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Medical Evaluation of Cosmonauts : Assessment of Vestibular System

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Assessment of Vestibular functions form an integral part of medical evaluation of cosmonauts. Since control of space motion sickness after it has set in is unsatisfactory, effort is directed towards selecting only those candidates who do not reveal any susceptibility. This paper describes a four stage approach to assessment of vestibular functions. A total of sixteen candidates were evaluated and only one was disqualified.

Introduction

The experience of last 25 years of manned space flights has confirmed that the human orientation system is among the most stressed systems during the space flights. The unfamiliar environment and absence of gravitational force i.e. the weightless state adversely affect the different sensory input needed for body's orientation by rendering the otolith organs and some of the proprioceptor mechanisms ineffective. Consequently every activity and movement on exposure to the weightless state produces strange and abnormal sensations with different degrees of disturbances of orientation. The human body is normally quick to adapt to the changed environment, but many cosmonauts suffer before adaptation occurs in about 3—5 days time. Some of them, however, fail to adapt adequately and continue to suffer. These manifestations are termed as 'Reflex vestibular Disturbance' (RVD) and 'Space Motion Sickness''. In the 'Salyut-6 and 'Soyuz' programme 12 out of 27 (i.e. 44%) cosmonauts were reported to have experienced symptoms of motion sickness. The incidence among the American astronauts was 30% in Appollo and 55% in the Skylab crew members[5]. Besides a majority of the crew members have reported illusory perceptions which included sensations of backward or forward tilt, overturning, hanging headdown, rotational sensations etc. The symptoms were worsened with increased motor activity, specially head movements. Anti-motion sickness drugs are frequently used but are not found to be very satisfactory. Restriction of activity is sometimes necessary which implies compromise on crew tasks and mission plans.

Enormous research effort has been directed at

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this problem during the last two decades, with limited success. Since control of motion sickness after it has set-in is unsatisfactory the effort is mainly directed towards selecting only those candidates who do not reveal any susceptibility. The process of selecting cosmonauts, therefore, necessarily involves extensive assessment of the vestibular system besides ensuring normal functioning of other sensory systems.

Ashton Graybiel (1975), the well known American vestibular physiologist, recommends a four stage approach to assessment of vestibular system, as described here.

1. Functional tests : This includes comprehensive clinical examination, tests for semicircular canal function by caloric and rotational stimulation, tests of otolith function by ocular counter rolling technique and finally postural equilibrium tests.

2. Provocative tests : These tests are aimed at provoking reflex vestibular disturbances and motion sickness and then to measure the ability to cope with such disturbances either with or without countermeasures, including the use of drugs. The provocation is essentially produced by carrying out active head movements out of the plane of rotation in a subject rotating at a steady rate, thereby inducing the coriolis effect. Examples of provocative tests are 'Coriolis Sickness Susceptibility Index' and the 'Off vertical Rotation Test'.

3. Adaptive capacity tests: These tests assess the ability of the candidate to adapt to the provocative stimulus which is repeated at regular intervals either till the vestibular disturbances are manifested or a predetermined number of repetitions are completed. A variety of such tests and test profiles have been employed.

4. Simulation tests : Regardless of the satisfactory performance on the tests mentioned so far, non-susceptibility to RVD and motion sickness can be confirmed only on actual exposure to the spacecraft environment. Since realistic simulation of the weightless state is not feasible the subjects are given a short experience for about 10 seconds at a time during the parabolic flights in suitable transport aircraft and their vestibular responses noted. Another simulation test is the 'Slow Rotation Room (SRR) which simulates the rotating environment of the space craft.

The approach to assessment of vestibular system is based on same philosophy. Our technique and findings are described here.

A total of sixteen candidates were examined. They were all asymptomatic and in good general health. Enquiry into the past history of vertigo, giddiness, motion sickness etc did not elicit any significant past history. They were examined clinically for vestibular functions, besides ear, nose, throat and audiological examinations. Clinical evidence of vestibular function deficit was not detected in any of them.

Special Tests

The candidates were then given the following special tests:-

1. Otolithic Reaction Test
2. Khilov's Swing Test
3. Continuous Cumulative Coriolis Acceleration (CCCA) Test.
4. Discontinuous Cumulative Coriolis Acceleration (DCCA) Test.

Each of these tests essentially caused provocation for vestibular disturbance. The adaptive capacity of the individual was assessed by watching the response to repetitions of such stimulations over a predetermined time duration or number of repetitions. The vestibular vegetative reactions were graded as per Khilov's classification shown in Table-1.

Table I

Grading of Vestibular Vegetative Reactions

Grade		Reactions
Zero	:	No vegetative reaction
I	:	Slight pallor, mild sweating, general state good.
II	:	Moderate pallor, moderate sweating, discomfort present but not pronounced. Pulse difference not exceeding 10 beats per minute.
III	:	Marked pallor and sweating, nausea, intense salivation, visible discomfort, pulse difference exceeding 10 beats per minute.
IV	:	Profuse sweating, nausea, vomiting, dizziness, vertigo, tendency to fall.

