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Correction made  
17

LITERATURE SUMMARY ON  
COUNTERMEASURES

January 1973  
References A23 to A29

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## EXERCISE

1

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A23	Ye.N. Biryukov et al, 1967 USSR	research experiment	human (6) 3 controls	bedrest, 62 days	exercise, rubber loops for exercising extremities, static support exercises, bicycle erometer, supine, 800,000 to 900,000 kgm/day by the end of the experiment	no (fluid balance)  no (electro- lyte metabolism) slight (Ca metabolism) very (bone density)	fluid balance, water intake, urine volume electrolyte metabolism Na, K, P, Cl, Mg, blood, urine, feces Ca metabolism, urine, feces bone density, x-radiograph	Subjects were exposed to trans- verse acceleration of 13 to 15 G prior to bedrest. Both groups returned to normal levels of fluid balance and electrolyte metabolism by the end of the bedrest.
A24	D. Cardus et al, 1965 USA	research experiment	human (6) own controls	bedrest, 3 days,	exercise, isometric, supine, 60% maximal O <sub>2</sub> uptake	See Notes	circadian rhythm, 17-hydroxy- corticosteroids, plasma	3 days of bedrest had no effect on circadian rhythm of 17-OHCS.
A26	B.N. Petukhov et al, 1968 USSR	research experiment	human (6) 3 controls	bedrest, 62 days	exercise, isotonic, 1,200 cal/day by end of experiment	*slight (day 1-33, EEG) *See Notes, day 33 to end	EEG, mono and bipolar, conditioned reflex	*Between day 33 and 43, the response fell off drastically in both groups, but, by the end of the experiment near normal values were noted. With lengthening of time of hypokinesia, a constant shift of cortical rhythm to slower frequencies was recorded. Subjects were exposed to pre- and post bedrest transverse acceleration.  See also Ref A27 Purakhin under exercise.
A27	Yu.N. Purakhin et al, 1968 USSR	research experiment	human (6) 3 controls	bedrest, 62 days	exercise, isotonic, 1,200 cal/day by end of experiment	slight (EEG) slight (seismo- tremography) slight (stabilo- graphy)	EEG, mono and bipolar, conditioned reflex seismotremography, nystagmoidal twitching, muscle tone, tendon reflexes stabilography, pre and post bedrest, stato-coordination, gait	Subjects were exposed to transverse acceleration twice before bedrest.  See Ref for further EEG analysis.  See also Ref A26 Petukhov under Exercise.



		DIET					
REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS
A25	P.B. Mack et al, 1967 USA	research experiment	human (30)	bedrest, 14 days, 7 experiments			
			(4)		Ca supplement, 0.3gm/day	no (Ca balance) no (bone density)	Ca balance, intake, urine, feces bone density, x-radiography, os calcis
			(5)		Ca supplement, 0.5gm/day	no (Ca balance) no (bone density)	
			(4)		Ca supplement, 0.7gm/day	slight-no (Ca balance) slight (bone density)	
			(4)		Ca supplement, 0.8gm/day	slight (Ca balance) slight (bone density)	
			(5)		Ca supplement, 1.0gm/day	moderate (Ca balance) moderate (bone density)	
			(4)		Ca supplement, 1.5gm/day	slight (Ca balance) moderate (bone density)	
			(4)		Ca supplement, 2.0gm/day	slight (Ca balance) moderate (bone density)	

During the control period, the subjects were adjusted to a diet containing 1.5gm/day, except for the group supplemented with 2.0gm/day which was adjusted to 2.0gm/day.

See also Ref A25 under Exercise and Diet.

(continued)



## DIET

3

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A25	P.B. Mack et al, 1967 (continued)	research experiment	human (2)	in-flight, Gemini IV, 4 days	Ca intake, 600-700mg/day	<del>moderate</del> slight (bone density)	bone density, x-radiograph, os calcis, phalanx 5-2	
			(2)	in-flight, Gemini V 8 days	Ca intake, 300mg/day	no <sup>slight</sup> (bone density)		



## G-SUIT

4

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A28	J.D. Rogge et al, 1967 USA	research experiment	human (8) own controls	See Notes	anti G-suit, CSU 3/P, 60 mm Hg	very (accelera- tion tolerance)	acceleration tolerance, arginine vasopressin in whole blood and plasma	Subjects were centrifuged for 30 min at 2G in a +G, position 13° degress back from vertical.



## EXERCISE AND DIET

5

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A25	P.B. Mack et al, 1967 USA	research experiment	human (2)	in-flight, Gemini VII, 14 days	Ca intake, 1.0gm/day exercise, isotonic, bungee cords, isometric 4 times/day	moderate (bone density)	bone density, x-radiograph, os calcis, phalanx 5-2 Ca balance	The bone density and Ca balance values were statistically significant between the exercise and control groups. No data was represented. Phalanx lost little density with or without exercise.  See Ref A25 also under Diet.
			human (2) own controls	bedrest, 14 days,	Same as Gemini VII regimen	See Notes.		
A29	F.B. Vogt et al, 1965 USA	research experiment	human (6) own controls	bedrest, 14 days	exercise, isometric, thrust rack, supine, knee partially flexed, 60 sec, full extension, 25 sec, 8 times/day diet, 1.0gm Cal, 2200 Cal	See Notes	bone density, x-radiograph, os calcis Ca balance, blood, urine, feces, P Tilt tolerance	Interpretation of the results is uncertain because of problems in adjusting the test diet and in evaluating experimental samples. An increase in bone density was observed with the regimen.



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- A29. Vogt, F.B., P.B. Mack, W.G. Beasley, W.A. Spencer, D. Cardus, and C. Vallbona. 1965.  
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For S.V. paper

Corrections ~~made~~  
p 2, 4, 18, 11, 12

LITERATURE SUMMARY ON  
COUNTERMEASURES

Addendum I

January 1973



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REVIEW

1

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A4 & A5	A.M. Genin et al, 1971 USSR	research experiment 85 exp. 7exp./ series	human (30)	water immersion 18 hrs, lying down, sitting (See Notes)	venous occlusion cuffs, 65 mm Hg, 1 min on/3 min off, 7 hrs	very (CV)	orthostatic tolerance	Chair studies showed no change in orthostatic resistance under any regimen. Suggested use of quotient of stress index of myocardium over systolic volume as predictive measure of severity of orthostatic tolerance. Methods recommended for use in Salyut craft were: physi- cal trainer, LBNP, secophene 1 hour prior to end of flight and G-suit during vertical position.
					venous occlusion cuffs, 65 mm Hg, 1 min on/3 min off, 6 hrs	no (CV)		
					LBNP -25 mm Hg	very (CV)		
					resistance to expiration, 200 mm water column, periodic for 2.5 hrs	no (CV)		
					positive pressure breathing, 300 mm water column, 3 hrs	slight (CV)		
					medication: caffeine, tea, strychnine, phenamine, 1 hr prior to end of exp.	moderate (CV)		
					G-suit, partial pressure suit, post experiment, 20, 35 or 50 mm Hg	very (CV)		A pressure from 35 - 50 mm Hg in the G-suit was preferred.

