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An Objective Approach for Assessment of Balance Disorders and Role of Visual Biofeedback Training in the Treatment of Balance Disorders : A Preliminary Study

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Abstract :

Normal equilibrium is defined as the ability to maintain the centre of body mass over its base support with minimal postural sway. Human balance is a sensitive and complex process and normal postural control underlying balance involves both motor and sensory processes.

The purpose of this preliminary study was to study the components of balance disorder in patients attending for balance rehabilitation and to find out the effectiveness of visual biofeedback training in reestablishing postural control in these patients.

Twenty out-patient cases presenting with various balance problems were included in this study. They included hemiplegic following stroke, post-head injury, cervical spondylosis, cerebellar ataxia, etc. Quantitative assessment about balance problems was done using force plate system in regard to centre of gravity (COG) alignment, postural sway and dynamic balance measures within limits of stability (LOS). Visual biofeedback training to improve COG alignment, to reduce postural sway and to increase LOS was given for 3-6 weeks duration on alternate days. Improvement in static balance was observed by 12% in hemiplegics, 14% in head injury patients, 16% in cervical spondylosis patients. Improvement in dynamic measures of balance was also recorded.

Quantitative assessment of balance problems allows better understanding of defective balance components. Observation from this preliminary study suggests that visual biofeedback training facilitates appropriate balance strategies and enables in achieving improved postural control.

***Key words* - postural sway, limits of stability, centre of gravity, biofeedback, balance.**

Introduction :

Balance control is an essential component for any locomotion system and may be defined as the ability to maintain the body's center of gravity (COG) over the base of support during quiet standing and movement. Balance control in a normal adult usually takes place at the subconscious level. It is a complex process involving the co-ordinated action of biomechanical, sensory, motor and central

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nervous system components[1]. Biomechanically, a person maintains his ability to move within the limits of stability (LOS) in order to maintain balance and LOS is an imaginary cone projecting upwards at an angle of about 12^{o} antero-postereorly and 16^{O} side-to-side[2].

Human balance is a complex process which involves the integration of sensory inputs from the end organs to detect body position and integrating these information by the central nervous system to produce adequate motor output responses in the form of automatic postural response. The sensory factors involved for the maintenance of balance are visual, vestibular and stomato-sensory (proprioceptive) inputs[3]. The sensory information so integrated by the central nervous system leads to discrete leg and trunk muscle responses to produce the required motor responses to maintain COG over the base of support[4]. When the balance mechanism fails, only then the importance of different factors responsible for the maintenance of balance is realized. In neurological conditions where balance problem is evident, the equilibrium or saving reaction is often slowed down or lost. Rehabilitation of balance disorders in such condition utilizes re-education by facilitation techniques, which use the approach based on stimulus response model for motor control. Advances in technology have assisted in the study and analysis of postural control although no one measure has been reported to adequately reflect postural control because of its complexity[5,6].

Force platform systems have advantages in objectively quantifying body sway and measuring the location of an individual's center of pressure related to the base of support. Hageman PA et al[7] observed measures of sway sensitive to age related changes in healthy elderly subjects. The Balance Master system was selected for the present study. It provides continuous feedback of the position of COG in relation to theoretical LOS, as a performance source during quiet standing and leaning in various directions. And moreover, the authors could easily access to the system for testing and training of the patients. Treatment strategies involving visual feedback exercises require training over repeated sessions. Postural exercises using visual feedback of positon have been shown to reduce body sway in selected patient population[3,5].

The purpose of this study was to find out the effectiveness of visual biofeedback training in re-establishing the postural control in a clinical spectrum of patients with balance disorders.

TABLE 1.

