

# *Effects of Four Weeks of Absolute Bed Rest on Circulatory Functions in Man*

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## ABSTRACT

Various effects of 4 weeks of absolute bed rest on the circulatory system were studied in 12 healthy male volunteers. Postural tolerance varied from day to day before and after bed rest. Repeated tilt table testing allowed a more accurate appraisal of changes in postural tolerance caused by bed rest. Postural syncope on the tilt table was more frequent after bed rest. Forty-two percent of the subjects, however, did not faint during repeated testing after bed rest. A comparison of the highest orthostatic heart rates recorded during each tilt table test without an antigravity suit before and after bed rest showed a distinctly higher range of orthostatic heart rates after bed rest in each subject studied. When an antigravity suit was worn during tilt table testing after bed rest, postural syncope occurred on one occasion only. The relation of these studies to proposed flights in the Manned Orbiting Laboratory is discussed.

**P**ROLONGED SPACE FLIGHT and prolonged bed rest are sufficiently analogous to justify concern that the tendency to faint upon standing observed in normal subjects after prolonged bed rest may also be present in crew members reexposed to the earth's gravity after a 30 day flight in the Manned Orbiting Laboratory. In both environments the need for physical activity is greatly diminished and significant positional changes in hydrostatic pressure in the body fluids are absent.

This paper presents a study of various effects of 4 weeks of absolute bed rest on the circulatory system of man. Its purpose is: (1) to provide data useful in the prediction of cardiovascular tolerance to gravity after landing from a 30 day mission in the Manned Orbiting Laboratory; (2) to provide a model for later use to compare the cardiovascular effects of 4 weeks of space flight to 4 weeks of bed rest; (3) to evaluate the efficiency of an antigravity garment in preventing postural intolerance after 4 weeks of bed rest, and by analogy, 4 weeks of space flight; (4) to determine the suitability of this period of bed rest for future studies

seeking effective cardiovascular maintenance procedures adaptable to space flight.

## METHODS

Subjects were 12 healthy male volunteers, 17 to 22 years old, who had just completed 8 weeks of basic training in the United States Air Force. The same schedule of tests was followed before and after bed rest:

	A.M.	P.M.
Monday—	Blood Volume, Transverse G (+G <sub>x</sub> )	
Tuesday—	Cardiac Catheterization—6 subjects Tilt Table—6 subjects	
Wednesday—	Positive G (+G <sub>z</sub> )	
Thursday—	Tilt Table—Antigravity Suit	Tilt Table—No Suit
Friday—	Tilt Table—No Suit	Tilt Table—Antigravity Suit
Saturday—	Tilt Table—Antigravity Suit	Tilt Table—No Suit
Sunday—	Tilt Table—No Suit	Tilt Table—Antigravity Suit

Blood volumes were determined before bed rest\* after 11 days of bed rest, and after 4 weeks of bed rest by a dilution method employing radioactive iodinated serum albumin. In 6 subjects additional blood volumes were measured after 2 days of bed rest, and 15 and 29 days after the completion of absolute bed rest.

The results of the acceleration and cardiac catheterization studies will be reported in subsequent articles.

Cardiovascular responses to gravity were evaluated on a tilt table on which the subjects were suspended in a parachute harness at a 90 degree head-up tilt. The subjects were tilted for 30 minutes unless syncope or obviously imminent syncope occurred. A marked loss of vision was the usual indication, other than outright syncope, for premature termination of a tilt table test. Episodes of imminent syncope were recorded as syncope. Electrocardiograms and indirect blood pressures

\* Initial blood volumes were measured 3 days before commencing bed rest.

were recorded in the horizontal position before tilting and during each minute of the tilt. Each heart rate was determined by counting the number of QRS complexes in a 12 second strip of electrocardiogram and multiplying by 5.

The antigravity garment was a modified partial pressure suit that provided 62 mm. Hg pressure to the lower extremities and the abdomen.

During the 4 weeks of bed rest the subjects did not leave the bed, and sitting was prohibited. Baths were given by medical technicians. During the week of testing after bed rest the subjects were returned to bed after each test procedure.

Five tilt table tests were performed during the first week of ambulation, 2 during the second week, and 1 during the third week. In 6 subjects additional tilt table tests were obtained during the fourth and fifth weeks of ambulation.