(continued)



REVIEW

3

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A4 & A5	A.M. Genin et al, 1971 USSR (continued)	research experiment	human (12)	bedrest 30 days, (4 series)	LBNP, day 26-30 exercise, day 1-30, vertical treadmill	very (CV)	orthostatic tolerance	*The subject who did not im- prove was trained in a smaller volume than did the others.
					LBNP, day 26-30, -15 to -30 mm Hg, gradual increase, 2.5-3 hr/day exercise, day 26-30, isotonic, up to -60 mm Hg	moderate (CV) and *no (CV)		
					LBNP, G-suit, 50 mm Hg, partial pressure suit	moderate (CV)		
					LBNP, G-suit, 50 mm Hg, partial pressure suit exercise	very (CV)		
			human (2)	in-flight, Salyut, 24-days	LBNP, -27mm Hg 2min/ -36mm Hg 3 min	very (CV)		Subjective and objective evaluation of ability to withstand LBNP was related to emotional state of crew. LBNP created sensation of returning to terrestrial conditions.



REVIEW

2

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A4 & A5	A.M. Genin et al, 1971 USSR (continued)	research experiment	human (22) <i># Controls?</i>	bedrest 70 days (5 series), 100 days (2 series)	medication: caffeine, securinine, phenamine, 1 hr. prior to end of exp.	slight (CV)	orthostatic tolerance muscle work ability, walking metabolism bone decalcification	
					venous occlusion cuffs, thigh	no (CV) very (muscle)		
					exercise horizontal position, expanders, bicycle ergometer, vertical treadmill	<i>moderate</i> very (CV) very (muscle)		
					venous occlusion cuffs, thigh, 1 min on/off, 9 hrs/day exercise, supine, expander, bicycle ergometer, vertical treadmill	<i>slight</i> moderate (CV)		
			human (12)	bedrest 30 days, (4 series)	LBNP, -30 mm Hg, 6 hrs/day	no (CV)	orthostatic tolerance	Tested various designs for LBNP. LBNP was more effective in brief experiments than in prolonged ones.

(continued)



REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A7	N.N. Gurovskii et al, 1972 USSR	research experiment	human (3)	in-flight Soyuz 11 and Salyut, 22 days	exercise, 2.5 hrs/24 hrs treadmill G-suit medication secophen leotard prior to re-entry	slight (CV)	CV heart rate, arterial pressure, myocardial dynamics, cardiac output, systolic volume, pulse wave propagation, orthostatic tolerance	LBNP was used a predictive test.
A15	J.W. Ord et al, 1971 USA	review	human	in-flight, Mercury, Gemini, Apollo, & some Soviet bedrest, See Notes	*exercise	moderate (orthostat- ic toler- ance) very (exercise tolerance) promising (red blood cell mass) promising (cellular metabolism) no (mineral metabolism)		Results from in-flight exper- iments were compared to ground-based simulation tests to evaluate man's ability to undertake 45 to 60 day missions. *Present in flight exercise regimens (elastic cord, rope- variable function device and isometrics) are inadequate to modify deconditioning. The authors suggest the use of the Aerospace Medical Divisions total body exerciser to provide the form, duration and intensity of exercise needed in space.
					LBNP	very (CV) very (fluid metabolism)		
					venous occlusion, cuffs	no (CV)		



## EXERCISE

5

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A3	L.F. Dietlein et al, 1971 USA	research experiment	human (1)	in-flight, Gemini IV, pilot, 4 days	exercise, rubber bungie cord, 1 full extension/ sec, 30 sec/period, 10 periods	very (exercise tolerance)	exercise tolerance, pulse rate, heart rate, blood pressure	
			human (1)	in-flight, Gemini IV, command pilot, 4 days	exercise, rubber bungie cord, 1 full extension/ sec, 30 sec/period, 7 periods	very (exercise tolerance)		
			human (2)	in-flight, Gemini V, 8 days	exercise, exp. M003, T.i.d.	moderate (exercise tolerance)		
			human (2)	in-flight, Gemini VII, 14 days	exercise, exp. M003, B.i.d. exercise, isotonic- isometric, T.i.d.	moderate (exercise tolerance)		
A6	J.E. Greenleaf et al, 1972 USA	research experiment	human (8) own controls	bedrest, 2 weeks	exercise, isotonic, 1/2 hr per day, to 1/2 maximal oxygen uptake post bedrest, 2.1G, 3.2G & 3.8G centrifuga- tion	no (acceler- ation tolerance) no (plasma volume)	G <sub>z</sub> tolerance	See also ref # A6 under Exercise and Rehydration.



## EXERCISE

6

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A8	A.A. Korobova et al, 1971 USSR	review	human		exercise, isotonic, isometric	very (motor function)	motor function, muscle tone, control, contractability	The literature on the nature of motor impairment and adaptability during real and simulated weightless condi- tions is reviewed. The author states that with the correct levels and types of exercises, optimum performance can be maintained, as well as ortho- static tolerance, mineral metabolism and immunological indices.
A13	M.C. Lancaster et al, 1971 USA	research experiment	human (8) 4 controls	bedrest, 5 weeks	total body ergometer, (TBE) 20 min T.i.d., 600 kcal/day	no (ortho- static tolerance) moderate (LBNP tolerance) slight very (exercise tolerance) no (psycho- motor)	orthostatic tolerance LBNP tolerance exercise tolerance psychomotor, reaction time, hand steadiness, pursuit task orthostatic tolerance 2 min seated, 5 min quiet standing heart rate	Preliminary report on TBE. All subjects spent increased time in stages 3 & 4 sleep. The controls spent more time in REM sleep.
A14	P.B. Mack 1971, USA	research experiment	human own controls	bedrest, 14 days	exercise, isotonic & isometric, 4 times/day	very (bone density) moderate (Ca balance)	bone density, x-radiograph, os calcis, central talus, distal talus, capitate, distal ulna, phalanx 4-2	See ref # A14 also under Diet.

