Physiologic Response to Subgravity

II. Initiation of Micturition

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THE development of rocket boosters and fuels capable of high orbital payloads, including manned space probes, has drawn attention to the immediate application of biologic studies in the weightless state. The meager evidence available from the dog in *Sputnik II* encourages us to believe that the human organism can endure zero gravity, but complications may arise from prolonged exposure. Attention has been directed to a number of basic and vital physiologic functions and the possible effect of weightlessness on these mechanisms. The present experiment was concerned with the elimination of liquid body wastes in the null-cavity state.

METHOD

A study was begun to ascertain whether elimination of urine by human subjects could be accomplished during the 30 to 40 seconds of weightlessness occurring in an F-94C *Starfire* jet aircraft under special flight maneuvers that have been described elsewhere.[1] Twenty-six male subjects, ranging in age from 18 to 42 years, were studied. These highly motivated volunteers—officers, airmen, and civilians—were chosen from the staff of this school. Their jet flying experience varied widely. Four subjects had no previous experience in jets, five had one to two hours, seven had between three and ten hours, nine had between eleven and one hundred hours, and one individual had more than one hundred hours of jet time. No information concerning the performance of other subjects was given to the individual under examination.

The subjects were requested to drink a glass of water every fifteen minutes for two hours prior to flight time. This was to assure that the urinary bladder would be distended at the time of the experiment. Most of the subjects complained of relatively severe discomfort. Several could not avoid micturating prior to takeoff or during the takeoff roll. Before maneuvering altitude was attained, however, they had partially or completely refilled the urinary bladder and were able to successfully complete the study.

The ordinary cockpit relief tube was found to be completely unacceptable for use in weightlessness because it was impossible, under zero gravity, to direct the flow of urine into the tube orifice. A simple urinal was devised from weather balloon material and oxygen hose (Fig. 1). The modified

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urinal could be used satisfactorily except when the force of the urinary stream was reduced. The urine tended to float out of the collection tube because of insufficient pressure to force the liquid column into the storage container.

The subjects were instructed to prepare for micturition by loosening the lap belt and parachute harness prior to entering the parabolic maneuver, but the actual initiation of urination was not to be attempted until weightlessness had been achieved. Each subject was allowed at least two parabolas per flight to accomplish micturition.

When a subject was unable to void during the brief exposure to weightlessness he was given an opportunity to empty his bladder during a similar specified time period while in "straight and level" flight. Three such attempts under a normal gravitational state were allowed per flight.

RESULTS

The basic results are presented in Table I. Twenty-six volunteer subjects participated in one or more micturition-null-gravity flights. Thirty-seven flights were made during which nineteen subjects were able to initiate micturition in the weightless state. Four of those able to perform micturition could force, with great effort, only small quantities of urine from the urinary bladder. It was necessary for two subjects, both with ten hours of jet time, to terminate the test prematurely because of marked nausea and vomiting. Of those five individuals unable to micturate during zero gravity, four were likewise unable to micturate into the cockpit relief tube during straight and level flight. This group of five subjects included one with no previous jet experience, three who had flown one to two hours only, and one pilot with slightly over fifty hours of jet time.

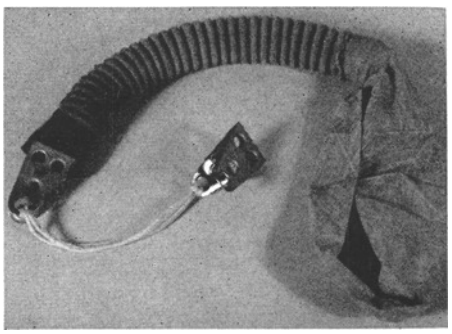

Fig. 1. Urine receptable fabricated from scrap oxygen hose and a weather balloon.

Ten subjects reported a marked decrease in urinary urgency during one or more of these brief exposures to weightlessness; four subjects noted slight to moderate loss of the sensation of urgency; however, ten subjects were unable to detect any difference. In each of the former fourteen cases, return of urgency paralleled the return of normal gravity. Several subjects became ill and vomited when they strained hard with tensed abdominal musculature, and it is believed that these may represent examples of the mechanical "weightless regurgitation phenomenon."[3] However, several other subjects became nauseated after beginning micturition or after emptying their bladders; these probably reflect the effect of the "vagal shower" phenomenon commonly observed by urologists. Four subjects reported that once micturition had been initiated in zero gravity they were unable, without

visual reference, to detect the usual pressure clues indicating that urination was being accomplished.

relatively high accelerations (3 G) before and after each parabola. This "impurity" of zero gravity exposure is