**RESULTS**

**Blood Volume:**—For 12 subjects an average loss of 500 ml. in plasma volume ( $P < .001$ ) was noted after 11 days of bed rest. Red cell mass showed no significant change (See Table I and Fig. 1). A loss in total blood

TABLE I. CHANGES IN CIRCULATING BLOOD

Subject	*	Before	During Bed Rest		After Bed Rest		
		Bed Rest	2 days	11 days	28 days	15 days	29 days
A	TBV	4.9	4.2	4.7	4.5	4.7	4.8
	PV	2.8	2.2	2.4	2.4	2.8	2.8
	RCM	2.1	2.0	2.3	2.1	1.9	2.0
	HEMAT	43.1	47.5	48.3	47	41.5	41.9
B	TBV	6.0	5.0	5.5	5.4	4.9	6.2
	PV	3.4	2.8	2.8	2.9	2.9	3.6
	RCM	2.6	2.2	2.7	2.5	2.0	2.6
	HEMAT	43.1	44.7	48.9	46.7	40.2	41.9
C	TBV	5.5	5.4	5.1	5.3	4.8	6.1
	PV	3.2	2.9	2.7	2.8	2.9	3.5
	RCM	2.3	2.5	2.4	2.5	1.9	2.6
	HEMAT	41.2	46.1	46.3	45.9	39.7	42.1
D	TBV	6.0	5.4	4.9	5.4	5.1	5.2
	PV	3.4	2.9	2.6	3.0	3.1	3.1
	RCM	2.6	2.5	2.3	2.4	2.0	2.1
	HEMAT	43.1	47.0	46.6	44.2	39.1	40.0
E	TBV	5.6	5.1	5.2	4.5	4.4	4.6
	PV	3.2	2.7	2.8	2.6	2.8	3.0
	RCM	2.4	2.4	2.4	1.9	1.6	1.6
	HEMAT	42.6	47.2	46.2	41.7	36.1	38.2
F	TBV	4.8		4.4	4.3		
	PV	2.8		2.5	2.4		
	RCM	2.0		1.9	1.9		
	HEMAT	42.1		42.3	43.1		
G	TBV	6.3		5.9	5.7		
	PV	3.6		3.1	2.9		
	RCM	2.7		2.8	2.8		
	HEMAT	42.2		47.1	49.0		
H	TBV	6.4		5.8	5.3		
	PV	3.5		3.0	2.8		
	RCM	2.9		2.8	2.5		
	HEMAT	44.9		48.0	47.0		
I	TBV	5.5		4.7	4.2		
	PV	3.0		2.4	2.2		
	RCM	2.5		2.3	2.0		
	HEMAT	45.4		48.2	47.0		
J	TBV	4.5		4.6	4.3		
	PV	2.8		2.7	2.5		
	RCM	1.7		1.9	1.8		
	HEMAT	38.5		41.1	42.4		
K	TBV	5.8	5.3	4.8	4.7	4.6	6.1
	PV	3.5	2.9	2.7	2.8	2.9	3.6
	RCM	2.3	2.4	2.1	1.9	1.7	2.5
	HEMAT	40.2	45.1	44.2	39.9	36.7	40.8
L	TBV	5.5		4.9	4.5		
	PV	3.2		2.7	2.5		
	RCM	2.3		2.2	2.0		
	HEMAT	41.7		44.2	45.1		
Mean	TBV	5.57		5.04	4.84		
All	PV	3.20		2.70	2.65		
Subj	RCM	2.37		2.34	2.19		
	HEMAT	42.34		45.95	44.92		
Mean	TBV	5.63	5.07	5.03	4.97	4.75	5.50
Subj	PV	3.25	2.73	2.67	2.75	2.90	3.27
A, B, C,	RCM	2.38	2.33	2.37	2.22	1.85	2.23
D, E, K	HEMAT	42.22	46.27	46.75	44.23	38.88	40.82

\* TBV—Total Blood Volume (Liters), PV—Plasma Volume (Liters), RCM—Red Cell Mass (Liters), HEMAT—Hematocrit.