Showing spectrum of patients (n = 20)

S.No.	Patient spectrum	No. of patients
1.	Cervical spondylosis with symptoms of vertigo.	11
2.	Cerebro-vascular accident with hemiplegia	5
3.	Post-head injury sequelae with balance problems.	3
4.	Cerebellar infarction (Ataxia) following complication of radioactive ablation in Rheumatic heart disease	1
	Total number of cases = 20	

Methods :

Subjects : Twenty outpatient subjects with various balance disorders were included in the study. All the patients were attending the Rehabilitation department, Safdarjang Hospital, New Delhi during August '95 to December '96. Distribution of the cases reporting with balance problems is shown in table no.1. Age ranges from 29 to 63 years. There were 3 females and 17 males.

After the initial clinical assessment was performed, quantitative assessment of balance problem was done using Balance Master system.

Apparatus : The Smart Balance master with software version 3.4 was used for this study. It consists of two adjacent forceplates measuring 9 inches X 18 inches. Each forceplate rests on two force transducers with the sensitive axes oriented vertically. The transducers are mounted along the front-to-back centerline of each forceplate. A cable carries the forces detected by the forceplates to a computer interface. Thus the computer receives force measurements from the dual forceplates, analyses the information, generates a screen display or gives a printed report. One of the monitors of the computer is positioned at the eye-level in front of the patient while the second monitor is provided for the operator. There is also a visual surround dome, which can either be moved separately or along with the forceplate system in the antero-posterior axis at various difficulty levels.

The system can assess quantitatively the basic components of balance control by means of six standard protocols. It has got facilities for assessment and treatment sessions under altered visual and surface support conditions. The assessment and training results using the visual feedback can be objectively documented for further reference to the changes in the post-treatment session.

Assessment : The particulars of the patient including patient demographics and height of the patient were recorded. According to the height of the individual, the foot placement on the force plate is adjusted into three standard positions. Then the following tests were carried out and recorded: (i) Align COG-eyes open, fixed surface (ii) Align COG-eyes closed, fixed surface (iii) Align COG-sway vision, fixed surface (iv) Align COG-normal vision, sway surface, (v) Align COG-eyes closed, sway surface (vi) Align COG-sway vision, sway surface.

The sensory organization tests can isolate the three sensory input components responsible for the disturbance of body balance system. Before the actual assessment, the patients were made familiarized with the test batteries. Weight bearing on two lower limbs in terms of percentage of weight distribution on the two lower limbs was also recorded for hemiplegic patients.

The software programme in the system can perform a standard sequence of tests for comparison to the normative data and can create or perform a customized sequence of tests or exercise program. Facilities for review of test or exercise data are also available with this system. The stored data can easily be retrieved later on, for easy comparability with post-training results. Thus, an objective outcome of the static and dynamic measures of balance between pre-and post training sessions can be obtained from this system.

Therapy protocol : After initial documentation of the balance deficit areas, thereapy using visual biofeedback was given using the system. It was aimed to improve COG alignment, to reduce postural sway and to increase LOS. Therapy session was given for 3-6 weeks duration on alternate days, each session lasting for 30-45 minutes duration. In addition, the hemiplegic patients also practised to transfer equal weight on the lower limbs, as they tend to transfer less percentage of body weight on the affected lower limb.