TABLE I. MICTURITION IN THE WEIGHTLESS STATE

Subject No.	Number of Flights Made	Total Jet Experience Hours	Micturition in Weightless State	Micturition in Level Flight (Normal Gravitational State)	Greatest Degree** of Loss of Urgency to Micturate Reported	Vomited During Flight
1	1	10	M.A.*	—	—	Yes
2	2	10	Yes	—	3	Yes
3	4	32	Yes	Yes	3	No
4	2	16	Yes	—	0	No
5	2	6	Yes	—	2	No
6	2	30	Yes	—	3	No
7	1	50	No	No	2	No
8	2	1	Yes	Yes	3	No
9	1	7	Yes	Yes	3	No
10	1	1,800	Yes	Yes	3	No
11	1	100	Yes	Yes	0	No
12	1	30	Yes	Yes	2	Yes
13	1	2	Yes	Yes	0	No
14	1	10	Yes	Yes	1	No
15	2	20	Yes	Yes	3	No
16	1	10	M.A.*	—	—	Yes
17	1	1	No	Yes	0	No
18	1	0	No	No	0	No
19	1	2	No	No	3	No
20	1	0	Yes	Yes	0	No
21	1	30	Yes	—	0	No
22	1	20	Yes	—	0	No
23	1	1	No	No	0	Yes
24	1	0	Yes	—	0	No
25	2	0	Yes	—	3	Yes
26	2	3	Yes	—	3	No

*Mission aborted.
**3—Marked to complete loss of urgency; 2—Moderate; 1—Slight; 0—No change.

DISCUSSION

Although no firm conclusions concerning man's response to weightlessness should be drawn from experiments utilizing the brief exposure technique, perhaps a few inferences can be made. It would appear from this study that relaxation of the urinary sphincters and initiation of micturition can be accomplished with little or no difficulty. However, a majority of the subjects reported a definite decrease in sensing the fullness of the bladder during exposure to weightlessness.

Perhaps the most obvious factor underlying the variability in subject awareness of urinary urgency in this experiment was the lack of a perfect zero gravity state (actually a varying subgravity field) and the presence of most undesirable but cannot be corrected at this time. Derived behavioral patterns may have an inhibitory effect which would explain, in part at least, the results obtained. In addition, the psychologic factors cannot be overlooked or ruled out. Diversion of attention, or even anxiety or apprehension caused by exposure to a new experience such as jet flying, may account for threshold changes with complete nullification of vesical contractions.

Only four of the subjects reporting no change in sensation of urgency had had more than two hours of jet flying time before the experiment, while the majority of those reporting a definite decrease in urgency were experienced in jet flying. This would indicate that there may be another explanation, on

a physiologic basis, for the results seen in this study. It seems reasonable to assume that the weight of the fluid pressing against the floor of the bladder may be responsible for perception of bladder fullness. This would mean that the primary sensory zone for this awareness must be sought in the vesicular trigone rather than in the stretch receptors located within the wall of the urinary bladder.

It is known that the trigonal area is most sensitive to tactile stimuli. It has been reported that when the volume of fluid in the bladder is held constant, a stimulation of the sympathetic fibers results in a short initial rise of the intravesical pressure that is quickly followed by a fall of pressure well below the normal resting level.[2] A loss of the normal weight of the liquid contained in the bladder may in some way cause stimulation of the sympathetic fibers of the trigone to give the results noted.

The market or complete dimunition of the sensation of urgency during weightlessness could constitute a potential problem on long range space flights. Crew members may neglect to attempt micturition except at long intervals. It would then be necessary to establish a rigid schedule for the elimination of body wastes to prevent severe stretching of the vesical wall which could lead to atrophy of the muscles, possible rupture of the urinary bladder, and extravasation of urine.

SUMMARY

Twenty-six subjects were exposed to a total of thirty-seven separate jet aircraft flights during which zero gravity parabolic flight maneuvers were performed. The capability of subjects to initiate micturition during weightlessness following a period of hydration was studied. Only one subject was unable to void in the zero gravity state but was able to micturate in straight and level flight. Four subjects were unsuccessful in either situtation. With one exception, all five of these subjects had two hours or less jet flying experience. A majority (58 per cent) of the subjects noted a slight to marked decrease in urinary urgency when exposed to weightlessness. The consideration is offered that the floor of the urinary bladder may be the primary sensory zone for the sensation of bladder fullness. Scheduling of body waste elimination should be incorporated into the crewman's standard operating procedures and check list. Special consideration must be given to the design and development of a satisfactory urine receptacle.

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