Effects of Moderate Physical Exercise During Four Weeks of Bed Rest on Circulatory Functions in Man

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Various effects on circulatory functions of light to moderate physical exercise during 4 weeks of bed rest were studied in 6 subjects. During exercise narrow cuffs inflated to 60 mm. Hg were worn on the upper thighs. Changes in plasma volume during and after bed rest paralleled those characteristic of simple bed rest. In contrast to simple bed rest, the major loss of red cell mass was noted at the end of bed rest and not during ambulation following bed rest. The mean resting heart rate for all subjects increased 15 beats per minute during bed rest. The degree of postural intolerance after bed rest appeared as marked as that observed after absolute bed rest. Physical endurance on the treadmill was decreased after bed rest.

IT IS WELL KNOWN that physical inactivity results in hypokinetic disease or deconditioning and has the opposite effects of exercise.[1-11,13] The effects of inactivity include a decrease in muscle tone, exercise tolerance, plasma volume, red cell mass, total blood volume, and orthostatic tolerance. These effects may occur during inactivity imposed by means other than bed rest.[6,7,8] This suggests that appropriate levels of exercise could be used to prevent deconditioning during prolonged manned space flight.

During walking or running, changes in the hydrostatic pressure in the circulation produced by gravity result in fluctuations in the venous and arterial pressure in the lower extremities. The fluctuations in pressure below the diaphragm cannot easily be simulated in the supine or weightless individual, but venous pressure can be changed by using pressure cuffs.

In this investigation the effects of pressure cuffs and exercise at intervals were studied during a 4-week period of bed rest.

METHODS AND MATERIALS

Subjects were six healthy male volunteers, 18 to 21 years old, who had just completed basic training in the United States Air Force. The same schedule of tests was followed before and after 4 weeks of bed rest:

	A.M.
Monday:	Tilt Table—no suit
Tuesday:	Tilt Table—antigravity suit
Wednesday:	Tilt Table—no suit
Thursday:	Tilt Table—antigravity suit
Friday:	Treadmill

	PM.
Monday:	Tilt Table—antigravity suit
Tuesday:	Tilt Table—no suit
Wednesday:	Tilt Table—antigravity suit
Thursday:	Tilt Table—no suit
Friday:	Treadmill

Using radioactive iodinated serum albumin, blood volume was measured before bed rest, after 2 days and 28 days of bed rest, and 4 days, 11 days, and 18 days following completion of bed rest.

To minimize laboratory variations, total blood volume, plasma volume, and red cell mass were calculated by more than one method and average values determined for each. Total blood volume and plasma volume were measured by direct counts of whole blood and plasma, the difference affording a direct value for red cell mass. Indirect values for plasma volume and red cell mass were calculated from the direct total blood volume and the corrected hematocrit. As in a previous study of simple bed rest,[10] the direct plasma volume and the corrected hematocrit were used to determine indirect values for total blood volume and red cell mass.

A 30-minute tilt table test was used to evaluate cardiovascular responses to gravity. The tilt table procedure has been described previously.[10] Subjects were tilted for 30 minutes unless syncope or imminent syncope occurred. Imminent syncope was recorded as syncope.

For 5 subjects the antigravity garment was a modified partial pressure suit that provided 62 mm Hg pressure to the lower extremities and the abdomen. In one subject, who could not be fitted with a pressure suit, an Air Force anti-G garment, type CSU/3P, was used; the leg, thigh, and abdominal bladders were inflated to 60 mm Hg.

The treadmill was operated at a speed of 3.3 miles per hour and with a two-thirds degree increase in in-

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clination at the end of each minute of exercise. Subjects exercised until the heart rate reached at least 180 beats per minute. Maximal oxygen consumption was measured by obtaining minute samples of expired air during the peak of physical exertion.

During the 4 weeks of bed rest the subjects did not leave the bed and sitting was prohibited. The subjects were returned to bed after each test procedure during the week of testing after the 4-week bed rest period.

A program of progressive physical exercise was started on the first day of bed rest. In a manner similar to bicycling, the supine subjects pumped foot pedals mounted on a horizontal track. The track allowed about 18 inches of motion. Weights were attached to the pedals by pulleys. The rate of pumping with each leg was timed with a metronome. The schedule of exercise in bed is shown in Table I.