(continued)



## EXERCISE

7

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A14	P.B. Mack 1971, USA (continued)	research experiment	human <del>(8)</del>	bedrest, 28 days	exercise, supine, exer-genie, 8 lb, hand gripper, isotonic, 20 min, isometric, 30 sec, 4 times/day	very (bone density)	bone density, x-radiograph, os-calcis, central talus, distal talus, capitate, distal ulna, phalanx 4-2	*The less frequently the astronauts exercised, the lower the bone density be- came.
			(3)					
			<del>(3)</del>	<del>bedrest,</del>	<del>exercise,</del> same as above, at will	no (bone density)		
			human (3)	in-flight, Apollo 7	exercise, exer-genie	*moderate- very (bone density)		
A18	W. van Beaumont et al, 1972 USA	research experiment	human (8)	*bedrest, 21 days	exercise, 30 min, Monark ergometer, upright, 50% max $O_2$ uptake, Collins ergometer, supine, 50% max $O_2$ uptake	moderate (plasma volume) very (plasma protein) very (plasma albumin)	plasma volume plasma protein plasma albumin	*Measurements were taken on 13th day of bedrest. The author conducted studies of the effect of exercise condi- tions on the relationship between Hct, plasma protein and plasma volume. The authors theorize that prolonged bed- rest may induce hypoprotein- emia as a factor contributing to hypovolemia.

*in control period* →

*During the control period, the subject exercised on a Monark ergometer at 50% of their max.  $O_2$  uptake for 30 min daily in an upright position.*



MEDICATION

8

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A9	T.N. Krupina et al, 1971 USSR	research experiment	human (10) 4 controls  (3)	bedrest, 120 days	Pituitrin, day 1-13, 5 units/day, subcutaneous, 10 units on certain days DOCA, day 72-90, 1 ml in 0.5% solution, Dieb. alt.	no (fluid balance) no (electro- lyte balance)	fluid balance electrolyte balance, blood & urine protein metabolism	Hypokinetic disturbances did not deteriorate past the end of the 3rd month. The authors recommended a medication with a broad spectrum of hormonal activity be used to counter the mechanisms of hypokinesia.  See also Petukhov and Yakovleva under Medication. Also reported by V.V. Parin ref # 53 of earlier Counter- measures report.
					<i>alt. day</i> Nerobol, day 1-72, 5 mg/day, intramuscular, day 72-100, 10 mg/day intramuscular	very (fluid balance) very (electro- lyte balance) very (protein metabolism)		
A12	K.H. Hyatt 1972, USA	research experiment	human (20) 10 controls  (10)	bedrest, 14 days	9 alpha-fluoro- hydrocortisone, 0.2 mgm daily	no (CV) slight (Na balance) slight (K balance) moderate (plasma volume) moderate (rbc mass)	CV, tilt tolerance, exercise tolerance, tyramine stimula- tion test, heat rate, EKG, arterial pressure Na balance K balance Plasma volume Red blood cell mass fluid balance	*Careful attention must be paid to avoid hypokalemia.
					human (8) bedrest, 10 days 9 alpha-fluoro- hydrocortisone, 0.4 mgm daily	very (CV) very (na balance) *no (K balance) moderate (fluid balance)		



MEDICATION

9

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A17	B.N. Petukhov et al, 1971 USSR	research experiment	human (10) 4 controls	bedrest, 120 days	Pituitrin, 1 day pre-bedrest 10 units, subcutaneous, day 1-7, 19-22, 30-35 & 41-71, 5 to 10 units, subcutaneous (3) DOCA, day 72-90, 1 ml of 0.5% solution, intramuscular, dieb. alt.	moderate (EMG)	Electromyograms, gastrocnemius, tibialis anterior	See also Krupina and Yakovleva under Medication.
			(3)		Nerobol, 1 day pre-bedrest 10 mg, day 1-7, & 19-22, 5 to 10 mg	no (EMG)		
A21	I.Ya Yakovleva 1972, USSR	research experiment	human (10) 4 controls	bedrest, 120 days	Pituitrin, day 1-30 5 units/day, 10 units on certain days Desoxy corticoster- one acetate, day 72-90, 1 ml dieb. alt.	no (intra- nasal cir- culation)	Intranasal cir- culation, rhinopneumometry	The author states that nasal vasomotor function is a reflection of a number of complex body processes associated with metabolism, the state of the endocrine and nervous systems, and general vascular tone. In-flight nasal stuffiness exhibited by cosmonauts was caused by space- flight factors of weightless- ness and acceleration on intranasal circulation, not increased oxygen atmosphere.  See also Krupina and Petukhov under Medication.
					Nerobol, day 1-28, 5 mg/day, day 72-100 10 mg/day	no (intra- nasal cir- culation)		



## DIET

10

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A10	D.R. Lockwood et al, 1972 USA	research experiment	human (5)  (3)	bedrest, 17 weeks	diet supplements, 1315 mg Ca as lactate, 1419 mg P as potassium phosphate	very (Ca balance, wks 1-11) no (Ca balance, wks 12-17) very (P balance, wks 1-11) no (P balance, wks 12-17) moderate (bone density)	Ca balance P balance bone density, gamma scan, calcaneus, tibia	See also S.B. Hulley under Diet.
A11	S.B. Hulley et al, 1971 USA	research experiment	human (5) own controls  (3)  (2)	bedrest,  24 weeks  30 weeks	12 week on/off or vice versa Hyper-Phos-K tablets, 165.9±2.3 mg P/tablet, 8 tablets/day, with meals and evening snack	moderate (Ca balance, wks 1-12) no (Ca balance, wks 12-24) very (P balance) no (calcaneus) very (radius) very (N balance) no (Mg balance) no (creatinine clearance) no (hydroxy- proline)	Ca balance, urine, feces, serum, sweat P balance, urine, feces, serum bone density, gamma scan, calcaneus and radius N balance, urine, feces creatinine clear- ance hydroxyproline, urine	See also D.R. Lockwood under Diet.
A14	P.B. Mack 1971, USA	research experiment	human (4)	bedrest, 14 days	Ca supplement, 300mg/day	no (bone density)	bone density, x-radiograph, os calcis, central talus, distal talus, capitate, distal ulna, phalanx 4-2	See also ref A14 under Exercise.