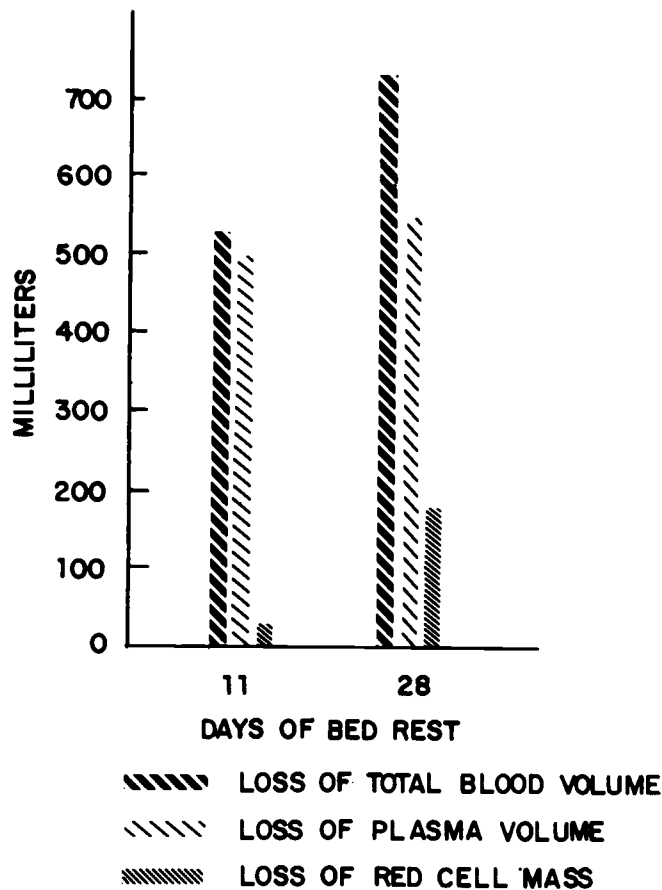


Fig. 1. Average losses of blood volume for 12 subjects.

volume, ranging from 200 ml. to 1300 ml., occurred during 4 weeks of bed rest (See Table I and Fig. 1). The average loss for 12 subjects was 730 ml. ( $P < .001$ ). Loss of plasma volume ranged from 300 ml. to 800 ml. with an average loss of 550 ml. ( $P < .001$ ). Red cell

mass decreased in 8 subjects, the decrease ranging from 100 ml. to 500 ml. It was unchanged in subject 1. Red cell mass increased 100 ml. in 2 subjects and 200 ml. in 1 subject. The average loss in red cell mass for all subjects during 4 weeks of bed rest was 180 ml. ( $P < .05$ ).

In the 6 subjects in whom additional blood volume studies were performed, an average loss of 520 ml. in plasma volume ( $P < .001$ ) occurred after 2 days of bed rest (see Table I and Fig. 2). Loss of plasma volume ranged from 300 ml. to 600 ml. No significant change in red cell mass occurred.

In these subjects the average loss of plasma volume after 4 weeks of bed rest was essentially unchanged from that recorded after 2 days of bed rest. After 4 weeks of bed rest, red cell mass was decreased in 4

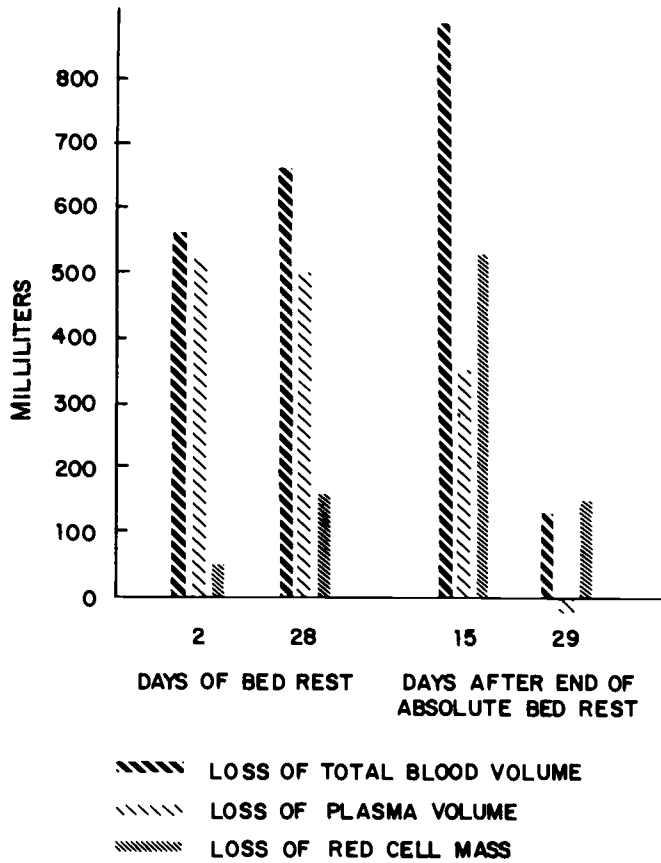


Fig. 2. Average losses of blood volume for 6 subjects.

subjects, unchanged in 1 subject, and increased in another. The average loss in red cell mass was 160 ml.

During a 15 day period following completion of absolute bed rest, red cell mass decreased in all subjects, the loss ranging from 200 ml. to 600 ml. with an average loss of 370 ml. ( $P < .005$ ). During this period plasma volume increased in 4 subjects, remained unchanged in 1 subject, and decreased in another. The average increase in plasma volume was 150 ml. ( $P < .05$ ).