Except during the first day of bed rest, narrow blood pressure cuffs (2 inches wide) inflated to 60 mm Hg were worn around the upper thighs during exercise. The degree of venous occlusion is not known but may have been slight, since narrow cuffs provide less constriction than wide cuffs. Therefore, venous pressure during exercise may not have been significantly increased. The narrow cuffs were chosen because standard leg cuffs inflated to 60 mm Hg caused pain during exercise in the muscle underneath the cuffs.

Heart rates and minute oxygen consumption during the last few minutes of exercise in bed are shown in Table II. Exercise in bed was continued during the week of testing that followed the four weeks of bed rest.

The subjects were fed an Air Force mess hall diet with no caloric restriction.

TABLE I. LEVELS OF EXERCISE DURING BED REST

Day of Bed Rest	Weight on each pulley	Metronome setting	Duration of Exercise
1-3	20 pounds	92/min	5 min, 8 x daily
4-7	20 pounds	100/min	10 min, 6 x daily
8-11	20 pounds	120/min	10 min, 6 x daily
12-15	20 pounds	130/min	10 min, 6 x daily
16-17	20 pounds	140/min	10 min, 6 x daily
18	40 pounds	140/min	10 min, 6 x daily
19	30 pounds	120/min	10 min, 6 x daily
20 28	30 pounds	140/min	10 min, 6 x daily

TABLE II. CIRCULATORY RESPONSES TO IN-BED EXERCISE

	Heart Rate				Oxygen Consumption			
	16th Day		27th Day		16th Day		19th Day	
		Exercise 20#-		Exercise 30#-	20#-140/min		30#-120/min	
Subj.	Rest	140/min	Rest	140/min	cc/min	cc/Kg/min	cc/min	cc/Kg/min
A	80	95	87	127	586	8.8	765	11.5
B	65	95	77	120	940	14.2	.....	.....
C	67	80	83	124	889	14.2	880	14.1
D	68	76	72	117	881	12.8	889	13.0
E	72	94	87	122	521	8.2	.....	.....
F	61	85	67	146	1060	12.3	.....	.....

TABLE III. BODY WEIGHT BEFORE AND AFTER BED REST

Subject	Weight in Kilograms Before Bed Rest	After Bed Rest
A	68.1	66.0
B	67.0	66.4
C	67.8	62.8
D	69.7	70.2
E	64.7	64.0
F	86.6	85.6
Mean	70.7	69.2

RESULTS

Body Weight—The body weight during bed rest decreased 0.5 Kg. to 5.0 Kg. in five subjects (Table III). Body weight increased 0.6 Kg. in one subject. The six subjects had a mean decrease in body weight of 1.5 Kg.

Blood Volume—Changes in blood volume calculated by various methods are shown in Table IV. The following changes in blood volume were calculated from the corrected hematocrit and a direct count of the plasma.

An average loss of 481 ml in plasma volume ($P<.01$) was noted after 2 days of bed rest (Table IV and Figure 1). Loss of plasma volume ranged from 324 ml to 603 ml. Red cell mass decreased from 128 ml to 322 ml in 4 subjects, increased 23 ml in 1 subject, and increased 160 ml in 1 subject. The average loss in red cell mass during two days of bed rest was 122 ml (no statistical significance).

After 28 days of bed rest an average loss of 1212 ml in total blood volume ($P<.01$) occurred, the loss ranging from 1019 ml to 1426 ml. Loss of plasma volume ranged from 486 ml to 836 ml with an average loss of 672 ml ($P<.01$). Loss of red cell mass ranged

