CHARACTHERISTICS OF THE TRUNK IN STROKE PATIENTS AND HEALTHY INDIVIDUALS

Summary of Ph.D. Thesis

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1. INTRODUCTION

1.1 Stroke

"Stroke is classically characterized as a neurological deficit attributed to an acute focal injury of the central nervous system by a vascular cause, including cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage." The Stroke Council of the American Heart Association/American Stroke Association claimed that the term "stroke" should be broadly used to include CNS infarction, ischemic stroke, silent CNS infarction, intracerebral hemorrhage, subarachnoid hemorrhage and cerebral venous thrombosis. Stroke is one of the most frequent diseases that interferes with independent activity of daily living leading to disability, resulting in activity limitations and/or participation restriction.

According to its pathomechanism, the 80-85% of acute cerebrovascular accidents occur due to occlusion in the brain vessels (thrombosis, lacunar infarct, embolism, or hemodynamic stroke) caused by focal cerebral, spinal, or retinal infarction, while 15-20% have haemorrhagic origin including intracerebral hemorrhage caused by a focal collection of blood within the brain parenchyma or ventricular system and subarachnoid hemorrhage due to the bleeding into the subarachnoid space. None of them is caused by trauma.

About two-thirds of stroke patients have initial problems with mobility, balance and/or poor postural control affecting the independence at the activity and participation level.

1.2 Rehabilitation

The physiotherapy interventions applied in the process of stroke rehabilitation is very important for recovery and for reducing the long-term consequences of stroke and to improve the patients' quality of life; and should start as early as possible. Stroke rehabilitation focuses on the optimization of functional performance and on the improvement of independence level.

In most cases one of the main goals of physiotherapy is to improve walking and balance to alleviate activity limitations and to reach the highest possible level of functional independence.

1.3 Concepts and methods applied by physiotherapists in the neurological rehabilitation

Various approaches may be applied by physiotherapists in stroke rehabilitation; however there are controversies and debates about the effectiveness of the different methods. It seems that there is no approach that would be superior to others. Physiotherapists use different approaches rather according to their personal preference than scientific rationale.

However, physiotherapists should rely on their clinical reasoning process and skill to select the appropriate treatment option to their patients' needs and goals.

Before the 1940s, patients with hemiparesis were treated mainly according to orthopaedic principles to improve the compensatory abilities of the non-affected side. In the 1950s and 1960s, neurological physiotherapy developed, and new approaches were introduced including Rood, Proprioceptive Neuromuscular Facilitation, Bobath, Brunnstrom methods/concepts, emphasizing the recovery and the use of the paretic side. Later, in the late 1970s and early 80s, motor learning and motor relearning approaches were introduced. The task-oriented training consider the movements as an interplay of many systems, based on the interactions of the individual, task (functional goal) and the environment.

Nowadays, robot technology, treadmill training, virtual reality and mental imagery are also play important roles in the rehabilitation of neurological patients.

Current evidence suggests that physiotherapy in the process of rehabilitation should include a mixture of components from different approaches, which is more effective for recovery of function and mobility after stroke. It is claimed that physical rehabilitation should not be limited to any named or specific approaches, but it should comprise clearly defined, well-described, evidenced-based physical treatment interventions, independently from their historical or philosophical origin. Physiotherapists should incorporate a wide range of strategies that are supported by the evidence in order to provide evidence-based practice.

According to Lennon and Basil eight principles should be used in the neurological physiotherapy such as (1) use of the International Classification of Functioning, Disability and Health domains; (2) team work; (3) patient-centred care; (4) neural plasticity; (5) system model of motor control; (6) functional movement re-education; (7) skill acquisition; and (8) self-management principle.

1.4 Postural control

One of the main functions of the CNS is the organization of information coming from different sensory systems including visual, somatosensory (tactile and proprioceptive) and vestibular ones. The CNS constantly weighs and integrates this information in relation to postural control. This is necessary for the determination of the body position in space in relation to gravity and the environment.