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REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A19	A.D. Voskresen- skii et al 1972, USSR	research experiment	human (15) 3 controls See Notes  (3)  (3)	*bedrest, 30 days	LBNP, horizontal position, -25-30 mm Hg, 30 hrs b.i.d., except for 3 days of rest LBNP, horizontal position, days 26-30, -50-55 mm Hg, 2.5 hrs daily	no (CV) hemodynamics (moderate)  very (CV) hemodynamics (moderate)	CV LBNP tolerance, pulse rate, arterial pressure hemodynamics, ESR, HCT, leucocyte count, erythrocyte count	Daily LBNP led to general asthenia. The authors recommend the application of LBNP only during the last 5 days of hypokinesia. No data is presented.  See also ref A2 under Exer- cise and LBNP; Electrical Stimulation of Muscle. *Also I.D. Pestov under LBNP.



## GRADIENT POSITIVE PRESSURE

13

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A1	J.F. Annis et al, 1971 USA	research experiment	human	See Notes	space activity, suit (SAS), elastic fabric, girdles, gradient pressure, 100 mm Hg to torso, 160 mm Hg to upper arms & legs, 152 mm Hg to lower arms & legs positive pressure breathing, 170 mm Hg, 3.9 psi	promising (CV)	See Notes	The history of the develop- ment of the SAS as well as the design specifications for the garment assemblies are presented; ground based laboratory and chamber tests have been conducted.



## CENTRIFUGATION

14

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A22	Ye. Yuganov, 1972 USSR	review	rats & mice	in-flight, Tu-104 aircraft	centrifuge, arm 1.25 m, 0.05 to 1.0G, See Notes	very (motor activity)	motor activity, normal posture, movement	0.28 to 0.31G minimal effective value.
			mice	rotational acceleration, ground based	centrifuge, 0.1G, disconnected vestibular apparatus	very (motor activity)	motor activity, normal posture, and movement	
			human	rotational acceleration, ground based	centrifuge, up to 0.3G, stable vestibular function	promising (work capacity)	work capacity motion sickness	Optimal tolerance level for prolonged rotation is speed of 10 degrees/sec and radius R=90 m where astronaut's weight in direction of rotation does not exceed 0.25-0.35G.



## ELECTRICAL STIMULATION OF MUSCLES

15

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A2	I.S. Balakhovskii et al, 1971 USSR	research experiment	human (15) 3 controls See Notes  (3)	bedrest, 30 days	antiorthostatic position, 4° incline to head electrical stimulation, of muscles, lower leg, hip, abdomen, back, 30 min b.i.d.	no (protein metabolism) moderate (lipid metabolism) slight (fluid metabolism) slight (mineral metabolism) moderate (carbohy- drate metabolism) no (hemo- dynamics)	protein metabolism, bilirubin, creatinine, C-reactive protein, total N, urea in blood lipid metabolism, beta-lipoprotein, non-esterized fatty acids, cholesterol, lipid P fluid metabolism, urine volume mineral metabolism, Ca, K, Na, 17-OCS, aldosterone carbohydrate metabolism, serum sugar, hydrocortisone hemodynamics, Hct, Hb, erythrocyte count, leucocyte count	Post hypodynamia water load- ing tests were the same for control and exp. groups.  See also ref A2 under Exercise and LBNP; A.D. Voskresenskii under LBNP.
A20	I.Ya Yakovleva 1972, USSR	research experiment	human (9) 3 controls  (3)	bedrest, 30 days	antiorthostatic position, 4° incline to head *electrical stimulation, of muscle	very (vestibu- lar response) very (vasomotor function)	auditory response, auditory threshold, "loudness", auditory orientatio. See Notes vestibular response, tolerance to corio- lis acceleration, spatial orientation, visual displacement, electrical stimu- lation of vestib- lar organ vasomotor function of nose, rhinopneumometry	Hearing sharpened with in- creasing duration of hypo- kinesia so that loudness dis- comfort increased.  *See I.S. Balakhovskii under Electrical Stimulation of Muscle.  See also ref A20 under Exer- ise and LBNP.



## EXERCISE AND LBNP

16

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A2	I.S. Balakhovskii et al, 1972 USSR	research experiment	human (15) 3 controls See Notes  (3)	*bedrest, 30 days	antiorthostatic position, 4° incline to head exercise, vertical tread- mill, 500 cal/day, day 1-24, 1 hr b.i.d., day 26-30, 1 hr, in LBNP LBNP, day 26-30, -35 to -45 mm Hg, 2.5 hrs/day See Notes	very (CV) moderate (protein metabolism) slight (lipid metabolism) moderate (fluid metabolism) moderate (mineral metabolism) no (carbohy- drate metabolism) very (hemo- dynamics) See Notes	CV LBNP tolerance, pulse rate, arterial pressure protein metabolism, bilirubin, creatinine, C-reactive protein, total N, urea in blood lipid metabolism, beta-lipoproteins, non-sterilized fatty acids, cholesterol, lipid P fluid metabolism, urine volume mineral metabolism, Ca, K, Na, 17-OCS, aldosterone carbohydrate metabo- lism, serum sugar, hydrocortisone hemodynamics, HCT, Hb, erythrocyte count, leucocyte count	Antiorthostatic position simulated weightlessness more effectively than horizontal bedrest. One subject re- ceived dianabol which may have increased mean Hb. LBNP exerted no appreciable effect on metabolism. Post hypo- dynamia water loading tests were the same for control and exp. groups.  See also ref A2 under Electri- cal Stimulation of Muscle; A.D. Voskresenskii under LBNP.  *See also Pestov under Exer- cise and LBNP.
A16	I.D. Pestov et, 1972 USSR	research experiment	human (9)	*bedrest, 30 days	antiorthostatic, position, 4° incline to head exercise, day 1-25, daily day 26-30, in LBNP, 1 hr & 45 min LBNP, day 26-30, -10 to -25 mm Hg, gradual increase	very (CV)	orthostatic tolerance	*See also under I.S. Balakhov- skii, Exercise & LBNP.