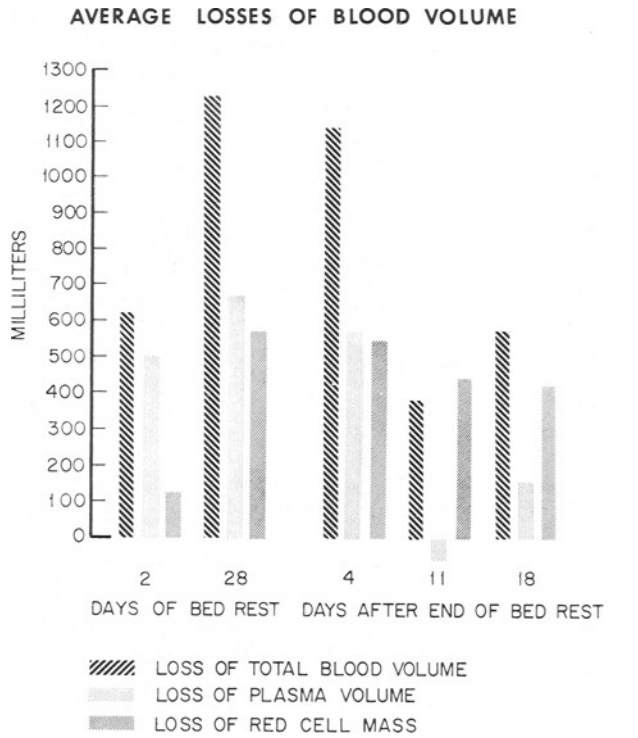

Fig. 1. Average losses in blood volume calculated from corrected hematocrit and direct count of plasma. Losses for five subjects only are shown 11 days after bed rest.

TABLE IV. CHANGES IN BLOOD VOLUME BEFORE AND AFTER BED REST WITH IN-BED EXERCISE

During Bed Rest	Subj.	Changes in Total Blood Volume (liters)			Changes in Plasma Volume (liters)			Changes in Red Cell Mass (liters)		
		Direct	Indirect	Aver.	Direct	Indirect	Aver.	Calculated by Plasma Volume	Calculated by TBV	Aver.
2 Days	A	— .663	— .910	— .787	— .587	— .455	— .521	— .076	— .322	— .208 — .202
	B	— .494	— .476	— .485	— .348	— .360	— .354	— .146	— .128	— .134 — .136
	C	— .471	— .582	— .527	— .324	— .260	— .292	— .147	— .258	— .211 — .205
	D	— .979	— .538	— .759	— .561	— .813	— .687	— .418	+ .023	— .166 — .187
	E	— .377	— .811	— .594	— .603	— .371	— .487	+ .231	— .208	— .001 + .007
	F	— .187	— .303	— .245	— .463	— .323	— .393	+ .276	+ .160	+ .217 + .218
	Mean	— .528	— .604	— .566	— .481	— .431	— .456	— .047	— .122	— .084 — .084
28 Days	A	—1.143	—1.426	—1.285	— .732	— .573	— .653	— .411	— .693	— .570 — .558
	B	— .972	—1.099	—1.036	— .642	— .579	— .611	— .330	— .457	— .393 — .393
	C	— .903	—1.119	—1.011	— .486	— .360	— .423	— .417	— .633	— .543 — .531
	D	—1.402	—1.019	—1.211	— .592	— .811	— .702	— .810	— .427	— .591 — .609
	E	—1.103	—1.360	—1.232	— .836	— .694	— .765	— .262	— .525	— .404 — .397
	F	— .967	—1.250	—1.109	— .746	— .511	— .629	— .221	— .504	— .375 — .367
	Mean	—1.082	—1.212	—1.147	— .672	— .588	— .630	— .408	— .539	— .479 — .475
After Bed Rest										
4 Days	A	—1.184	— .995	—1.090	— .448	— .554	— .501	— .736	— .546	— .630 — .637
	B	—1.002	—1.550	—1.276	— .539	— .201	— .370	— .463	—1.011	— .801 — .758
	C	— .801	—1.279	—1.040	— .628	— .346	— .487	— .173	— .651	— .455 — .426
	D	— .948	— .632	— .790	— .426	— .608	— .517	— .522	— .206	— .340 — .356
	E	— .963	—1.133	—1.048	— .622	— .526	— .574	— .341	— .511	— .432 — .428
	F	— .636	— .999	— .818	— .522	— .238	— .380	— .114	— .477	— .317 — .303
	Mean	— .922	—1.098	—1.010	— .531	— .412	— .471	— .392	— .567	— .496 — .485
11 Days	A	— .350	— .359	— .355	+ .172	+ .180	+ .176	— .522	— .530	— .530 — .527
	B	— .581	— .383	— .482	— .120	— .225	— .173	— .461	— .263	— .356 — .360
	C	—	—	—	—	—	—	—	—	— —
	D	— .731	— .287	— .509	+ .038	— .216	— .089	— .769	— .325	— .515 — .536
	E	— .269	— .547	— .408	— .002	+ .161	+ .080	— .262	— .545	— .425 — .411
	F	+ .072	— .357	— .143	+ .219	+ .563	+ .391	— .147	— .576	— .410 — .378
	Mean	— .372	— .387	— .380	+ .061	+ .092	+ .077	— .432	— .448	— .447 — .442
18 Days	A	— .633	— .088	— .361	+ .211	— .108	+ .052	— .844	— .298	— .525 — .556
	B	— .630	— .648	— .639	— .181	— .164	— .173	— .449	— .467	— .466 — .461
	C	— .300	— .411	— .356	— .056	+ .006	— .025	— .244	— .355	— .306 — .302
	D	— .681	— .622	— .652	— .339	— .371	— .355	— .342	— .283	— .310 — .312
	E	— .116	— .641	— .379	— .189	+ .114	— .038	+ .078	— .452	— .225 — .200
	F	— .312	— .844	— .578	— .114	+ .291	+ .089	— .198	— .730	— .522 — 483
	Mean	— .445	— .542	— .494	— .111	— .039	— .075	— .333	— .431	— .392 — .385

