STABILOMETRIC MEASUREMENTS IN THE CENTRAL NERVOUS SYSTEM DISEASES. DETECTING POSTURAL INSTABILITY

Abstract of PhD Thesis

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1. Introduction

Central nervous system diseases are often accompanied by balance impairment deteriorating life quality and leading to falls, unconditionally of its etiology. The person is locked up in his own apartment because of the feeling of insecurity.

In the first part of my thesis I defined the concepts implicated in the topic. The most important of these is the definition of postural instability, which refers to the maintenance of balance against gravity in a sitting and/or standing position. In general, it refers to the standing position. Balance is controlled by peripheral and central factors. The impulses are transferred to the central vestibular ganglions and the cortex via vestibular, somatosensory, and visual stimuli. The maintenance of balance is provided at a spinal level by spinal long-latency reflexes. The peripheral sensory input is transferred to different parts of the brain. The greatest coordinator of balance is the cerebellum. The role of the somatosensory cortex is also significant. Postural instability, or balance is provided by the coordinated operation of numerous pathway systems at various levels of the central nervous system.

As for the peripheric region, the head's position and its changes must be highlighted in the maintenance of balance. Another significant somatosensory input is the impact of the proprioceptive receptors in the tendons of the ankle, and their role is increased in Parkinson's disease (PD) and in post-stroke state. Although, it is well-known that lesions of the cerebellum lead to balance impairment, I draw the attention to the assumed involvement of the cerebellum in conditions where the cerebellum is indirectly affected.

I present several methods for the assessment of balance. Clinically, the Push test and Tandem walking is the most frequently used but not quantified methods. Although, static and dynamic stability can be assessed by the Berg Balance Scale, it is not generally applied in the clinical practice. Posturography is a quantifiable assessment method of stability. Therefore, I used static (standing with the eyes open and closed) and dynamic posturography in my work.

2. Goal

The goal of my work was to examine postural instability in several kinds of central nervous system diseases and in healthy persons, and to compare the results assessed by posturography.

2.1 Presentation of static and dynamic posturography. Analysis of the new method of dynamic posturography, namely the ball test. Is it suitable for the examination of balance, or not?

2.2 Analysis of the stability of patients in the early stages (Hoehn and Yahr stages 1 and 2) of Parkinson's disease with static and dynamic posturography. Is it possible to detect balance impairment when the Push test is negative?

2.3 Is it possible to show an age-dependent difference in the characteristics of postural instability in the age groups under and above 65 years?

2.4 Dyskinesis is a side effect of Levodopa treatment and it implies involuntary and exaggerated movements. It appears in 5-10 years during the treatment. We examined how the unpleasant unintentional movements affected postural instability.

2.5 Stroke leads to a high degree of postural instability already at the onset of the disease. How long is the balance impairment maintained? Does it cease to exist after the improvement of the paresis and the equalization of the burdening of the limbs during standing or walking? We wondered if it could be detected after several years.

2.6 It is well-known that the different kinds of ataxias lead to balance impairment. We tried to differentiate between spinal and cerebellar ataxia.

2.7 Based on the above examinations I could draw theoretical and practical conclusions.

3. Methods

3.1. Static and dynamic posturography

Considering the literature, static and dynamic posturography are the most objective and well reproducible methods, therefore I applied them in my work.

During static posturography the person was standing on a balance board (Nintendo Wii) for one minute. We examined static posturography with the eyes open and closed. The path and velocity were assessed by a computer program. In addition, forward-backward and latero-lateral oscillation was also measured.

Dynamic posturography might be considered a provocation test. The center of body mass is moved and the person is forced to an adjustment to maintain balance. Instead of using complicated instruments, we applied a simple and effective method. The participants were turning various balls of different weights in a standing position around their body, so the center of their body mass was permanently moved, and they were forced to change their posture in order to maintain balance. The balance impairment depended on the weight of the balls.

