- G. Robertson, Professor of Biomechanics, University of Ottawa
- C. Hong, Physiotherapist, Ottawa General Hospital

The purpose of the study is to compare balance responses of people who have had a stroke on the right side with people who have had a stroke on the left side.

The study is done in the Gait Laboratory at The Rehabilitation Centre and is connected to the Ottawa General Hospital by a corridor. You will be taken there in a wheelchair. Taking part in the study will require 2 visits of about 1 hour each or 1 longer visit if you prefer. You will have rest periods during that time.

You will be assisted on to the seat in the photograph which was shown to you. Your movements on the seat will be recorded on video tape. Paper markers will be placed just below the front of your neck and on your forehead. You will be assisted to put on a hospital gown so the physiotherapist can see that your back is straight in the starting position. A belt with handles will be placed around your waist. There are 4 parts to the test.

1. The seat will be tilted about 15° to each side to test the response of your trunk.
2. The seat will be tilted a little to each side and slowly straightened. You will be asked to indicate when you feel that the seat is level.
3. You will be asked to sit on a chair or to stand for 20 seconds.

Each test will be done 3 times with eyes, open and closed.

4. A small instrument which registers pressure will be held on the side of your trunk. You will be asked to push against it to measure muscle strength. The test will be done 3 times to each side.

You may experience a feeling of instability during the testing. The risk of falling is controlled by the physiotherapist standing behind you and holding the belt. A second person is available if needed. The seat is controlled by a motor. It has a locked position when it is flat and a limited amount of tilt which can be stopped at any point.

The results of your balance testing will be given to your physiotherapist if you wish. Otherwise your name and any information which identifies you will be kept confidential. You will not be paid for participating in the study.

I have been told that I can withdraw my consent and stop my participation in the study at any time and for any reason and that such action will not affect the quality of my ongoing care.

If you have any questions, please contact Marlene Eckstrand at 737-7350 Ext. 5313 or Chang Hong at 737-8359. If you wish you may talk to the Chairperson of the Research Ethics Board at 737-8930.

## **FEUILLET D'INFORMATION**

### **Les effets de l'accident cérébrovasculaire sur l'équilibre**

#### **Chercheurs:**

- M. Eckstrand, physiothérapeute, Centre de réadaptation  
candidat à la maîtrise, Ecole des sciences de l'activité physique
- G. Robertson, professeur de biomécanique, Université d'Ottawa
- D. Grinnell, physiatre, Centre de réadaptation
- C. Hong, physiothérapeute, Hôpital Général d'Ottawa

L'objectif de ce projet de recherche est de comparer les réactions d'équilibre des personnes ayant eu un accident cérébrovasculaire du côté droit à celles qui ont été atteintes du côté gauche.

Les tests du projet de recherche s'effectueront au Laboratoire de la démarche au Centre de Réadaptation lequel est joint à l'Hôpital Général par un corridor. Vous serez amené au laboratoire par fauteuil roulant. La participation à ce projet comporte soit deux visites d'environ une heure chacune au Laboratoire de la démarche ou une plus longue visite. Il y aura des pauses pendant les tests si vous le voulez.

Pour les tests, vous serez positionné, avec assistance d'une personne sur le siège illustré sur la photographie. Vos mouvements sur le siège seront enregistrés sur vidéo. Un marqueur en papier sera placé au dessous de votre cou et sur votre front. Nous vous aiderons à changer vos vêtements pour porter une chemise d'hôpital afin que la physiothérapeute puisse vérifier la position de votre dos. Une ceinture avec des poignées sera placée autour de votre taille pour plus de sécurité.

Les tests comportent 4 parties:

1. Le siège sera incliné 15 degrés vers chaque côté pour tester les réactions de votre tronc.
2. Le siège sera alors incliné légèrement vers chaque côté et redressé lentement. On vous demandera d'indiquer quand vous aurez l'impression que le siège est droit.
3. On vous demandera de rester debout/assis pendant 20 secondes.  
Chaque test sera répété trois fois, avec les yeux ouverts et les yeux fermés.
4. Les chercheurs vérifieront la force musculaire des muscles de votre dos grâce à un instrument de mesure à pression placé sur un des côtés de votre dos.  
Le test sera répété trois fois de chaque côté.

Il se peut que vous ayez une sensation de faiblesse pendant les tests. Le risque de tomber sera contrôlé par une physiothérapeute qui sera debout derrière vous, tenant la ceinture pour plus de sécurité. Une deuxième personne sera disponible au besoin. L'inclinaison du siège sera contrôlée par un moteur. Le siège, en position neutre, sera immobilisé. Le degré d'inclinaison est limité et peut être arrêté à tout moment.