## EXERCISE AND LBNP

17

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A20	I.Ya. Yakovleva 1972, USSR	research experiment	human (9) 3 controls  (3)	bedrest, 30 days	antiorthostatic, position, 4° incline to head *exercise & LBNP	very (vestibular response)	auditory response, auditory threshold, "loudness", auditory orientation See Notes vestibular response, tolerance to corio- lis acceleration, spatial orienta- tion, visual displacement, electrical stimula- tion of vestibular organ vasomotor function of nose, rhinopneumometry	Hearing sharpened with in- creasing duration of hypo- kenesia, so that loudness discomfort increased. *See I.S. Balakhovskii under exercise and LBNP. See also ref A20 under Electrical Stimulation of Muscle.



## EXERCISE AND REHYDRATION

18

REF #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
A6 .	J.E. Greenleaf et al, 1972 USA	research experiment	human (8) own controls see notes	bedrest, 2 weeks	exercise, isotonic 1/2 hr per day, to 1/2 maximal oxygen uptake rehydration, 1.0 to 1.9 ml, saline-grapefruit drink, during 3 hrs prior to centri- fugation at 2.1G 3.2G and 3.8G	moderate (G <sub>z</sub> toler- ance at 2.1G) no (G <sub>z</sub> toler- ance at 3.2G & 3.8G) no (plasma volume)	G <sub>z</sub> tolerance plasma volume, HCT	Two weeks between bedrest and rehydration test was not sufficient to restore +G <sub>z</sub> tolerance to control levels. See ref # A6 also under Exercise.



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REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	EXERCISE		MEASUREMENT	NOTES	REF #
				COUNTERMEASURE REGIMEN	EFFECTIVENESS			
P.B. MACK et al. 1970 USA	research experiment	human (8) 4 controls	bedrest 56 days	Exercise, T.i.d., isotonic, Exer-genie, 8lbs, 1 beat/ sec, leg, 12 min, arm, 6 min, Exer-grip, 2 min,  isometric, 30 sec.  Daily except when 48 hr blood sam- ples were taken every 11-12th days	moderate (Ca balance)  slight (P balance)  slight (N balance)  very (water ba- lance)	Ca balance intake, urine, feces  P balance intake, urine, feces  N balance intake, urine, feces  Water balance intake, urine, est. feces	A 6 day equilibration to environment of 14L:10D, lights on 0900-2300, in- tensity 30 ft-C; ambient temperature 72± 2°F; 4 day cycle of Apollo diet.  Two subjects switched exercise/non- exercise regimes half way through bedrest.  See also P.B. Mack ref #      and C.M. Winget Ref #,      under Exercise.	

MACK, P.B., P.C. RAMBAUT, C.S. LEACH, C.M. WINGET, and J. VERNIKOS-DANELIS. 1970.  
Evaluation of Flight Foods Under Hypokinetic Conditions. Part I.  
National Aeronautics and Space Administration, NASA-CR-114780, Washington, D.C. 195 pages.



# EXERCISE

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
P.B. MACK et al 1970 USA	research experiment	human (8) 4 controls	bedrest 56 days	Exercise, T.i.d., isotonic, Exer-genie, 8 lbs, 1 beat/ sec., legs, 12 min, Exer-grip, 2 min, isometric, 30 sec  daily except when 48 hr blood sam- ples were taken every 11-12th days	See notes (17-OHCS)  no (hydroxy- proline).	17-hydroxycortico- steroids, urine, circadian rhythm  hydroxyproline urine, circadian rhythm	Subjects showed great individual varia- tion in 17-OHCS and hydroxyproline ex- cretion.  A 6 day equilibration to environment of: 14L:10D, lights on 0900-2300, intensity of 30 ft-c, ambient temperature 72± 2°F; 4 day cycle of Apollo diet.  Two subjects switched exercise/non-exercise regimes half way through bedrest.  See also P.B. Mack ref # and C.M. Winget ref # under Exercise	
		human (6) own controls (3)	bedrest 28 days (2 series)	Exercise regularly, isotonic and isometric	moderate (17 KS)	17-ketosteroids, urine, circadian rhythm	The highest amount was excreted from 8AM to noon and the lowest amount was from 8PM to 8AM	
		(3)		Exercise at will, isotonic and isometric	very (17 KS)			

MACK, P.B., P.C. REMBAUT, C.S. LEACH, C.M. WINGET and J. VERNIKOS-DANELLIS. 1970.  
Evaluation of Flight Foods Under Hypokinetic Conditions. Part III.  
National Aeronautics and Space Administration, NASA-CR-114782, Washington, D.C. 180 pages.



REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
V.I. STEPANTSOV et al 1972 USSR		research experiment	*human	bedrest, 30 days	exercise, complex trainer, training-load suit, foot-gear, elastic shock- absorbing system, treadmill, up to 10 km/hr, 50 kg horizontal work load, 1 hr, b.i.d., 4 day cycle, day 1, 1,500 kg·m/min, 320-360 Cal.  day 2, 800-1,000 kg·m/ min  day 3, 500-600 kg·m/min 450-500 Cal.  day 4, active rest, 100 Cal.	very (CV)  very (metabolism)  very (muscle coordin- ation)	CV, ECG  Metabolism, gas exchange, physical load, pre & post training  Muscle Coordination length of pace, deviation from direction of movement, walking, running, jumping	The exercise program described included exercises for maintain- ing and developing muscular strength, speed of movements, static endurance, movement coordination, & antiorthostatic load- ing.  *See I.S. Balakhovskii, I.D. Pestov & I. Ya. Yakovleva under Exercise and LBNP



## EXERCISE

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
J. Vernikos-Danellis et al USA 1972	research experiment	human (8) 56 days	bedrest, 56 days	Exercise, T.i.d., Exergenie isotonic, 20 min., isometric, 30 sec., > 800 Cal/day	*See Notes (cortisol - CR) no (triiodo- thyronine - CR) no (thyroxine - CR)	cortisol, plasma-free, circadian rhythm triiodothyronine, serum, total, circadian rhythm thyroxine, serum, circadian rhythm	<p>*Bedrest reduced the amplitude of the cortisol rhythm, but, did not affect the circadian pattern. The exercise group peaked about 1 hr prior to the controls.</p> <p>Thyroid hormone rhythms were unstable and showed rephasing with progressive bedrest.</p> <p>Six days pre-bedrest were provided for equilibration to the environment: 14L/10D, intensity of 30 ft-c at eye-level, lights on from 0900 to 2300; 20<math>\pm</math> 1°C ambient temperature; Apollo diet, 2,600 Cal/day.</p> <p>Blood samples were drawn at 4 hr intervals for 48 hour periods on 10, 20, 30, 42 and 54 during bedrest, and pre and post bedrest.</p> <p>The authors suggest: thyroid rhythms may be posture dependent; preventive measure other than exercise should be sought.</p> <p>See also C. Winget et al ref # under Exercise.</p>	
VERNIKOS-DANELIS, J., C.S. LEACH, C.M. WINGET, P.C. RAMBAUT, and P.B. MACK. Thyroid and Adrenal Cortical Rhythmicity During Bedrest. Journal of Applied Physiology 33(5):644-648.					1972.			