from 427 ml to 693 ml with an average loss of 539 ml ($P<.01$).

During the 4 days of tilt table testing after 4 weeks of bed rest no significant changes in blood volume occurred. During the first week of ambulation on the ward plasma volume returned to normal and red cell mass increased an average of 119 ml. After 2 weeks of ambulation on the ward, mean plasma volume was 111 ml less and mean red cell mass was 431 ml less ($P<.01$) than before bed rest.

Tilt Table Tests—Supine resting heart rates were higher after bed rest than before in each subject studied (Table V). The supine heart rate increased from a mean of 75 beats per minute for all subjects before bed rest to 90 after bed rest.

As in a previous study of absolute bed rest,[10] the highest heart rate recorded during each head-up tilt was chosen as one index of orthostatic tolerance. The range of highest orthostatic heart rates in subjects unprotected by an anti-gravity suit was clearly higher after bed rest than before (Table VI and Figure 2).

In each of the 5 subjects wearing the modified partial

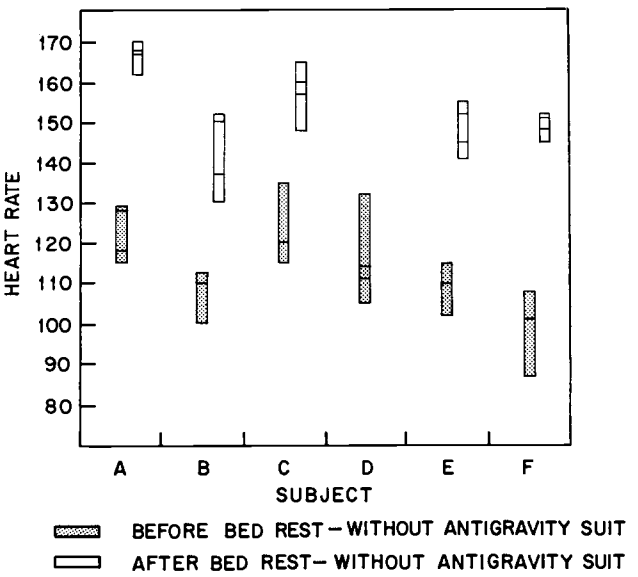

Fig. 2. Range of highest heart rates recorded during orthostasis in each tilt table test without antigravity suit performed during week of testing before and after bed rest. Lines within bars indicate heart rates within range. Duplication of heart rates is not shown.

pressure suit during tilt table testing after bed rest, the range of highest orthostatic heart rates was not as high as that recorded during testing without an antigravity suit before bed rest (Table VI and Figure 3). In the subject wearing the bladder type of anti-G garment orthostatic heart rates were higher after bed rest.

TABLE V. AVERAGE RESTING HEART RATES* BEFORE AND AFTER BED REST

Subject	Heart Rate		P
	Before	After	
A	76.1	94.1	<.005
B	80.5	91.2	<.005
C	74.7	93.5	<.005
D	71.0	86.4	<.005
E	87.4	98.8	<.005
F	59.0	75.3	<.005
Mean	74.8	90.0	<.001

*Heart rates were recorded during the 8th, 9th, and 10th minute in the horizontal position on the tilt table during repeated testing before and after bed rest.