On m'a dit que je pouvais retirer mon consentement et suspendre ma participation à l'étude à n'importe quel moment et pour quelque motif que ce soit et que cette action n'affectera pas la qualité de mes soins.

Une copie des résultats des tests sera donnée à votre physiothérapeute si vous le désirez. Votre nom et toute information vous concernant seront gardés confidentiels. Il y a un remboursement pour votre participation dans cette étude. Si vous avez des questions, s'il vous plaît contacter Marlene Eckstrand au 737-7350 ext 5313 ou Chang Hong au 737-8359. Si vous le désirez, vous pourrez discuter du projet avec le président du Conseil d'éthique en recherches au 737-8930.

## CONSENT FOR MEDICAL RESEARCH

Name of research project The Effect of a Stroke on Balance

### Investigators:

M. Eckstrand, Physiotherapist, The Rehabilitation Centre  
Master of Science candidate in Human Kinetics, University of Ottawa  
D. Grinnell, Physiatrist, The Rehabilitation Centre  
G. Robertson, Professor of Biomechanics, University of Ottawa  
C. Hong, Physiotherapist, Ottawa General Hospital

I consent to the participation of:

In the above study and hereby authorize the physician(s) and investigator(s) to proceed with the following examinations and/or to administer these treatments:

Test sitting balance on tilting seat.  
Test sitting or standing balance on stable surface.  
Test strength of trunk muscles.

I have had a detailed description of all the known side effects and risks related to the examinations and treatments.

I have also received a description of any benefits that may be expected from these examinations and treatments. Alternative forms of examinations and treatments have been disclosed to me.

I have been given an opportunity to ask questions concerning the examinations and treatments involved and the questions which I have asked have been adequately answered.

I have been told that I can withdraw my consent and stop my participation in the study at any time and for any reason, and that such action will not affect the quality of my ongoing care.

With full knowledge of this, I voluntarily consent to participate in the study.

This protocol has been approved by the Research Ethics Board of the Ottawa General Hospital. This Board considers the ethical aspects of all hospital research projects using human subjects. If you wish, you may talk to the Chairperson of the Research Ethics Board at 737-8930.

Name	Signature	Relationship
<b>PATIENT OR PERSON LEGALLY RESPONSIBLE</b>		
1. name	Witness	Signature
2. name	Witness	Signature
		Date:
		Date:

## CONSENTEMENT À DES RECHERCHES MÉDICALES

**Nom de l'étude:** Les effets de l'accident cérébrovasculaire sur l'équilibre.

**Chercheurs:** M. Eckstrand, physiothérapeute, Centre de réadaptation  
candidat à la maîtrise, Ecole des sciences de l'activité physique  
G. Robertson, professeur de biomécanique, Université d'Ottawa  
D. Grinnell, physiatre, Centre de réadaptation  
C. Hong, physiothérapeute, Hôpital Général d'Ottawa

Je consens à la participation de:  
(nom du patient)

à l'étude précitée et j'autorise par la présente le(s) médecin(s) et chercheur(s) à procéder aux examens et/ou à dispenser les traitements suivants:

- Vérifier l'équilibre assis sur un siège pivotant.
- Vérifier l'équilibre debout ou assis.
- Vérifier la force musculaire du tronc.

J'ai reçu une explication détaillée de tous les effets secondaires et des risques connus ayant trait aux examens et aux traitements. J'ai également reçu une description de tous les avantages à attendre de ces examens et de ces traitements. On m'a fait connaître d'autres formes d'examens et de traitements.

J'ai eu l'occasion de poser des questions au sujet de ces examens et de ces traitements et on y a bien répondu.

On m'a dit que je pouvais retirer mon consentement et suspendre ma participation à l'étude à n'importe quel moment et pour quelque motif que ce soit et que cette action n'affectera pas la qualité de mes soins.

En toute connaissance de cause, je consens volontairement à participer à cette étude.

Ce protocole a été approuvé par le Conseil d'éthique en recherches de l'Hôpital Général d'Ottawa. Ce conseil étudie les aspects éthiques de tous les projets de recherche sur les humains. Si vous le désirez, vous pouvez parler au président du conseil, au 737-8930.