### Exercise

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
C.M. Winget et al USA 1972	research experiment	human (8) 4 controls	bedrest, 56 days	Exercise, T.i.d., Exergenie isotonic, 20 min., isometric, 30sec., > 800 Cal/day	*See Notes (body tempera- ture - CR)  **See Notes (heart rate - CR)	Body temperature, circadian rhythm,  Heart rate, circadian rhythm, pulse rate, cardiotachometer	*Bedrest produced a desynchronization from the environment and a decrease of the mean BT, but did not affect the circadian periodicity .  **All subjects showed a well-defined HR circadian rhythm.  Exercise did not affect the BT and HR phase relations to endocrine factors (CS, T <sub>3</sub> & T <sub>4</sub> ).  Six days pre-bedrest were provided for equilibration to the environment: 14L/10D, intensity of 30 pt-c at eye-level, lights on from 0900 to 2300; 20± 1°C ambient temperature; Apollo diet, 2600 Cal/day.  Measurements were taken at 0330, 0730, 1130, 1530, 1930 and 2330 hrs.  See also J. Vernikos-Danellis et al. Ref #                under Exercise.	
WINGET, C.M., J. VERNIKOS-DANELIS, S.E. CRONIN, C.S. LEACH, P.C. RAMBAUT, and P.B. MACK. Circadian Rhythm Asynchrony in Man During Hypokinesia. Journal of Applied Physiology 33(5):640-644.						1972.		



# EXERCISE

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
C.M. WINGET et al 1970 USA	research experiment	human (8) 4 controls	bedrest 56 days	Exercise, T.i.d., isotonic, Exer-genie, 8 lbs, 1 beat/ sec, leg, 12 min, arm, 6 min, Exer-grip, 2 min. ↑ isometric, 30 sec  Daily except when 48 hr blood samples were taken every 11-12th days.	no (tempera- ture - CR)  very (heart rate - CR)  no (creatin- ine)  no ( creatine)	temperature, deep body, circadian rhythm  heart rate pulse rate, cardiotachometer, circadian rhythm  creatinine, urine  creatine, urine	Body temperature rhythms lagged those of heart rate by an average of about 3 hours.  A 6 day equilibration to environment 14L:10D, lights on 0900-2300, inten- sity 30 ft-c; ambient temperature 72± 2°F., 4 day cycle of Apollo diet  Two subjects switched exercise/non- exercise regimes half way through bedrest.  The highest amount of creatinine and creatine was excreted from 8PM until midnights while the smallest amount was found between midnight and 8AM.  See also P.B. Mack refs # and # under Exercise	

WINGET, C.M., S.E. CRONIN, N.W. HETHERINGTON, and L.S. ROSENBLATT. 1970.  
Evaluation of Flight Foods Under Hypokinetic Conditions. Part II.  
National Aeronautics and Space Administration, NASA-CR-114781, Washington, D.C. 126 pages.



MEDICATION

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES
D.A. HANTMAN et al 1973 USA	research experiment	human (2) own controls	*bedrest 19 weeks  weeks 1-7	** Calcitonin, synthetic salmon, 100 MRC units/day, subcutaneous	no(Ca balance)  no(P balance)  no(bone density)  no(hydroxy- proline)	Ca balance, intake, urine, feces  P balance, intake, urine, feces  Bone Density, 125I gamma transmission scan, calcaneous  Hydroxyproline, urine	*Treatment was stopped at the beginning of the 7th week because of nephrotoxicity. The dose may have been too large for bedrest patients.  The entire study included 19 weeks of continuous bedrest. 4 different countermeasure regimes were applied during weeks 1-8 and 12-19, with the 3 intervening weeks of bedrest being without any type of treatment.  See D.A.Hantman ref # also under Diet; Bone Stress; and, Medication, Diet and Bone Stress,
HANTMAN, D.A., J.M. VOGEL, C.L. DONALDSON, R. FRIEDMAN, R.S. GOLDSMITH, and S.B. HULLEY. 1973.	Attempts to Prevent Disuse Osteoporosis by Treatment with Calcitonin, Longitudinal Compression, and Supplementary Calcium and Phosphate.	Journal of Clinical Endocrinology and Metabolism					



DIET

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF#
D.A. HANTMAN et al 1973 USA	research experiment	human (5) own controls	*bedrest, 19 weeks	Ca supplement, 780 mg/day,	moderate(Ca balance)	Ca balance, intake, urine, feces	*The entire study included 19 weeks of continuous bedrest. 4 different counter- measurement regimes were applied during weeks 1-8 and 12-19, with the intervening 3 weeks of bedrest being without treatment.  See D.A. Hantman ref# also under Medication; Bone Stress; and, Medication, Diet, and Bone Stress.	
		(1)	weeks 1-8	P supplement, 1327 mg/day	very(P balance)	P balance, intake, urine, feces		
		(2)	weeks 12-19	Ca supplement, 733 mg/day,  P supplement, 1327 mg/day	moderate-very (hydroxyproline)	Bone Density, <sup>125</sup> I gamma transmission scan, calcaneous		
		(2)	weeks 12-19	Ca supplement, 1294 mg/day,  P supplement, 1327 mg/day		Hydroxyproline, urine		
HANTMAN, D.A., J.M. VOGEL, C.L. DONALDSON, R. FRIEDMAN, R.S. GOLDSMITH, and S.B. HULLEY. 1973. Attempts to Prevent Disuse Osteoporosis by Treatment with Calcitonin, Longitudinal Compression, and Supplementary Calcium and Phosphate. Journal of Clinical Endocrinology and Metabolism								