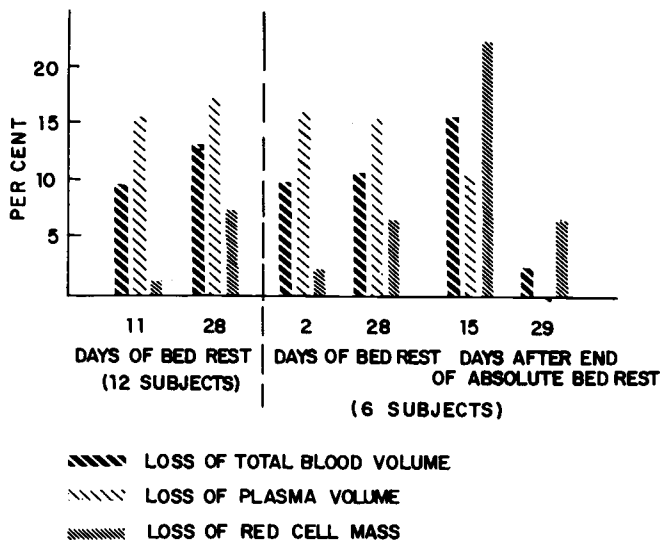


Fig. 3. Average losses in blood volume expressed in per cent loss.

Four weeks after completion of absolute bed rest 2 subjects still had significant reductions of total blood volume when compared to total blood volume before bed rest. Total blood volume was decreased 800 ml. in 1 subject and 1000 ml. in the other. Respective decreases in red cell mass were 500 ml. and 800 ml. Losses of blood volume expressed in per cent loss are shown in Figure 3.

*Tilt Table Tests:*—Average resting heart rates were higher after bed rest than before bed rest in each subject studied (Fig. 4). Mean resting heart rate for all subjects were 58 beats per minute before bed rest and 71 beats per minute after bed rest.

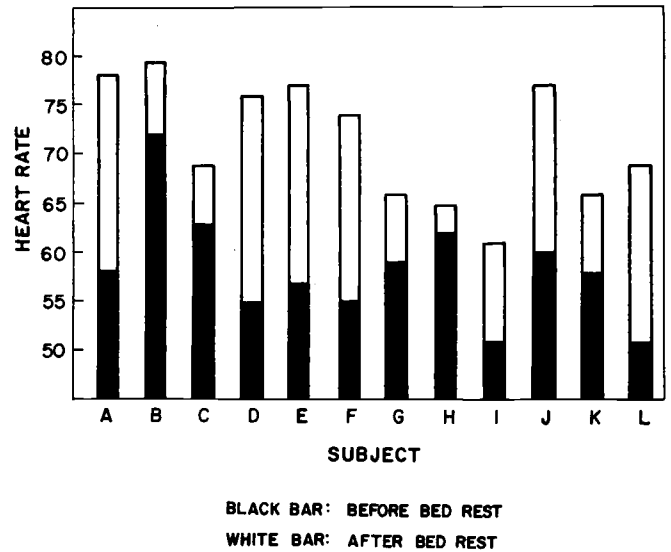


Fig. 4. Average resting heart rates in horizontal position on tilt table for week of testing before and after bed rest.

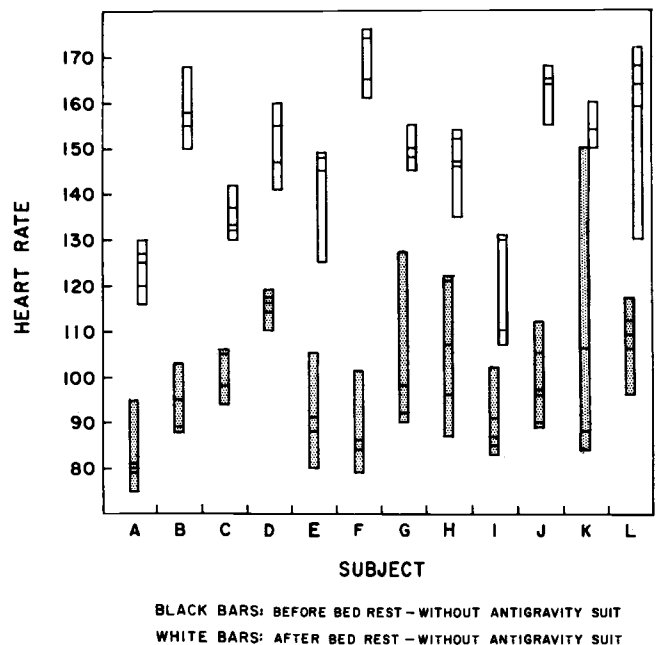


Fig. 5. Range of highest heart rates recorded during orthostasis in each tilt table test without antigravity suit performed during week of testing before and after bed rest. Lines within bars indicate heart rates within range. Duplication of heart rates is not shown.