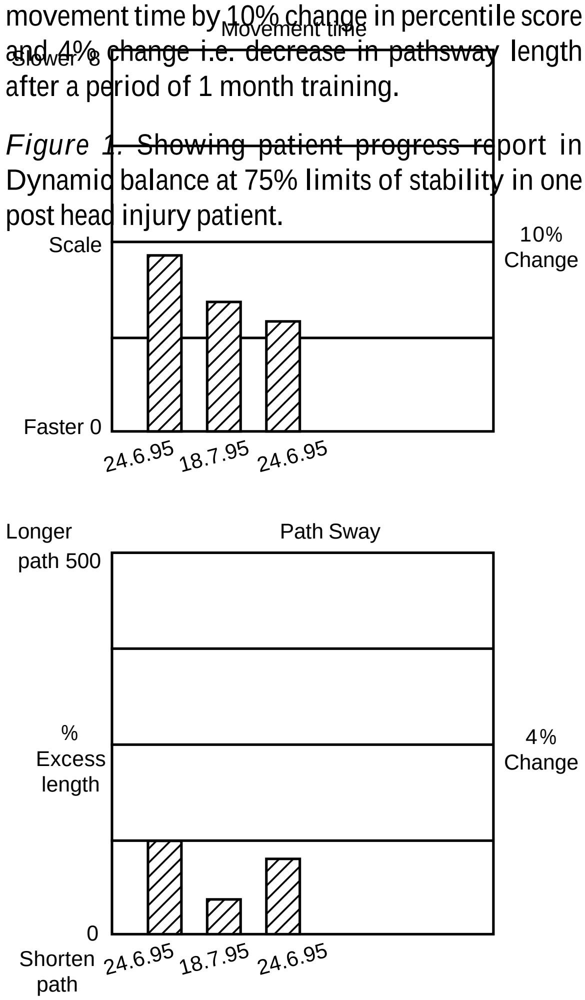
Dynamic control of balance was practised as the patient attempted to reach the peripheral targets at increasing LOS cone, while considering the factors like movement time, excess pathsway, distance error, asymmetry etc.

Data analysis : Pre-test and post-test scores in static and dynamic measures of balance were analysed in percentile scrores relative to a clinically normal population. Though no functional improvement scores were used in this preliminary study, we attempted to find out the quantitative progress in percentile scores with available normative data.

Results :

Figure no. 1. shows a progress of record on a patient of post-head injury with balance problem over the period of treatment course. We found improvement in dynamic balance measures like movement time by 10% change in percentile score and 4% change i.e. decrease in pathsway length after a period of 1 month training.

Figure 1. Showing patient progress report in Dynamic balance at 75% limits of stability in one post head injury patient.



– Bar shows average score
– % change is from the first to the last test period shown

Even though we did not use to record functional improvement scores in these patients, subjective improvement was reported by all the patients in mobility and locomotion with confidence. The mean improvement in percentile scores in case of cervical spodylosis patients with symptoms of dizziness, after the treatment course is shown in table no. 2. All the scores were expressed in percentile relative to a clinically normal population available with the software of the system. The average number of treatment session lasted about 18 sessions. The average stability improved from pre-treatment 54% to 70% at post-treatment. And the improvement for static balance was 16% while that of dynamic measures of balance were recorded as 25% decrease in movement time and 40% decrease in pathsway length.

TABLE NO. 2

Showing mean improvement in % scores expressed in percentile scores in patients of cervical spondylosis with symptoms of dizziness after treatment course (n = 10).

Sl. No.	Balance components	Mean % improvement	Range
1.	Static balance improvement	16%	7-26%
2.	Dynamic balance improvement		
	Movement time	25%	15-53%
	Excess pathsway	40%	18-47%
	Distance error	12%	6-16%
	Asymmetry	11%	9-22%
3.	Average stability		
	Pre-treatment	54%	49-58%
	Post-treatment	70%	63-84%
4.	Average Number of treatment sessions	18	15-21

Table no. 3. shows the mean improvement in balance components in hemiplegic patients after the treatment course. Static balance improvement was 12%. In regards to dynamic balance measures, the improvement observed in the hemiplegic patient group was maximum decrease in excess pathsway by 72%, while movement time and

TABLE NO. 3

Showing mean improvement in percentile scores in patients of hemiplegia with balance problems (n = 5).

Sl. No.	Balance components	Mean % improvement	Range
1.	Static balance improvement	12%	8-18%
2.	Dynamic Balance improvement		
	Movement time	33%	25-39%
	Excess pathsway	72%	50-81%
	Distance error	32%	28-36%
	Asymmetry	14%	7-24%
3.	Average stability		
	Pre-treatment	49%	36-60%
	Post-treatment	61%	54-67%
4.	Average Numer of treatment sessions	20	15-24

TABLE NO. 4

Showing mean improvement in percentile scores in patients of head injury with balance problems (n = 3).