## BONE STRESS

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
D.A. HANTMAN et al 1973 USA	research experiment	human(3)	*bedrest, 19 weeks	Longitudinal Compression, gravitational acceleration simulating suit, force equal to 80% of body wt., 200 min/day	no(Ca balance) no(P balance) very(bone density) slight(hydroxy- proline)	Ca balance, intake, urine, feces  P balance, intake, urine, feces  Bone Density, <sup>125</sup> I gamma transmission scan, calcaneous  Hydroxyproline, urine	*The entire study included 19 weeks of continuous bedrest. 4 different countermeasure regimes were applied during weeks 1-8 and 12-19, with the 3 intervening weeks of bedrest being without treat- ment.  See D.A. Hantman ref # also under Medication; Diet; and, Medication, Diet and Bone Stress.	
		(1)	weeks 1-8					
		(2)	weeks 12-17  weeks 18-19	Longitudinal Compression. gravitational simulatin simulating suit. force equal to 80% of body wt., 200 min/day  Same as above, force equal to 100% of body wt., 300 min/day				

HANTMAN, D.A., J.M. VOGEL, C.L. DONALDSON, R. FRIEDMAN, R.S. GOLDSMITH, and S.B. HULLEY. 1973.  
Attempts to Prevent Disuse Osteoporosis by Treatment with Calcitonin, Longitudinal Compression,  
and Supplementary Calcium and Phosphate.  
Journal of Clinical Endocrinology and Metabolism



## MEDICATION, DIET and BONE STRESS

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
D.A. HANTMAN et al 1973 USA	research experiment	human (2)	*bedrest, 19 weeks  weeks 1-8	Calcitonin, synthetic salmon, 100 MRC units/ day, subcutaneous,  Ca supplement, 780 mg/day,  P supplement, 1327 mg/day,  Longitudinal Compression, gravitational acceleration simulating suit, force equal to 80% of body wt., 200 min/day	very(Ca bal- ance)  very(P balance)  no(bone density)  very(hydroxy- proline)	Ca balance, intake, urine, feces  P balance, intake, urine, feces  Bone Density, 125I gamma transmission scan, calcaneous  Hydroxyproline, urine	*The entire study included 19 weeks of continuous bedrest. 4 different countermeasure regimes were applied during weeks 1-8 and 12-19, with the 3 intervening weeks of bedrest being without treatment.  With the combined treatment, longitudinal compression did not prevent the loss of bone density as it did when used alone.  See D.A. Hantman ref # also under Medication; Diet; and, Bone Stress.	
HANTMAN, D.A., J.M. VOGEL, Attempts to Prevent Disuse Osteoporosis by Treatment with Calcitonin, Longitudinal Compression, Journal of Clinical Endocrinology and Metabolism		C.L. DONALDSON, R. FRIEDMAN,	R.S. GOLDSMITH,	and S.B. HULLEY. 1973.				



DIET								
REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
Hoffman, R.A. .1972 USA	et al	research experiment	monkey (10) M. nemestrina adolescent	immobilization, 2 weeks See Notes	diet, adjusted to weight, 1.482 gm Ca/100 gm of diet  0.723 gm P/100 gm of diet  4.26 gm N/100 gm of diet	very (Ca balance) moderate (P balance)  moderate (N balance) no (creatinine)  moderate (creatinine) slight (serum Ca)  slight (serum P) very (serum protein) *no (bone density)	Ca balance, intake, urine, feces,  P balance, intake, urine, feces  N balance, intake, urine, feces  Creatine, urine  Creatinine, urine  Serum Ca  Serum P  Serum Protein  Bone Density, x-radiograph, lumbar vertebrae, 4,3,2 & 1 hand phalanx 4/2, capitate, distal radius, distal ulna, olecranon, medial humeral, epicondyle, patella, neck of femur, os calcis	Restraint was identical to the type used on Biosatellite III.  *Serum pool and excretion in urine & feces cannot explain discrepancy between bone density loss and Ca & P balance findings.  Authors suggest that there is a migration of minerals from the parts of the skeleton that lose density to the epiphyseal areas.

HOFFMAN, R.A., P.B. MACK, and W.N. HOOD. 1972.  
Comparison of Calcium and Phosphorus Excretion with Bone Density Changes  
During Restraint in Immature Macaca nemestrina Primates.  
Aerospace Medicine 43(4):376-383.



## EXERCISE

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
S.B. HULLEY et al 1972 USA	research experiment	human (3)	bedrest, 12 weeks	Exer-Genie, 8 lbs resistance, one stroke/sec, 3 periods/day, 80 min/day total	no(Ca balance) no(P balance) no(hydroxy- proline) no(bone density)	Ca balance, intake, urine, feces  P balance, intake, urine, feces  Hydroxyproline, urine  Bone Density, <sup>125</sup> I gamma trans- mission scan, calcaneous	Magnitude and duration of the program were deemed insufficient to effectively simulate ambulation.  Calcaneal mineral remaining at any time during bedrest was a function of the baseline calcaneal material divided by the baseline urinary hydroxyproline.  See S.B. Hulley ref # also under Medication; Diet; and, Gradient Positive Pressure.	

HULLEY, S.B., D.R. LOCKWOOD, C.L. DONALDSON, and J.M. VOGEL. 1972.  
Attempts to Prevent Bone Mineral Loss During Prolonged Bed Rest.  
In: International Astronautical Federation, Paris, France, International  
Astronautical Congress, 23rd, Vienna, Austria, 8-15 Oct, 1972. 10 pages.



MEDICATION

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	<del>REF</del>
S.B. HULLEY et al 1972 USA	research experiment	human (3)	bedrest, 16 weeks	Medication, calcitonin, synthetic salmon, 100 MRC units,	no(Ca balance) no(hydroxy- proline) no(bone density)	Ca balance, intake, urine, feces Hydroxyproline, urine Bone Density, <sup>125</sup> I gamma transmission scan, calcaneous	Calcaneal material remaining at any time during bedrest was a function of the baseline calcaneal material divided by the baseline urinary hydroxy- proline.  See S.B. Hulley ref # also under Exercise; Diet, and Gradient Positive Pressure.	

HULEEY, S.B. D.R. LOCKWOOD, C.L. DONALDSON, and J.M. VOGEL. 1972.  
Attempts to Prevent Bone Mineral Loss During Prolonged Bed Rest.  
In: International Astronautical Federation, Paris, France.  
International Astronautical Congress, 23rd, Vienna, Austria, 8-15 Oct., 1972. 10 pages.