TABLE VI. HIGHEST ORTHOSTATIC HEART RATES IN EACH TILT TABLE TEST BEFORE AND AFTER BED REST

Subject		Without Anti-G Suit				With Anti-G Suit			
A	Before	129	118	128*	115	93	98	102	93
	After	167*	168*	162*	170	115*	104	112	108
B	Before	113	110	100	100	82	81	81	81
	After	150	137	130	152	94	92	91	110
C	Before	135*	120*	135*	115	94	75	103	106
	After	160*	148*	157*	165*	94	105	98	101
D	Before	105	114	111	132	100	85	88	80
	After	155*	155	155	155	105	98	90	93
E	Before	110	115	102	110	96	94	85	83
	After	155*	141	152	145*	106	105	95	107
F	Before	101	108	101	87	83	83	90	79
	After	148*	145*	152*	151	141*	143	113	116

*These subjects experienced syncope during tilt table test.

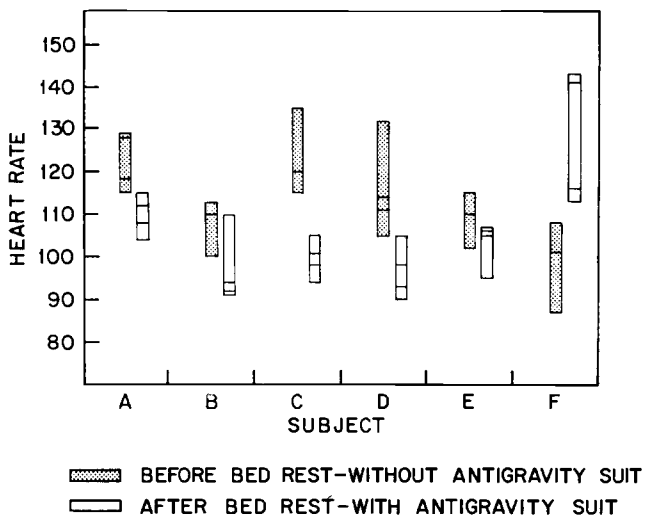

Fig. 3. Range of highest heart rates recorded during orthostasis in each tilt table test performed during week of testing before bed rest without antigravity suit and after bed rest with antigravity suit. Subject F wore the bladder type of anti-G suit.

When no antigravity suit was worn during tilt table testing, 13 episodes of syncope occurred in 5 subjects after bed rest in contrast to 4 episodes in 2 subjects before bed rest (Table VII). During tilt table tests in which no fainting occurred, blood pressures during the 30th minute of orthostasis tended to be lower after bed rest than before (Table VIII). The marked cyanosis and blotching of the feet and ankles previously observed during orthostasis after absolute bed rest was not seen in the present study.

Before bed rest, 2 tilt table tests performed with an antigravity garment were terminated because the subjects complained that the pressure of an athletic cup under the inflated partial pressure suit caused marked testicular discomfort (Table VII). Two subjects fainted while wearing an antigravity garment during tilt table testing on the first day after bed rest. One of these subjects wore the bladder type of anti-G suit. In this subject no blood pressure could be recorded during the 30th minute of orthostasis on the second day of testing after bed rest (Table VIII).

Treadmill Tests—As a group, the subjects had a high normal level of physical fitness before bed rest as indicated by a mean exercise time of 18.2 minutes and a mean maximal O_2 consumption of 2911 ml (Table IX). One subject (C) had a below normal exercise time of 15 minutes and a maximal oxygen consumption of 2363 ml. He had syncope on three of four tilt table tests before the bed rest phase.

As judged by the time required to reach a pulse rate of 180 or greater and by maximal oxygen consumption, performance on the treadmill decreased after bed rest in each subject studied. After bed rest, mean time on the treadmill decreased 8.9 minutes and mean maximal oxygen consumption decreased 635 cc/min.

DISCUSSION

The loss of plasma volume during bed rest paralleled changes in plasma volume previously observed during absolute bed rest.[10] The major loss of plasma volume was again noted after only 2 days of bed rest.