In general, candidate with grade zero or nil reaction is preferred. A clear cut Grade I is acceptable, Grade II or doubtful grade calls for repetition of test. Grades III & IV are not acceptable.

Otolithic Reaction test (Figs 1 & 2)

Fig. 1 *Subject bent forward during rotation*

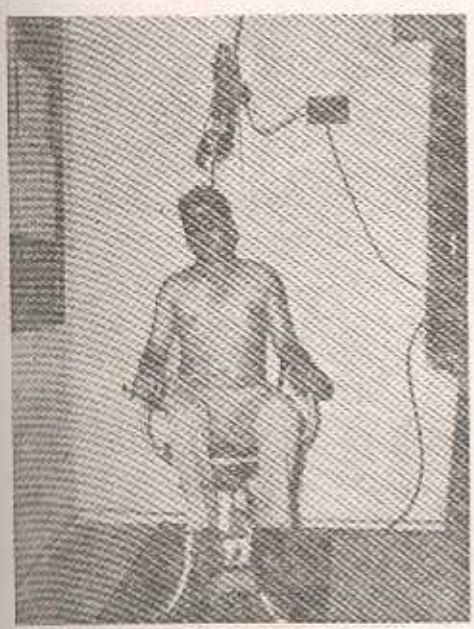

Fig. 2 *Subject assuming erect position immediately on stopping of rotation*

The subject was seated with eyes covered, in the Barany Rotation chair with trunk bent fully forward. The chair was rotated clockwise (CW) at 30 RPM and on completing 10 rotations, stopped instantly. The subject was asked to return to upright position. He should be able to attain the position without any tilt. A well marked tilt or tendency to fall entailed rejection. The test was repeated 10 times in each direction of rotation i.e. a total of 20 runs. The subject was observed for vegetative reactions after each run.

During this test when the body is fully bent forward the subject's superior vertical canals which are in the plane of rotation, are moved out during the return to upright altitude in the immediate post-rotatory phase thereby inducing the coriolis effect. The resulting vestibular input is further modified by otolithic stimulation following the change in head position. The results were as shown in Table II.

Table II

Results of Otolithic Reaction Test

Grade	No. of subjects N : 16
Zero	5
I	8
II	1, Grade-I on repetition
III	1
Severe Otolithic Reactions	1 Marked tilt

Khilov's Swing test (Fig. 3)

The subject sat semireclined, on a four pole swing. His baseline parameters of pulse, respiration and blood pressure were noted. With his eyes closed he was given swings headward and footward for 15 minutes. He was periodically observed for any symptoms and signs of motion sickness. The time of onset of various symptoms was noted and

Fig. 3 *Subject undergoing the Swing Test*

the test was terminated on completion of 15 minutes. The physiological parameters were noted again.

All the candidates could go through this test without any degree of motion sickness.

Tests for Cumulative Effect by Coriolis Acceleration

These tests were performed on nine cosmonaut candidates. The two tests were carried out with the subject seated in Barany's chair and continuous recording of horizontal nystagmus and ECG. The respiration rate and BP were noted before and after each run.

(a) *Continuous cumulative coriolis Acceleration (CCCA)* (Fig. 4 & 5)

Fig. 4 *The test set up with Barany Rotation Chair. Control panel and Electronystagmograph. Subject being rotated with head in central position*

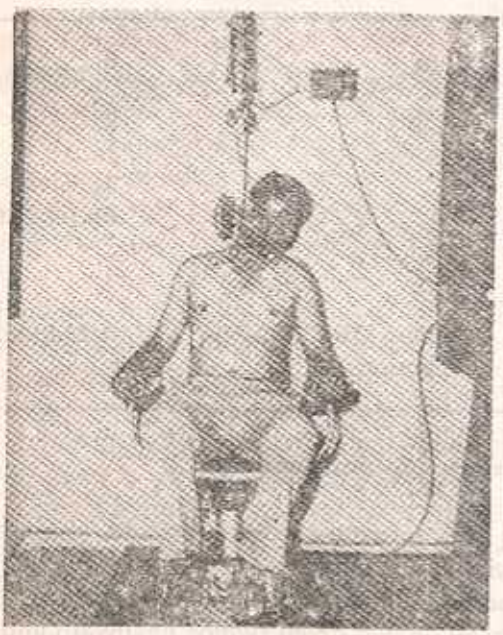

Fig. (a)

Fig. (b)

Fig. 5 *Subject tilting head to right & left alternately*

In this first test the subject sat upright with eyes closed. On attaining steady 30 RPM rotation rate, he was ordered to tilt his head right and left alternately, in a rhythmic manner taking two seconds for each movement. The process was continued till 30 head movements were carried out in 1 minute and then the chair decelerated to a stop. The subject was asked to report his symptoms as and when they occured. The observer looked for any visible evidence of vegetative reactions. If there were no severe reactions the test was repeated after 1 minute interval in counter clockwise direction (CCW) of rotation.

