Use of Stabilometric Platform and Visual Feedback in Rehabilitation of Patients after the Brain Injury

Pokorná K.
Department of Rehabilitation Medicine of the First Faculty of Medicine, Charles University in Prague, and General Teaching Hospital, Czech Republic

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Mailing Address: Pokorná Karla, MD., Department of Rehabilitation Medicine of the First Faculty of Medicine, Albertov 7, 128 00 Prague 2, Czech Republic, Phone: +420 224 968 489, Fax: +420 224 917 898, e-mail: kpoko@lf1.cuni.cz

Abstract: Rehabilitation of patients after the brain injury requires employing of all available mechanisms of neuroplasticity. To achieve it, the voluntary activation of brain systems that are involved in the signal processing, represents the most effective tool. The control of balance is a complex neuronal mechanism based on unconditioned and conditioned reflexes, as well as on the actual cognitive processes. As it requires participation of several brain regions, training of the posture support mechanisms can provide a highly effective tool for rehabilitation. The aim of the study was to develop methods for the long-term follow up and training of the balance skills in patients with different types of brain impairment. To obtain standard data, the stabilometric platform Posturograph STP-03 and special examination programs were also used in the study of the equilibrium skill training by healthy volunteers. For the assessment of the learning efficiency two criteria from the recorded data were used – the velocity of adjustment of the gravity centre and the accuracy of the movements. Stabilometric platform was used also for the balance skill training with the visual biofeedback. Our results show that the proposed program for the equilibrium skill training offers a comparatively simple method of the adequate duration with numerical and graphical output, which allows fast interpretation of the treatment results. The synoptic form of results can also stimulate the patient's motivation during the long-term training for the mobility improvement.

Introduction

The most frequent cause of the nervous tissue damage in humans is the vascular impairment, tumours and brain injuries. They can cause various combinations of motor, sensory and cognitive dysfunctions. Intensity of these clinical symptoms depends on the extent and localization of the lesion and on the intensity and affectivity of the processes of recovery. The first signs of improvement come about few days after the pathogenic process was mollified (e.g., the brain oedema). Other defects can recover more slowly and improvements probably result from the plastic remodelling of neuronal circuits and from changes in the functional load of individual brain areas. Such progress is not usually parallel in all functional systems: Motor dysfunctions are typically recovered earlier than the sensory ones. The neuroplastic process of recovery is generally based on a genetic program, which can be triggered, modulated or potentiated by factors of the local microenvironment, by conditions of the patient's milieu, and by his own activity [1, 2]. The first category includes factors of blood and oxygen supply, clearance of locally produced toxic factors or activity of local neurotropic factors. Treatment of the neuronal microenvironment is mostly within the reach of the clinical therapy, including the pharmacotherapy. The positive effect of factors within the patient's environment as well as the essential role of appropriate activity of the patient's nervous system is, at least partly, the task of the rehabilitation program.

The clinical rehabilitation praxis is aimed to influence the impaired function by activation of neuronal circuits by a proper and diverse information load in order to rebuild the required integration functions. All therapeutic programs of physiotherapy, occupational therapy, speech therapy and neuropsychology are aimed in that way. The more techniques are employed simultaneously, the larger part of the lost function is possible to recover.

Learning and memory belong to the most important mechanisms of neuroplasticity. The rehabilitation program employs mainly the procedural forms of memory (non-declarative memory). This phylogeneticaly old form of memory is anatomically linked to the primary association cortical areas, to the cerebellum, thalamus and basal ganglia. Memory traces are formed by multiple repetitions, they are accompanied with improvement of the performance and frequently they have no conscious correlate. In the rehabilitation, procedural memory has the key role for improvement of motor skills (motor patterns, their timing and space organization). Rehabilitation can also improve the recovery of sensory input (formation of perception patterns and procedures for the information processing). The procedural memory determines the recovery of most of the daily activities of the patients.

Equally important role in neuroplastic processes of recovery appears to have the declarative memory. It relies on cognitive processes such as evaluation, comparison, and deduction. It encodes information about specific autobiographical events as well as the temporal and personal associations for those events. Declarative memory trace is frequently formed by a single trial or experience. Memory items can be retrieved explicitly as a pattern, image or relationship, and the brain can use them to reconstruct past events or episodes. Repetition can transform declarative memory traces into the procedural type. Declarative memory is phylogenetically recent; its development coincides with the full elaboration of the medial temporal cortex, including the hippocampal formation and association cortical areas. Modern rehabilitation techniques frequently employ procedures activating the declarative memory, namely for its general stimulatory effect on the neuroplastic processes and because it is assumed to be a more "patient friendly" method for improving the patient's performance.