Sl. No.	Balance components	Mean % improvement	Range
1.	Static balance improvement	14%	10-16%
2.	Dynamic Balance improvement		
	Movement time	25%	21-27%
	Excess pathsway	23%	12-40%
	Distance error	13%	9-16%
	Asymmetry	10%	7-18%
3.	Average stability		
	Pre-treatment	40%	39-42%
	Post-treatment	55%	50-58%
4.	Average Number of treatment sessions	17	12-24

asymmetry decreased by 33% and 32% respectively. Overall average stability improved from 49% at pre-treatment to 61% at post-treatment.

Table no. 4. shows the mean improvement in balance components in the head injury group. The improvement in static balance after the treatment course was 14%. They also showed improvement in dynamic measures of balance. The decrease in movement time was 25% and those of excess pathsway, distance error, asymmetry were 23%, 13%, 10% respectively. Moreover, the average stability improved from 40% at pre-treatment to 55% at post-treatment.

One patient with cerebellar ataxia showed improvement in the static balance by 10%. Decrease in 30% movement time, 68% decrease in excess pathsway, 32% decrease in distance error and 13% decrease in asymmetry was recorded as the improvement in dynamic balance. The overall average stability improvement was from 42% at pre-treatment to 68% at post-treatment.

Discussion :

The measure of body sway in a static central position is often used as an indicator of postural stability[5]. Hamman and colleagues[5] observed no significant change in static postural sway in normal population subjected to visual feedback of COG from Balance Master system. However, in the present study, all patient spectrums showed improvement in static postural sway. All the patients had significant balance deficit. Hence, the improvement in static postural sway was significant in this study group. This finding is in agreement with Brandt T et al[8], who have also concluded that the percentage of improvement through training depends upon the degree of initial instability. The present finding of improved static balance in terms of postural sway using visual biofeedback was also in agreement with the finding of other series on hemiplegic patients[3,9]. Winstein CJ and collegues[9] studied the effects of standing balance training using forceplate system in hemiparetic adults. They observed that hemiplegic subjects trained with feedback device showed significantly better static standing symmetry than those who did not receive augmented feedback ($p < 0.05$). Shumway-Cook A et al[3] also studied the effects of centre of pressure biofeedback in hemiplegic patients and found greater improvement in stance symmetry and static postural stability in experimental group of patients than those in conventional therapy groups.

In the dynamic balance assessment also, all the patient groups showed significant changes from pre-treatment to post-treatment mean scores. In all the groups this was more so in the two variables viz., movement time, pathsway or path length. The mean improvement in movement time ranges from 25% to 33% and that of pathsway from 23% to 72%, while trying to reach the peripheral targets within the LOS cone. Liston RAL et al[9], in a study of stroke patients to find out the validity outcome measures of Balance Master system, observed that movement time and pathsway were found as highly reliable measures of balance performance in stroke patients. Therefore, the present finding showing maximum improvement in the two dynamic measures of balance viz., movement time, pathsway could be taken as comparable with such observation in stroke patients[9]. Moreover, all patients reported subjective improvement in mobility, locomotion and skills of transfer with more confidence, even though we did not use functional improvement scores in this preliminary study.

Inspite of the improvement in average stability after the treatment as observed in this preliminary study, proper patient stratification, valid and reliable paramenter selection is warranted to come to a definite conclusion. However, quantitative assessment of balance problems allows better understanding of defective balance components. And, we can specifically plan to stimulate the defective component or other functioning sensory inputs to compensate the defective components of balance. Observation from this preliminary study suggests that visual biofeedback training facilitates appropriate balance strategies and also enables in achieving improved postural control. Functionally also, improvement in mobility and locomotion with confidence is achieved with improved postural control.

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