During this test the horizontal semicircular canal which are in a steady state of rotation, are moved out of the plane of rotation in the lateral directions alternately, which induces the coriolis effect. The tendency for vegetative reactions, even if mild and latent at first, becomes manifest due to cumulative effect on continued repetitions of the head movements. Many of our subjects reported swinging sensations forward-backward as expected. Mild pallor and sweating particularly in the armpits and on forehead, was observed in 5 of them. But all of them maintained good general state. All subjects showed tachycardia on the onset of rotation which reduced gradually and returned to within 10 beats of the base line level after cessation of rotation. No abnormal heart rate pattern was observed. BP level followed the pattern of heart rate but returned to baseline level 5 mts after second run. The respiration rate showed increase during the run from 2 to 8 cycles/minute. The ENG typically showed loss of normal per rotatary horizontal nystagmus during the phase of head movements (Fig.6).

Fig. 6 *Shows the typical ENG response at the start and completion of head movements during the CCCA test*

(b) *Discontinuous Cumulative Coriolis Acceleration (DCCA)* (Figs 7 & 8)

Fig. 7 *The subject assuming bent farward position*

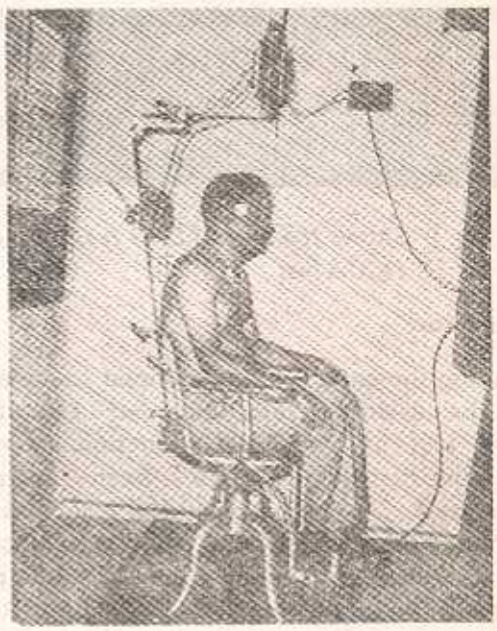

Fig. 8 *The subject assuming upright position during rotation*

The test preparation was similar to that described for the previous test and the difference was only in the type of body movements of total duration of test. To start with the subject had his trunk and head bent as far forward as possible. On attaining steady 30 RPM rotation he was ordered to gradually assume erect attitude which was maintained for 5 seconds followed by return to bent position. This cycle was repeated at intervals of 5 seconds till the completion of 1 minute. After a rest period of 1 minute the test was repeated in opposite direction of rotation. Such repetitions were continued till at least six minutes of testing was completed without any significant vestibular vegetative reactions. In case of a doubtful response more such runs were given.

Six of the subjects qualified after six minutes of testing and two others required seven minutes. One subject who had Grade II reactions from 5th minute onwards vomitted during the 7th minute and was disqualified. The physiological parameters of the subjects showed similar pattern of response as with the CCCA test with proportionate increases due to extended duration of this test. The ENG patterns were normal. One such typical pattern is shown in Figure 9.

Fig. 9 *Shows the typical ENG response on DCCA test*

Discussion

During the early years of manned space exploration, the selection tests included almost every known test of vestibular function. Over the years the assessment has been increasingly rationalised. As the newer useful tests have been introduced many older tests found superfluous have been deleted. In addition to the procedure described already vestibulometric investigations like electronystagmography with positional tests, caloric tests, cupulometry, threshold tests for angular and linear accelarations, stabliometry etc are employed whenever indicated. These tests help reveal any asymmetry of vestibular responses to various stimuli which predispose to disturbances observed on provocative tests. In the final phase the prospective candidates are exposed to simulated weightlessness in parabolic flights which was beyond the scope of our assessment. During the parabolic flights vestibular responses to stimulation and provocative tests are again noted and are then compared with the ground based tests. Susceptibility to motion sickness or vestibular disturbances does get revealed for the first time during the exposure to weightless state, in subjects who never showed any such tendency during the ground based tests.

Development of reliable ground based tests which can serve as predictors of motion sickness in space flights has not been possible inspite of enormous research effort. No such reliable tests exist even for the terrestrial conditions. This is largely because there is lack of complete understanding regarding the origin of motion sickness, whether it is really vestibular in origin or psychogenic or both. Research on motion sickness received great boost after man's ventures in space have started and will have to be a continuing process. The approach to assessment of vestibular system will necessarily undergo changes as the understanding of the problem of motion sickness improves.

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