3.2. Persons involved in the study

Our work has been given a permission from the Regional Research Ethic Commission in Győr. Patients were recruited from 2016 to 2019 in Neuro Rehabilitation in Sopron. The persons participating in our study have provided written informed consent, according to the Helsinki Declaration.

There were 45 persons involved in Hoehn and Yahr stages 1 and 2 of Parkinson's disease. The main inclusion criterion was the Levodopa responsiveness to the Parkinsonian symptoms to exclude those suffering from other diseases similar to Parkinson's disease. We excluded patients with dementia and musculoskeletal diseases. The patients were examined on-medication. We examined nineteen Parkinsonian patients with dyskinesia.

We assessed the postural stability of twenty-nine post-stroke patients. Inclusion criteria were: only one stroke event, and the ability of standing and walking independently. Exclusion criteria were: fluent aphasia and/or dementia. The number of

age-matched healthy controls was 38. The groups were divided into age groups of ≤ 65 years and > 65 years.

4. Results

4.1. Correlations between the different weighted balls and postural instability

There was a high correlation between the weight of the balls and the pathway and velocity during dynamic posturography ($r = 0{,}83$ $p < 0.001$). The balance impairment was directly proportional to the weight of the balls. This made us draw the conclusion that this method is suitable for the examination of dynamic balance.

4.2. Our examinations in the early stage of Parkinson's disease

In the age group of ≤ 65 years during dynamic posturography (1/2 kg, 1 kg, and 2 kgs balls passing around the body for 1 minute) the oscillation in the antero–posterior direction was significantly increased ($p < 0.05$), compared to the age matched healthy control participants. The path and the velocity assessed by static and dynamic posturography did not show any changes in the age group of ≤ 65 years.

In the age group > 65 both the pathway and the velocity significantly increased with the eyes open and with the eyes closed ($p < 0.05$). During the examination with dynamic posturography and with the use of ½ kg balls the Parkinson's disease patients were significantly different from the age matched healthy participants. The testing with 1 kg and 2 kg balls did show no significance, probably due to the high value of variance.

We had only a few opportunities to assess the postural stability of Parkinson's disease patients during dyskinesis. Although, their static stability was significantly higher compared to the control persons, it was actually the dynamic posturography which increased their balance impairment to a great extent. The dyskinetic state was different in a highly significant way from even the Parkinson's disease ($p < 0.001$).

While in the early stage of Parkinson's disease in the younger age group the postural instability was generated only by dynamic posturography, in the older age group we detected significant postural instability during both the static and the dynamic

posturography with our assessments. The greatest oscillation of stability was generated by the dyskinesis. The risk of fall is the highest in this state.

4.3. Examinations of postural instability in post-stroke state

Stroke is accompanied by balance impairment. Does the paresis cease to exist by the improvement of the weight loading to the weakened lower extremity or can it be detected several years later?

We detected no digression with static posturography in the age group under 65 years compared to the age matched healthy control group. However, both the pathway and the velocity were significantly higher assessed with dynamic posturography ($p < 0.05$) compared to the control group.

Both the pathway and the velocity assessed with static posturography (with eyes open and with the eyes closed) were significantly higher in the age group of > 65 years ($p < 0.05$) compared to the control group. The dynamic posturography also showed significantly higher values ($p < 0.05$) during the ball tests.

4.4. A comparison of spinal and cerebellar ataxia assessed by posturography

Spinal and cerebellar ataxia is not always easy to be differentiated clinically. I examined the support of static and dynamic posturography in the diagnostics. Although, the number of our cases was low, therefore no significance could be determined, there is a biological importance of the differences, based the extent of the digressions.

In spinal ataxia assessed by static posturography with the eyes closed a significant balance impairment can be detected, compared to the assessment with the eyes open. Although the pathway and the velocity increased during the dynamic posturography, its values are less than the values assessed with the eyes closed.