The postural control is a complex skill that relies on the interaction of multiple systems including movement and sensory strategies, biomechanical constraints, perception, cognitive processes and also the environmental context. Improving postural control is one of the main parts of physiotherapy interventions.

Anticipatory postural alignment should offer the background for planned and then executed activities. Besides anticipatory postural adjustments, compensatory postural adjustments as reactive strategies (feedback mechanisms) occur after perturbations, and they are responsible for the control and restoration of the centre of mass.

1.4.1 Postural control and weight bearing

Controlled trunk stability and mobility including weight shifting are essential components of balance and/or postural control for everyday activities. Since most parts of the brain are involved in postural control, stroke is frequently accompanied by impaired postural control.

After stroke usually one side of the body is much more involved, and this will lead to asymmetrical weight bearing in standing and problems with balance.

These impairments significantly interfere with the common activities, therefore, physiotherapists, in order to improve balance and postural control, first have to pay attention to the assessment of the impairments to plan appropriate treatment, and, secondly, teach the patients how to avoid compensatory strategies, but not at the expense of functional activities.

Many studies described weight bearing asymmetries in stroke patients. These studies applied different ways and equipment for measurements, including clinical examination, bathroom scales, biofeedback systems, ambulatory devices and platforms. However, most of these studies determined only movement quantity and functional mobility, or investigated asymmetry in relation to weight distribution on the lower extremities in stroke patients and/or in healthy individuals. Sophisticated methods have been applied to underscore the importance of trunk alignment during quiet standing and following weight shift in healthy subjects, while no data are available in stroke patients in this respect.

2. AIMS AND HYPOTHESISES

Our aims were:

1. to characterize and compare the weight bearing during quiet standing in healthy subjects and patients with stroke.
2. to determine the trunk alignment during quiet standing in healthy subjects and patients with stroke.
3. to reveal the changes in weight bearing during lateral weight shift in healthy subjects

and patients with stroke.

4. to describe the changes in trunk alignment during lateral weight shift in healthy subjects and patients with stroke.
5. to describe the correlations between weight bearing and trunk alignment in healthy subjects and patients with stroke during quiet standing and lateral weight shift.

3. METHOD

Two groups of subjects (healthy controls and patients with stroke n=17-17) with comparable anthropometric parameters were involved in the study. Participation was voluntary. All of the subjects gave their informed consent prior to participation in the study, which was approved by the local Institutional Ethics Committee and conformed to the Declaration of Helsinki in all respects.

3.1 Subjects

In the patient group the subjects with hemiparesis due to a single cerebrovascular accident between 3 and 45 months previously [right: 10, left: 7, male 9, female: 8, age:59 (SEM: 2.9) years, weight: 78 (2.7) kg, height: 167 (1.8) cm] were included. The patients physical function was not analysed in a large detail, but they were eligible for the study, if they were able to meet the following conditions: (1) at least 3 months had passed since their cerebrovascular event, (2) they had hemiparesis, (3) they were able to stand independently, and (4) they were free of any musculoskeletal or neurological disorder other than the cerebrovascular accident.

The healthy controls participated in the study were matched for age and sex (male: 7, female: 10, age: 60 (2.5) years, weight: 75 (4.0) kg, height: 168 (2.5) cm]. The control subjects were free of any known musculoskeletal or neurological disorder.

3.2 Measurements

3.2. 1 Assessment of ground reaction force

All subjects were tested on a force platform (ZWE-PII Stabilometer; 50x50 cm; Elektro-Bionika LTD, Budapest, Hungary) to determine the weight load (as a measure of weight bearing capability) of both legs, separately. The measurements were preceded by verbal instruction and demonstration of the actual task. Initially, the subjects were instructed to stand on the platform with their feet 10 cm apart with their arms by their side and to gaze at the wall 3 m in front of them. Then, the subjects were asked to stand quietly while distributing the body weight equally on their lower extremities (starting position: SP). Next, the subjects were instructed to shift as much weight as possible onto the right leg without lifting off the left foot (Weight shift position: WS), then return to SP. The next task was to shift as much weight as possible onto the left leg without lifting off the right foot, and return to SP.