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TABLE II. HIGHEST ORTHOSTATIC HEART RATES BEFORE AND AFTER BED REST

		Day of Testing					Day of Testing					Day of Testing					Day of Testing				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Without	Before	95	80	79	81	75	* 102	95	89	88	106	98	105	100	94	114+	110+	116+	119	117	
Anti-G Suit	After	125	130	116	120	127	150	158	168	155	133+	132+	137	142	130	155+	160+	141+	160+	147+	
With	Before	68	61	75	62	89	86	88	76	79	77	78	75	80	73	69	58				
Anti-G Suit	After	90	89	98	94	90	86	85	88	94	93	98	87	77	130+	95	102				
	Subject			A			B			C				D							
Without	Before	*	105	88	91	80	* 101	84	86	79	*	98	90	92	127	122+	107	121	96	87	
Anti-G Suit	After		125+	149+	145+	148+	174	176	161	165		148	150	145	155	146+	147	152	135	154	
With	Before		68	56	65	66	70	63	66	65		60	68	71	74	83	81	86	76		
Anti-G Suit	After		90	95	90	96	100	84	103	107		120	80	96	112	108	102	101	92		
	Subject		E				F			G				H							
Without	Before	85	83	87+	91	102	* 105+	97	89	112	*	107	150	88	84	112+	106	109	96	117	
Anti-G Suit	After	107	131	131	130	110	155+	164+	165	168+		150+	150+	154+	160+	159	172+	164	130	168	
With	Before		67	75	62	72	75	74	65	79		75	80	67	67	65	69	79			
Anti-G Suit	After		90	90	91	102	88	99	101	94		75	76	83	115	82	96	103	121		
	Subject			I			J			K				L							

\* These subjects had cardiac catheterization on first day of tilt table testing.  
 + These subjects experienced syncope during tilt table test.

The highest heart rate recorded during each head-up tilt was chosen as one index of orthostatic tolerance. Although this value varied rather widely from day to day in each individual tested, the range of highest orthostatic heart rates in subjects unprotected by an anti-gravity suit was clearly higher after bed rest than before bed rest (see Fig. 5 and Table II). The range of highest orthostatic heart rates recorded before bed rest bordered that recorded after bed rest in only one instance.

The range of highest orthostatic heart rates recorded during tilt table testing with an anti-gravity suit after bed rest was essentially no different from that recorded without an anti-gravity suit before bed rest (see Fig. 6 and Table II). Comparison of the range of highest

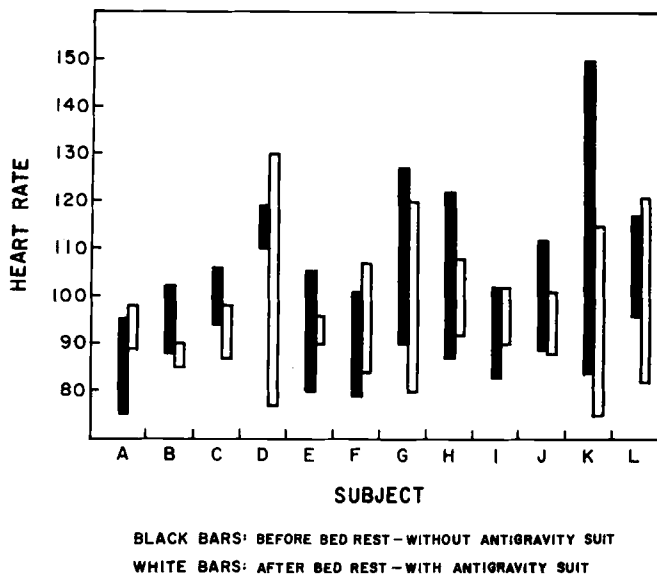


Fig. 6. Range of highest heart rates recorded during orthostasis in each tilt table test performed during week of testing before bed rest without anti-gravity suit and after bed rest with anti-gravity suit.

orthostatic heart rates recorded during testing with an anti-gravity suit after bed rest to that recorded with an anti-gravity suit before bed rest shows that the anti-gravity suit does not eliminate completely the effects of bed rest on orthostatic tolerance (see Fig. 7 and