Biofeedback is a method for improving some physiological function. It is based on technical device, which offers parallel information about the course of the followed function for the additional sensory processing (visual, auditory). The feedback mechanism is an essential component of any control mechanism of body functions (e.g., the neuronal circuits of cerebellum as well as the visual system can correct deviations in the direction of movement). Patients can therefore learn to employ the information mediated by an instrument for the conscious correction of the course of the given function. In reality the instrument continually monitors the course of the function and provides information for the visual or auditory input [3].

Stabilometric platforms are usually a part of the automated system called computer posturography. They enable objective and reproducible evaluation of the balance. Computer program continuously records the data and displays them in a graphical form for the evaluation of movements of the gravity centre on the basis of its projection onto the plane of the supporting basis.

Balance is defined as the ability to maintain the centre of gravity above the supporting base [4]. Balance of human posture is a complex process, which requires adequate input of the sensorimotor information for the execution of appropriate response of the muscle-skeletal system. In the healthy individual, balance has a reflexive character. It is primarily controlled by motor centres in the brain stem, namely from the reticular formation and vestibular nuclei by means of the vestibular and neck reflexes. Input information comes mainly from the proprioceptors, vestibular apparatus and retina (vision). The most important output pathways are the vestibulospinal and reticulospinal tracts [5]. Despite its redundant mechanisms of control, the balance of human body is frequently subjected to various forms of impairment. Disorders can result form lesions of any component of the control system – brain centres, afferent or motor pathways. Also the muscle weakness, hypoesthesia and anaesthesia, defects of vision, contractures or problems with joints can harm either the static form of balance (sit-up, stance) or the dynamic form (gait). Patients after the vascular lesions display specific balance abnormalities – their conscious control of displacements during comfortable stance is lower, balance reactions have longer latency on the paretic site where lower amplitude of reactive forces is also observed. In addition, balance can worsen by incorrect choice of muscles employed in the corrective motor response [6].

Serious problem for the full self-care of patients after the brain lesion is the defect of balance, which sometimes continues even after the good recovery from paresis. The common problem of patients with hemiparesis is the inability to slip the not affected leg, which is weighed down by the body, and move it forward. Only after the patient learns to transfer the body weight upon the impaired extremity, the correct pattern of gait can recover. Those patients have similar problem during the shift of the centre of gravity above the supporting base during hoisting from the sit-up [7]. Patients have to learn how to control the shifts of the

Figure 1 – The use of a stabilometric platform.

centre of gravity in order to master motor skills of basic locomotion as well as the performance during the common daily activity.

The aim of the study was to develop instrumental methods for the improvement of the patient's ability to control his centre of gravity and to improve the balance in order to facilitate the use of impaired extremity in the complex movements. To obtain standard data for future evaluation of the learning dynamics of balance skills in relation to the type and degree of patient's disability, the stabilometric platform Posturograph STP-03 and special examination programs were also used in the study of the equilibrium skill training by healthy volunteers.

Methods

Stabilometric platform Posturograph STP-03 of the Czech production has been used (Figure 1) [8]. The first task was to develop methods for the long-term follow up and evaluation of the balance skills in patients with brain impairment. The next step was to develop procedures for the training of the balance skills using the visual biofeedback adjusted to the patients with brain damage.

Stabilometry is an objective and reproducible method for the recording and evaluation of the balance skills. The examined person stands on a rigid stepping square platform (420 × 420 × 15 mm – Figure 1). Projection of the gravity centre and its movements relative to the centre of the platform is monitored by four mechanic-electric sensors (tensometers), which support the platform. Electrical signal is digitalized, evaluated by special computer program and results are visualized on the monitor and recorded for future statistical evaluation [8].

Evaluation of the balance dexterity is the first step before the training of balance skills. As the routine examination methods are aimed on the analysis of the vestibular apparatus impairments, a special sequence of tests was developed to study patients with brain impairment, aimed at the ability to shift and relocate the weight and gravity centre.