This sequence was repeated 3 times, and every position was held for 3 seconds. The movement of the patients was also recorded with a video camera, and the positions of the markers were analysed offline (see below: 3.3).

Ground reaction forces were determined for each leg in all positions and expressed as percentage of body weight (relative ground force: RGF).

3.3 Estimation of trunk angles

To enable the description of trunk alignment in standing with different weight distribution on the lower extremities, five markers (circular patches of 4 cm diameter, white with black point [3 mm] in the middle) were placed on the subjects' back, accordingly:

Marker 1 and 2: bilaterally and symmetrically on the posterior angle of the acromion (A)
Marker 3: on the spinal process of the 7th thoracic vertebra (the apex of kyphosis; V)
Marker 4 and 5: bilaterally and symmetrically at the level of the iliac crests (I)

The angles of the trunk (Acromion–Vertebra–Iliac crest Angles: AVIAs) on both sides in the different positions were determined with the use of an angular dimension tool of Corel Draw (Corel Corp., Canada).

3.4 Data and statistical analyses

Regarding SP, the mean of the first 3 measurements, and during 3 trials of WS, the mean of them were analysed.

Two categories were defined according to RGF: the more loaded side (MS) and the less loaded side (LS) for both groups. All of the patients had more load on their non-paretic side compared to the paretic side, therefore, the MS was the non-paretic side, while the LS was the paretic side in this group.

In the WS position, the two sides were designated as loaded side (weight bearing side: WBS) and unloaded side (non-weight bearing side: NWBS).

Four categories were introduced for WS. Two were based on the side of weight bearing (WBS vs. NWBS) and the categories were determined during SP (LS vs. MS):

In the case of weight shift to the LS: WBS-LS and NWBS-MS

In the case of weight shift to the MS: WBS-MS and NWBS-LS

Asymmetry indices (AIs) were introduced based on a formula of symmetry index. These indices measured the asymmetries of RGFs (Asymmetry Indices of Weight bearing: AIW) and AVIAs (Asymmetry Indices of Angles: AIA) on both sides.

The asymmetry index of WB in starting position (AIW-SP) was determined as follows:

$$AIW\text{-}SP=([RGF_{MS}-RGF_{LS}]*100)/(0.5[RGF_{MS}+RGF_{LS}])$$

An asymmetry index for AVIAs in starting position (AIA-SP) was also calculated:

$$AIA\text{-}SP=([AVIA_{MS}-AVIA_{LS}]*100)/(0.5[AVIA_{MS}+AVIA_{LS}])$$

where positive scores represent a greater angle on the WBS, '0' represents perfect symmetry, while negative scores indicate a slighter angle on the WBS.

To determine the degree of trunk elongation or shortening on both the WBS and NWBS and using SP as the baseline, an elongation index (EI) was introduced:

$$EI\text{-}WBS=(AVIA_{WBS}-AVIA_{SP})$$

and

$$EI\text{-}NWBS=(AVIA_{NWBS}-AVIA_{SP})$$

where a positive value means elongation, and a negative value means shortening at the given side.

The analysis of variance and correlation analysis were performed.

4. RESULTS

4.1 Analysis of the starting position

Regarding RGF, both groups exhibited significant differences between the two sides. Thus, the control subjects also have a more loaded side. However, there were significant differences between the two groups for both sides, i.e. the patients had significantly higher RGF at the MS (non-paretic side), while significantly lower values at the LS compared to controls. Therefore, AIW-SP values showed significant asymmetry for both groups, but they also indicated significant differences between the two groups with higher level of asymmetry in the patient group

As for the AVIAs, no significant differences were found between the two groups on either side; however, the patient group was characterized by significantly smaller AVIAs on the LS than on the MS ($P<0.05$). Furthermore, the AIA-SP also showed significant differences between the two groups, and only the patients had significant asymmetry in this respect.