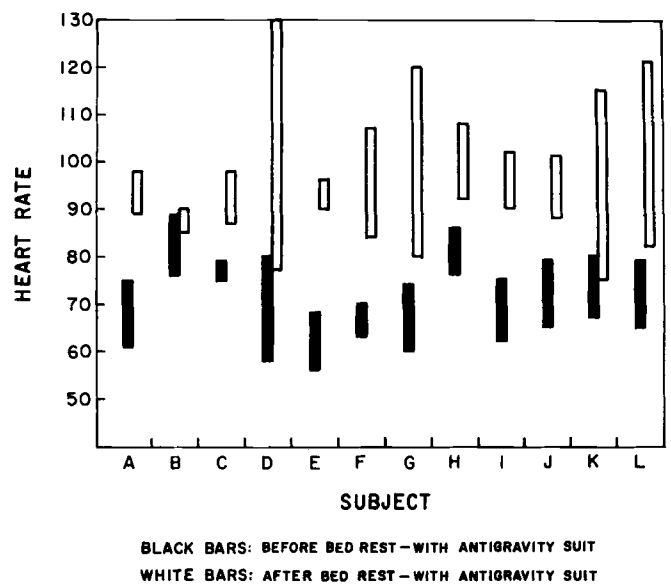


Fig. 7. Range of highest heart rates recorded during orthostasis in each tilt table test performed with anti-gravity suit during week of testing before and after bed rest.

Table II). Heart rates are higher after bed rest. When no anti-gravity suit was worn during testing, twenty episodes of syncope occurred after bed rest in contrast to 7 episodes before bed rest (Table III). Forty-two per cent of the subjects, however, experienced no syncope after bed rest. In some tilt table tests blood pressure became unobtainable at times, but the subjects did not faint. When these tests are added to those in which syncope occurred, an increased tendency for circulatory collapse after bed rest is more apparent (Table III). In other tilt table tests, a comparison of blood pressures recorded during the thirtieth minute of orthostasis before and after bed rest reveals further evidence of postural hypotension induced by bed rest (Table IV).

One subject experienced neither syncope nor a profound drop in blood pressure after bed rest. Nausea, faintness, visual dimming, diminished auditory acuity, a feeling of warmth, yawning, sweating, and hyperventilation were much more common after bed rest than before. Marked cyanosis and blotching of the feet and

ankles was observed during orthostatis after bed rest.

When an antigravity suit was worn during tilt table testing after bed rest, syncope occurred on one occasion only (Table III). During this test the subject complained of testicular discomfort from the parachute straps, a circumstance sufficient in itself to trigger syncope. For the most part, the subjects remained asymp-

tomatic when wearing an antigravity suit during tilting after bed rest.

Loss in total blood volume and loss of postural tolerances showed no quantitative correlation. For example, subject J, whose blood volume decreased only 200 ml. during 4 weeks of bed rest, fainted 3 times out of four during tilting after bed rest and showed high orthostatic

TABLE III. SYNCOPE AND HYPOTENSIVE EPISODES BEFORE AND AFTER BED REST

Subject	No Suit										Anti-Gravity Suit								
	Before Tilt Table Test					After Tilt Table Test					Before Tilt Table Test				After Tilt Table Test				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	4	
A																			
B	*					*													
C						S	S												N
D	S	S	S			S	S	S	S	S			N					S	
E	*					*	S	S	S	S									
F	*					*				N									
G	*					*	N		N	N							N		
H	S					S	N	N									N		
I			S				N			N									
J	*	S				*	S	S	N	S									
K	*		N			*	S	S	S	S									
L	S					N	S												

S: Syncope.  
 N: No blood pressure recordable—did not faint.  
 \*: These subjects had cardiac catheterization on first day of tilt table testing.