TABLE VII. SYNCOPE DURING REPEATED TILT TABLE TESTING BEFORE AND AFTER BED REST

Subject		Without Anti-G Suit				With Anti-G Suit			
A	Before	–	–	S-28	–	–	–	–	–
	After	S-9	S-21	S-29	–	S-18	–	–	–
B	Before	–	–	–	–	–	–	–	–
	After	–	–	–	–	–	–	–	–
C	Before	S-26	S-30	S-29	–	–	*	–	–
	After	S-14	S-16	S-15	S-18	–	–	–	–
D	Before	–	–	–	–	*	–	–	–
	After	S-21	–	–	–	–	–	–	–
E	Before	–	–	–	–	–	–	–	–
	After	S-21	–	–	S-22	–	–	–	–
F	Before	–	–	–	–	–	–	–	–
	After	S-12	S-19	S-30	–	S-12	–	–	–

* : Tilt table test terminated because of testicular discomfort from parachute straps.

S : Syncope. Number after S indicates time of syncope.

TABLE VIII. BLOOD PRESSURE DURING 30th MINUTE OF ORTHOSTASIS IN EACH TILT TABLE TEST BEFORE AND AFTER BED REST

Subject		Without Anti-G Suit				With Anti-G Suit			
A	Before	98/80	106/84	S-28	100/72	122/78	114/68	126/84	136/80
	After	S-9	S-21	S-29	90/86	S-18	142/80	136/94	148/90
B	Before	128/	138/124	144/116	144/102	144/108	152/112	172/120	172/118
	After	130/108	134/88	128/96	122/100	150/108	128/84	132/94	140/100
C	Before	S-26	S-30	S-29	92/70	118/64	*	136/88	118/86
	After	S-14	S-16	S-15	S-18	130/92	124/78	118/96	110/84
D	Before	126/84	144/104	122/94	122/96	*	140/84	140/78	126/68
	After	S-21	118/92	108/86	126/82	124/78	142/102	134/98	142/88
E	Before	120/102	128/106	132/94	140/98	108/	134/98	144/102	134/86
	After	S-21	108/78	104/84	S-22	134/106	122/80	120/84	118/82
F	Before	118/90	102/88	122/100	140/102	116/84	158/98	132/90	142/92
	After	S-12	S-19	S-30	102/88	S-12	N	122/84	148/92

* : Tilt table test terminated because of testicular discomfort from parachute straps.

S : Syncope. Number after S indicates time of syncope.

N : No blood pressure obtainable.

A return of plasma volume to normal following one week of ambulation after bed rest observed in this study was also reported by Taylor, et al.[13] In their study a program of vigorous physical conditioning was carried out before and after bed rest. In another study, in which no physical conditioning was performed before or after bed rest, plasma volume returned more slowly to normal after bed rest.[10]

Changes in red cell mass were different from those observed during and after simple bed rest.[10,13] In the present study the peak loss of red cell mass was recorded at the end of bed rest in contrast to simple bed rest in which the peak loss of red cell mass was noted following 7 to 8 days of ambulation after bed rest. The magnitude of the decrease in red cell mass was much greater during bed rest with exercise than that noted in simple bed rest. In this study all 6 subjects had a decrease from 427 to 693 ml with an average decrease of 539 ml. During simple bed rest 3 of 12 subjects showed a slight increase in red cell mass and 1 subject had no apparent change. The remaining 8 subjects had a decrease of 100 to 500 ml. The average decrease was only 180 ml.

It is possible that the increased level of physical exercise during the last 11 days of bed rest in this study was responsible for the greater loss of red cell mass during bed rest. In dogs, Broun[2] reported an increased destruction of red blood cells during physical exercise following inactivity.

The loss in total blood volume at the end of 4 weeks of bed rest with in-bed exercise varied from 1019 to 1426 ml with a mean of 1212 ml, 482 ml more than the average decrease previously noted after 4 weeks of absolute bed rest. The greater decrease in total blood volume, represented mainly by red cell mass, may have contributed to the orthostatic intolerance and decreased exercise tolerance at the end of bed rest and could have negated any benefit from in-bed exercise. With less marked decreases of blood volume a correlation between the degree of loss of blood volume and the degree of loss of postural tolerance has not been noted after bed rest.[10,13]

TABLE IX. TREADMILL PERFORMANCE BEFORE AND AFTER BED REST

Subject	Minutes on Treadmill		Peak Heart Rate		Maximal O_2 Consumption (cc/min)		O_2Utilization (cc/kgm/min)	
	Before	After	Before	After	Before	After	Before	After
A	17	8	180	182	2678	2260	39.3	33.0
B	21	10	180	185	3136	2425	49.3	36.0
C	15	7	180	180	2363	2046	33.0	33.0
D	18	11	182	180	2924	2439	41.5	36.0
E	18	8	180	180	2839	1782	43.1	28.0
F	20	12	182	180	3528	2703	40.0	32.0
MEAN	18.2	9.3	181	181	2911	2276	41.0	33.0