4.2 Analysis of weight shift position

Regarding the WS position, while both groups shifted significantly less weight on their LS than on the MS, the patients shifted a significantly smaller amount of weight on the LS compared to the controls. Thus, both groups were characterized by less asymmetry when shifting weight to LS than to MS, but the degree of the asymmetry was significantly lower in the patients when shifting weight to LS than in the control subjects.

Regarding the changes of AVIAs in WS position at the MS, there were no significant differences between the two sides (WBS and NWBS) and between the two groups. Therefore, the asymmetry index for the angles in WS to the MS did not reveal significant differences between the two groups. On the contrary, in the case of WS on the LS, the stroke patients showed a perfectly opposite trend in the angles at the two sides compared to the control group, i.e., the AVIA values increased on the NWBS and decreased on the WBS, thus a significant difference was detected between the NWBS and WBS values. In the control group the AVIAs slightly increased on the WBS and moderately decreased on the NWBS without significant differences between the two sides. Regarding the AIA values, the patients had a decrease, while the controls an increase in these parameters in WS to LS, therefore a significant difference was observed between the two groups, furthermore, significant asymmetry was detected only in the patient group.

Regarding the elongation index of the trunk (EIs), the patients showed significant shortening on the WBS in WS to the LS.

4.3 Correlation analyses

No significant correlations were found between the different RGFs in either group. As for the correlation between AVIAs and RGFs, only few significant correlations were found. Thus, during quiet standing, only the patient group showed significant correlation between RGF and AVIA at the MS side.

During WS at LS, the control group showed significant a correlation between RGF-SP and AVIA at NWBS, and in the patient group inverse correlation was detected between RGF-WS-LS and AVIA at NWBS.

The correlation analysis of asymmetry indices and elongation indices also revealed some significant values. Thus, inverse correlation was observed in the patient group between AIW-SP and AIW-WS at LS. Positive correlation was found between AIW-WS and AIA-WS, but negative between AIW-WS and EI-NWBS at LS. Furthermore, significant correlations were observed between trunk angles asymmetry in SP and in WS in both groups and on both sides with opposite direction in MS vs. LS. Since the EIs and AIs were calculated from the AVIAs, there were several significant correlations between these indices.

5. DISCUSSION

Our aim was to characterize the trunk alignment with a simple and reproducible method during quiet standing, and following voluntary lateral WS in the frontal plane in healthy subjects and patients with stroke. The main findings of this study were that it revealed significant differences in trunk alignment between healthy subjects and stroke patients, which were partially independent from their weight bearing ability.

These data suggest that the patients, due to decreased weight bearing ability, apply compensatory pattern in their trunk during quiet standing and lateral weight shift to ensure their stability and to perform movements.

5.1 Trunk alignment

The markering of the body by a simple way to characterize the AVI angles on the trunk at both sides during different amount of weight distribution between the two lower extremities in healthy subjects and hemiparetic patients revealed that:

1. Trunk alignment was asymmetrical in stroke patient during quiet standing.
2. The patients have utilized inverse pattern during weight shift to the LS compared to healthy subjects.

In contrast with our hypothesis, not any significant changes in the elongation indices could be detected in the control group during weight shift to any sides. This supports the findings that lateral WS requires a higher level of muscle activity than displacement in trunk position in healthy subjects.

In the patients' group, the larger trunk angles at the NWBS compared to WBS during WS to LS revealed an altered (i.e. compensatory) strategy of trunk movement. According to our observation, at WS to either side, the patients tried to compensate with the upper trunk, mainly by trunk lateral flexion and it was more pronounced during WS to LS. The compensatory movement can be explained by the reduced force production and the delayed trunk muscle activation on the paretic side and/or by the decreased activation of the leg muscles for support and balance.