The designed paradigm of examination includes:

1) Recording of the stance with wide and narrow basis, always with open and closed eyes.
2) Recording of single limb stance, subsequently the unimpaired and weakened leg, on the tiptoes and heels.
3) Test of ability to control voluntarily the titubation shifts during the comfortable stance, when the proband pursues the mark representing the gravity centre to maintain at the centre of the target area and the deviations compensate by active return to the mark.
4) Several shorter trials aimed to analyse the capacity for the voluntary displacement of the gravity centre in a given direction: latero-lateral, forward to the right, forward to the left, backward to the right, backward to the left. These initial tests can usually disclose the weak points in the patient's balance

skills. More demanding tests are based on previous sequence with returning to the centre of the target area, on the continuous testing of such sequence with the centre of the target area moving along the sides of a square, along the sides of a half length square, clockwise or counter clockwise.

Our battery of test is based on the tests of active stance „Functional Reach Test" and „Rhythmic Weight Shifts Test". [9]

If the patient was selected for the visual feedback training, he underwent repeated trials with the tests with the complexity level, which he had successfully finished (in our experimental group it was the test with two squares). The reasons why some patients were not included into the program were: vision problems and cognitive incapacity to understand and perform the test (fatic defect, mental deficit, defect of personality).

One therapeutic trial lasted 10 to 15 minutes according to the skill of the proband. For the evaluation only the data recorded during the first and the last trial, which the examined person performed without any involvement of the therapists, were included. Among the evaluated trials three training sequences for the control of the gravity centre with the verbal or, in highly impaired patient with physical guiding, were inserted. The examined person could see the movements of the projection of his centre of gravity (a red mark) and try to target it up with the highlighted actual aim point. When the target was reached the visual feedback was enhanced by an acoustic signal.

Stabilometric platform and its computer evaluates automatically some parameters (type of the trial, location of target points, length of the ideal

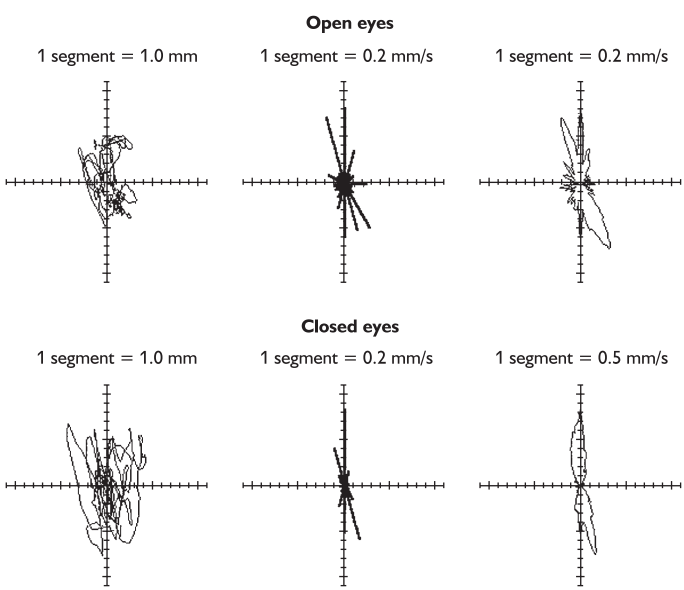
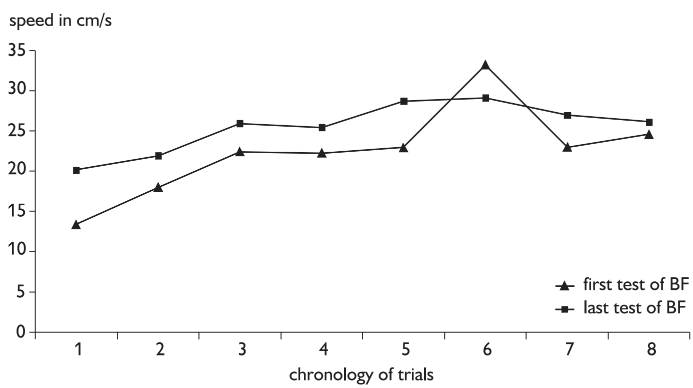


Figure 2 – Graphical presentation of results from the test of stance – length and speed of the trajectory of the projection of the centre of gravity between target points in conditions of open and closed eyes; left – real trajectory of the projection of the centre of gravity; centre – dominant directions of deviations; right – wrapping curve of the maximal deviations.