# DIET

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES	REF #
S.B. HULLEY et al 1972 USA	research experiment	human (5)	bedrest, 16 weeks	Diet, P supplement, 1.3 gm/day, oral	no(Ca balance) no(hydroxy- proline) no(bone density)	Ca balance, intake, urine, feces Hydroxyproline, urine Bone Density, 125I gamma transmission scan, calcaneous	*The use of Ca & P supplements prevented bone loss in 2 subjects, but the data lie within the 95% confidence limits; the third subject lost mineral rapidly.  Calcaneal mineral remaining at any time during bedrest was a function of the baseline calcaneal material divided by the baseline urinary hydroxyproline.	
		human (3)	" "	Diet, Ca supplement, 1.2 gm/day. oral,  P supplement, 1.3 gm/day, oral	very(Ca balance) no(hydroxy- proline)  *no-very (bone density)		See S.B. Hulley ref # also under Exercise; Medication; and, Gradient Positive Pressure.	

HULLEY, S.B., D.R. LOCKWOOD, C.L. DONALDSON, and J.M. VOGEL. 1972.  
Attempts to Prevent Bone Mineral Loss During Prolonged Bed Rest.  
In: International Astronautical Federation, Paris, France.  
International Astronautical Congress, 23rd, Vienna, Austria, 8-15 Oct., 1972. 10 pages.



## BONE STRESS

REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENT	NOTES
S.B. HULLEY et al 1972 USA	research experiment	human (4)	bedrest, 13 weeks	Longitudinal Compression, gravitational acceleration simulating suit, force equal to 80% of body weight, 4 hrs/day	no(Ca balance) no(P balance) no(hydroxy- proline) no(bone density)	Ca balance, intake, urine, feces  P balance, intake, urine, feces  Hydroxyproline, urine  Bone Density, <sup>125</sup> I gamma transmission scan, calcaneous	Magnitude and duration of the program were deemed insufficient to effectively simulate ambulation  Calcaneal mineral remaining at any time during bedrest was a function of the baseline calcaneal material divided by the baseline urinary hydroxyproline.  See S.B. Hulley ref # also under Exercise; Medication; and Diet.

HULLEY, S.B. D.R. LOCKWOOD, C.L. DONALDSON, and J.M. VOGEL. 1972.  
Attempts to Prevent Bone Mineral Loss During Prolonged Bed Rest.  
In: International Astronautical Federation, Paris, France.  
International Astronautical Congress, 23rd, Vienna, Austria, 8-15 Oct., 1972. 10 pages.



## DIET

REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
P.B. MACK, 1966 USA		research experiment	human (4)	bedrest, 14 days	Ca Supplement, 0.5 gm/day	no(bone density) no (Ca balance)	Bone Density, x-radiograph, os calcis, phalanx 5-2	Phalanx showed little bone loss during 14 day bed- rest, but, a signi- ficant amount during the last half of the 30 day bedrest. Phosphorus was provided during each experiment to keep the Ca:P ratio within the 2:1 to 1:2 range.
			(4)	"	Ca Supplement, 0.7 gm/day	no-slight (bone density) slight (Ca balance)	Ca balance, intake, urine, feces	
			(4)	"	Ca Supplement, 1.5 gm/day	slight (bone density) moderate (Ca bal- ance)		
			(4)	"	Ca Supplement, 2.0 gm/day	moderate (bone density) slight (Ca balance)		
			(5)	bedrest, 30 days	Ca Supplement, 2.0 gm/day	moderate (bone density) moderate (Ca bal- ance)		

[MACK, P.B. Calcium Loss Studies During Human Bed Rest: A Preliminary Report.  
In: NASA, Progress in Development of Methods in Bone Densitometry. pp. 169-177.  
National Aeronautics and Space Administration, NASA-SP-64, Washington, D.C. 1966]



EXERCISE								
REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
P.B. MACK et al, 1967 USA		research experiment	human	bedrest, 14 days	Exercise, isotonic & isometric, 4 times/day	moderate (bone density, os calcis)  no (bone density, phalanxes)	Bone Density, x-radiograph, os calcis, phalanx 4-2 & 5-2	Report of flight findings on bone density for Gemini IV, V, and VII were compared to bedrest data.  See ref # also under Diet; Exercise and Diet.
<p>[MACK, P.B., G.P. VOSE, P.A. LACHANCE, and F.B VOGT. 1967. Bone Demineralization of Foot and Hand of Gemini-Titan IV, V, and VII Astronauts During Orbital Flight. American Journal of Roentgenology, Radium Therapy and Nuclear Medicine 100(3):503-511.]</p>								



REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
P.B. MACK et al 1967 USA		research experiment	human (2)	In-flight, Gemini IV, 4 days	Ca Supplement, ≈0.7 gm/day	no-slight (bone density)	bone density, x-radiograph, os calcis, talus, phalanx 4-2 & 5-2, capitate	See ref # also under Exercise; Exercise and Diet.
			(2)	In-flight, Gemini V, 8 days	Ca Supplement, ≈0.35 gm/day	no (bone density)		

[MACK, P.B., G.P. VOSE, P.A. LACHANCE, and F.B. VOGT. 1967.  
Bone demineralization of foot and hand of Gemini-Titan IV,V, and VII  
astronauts during orbital flight.  
American Journal of Roentgenology, Radium Therapy and Nuclear Medicine  
100(3):503-511.]



## EXERCISE and DIET

REF. #	REFERENCE	DOCUMENTATION	EXPERIMENTAL SUBJECTS	WEIGHTLESSNESS ANALOG	COUNTERMEASURE REGIMEN	EFFECTIVENESS	MEASUREMENTS	NOTES
P.B. MACK et al 1967 USA		research experiment	human (2)	In-flight, Gemini VII, 14 days	Exercise, isotonic & isometric, 4 times/day  Ca Supplement, ≈0.9 gm/day	moderate (bone density)	bone density, x-radiograph, os calcis, talus, phalanx 4-2 & 5-2, capitate	See ref # also under Exercise; Diet.
[MACK, P.B., G.P. VOSE, P.A. LACHANCE, and F.B. VOGT. 1967. Bone demineralization of foot and hand of Gemini-Titan IV, V, VII astronauts during orbital flight. American Journal of Roentgenology, Radium Therapy and Nuclear Medicine 100(3):503-511.]								