

# BODY REACTIONS TO PROLONGED CORIOLIS ACCELERATION

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There is a well known symptom-complex of reactions which arises in response to prolonged stimulation of the vestibular analyzer ("motion sickness," seasickness, etc.), and which are based on functional disturbances of the autonomic and cerebrospinal nervous systems and of the neuro-humoral regulatory mechanisms. However, the character of the reactions developing during the prolonged action of Coriolis acceleration is discussed in only a few papers [2, 3, 5]. We have studied these reactions in human subjects in a slowly revolving chamber (MVK-1), the first Soviet apparatus designed for investigating the reactions of the human body to prolonged Coriolis acceleration (Fig. 1).

The MVK-1 apparatus consists of a metal chamber (1), cylindrical in shape, with a door in its side. The dimensions of the chamber are as follows: diameter 2.1 m, height 2.3 m, volume 8 m<sup>3</sup>. Inside the chamber is a round platform (2), rigidly fixed to a vertical shaft (3), revolving in bearings (4 and 5). The upper end of the shaft passes through the roof of the chamber, outside which it ends in a pinion (6). Rotation of the platform is caused by an electric motor (7), fitted with a reducing gear (8) and pinion (9) engaging with the pinion (6). Two chairs for the subjects are secured to the platform (10). To prevent the subjects from seeing the rotation of the platform in relation to the walls of the chamber, it is covered on every side and above by a cloth screen, mounted on a metal framework (14). The chamber is illuminated by electric lamps (3). Ventilation is provided by means of a system of pipes in the metal framework and openings in the screen (15). The various physiological functions of interest to the experimenter can be recorded during revolution of the chamber via contact rings (12) and brushes (13).

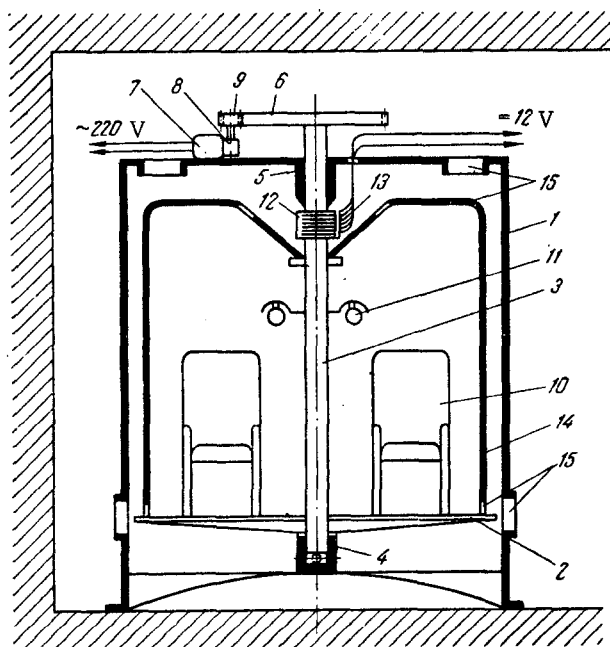


Fig. 1. Diagram of the MVK-1 slowly revolving chamber.

Observations were made on 13 apparently healthy persons of both sexes (3 women and 10 men) aged between 23 and 36 years. The subjects were revolved in the MVK-1 apparatus for 1 h at a constant angular velocity of 5°/sec. Coriolis acceleration was created periodically by tilting the trunk in the sagittal plane at a velocity of one movement/2 sec, and also by inclining the head in the frontal and sagittal planes at the rate of 1/sec, i.e., as a result of movement of the head and trunk in planes intersecting the plane of revolution of the chamber at right angles.

Control observations were made on 9 subjects performing the same movements in a static chamber.