TABLE IV. BLOOD PRESSURE DURING 30TH MINUTE OF ORTHOSTASIS BEFORE AND AFTER BED REST

		Day of Testing					Day of Testing				
		1	2	3	4	5	1	2	3	4	5
Without Anti-G Suit	Before	118/94	114/86	110/86	102/80	100/80	*	120/94	132/102	124/82	124/64
	After	118/100	120/90	N-30	116/90	124/88		156/112	126/88	126/88	118/88
With Anti-G Suit	Before		120/84	112/82	116/86	102/80		150/104	148/108	162/94	134/86
	After		116/82	120/94	126/88	130/86		196/100	144/86	158/92	132/88
Subject		A					B				
Without Anti-G Suit	Before	92/72	114/82	124/86	122/84	110/82	S-13	S-22	S-28	128/82	106/78
	After	S-12	S-12	86/84	92/88	92/78	S-6	S-11	S-9	S-11	S-22
With Anti-G Suit	Before		104/76	120/92	130/98	130/92		106/80	112/84	N-1	122/90
	After		130/96	126/94	N-12	136/98		116/92	S-24	118/90	116/88
Subject		C					D				
Without Anti-G Suit	Before	*	106/74	112/78	92/70	98/70	*	120/72	118/80	118/84	114/90
	After		S-28	S-26	S-14	S-21		82/70	80/60	90/66	N-29
With Anti-G Suit	Before		126/94	108/80	128/98	120/76		128/84	128/88	142/98	128/82
	After		130/82	142/90	118/82	122/78		128/78	130/90	122/72	118/98
Subject		E					F				
Without Anti-G Suit	Before	*	112/72	110/88	118/82	112/84	S-8	100/82	90/70	98/52	100/72
	After		N-22	90/82	N-1	N-22	S-18	N-15	N-22	90/82	90/82
With Anti-G Suit	Before		124/82	140/78	138/86	138/80		120/84	112/74	112/88	110/80
	After		N-6	124/90	108/76	120/80		N-19	108/90	108/100	108/86
Subject		G					H				
Without Anti-G Suit	Before	110/64	108/82	S-24	116/80	62/50	*	S-29	118/64	116/86	100/74
	After	120/100	N-29	100/94	106/68	N-27		S-15	S-11	N-7	S-25
With Anti-G Suit	Before		130/90	122/86	140/106	132/92		132/98	130/88	110/80	110/88
	After		130/104	124/100	132/100	120/102		108/90	120/98	132/82	120/86
Subject		I					J				
Without Anti-G Suit	Before	*	100/84	N-15	120/88	112/90	S-19	112/86	100/98	116/82	108/88
	After		S-12	S-24	S-24	S-22	N-3	S-30	108/84	112/100	110/88
With Anti-G Suit	Before		124/78	112/82	134/84	138/106		138/118	128/98	122/90	122/86
	After		136/78	118/82	136/84	120/98		130/102	120/86	152/122	106/74
Subject		K					L				

\* These subjects had cardiac catheterization on first day of tilt table testing.  
 S: Syncope.  
 N: No blood pressure obtainable at some time during test—subject did not faint.  
 Number after S and N indicates time of syncope or inability to obtain blood pressure.

TABLE V. ORTHOSTATIC TOLERANCE DURING AMBULATION AFTER BED REST

Subject	First Week					Second Week		Third Week	Fourth Week	Fifth Week
	M	T	W	Th	F	M	F	F	Th	Th
A	109	114	122	115	107	106	100	103	103	104
B	125	116	119	114	122	136	118	108	104	108
C	107	117	114	121	107	100	105	103	112	118
D	<i>134</i>	<i>125</i>	<i>167</i>	<i>142+</i>	<i>150</i>	<i>132+</i>	<i>154+</i>	<i>128+</i>	<i>125</i>	<i>139</i>
E	<i>141</i>	115	142	128	112	135	117	110	135	134
F	139	125	*	92	104	90	95	68		
G	155+	150+	120	115	128	124	96	77		
H	<i>165</i>	118	106	126	112+	105	109+	109		
I	122	134	106	99	105	95	85	68		
J	178	142	114	117	97	129	141	104		
K	126+	135	137	151	137	141	148	143+	104+	126
L	175	174+	116	123	102	155	129	114		

Numbers are highest orthostatic heart rates during each tilt table test.

Numbers in italics indicate occurrence of syncope during test.

+ No blood pressure recordable at sometime during tilt—did not faint.

\* Record Lost.

heart rates. In contrast, subject I, whose blood volume decreased 1300 ml., did not faint after bed rest and showed relatively low orthostatic heart rates. The average reduction in total blood volume after 4 weeks of bed rest was 13.1 per cent for the 4 subjects (A, B, F, I) with the best orthostatic tolerance after bed rest and 13.3 per cent for the 4 subjects (D, E, J, K) with the worst orthostatic tolerance after bed rest.

Six subjects fainted during tilt table testing on the first day following resumption of physical activity on the ward (Table V). After this, syncope on the tilt table was no more frequent than before bed rest. In the majority of the subjects for a number of weeks after bed rest orthostatic heart rates remained higher than those recorded before bed rest (Table V).

Lightheadedness was common during the first few days of activity on the ward, but no subject fainted or experienced a severe presyncopal reaction. The subjects also complained of weakness, pain in the soles of their feet during walking, and soreness in the muscles of the legs and thighs.

**Weight Changes:**—An average weight loss of 2.55 Kg. occurred in the 12 subjects during 4 weeks of absolute bed rest and 1 week of testing after bed rest. Weight loss ranged from 0.6 Kg. to 5.8 Kg.; one subject gained 0.5 Kg. The degree of weight loss did not correlate with the degree of orthostatic intolerance or the degree of loss of blood volume.

## DISCUSSION

The wide variation in loss of blood volume in different individuals during bed rest conforms with the reports of other investigators.<sup>1, 4</sup> A lack of correlation between loss of blood volume and loss of orthostatic tolerance was also observed by Taylor et al.<sup>4</sup>

In the present study the greatest decrease in red cell mass was noted 8 days after resumption of full physical activity. Taylor et al.<sup>4</sup> reported an apparent loss of red cells during the first week of reconditioning after 3 weeks of bed rest. In their study, plasma volume had returned to pre-bed rest levels after 1 week of reconditioning.