Surprisingly, asymmetry in weight bearing and trunk angles (AIW and AIA) correlated significantly (R=0.64) only in patients' group, while WS to the paretic side (LS) suggested that asymmetry in WB is not necessarily linked to the asymmetries of trunk alignment. The few correlations between trunk angles and relative ground forces suggest that trunk angles may reflect not only the WS ability, but also the compensatory strategy (increasing trunk lateral flexion on the WBS e.g. shortening, while shifting the weight). Earlier results proved that mainly the hip abductors and adductors control the postural stability in the frontal plane contributing to the alternate loading and unloading of the lower extremities (load/unload strategy), and if WS is initiated from the pelvis and it moves to the WS direction in the frontal plane, the trunk will move in the opposite direction as a counteraction to control the movement of the centre of pressure, generating elongation at the weight bearing side.

Significant correlations between angles asymmetry in SP and WS in both groups and on both sides show that subjects with a higher degree of asymmetry during SP will have higher degree of asymmetry in WS, too. Strong correlations between EIs and AIAs suggest that EIs might be used as parameters for the characterization of trunk alignment in different WS positions.

The alterations of trunk alignment (excessive shortening in the paretic side) in SP and in different WS positions indicate that the stroke patients were not able to elongate the affected side; therefore, they performed WS in a compensatory manner. The video recordings revealed that healthy subjects usually initiated the WS at their hip to the WBS, and then the shoulder girdles (upper trunk) moved in the opposite direction, but these movements were not accompanied by significant elongation/shortening in the trunk (AVIAs), suggesting the load/unload strategy. In contrast, patients usually initiated the WS at the hip to the WBS, but after reaching their stability limit, they very early moved the upper trunk into the direction of WBS in order to force more load on the WBS. This compensatory movement resulted in shortening of the trunk on the WBS. The patients used this compensatory strategy of the trunk for shifting and bearing weight both to the paretic side and the non-paretic side. Since WS to the paretic side is a challenging task for these patients, it is assumed that the abnormal elongation/shortening strategy might compensate the impaired WB ability, and may protect them against falling.

6. CLINICAL SIGNIFICANCE

The major focus in the rehabilitation of stroke patients is weight bearing symmetry. During the treatment the aim is to increase the patients' ability to bear more weight on the paretic limb and to decrease the over-activity on the non-paretic side. It is assumed that enhanced symmetry in weight distribution in weight bearing position will result in better postural control. Thus, early applied trunk (trunk muscles) exercises during sitting, standing and walking might improve standing balance and mobility after stroke, especially when they are implemented as functional tasks, such as rolling and reaching.

However, so far, no particular attention has been paid to hemiparetic patients' trunk alignment in different standing positions. Our results suggest that a quantitative analysis of WB in itself is not enough to build up a correct treatment plan, since trunk alignment may also contribute to movement performance. With more information about pathological postural alignment associated with stroke, the therapist is better equipped to determine the state of the patients and to establish appropriate interventions. For instance, in patients with shortening on the paretic side, attention must be paid to the correction of this alignment, that is, elongation should be facilitated on the paretic side either in the SP or WS.

According to our observation, the performance in WB during SP and WS depends not only on the patients' motor, sensory and cognitive abilities, but also on the instructions on how to perform the task and the complexity of the functional task.

7. CONCLUSIONS

To our knowledge, this study was the first attempt to give an exact characterization of trunk alignment during quiet standing and lateral weight shift in healthy and stroke patients. Obviously, this study was not designed to substantiate ultimate conclusions, rather to claim its practical significance. The results revealed that the stroke patients' weight bearing ability is deficient and that they tend to compensate for this deficiency by abnormal trunk alignment. Therefore, the measurement of weight bearing ability alone might be an unsatisfactory proxy of therapeutic success, and attention must also be paid to how the individual patient performs weight shift, and incorporate this information in the therapeutic plan. Our method can help to reach this by precise, numeric parameters of patients' trunk alignment by the application of a simple method.

Our results have proved that the therapist need to work on trunk elongation of the WB side while practicing lateral WS to provide better trunk and whole body alignment to activate the appropriate muscles necessary for the function.

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