Before and after revolution the general condition and neurological state of the subjects were assessed, their skin temperature measured, and their peripheral blood analyzed. The functional state of the vestibular analyzer was investigated by means of the BU-2 apparatus described previously [1], taking note of the sensory (sensation of counter-rotation), somatic (nystagmus), and autonomic (maximal arterial pressure, velocity of spread of the pulse wave, pulse and respiration rates) components of the vestibular reaction

TABLE 1. Changes in the Thresholds of Sensory (Sensation of Counter-rotation – SCR) and Somatic (Nystagmus) Reflexes in Subjects after a Stay of 1 h in the MVK-1 Apparatus

Subject	Test	Threshold (in °/sec)	
		Initial	after stay in MVK-1
A	SCR	5	5
	Nystagmus	3	2
B	SCR	4	4
	Nystagmus	7	6
G	SCR	3	5
	Nystagmus	—	6
K	SCR	12	12
	Nystagmus	5	7
P	SCR	2	4
	Nystagmus	—	4
F	SCR	4	3
	Nystagmus	4	3
Sh	SCR	8	20
	Nystagmus	7	7

TABLE 2. Character of Quantitative Relationship between Vestibular Reactions and Adequate Stimulus in Subjects before and after Stay of 1 h in a Slowly Revolving Chamber

Subject	Stop – stimulus (in °/sec)	Test (duration of reaction in sec)			
		before stay in MVK-1		after stay in MVK-1	
		SCR	nys-tagmus	SCR	nys-tagmus
A.	30	5,5	18	8,2	17,2
	60	11	26,5	15,5	25,5
B	30	35	33,5	30	20
	60	53,5	39	35	35
G	30	17	22	15,5	25
	60	22	34,5	23	34
K	30	10	30	16	19
	60	17,5	35,5	20	34
D	30	17,5	18	22,5	25
	60	22,5	32	29	34
F	30	20	35	22	35
	60	27,5	40	29,5	44
Sh	30	3,5	25	2	22
	60	5	39,5	2	30,5

sharp rise in the threshold of sensation of counter-rotation observed (Table 1). This may be explained by the fact that the subject had frequently had attacks of bilateral otitis media.

When the character of the relationship between the vestibular reactions and the magnitude of the adequate stimulus was compared (reactivity test) before and after the subjects had stayed for 1 h in the MVK-1 apparatus, no visible changes were noted in the duration of the sensory and somatic reflexes in response to stimuli of increasing intensity (Table 2). The reactivity test likewise revealed no abnormality of the magnitude of the vestibulo-autonomic reflexes; the variations of the pulse and respiration rates, the arterial pressure, and the velocity of spread of the pulse wave after the stay in the MVK-1 apparatus were within the same limits as before the experiment.

The degree of limitation of the duration of the sensation of counter-rotation and of nystagmus during the action of light in the test for interaction between the analyzers remained unchanged after rotation of the subjects in the MVK-1 apparatus.

in response to threshold levels of stimulation. In these conditions an assessment was also made of the reactivity and adaptation of the analyzer and of its interaction with the optic analyzer. The changes in the functional state of the vestibular analyzer after the subjects had become accustomed to the MVK-1 apparatus were also judged from the gait disturbances (the ordinary gait forward and backward with eyes open and closed, and walking "heel to toe" in the same conditions). The mean rate at which each exercise was performed and the number of mistakes made were determined.

Only a few of the subjects exposed to the action of Coriolis forces observed subjective disturbances in the form of mild vertigo, a feeling of heaviness in the head, and indefinite, unpleasant sensations which developed at the moment of performance of the exercises in the revolving chamber. Visual illusions (the apparent tilting of an illuminated test object, consisting of a cube with edges of 50 mm) did not develop in the subjects in these experimental conditions.

From the results of the finger-nose, finger-finger, and Romberg's tests, no neurological abnormality could be detected in the subjects after staying in the chamber for 1 h.

The skin temperature of the subjects after staying for 1 h in the chamber fell on the average by 0.6° on the chest, 1.0° on the forehead, 1.8° on the left hand, and 2.0° on the right hand. The pulse rate fell on the average by 9 beats/min. The blood pressure after rotation was not significantly changed. The erythrocyte and total leukocyte counts in the peripheral blood varied within physiological limits. Control investigations on the same subjects showed that a stay of 1 h in the chamber when it was stationary had no effect on the tested functions.