In the cerebellar ataxias the pathway and the velocity were significantly increased by dynamic posturography, and the results of static posturography showed very similar values to each other.

I demonstrated a case of cerebellar ataxia caused by a car accident. The alterations of pathway and velocity are demonstrated depending on the time. At the

beginning of the follow-up the assessment could not be completed with higher weights because the person could not maintain his standing position on the balance board. During the succeeding months his state gradually improved.

The next case presented is a genetic case where a combined ataxia was generated by spinal, brainstem and cerebellar xanthomas. The alterations of the static and dynamic values are illustrated by tractography.

5. Conclusions

5.1. The usefulness of static and dynamic posturography

The importance of static and dynamic posturography and their usefulness in several diseases have been proved by my experimental work. My study has been suitable for the comparison of several scientific research publications. The method of dynamic posturography elaborated in the Neuro Rehabilitation Institution in Sopron was suitable to detect postural instability in the early stages of several diseases (Parkinson's disease, post-stroke).

5.2. Analysis of postural instability in the early stage of Parkinson's disease

We were able to detect a well differentiated postural instability with posturography in those cases of Parkinsonism where the clinically applied Push test was negative. We detected an age dependent alteration. While in the age group of ≤ 65 years the dynamic posturography generated a significant change, in the age group of > 65 years both the static and the dynamic posturography significantly differed from that of the healthy control persons. So, the balance impairment can be detected even in the early stage of Parkinson's disease which shows age dependent characteristics.

Considering that balance impairment cannot be influenced by Levodopa, I supposed the impairment of non-dopaminergic pathways even in the early stages of Parkinson's disease. My assumptions are underpinned with data of previous publications.

5.3. Balance impairment assessed in post-stroke state

The involvement of the cerebellum and/or its pathway systems can be supposed in balance impairments. The balance disorder can hardly be affected even with physiotherapy.

5.4. Conclusion based upon the analysis of ataxias

Spinal and cerebellar ataxia can be well differentiated with posturography. While spinal ataxia increased with the eyes closed, cerebellar ataxia was significantly heightened with dynamic posturography.

5.5. Theoretic conclusions

It was interesting that the two distinct diseases (Parkinson's disease and stroke) demonstrated similar characteristics associated with age dependency during the assessment of postural instability. When the onset of the disease is > 65 years there are more areas of the brain affected than in younger age.

Based upon the examinations of Parkinson's disease patients the involvement of the non-dopaminergic pathway system can be supposed to take part in the generation of the balance impairment that cannot be influenced by Levodopa. In both diseases the impairment of the cerebellum can be supposed to be involved behind this symptom.

5.6. Practical conclusions

Even the fact that the balance impairment can be provoked indicates the necessity of balance exercises in the early stage of Parkinson's disease. With the eyes closed or not.

Balance impairment remains in post-stroke state even after several years, and it can be improved, e.g., standing on a plastic disc in upright position, and on an uneven road or an obstacle course.

6. Summary of the new results of my thesis

- I proved that the ball test is a suitable method for dynamic posturography as a new assessment method.

- I observed postural instability in the early stage of PD when it could not be detected by any other clinical measurements.
- The postural instability can be detected late after the onset of stroke in spite of the improvement of the paresis.
- I discovered that the characteristics of postural instability are age dependent.
- The brain in younger age reacts differently to the diseases compared to the brain in older age.
- I claimed the etiopathological importance of the cerebellum in both of my papers.
- I stress the usefulness of physiotherapy in every stage of the central nervous system diseases.

Publications

1. Halmi Z, Stone T, Dinya E, Málly J. (2020) Postural Instability Years after Stroke. J Stroke Cerebrovasc Dis, 29: 1-6.
2. Halmi Z, Dinya E, Málly J. (2019) Destroyed non-dopaminergic pathways in the early stage of Parkinson's disease assessed by posturography. Brain Res Bull, 152: 45-51.