The increase in resting heart rates after bed rest had been observed in other studies of bed rest.<sup>1, 5</sup>

Sedentary individuals tend to have heart rates higher than those of trained athletes.

In previous studies of bed rest using simple tilt table tests, the subjects were not continuously in bed. In one study weekly tilt table tests were performed,<sup>1</sup> and in others<sup>3, 5</sup> bathroom privileges were allowed. The possibility that the brief exposures to gravity in the erect position might have counteracted to some degree the adverse effects of bed rest dictated the use of absolute bed rest in the present investigation.

In this study postural fainting on the tilt table occurred much more frequently after bed rest than before, but 42 per cent of the subjects did not faint during repeated testing after bed rest. No subject experienced syncope during activity on the ward after bed rest, although occasional faintness was common. The effectiveness of contraction of the leg muscles in returning venous blood in the legs to the heart is well-known. Thus a prediction based on this study of the astronaut's postural intolerance after a 30 day mission in space should not be overly pessimistic. A predisposition to fainting will probably be present, but the likelihood of fainting may not be as great as some believe.

Postural intolerance has been reported after American and Soviet space flights. It is not yet known whether a given period of space flight will produce a greater degree of postural intolerance than the same period of bed rest. Since postural intolerance has been demonstrated in only 4 days of inactivity at chair rest,<sup>2</sup> one cannot conclude that the postural intolerance noted after space flights up to 5 days in duration augurs a more serious problem with longer flights than that observed during immobilization studies of similar duration on earth.

Previous studies showed the antigravity garment to be an effective counter-measure against the occurrence of postural syncope after 2 weeks of bed rest.<sup>3</sup> The present study proves its equal value in preventing syncope after the greater stress of 4 weeks of bed rest. The antigravity garment provides an important stopgap measure to protect the astronaut until the extent of the problem of prolonged weightlessness is known, and until effective inflight cardiovascular maintenance procedures are discovered.

A major objective of this investigation was to deter-

mine if 4 weeks of absolute bed rest would produce unequivocal evidence of a loss of postural tolerance in each person studied. One cannot assess the effects of space flight nor evaluate the efficacy of cardiovascular maintenance procedures without reliable criteria to judge changes in postural tolerance.

It is apparent from this study that postural tolerance both before and after bed rest varies from day to day in the individual. Repeated testing on the tilt table solves the problem of separating changes secondary to day to day variation in the individual from changes caused by bed rest. Susceptibility to syncope, before and after bed rest, varies greatly among individuals. In each subject, regardless of susceptibility to postural syncope, the distinct increase in orthostatic heart rates after bed rest provided a reliable criterium of loss of orthostatic tolerance.

### SUMMARY AND CONCLUSIONS

Various effects of 4 weeks of absolute bed rest on the circulatory system were studied in 12 healthy male volunteers. An identical schedule of tests was followed before and after bed rest.

An average loss of 730 ml. in total blood volume occurred after 4 weeks of bed rest, the loss ranging from 200 ml. to 1300 ml. An average decrease of 550 ml. in plasma volume and 180 ml. in red cell mass was noted. An additional average loss of 370 ml. in red cell mass was observed 15 days after the completion of absolute bed rest.

Postural tolerance varied from day to day before and after bed rest. Repeated tilt table testing before and after bed rest allowed a more accurate appraisal of changes in postural tolerance caused by bed rest.

Postural syncope on the tilt table was more frequent after bed rest. Forty-two per cent of the subjects, however, did not experience syncope during repeated testing after bed rest. A comparison of the highest ortho-

static heart rates recorded during each tilt table test before and after bed rest showed a distinctly higher range of orthostatic heart rates after bed rest in each subject studied.

When an antigravity suit was worn during tilt table testing after bed rest, postural syncope occurred on one occasion only. Orthostatic heart rates tended to be no higher during testing with an antigravity suit after bed rest than during testing without an antigravity suit before bed rest.

These studies suggest that postural tolerance after landing from a 30 day flight in the Manned Orbiting Laboratory may vary widely among different individuals. They provide a model for later use to compare the cardiovascular effects of 4 weeks of space flight to 4 weeks of bed rest. They suggest that an antigravity garment should protect an astronaut from the development of postural syncope after landing from a prolonged space flight. They indicate that 4 weeks of absolute bed rest should prove an excellent part of any experimental design used for the evaluation of cardiovascular maintenance procedures adaptable to space flight.

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