The observation that simple bed rest resulted in marked dependent cyanosis suggests that venous pooling with stagnant hypoxia occurred, possibly due to loss of venous tone or extravascular muscle tone. Its absence in the exercised subjects suggests the possibility that exercise prevented this degree of venous pooling, perhaps because of better venous or extravascular muscle tone. Both venous tone (regulating the amount of venous pooling) and blood volume may influence orthostatic tolerance. When blood volume is normal but excessive venous pooling occurs syncope may result. If the blood volume is sufficiently reduced in the presence of normal dependent venous pooling the pooled volume may represent such a large portion of the total blood volume that syncope ensues.

The exercise program in bed did not prevent an increase in the resting heart rate comparable to that seen during absolute bed rest.[10] The mean resting heart rate increased 15 beats per minute during bed rest with exercise and 13 beats per minute during absolute bed rest.

Orthostatic intolerance after bed rest with exercise appeared as marked in this study as in a previous study involving 4 weeks of absolute bed rest.[10] In both, syncope on the tilt table occurred approximately 3 times more frequently and orthostatic heart rates were clearly higher than before bed rest.

The modified partial pressure suit again proved ef-

fective in preventing orthostatic intolerance after bed rest.[10] The bladder type of anti-G suit worn by one subject appeared less efficient. The bladders provide less uniform constriction to the legs than the tightly fitting fabric of the partial pressure suit. A different effectiveness of the two suits in maintaining postural tolerance was demonstrated by Nicholas[12] in a patient with severe postural hypotension secondary to a thoracolumbar sympathectomy. The bladder type of anti-G suit did provide relatively good protection from fainting on the tilt table after 2 weeks of bed rest.[9] Fainting occurred in 40 per cent of the subjects while not wearing the suit and in only 10 per cent while wearing the suit.

In a previous study, as judged by orthostatic heart rates, no clear-cut protection against the loss of orthostatic tolerance could be demonstrated with the use of isometric exercise during two weeks of bed rest.[9] In the present investigation, vigorous isotonic exercise of the legs at light to moderate work loads did not prevent the adverse circulatory effects of bed rest. The heart rates and oxygen consumptions during in-bed exercise indicate that the subject's circulatory systems were not greatly taxed by the exercise. The effect of heavier exercise loads needs evaluation. On the other hand, one cannot conclude that a constant level of light exercise during bed rest would not benefit orthostatic tolerance, since the heavier exercise load during the latter part of bed rest in the present study may have diminished blood volume and thus compromised postural tolerance. In designing exercise programs adaptable to prolonged space flight, it appears advisable to train subjects to the desired degree of physical conditioning prior to bed rest and then to maintain this level during bed rest.

SUMMARY AND CONCLUSIONS

Various effects on circulatory functions of light to moderate physical exercise during 4 weeks of bed rest were studied in 6 healthy male volunteers. During exercise narrow cuffs inflated to 68 mm Hg were worn on the upper thighs. An identical schedule of tests was followed before and after bed rest.

An average loss of 1212 ml in total blood volume occurred during 4 weeks of bed rest. An average decrease of 672 ml in plasma volume and 539 ml in red cell mass was observed. Changes in plasma volume during and after bed rest paralleled changes characteristic of simple bed rest. In contrast to simple bed rest, the major loss of red cell mass was noted at the end of bed rest and not during ambulation following bed rest.

The mean resting heart rate for all subjects increased 15 beats per minute during bed rest. Syncope on the tilt table was more frequent and orthostatic heart rates were higher after bed rest than before. The degree of postural intolerance after the bed rest conditions of this study appeared as marked as that observed after absolute bed rest.

As judged by the time required to reach a heart rate of 180 or greater and by maximal oxygen consumption, physical endurance on the treadmill was not maintained by the in-bed isotonic exercise program utilized in this study. On the basis of the heart rates and oxygen consumptions during the in-bed exercise, the circulatory system was not greatly stressed. These results do not preclude the possibility that other exercise programs would favorably influence the maintenance of orthostatic tolerance and physical work capacity during bed rest.

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