Nom	Signature	Lien de parenté
-----	-----------	-----------------

### Patient ou personne légalement responsable

1. Témoin	Signature	Date
2. Témoin	Signature	Date



**CONSENTEMENT À DES PHOTOGRAPHIES / ENREGISTREMENTS**  
 patient(e), employé(e), autre  
**CONSENT FOR PHOTOGRAPHY / RECORDINGS**  
 Patient, employee, other

J'autorise l'Hôpital général d'Ottawa et /ou

I authorize the Ottawa General Hospital and /or

à :

to :

- a) Photographier
- b) Filmer/Enregistrer sur vidéo
- c) Enregistrer sur bande sonore
- d) Interviewer
  - radio
  - télévision
  - publication
  - autre

- a) Photograph
- b) Film/Video record
- c) Audio record
- d) Interview
  - radio
  - television
  - publication
  - other

L'Hôpital général d'Ottawa et /ou

The Ottawa General Hospital and /or

- peut utiliser l'information à des fins médicales, scientifiques ou éducatives incluant des présentations audio-visuelles.
- peut utiliser le matériel aux fins de publication, ou de diffusion, pour des présentations audio-visuelles ou pour tout autre projet de promotion.
- Je comprends et j'accepte que mon nom soit utilisé relativement avec cela.
- Je n'accepte pas que mon nom soit utilisé ni dévoilé relativement avec cela.

- may use the information for medical, scientific and/or educational objectives including slide presentations.
- may use this material for publication, broadcast, news stories, news releases, slide presentations or other promotional projects.
- I understand and agree that my name will be used in connection therewith.
- I understand and agree that my name will not be used in connection therewith.

Je ne m'attends à aucun paiement ou compensation relativement à l'information ci-dessus.

I expect no payment or other compensation in connection with the above mentioned information.

PATIENT OU PERSONNE LÉGALEMENT RESPONSABLE

PATIENT OR PERSON LEGALLY RESPONSIBLE

Nom : \_\_\_\_\_

Name : \_\_\_\_\_

Signature : \_\_\_\_\_

Signature : \_\_\_\_\_

Lien de parenté : \_\_\_\_\_

Relationship : \_\_\_\_\_

Témoïn : \_\_\_\_\_

Witness : \_\_\_\_\_

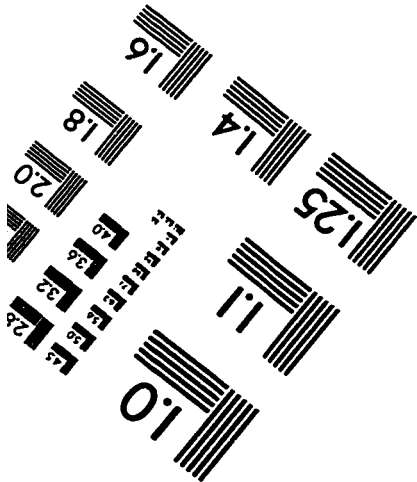
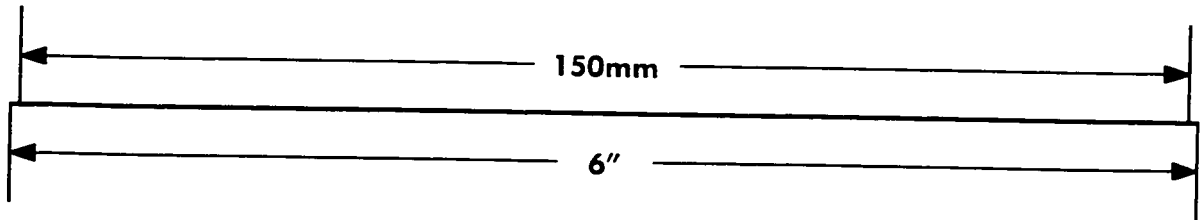
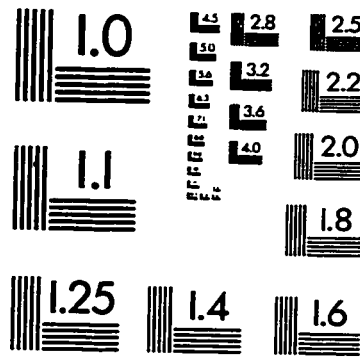
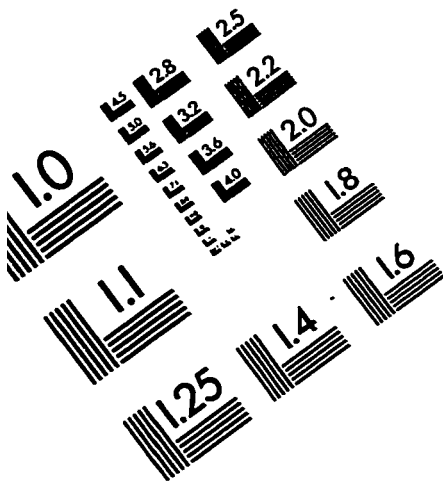
Signature : \_\_\_\_\_

Signature : \_\_\_\_\_

Date : jour \_\_\_\_\_ mois \_\_\_\_\_ année \_\_\_\_\_

Date : day \_\_\_\_\_ month \_\_\_\_\_ year \_\_\_\_\_

# IMAGE EVALUATION TEST TARGET (QA-3)



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