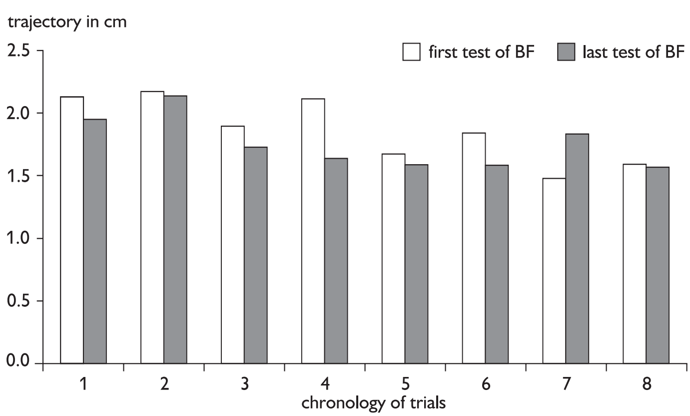
trajectory, the length and speed of the real trajectory of the projection of the centre of gravity between target points) (Figure 2). As criteria of improvement two parameters were selected: the speed of movements of the projection of the centre of gravity and the accuracy of movements expressed by the ratio between the real and ideal trajectory. Numerical data from the evaluation are presented in the form of tables or they can be converted into the graphical charts.

Results

To illustrate the possibilities of biofeedback training in rehabilitation of patients with brain injury, graphs representing the analysis of two measured parameters in the healthy and impaired person are included (step 3 in the above designed recording paradigm). Graph 1 and 2 gives typical dynamics of the performance improvement during the training in a healthy person. Graph 1 shows the increasing speed of the control adjustment of the centre of gravity during individual training sessions; in most of these trials the value found at the beginning is smaller than after the training. Contrary to it, the results of trajectory ratio (the ratio between



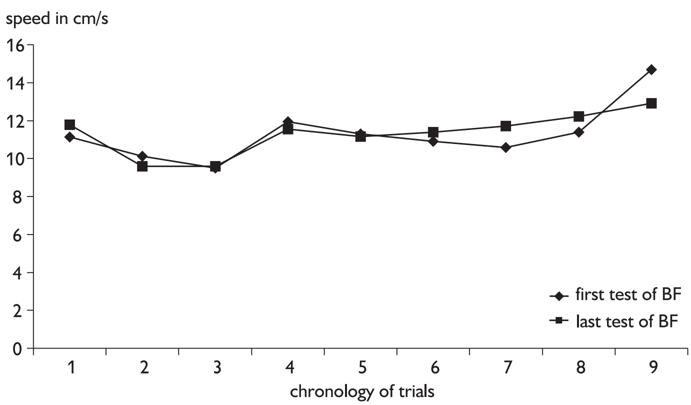
Graph 1 – Progress in the training of the control the gravity center by means of visual feedback expressed in the speed of movements. Record of a healthy young volunteer. Speed of the control adjustment of the centre of gravity is given for the first and last test of the biofeedback balance testing (BF) in eight trial sessions.



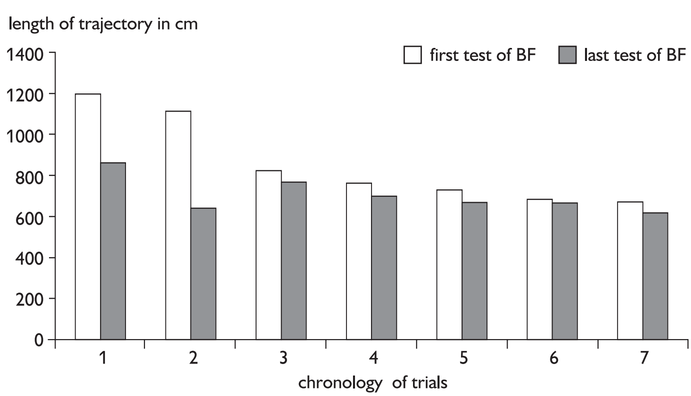
Graph 2 – Progress in the training of the control the gravity center by means of visual feedback expressed in the length of trajectory of projection of gravity center. Record of a healthy young volunteer. Length of trajectory of the control adjustment of the centre of gravity is given for the first and last test of the biofeedback balance testing (BF) in eight trial sessions.

the real and ideal trajectory – Graph 2) show decreasing trend with the training, which means that the relocation of the centre of gravity comes closer to the ideal trajectory with the ratio approaching to one. Values after the training are also better than before it.