In 6 of the 7 subjects investigated by the BU-2 apparatus, no obvious changes in the sensitivity of the vestibular analyzer to negative angular acceleration could be found after the subjects had been in the slowly revolving chamber. As regards both the sensory and the somatic reactions, the variations in the threshold of sensation were within limits of 1-2°/sec. Only in the subject Sh. was a

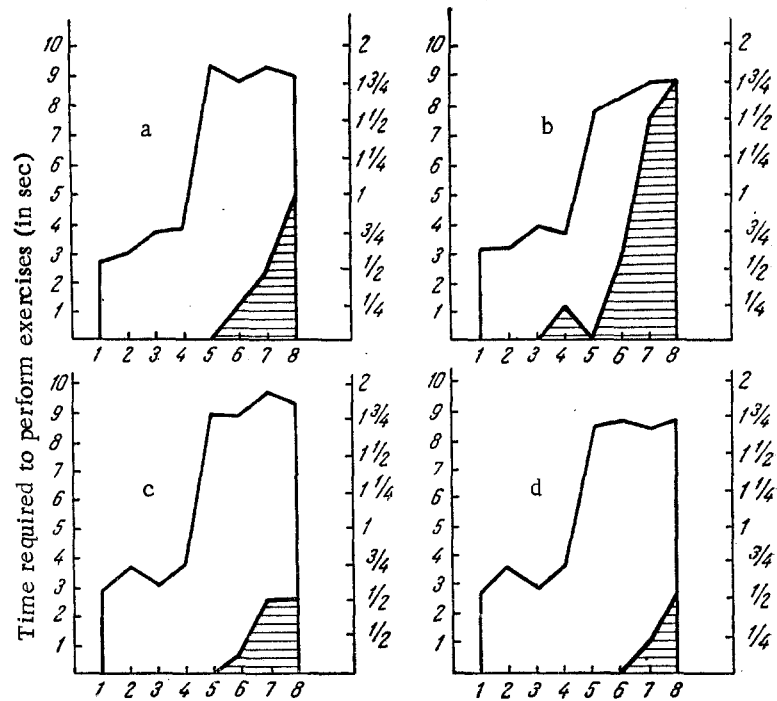


Fig. 2. Mean number of mistakes (—) and mean speed of performing walking exercises (hatched): before experiment (a), after the subjects had stayed 1 h in the chamber (b), and in control experiments before (c) and after (d) the subjects had stayed 1 h in the stationary chamber. Along the axis of abscissas — number of walking exercises in the following order: 1) ordinary walking forward with eyes open; 2) ordinary walking backward with eyes open; 3) ordinary walking forward with eyes closed; 4) ordinary walking backward with eyes closed; 5) walking "heel to toe" with eyes open; 6) walking "toe to heel" with eyes open; 7) walking "heel to toe" with eyes closed; 8) walking "toe to heel" with eyes closed.

The stay of the human subject in a slowly revolving chamber, exposed to the action of Coriolis forces on the vestibular analyzer, leads to the development of definite disturbances of the function of balance. The number of mistakes made by the subjects during the performance of exercises such as walking "heel to toe" and "toe to heel" with the eyes closed was almost doubled. Mistakes also appeared during the performance of other, simpler exercises (Fig. 2, b). Meanwhile, the mean results of the control experiments revealed no difficulty in walking by the subjects after a stay of 1 h in the stationary chamber (Fig. 2, c and d).

Hence, the periodic action of Coriolis acceleration on human subjects staying for 1 h in a slowly revolving chamber (velocity 5°/sec) is not followed by any significant functional disturbance. Changes were observed in the skin temperature and more obvious disturbances were found in movement coordination. Apparently the Coriolis acceleration, which arose in these experimental conditions as a result of the combined action of rotation of the subject at a uniform velocity of 5°/sec (the centrifugal force acting on the subject in these circumstances at a distance of 0.5 m from the center of rotation did not exceed 0.00045 g) and of the movement of his head and body in different planes, was close to the threshold magnitude. Judging from data in the literature, a further increase in the Coriolis acceleration as a result of an increase in the velocity of rotation of the chamber, and also an increase in the duration and intensity of the inclinations of the head and trunk of the subjects, must lead to a more marked manifestation of the symptoms grouped together by Graybeil and his co-workers, after similar experiments, under the name of the "stress reaction."

The suggested method of stimulation of the labyrinth during slow rotation with periodic exposure to Coriolis forces is a convenient method of investigating the phenomena arising in man and animals in "motion sickness" and in other specific functional disturbances of the vestibular analyzer.

#### SUMMARY

Reactions to the prolonged action of Coriolis acceleration against the background of slow rotation were studied in a special slowly rotating chamber (MVK-1) for two persons. After an hour of rotation the greatest changes of somatic and autonomic functions investigated were noted in the gait and in the skin temperature.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

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