Graphs 3 and 4 demonstrate effects of the feed back training in one of our patients. The patient suffered from right side hemiparesis (consequence of the excision craniopharyngeoma). Records were obtained during her four weeks treatment in the Day centre for patients with brain injury of the Rehabilitation Clinic. In comparison with previous healthy person, records of the patient show that the displacement of the centre of gravity is slower and the training procedure brought about less apparent results (Graph 3). Records of trajectories ration show a big difference between the record before and after the training, given by markedly worse initial performance. The gradual improvement of the patient's performance is well visible (Graph 4). It clearly demonstrates the positive results of the training in the rehabilitation of balance impairment. The downgrade in the last record represents a frequent phenomenon observed in records obtained in



Graph 3 – Progress in the training of the control the gravity center by means of visual feedback expressed in the speed of movements. Record of a patient with right side hemiparesis. Speed of the control adjustment of the centre of gravity is given for the first and last test of the biofeedback balance testing (BF) in nine trial sessions.



Graph 4 – Progress in the training of the control the gravity center by means of visual feedback expressed in the length of trajectory of projection of gravity center. Record of the same patient as at Graph 3. Length of trajectory of the control adjustment of the centre of gravity is given for the first and last test of the biofeedback balance testing (BF) in seven trial sessions.

the daily stationary. It can result from the evident nervousness of the patients before their dismissal.

Discussion

Literature as well as the newest electronic sources reports the use stabilometric platforms only as a tool for examination with the aim to objectify balance disorders resulting from the vestibular and cerebellar impairment [10, 11]. Similar aim had the Czech authors who designed the original platform and its software. However, the possible use of stabilometric platform arose in several other fields of medicine, e.g., in the recording the progress in exercise for elderly women [12] or in study of effects of cryotherapy in stability of stance in patients with multiple sclerosis [13]. Also Czech authors [14] brought recently valuable information on the clinical use of the platform. Our contribution extends the use of platform in another medical specialization, namely in the neurorehabilitation. Stabilometric platform enables not only the objectification of the degree of balance disorder resulting from the impairment of motor centres after the stroke, injury and other brain damage, but it represents a valuable tool for the active rehabilitation of various forms of balance disorders.

The described method of the examination and training of balance skills enables modern approach in the improvement and renewal of kinezitherapeutic techniques; it can objectify clinical description of patients with impairment of balance functions resulting from the brain injury [15]. Stabilometric platform makes possible to train trunk and lower extremities coordination, muscle strength at the impaired side, leg load, and control of the position of the gravity centre. The major advantage of the described method is its relative simplicity, reasonable duration and synoptic graphical presentation of results. Another advantage of the method is the possibility to adjust and modify tests and training programmes according to the actual problem, for example by the setting of points, giving more to the impaired side, or by the subsequent increase of the distance of goal points etc. Clinically important is also its benefit to the patient's motivation to continue the cooperation in the long-lasting programs of rehabilitation of motor functions.

It was demonstrated that neuroplasticity mechanisms are responsible for repairing of brain functions after the injury [1]. Learning and formation of memory traces can participate in the rearrangement of neuronal circuits which are necessary for the recovery of impaired neuronal functions. The procedural and partly also to the declarative learning, which are the basis of our training procedures, resulted in the improved function (body balance) and had a positive effect on the patient's self-care. Above that, the described methods enabled the objective evaluation of the learning processes of the balance control and the dynamics of stability during shifts of the gravity centre. In the future, our method will serve to the evaluation of the learning dynamics of balance skills in relation to the type and degree of patient's disability and it will help to set criteria of the learning progress.

Conclusions

The presented methods of objective recording and evaluation of the balance skills and abilities of patients enables to assume modern approach in medial fields of kinesiology, which is traditionally based on the subjective evaluation only, however, in the era of evidence based medicine it will require the objective assessment of the patient's status.

The designed system, which employs visual biofeedback derived from a posturometric platform, allows also analysing theoretical questions of the mechanisms of balance disorders, the dynamics of the transfer of the learned memory trace from the declarative to procedural memory, and the role of rehabilitation techniques in the process of recovery. The system will help to classify balance disorders, to measure the dynamic of their improvement during rehabilitation and to use this data for the prognostic purposes.

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