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THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS WEARING PRESSURE SUITS AND ON A DIET OF PRECOOKED FREEZE DEHYDRATED FOODS

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MIAMI VALLEY HOSPITAL

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JOINT NASA/USAF STUDY

Aerospace Medical Research Laboratories

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AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169–8.

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FOREWORD

This research was initiated by the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, and was accomplished by the Department of Research of the Miami Valley Hospital, Dayton, Ohio, and the Biotechnology Branch, Life Support Division, Biomedical Laboratory, Aerospace Medical Research Laboratories. This effort was supported jointly by the USAF under Project No. 7164, "Biomedical Criteria for Aerospace Flight," Task No. 716405, "Aerospace Nutrition," and NASA Manned Spacecraft Center, Houston, Texas, under Defense Purchase Request R-85, "The Protein, Water, and Energy Requirements of Man Under Simulated Aerospace Conditions." This contract was initiated by 1st Lt John E. Vanderveen, monitored by 1st Lt Keith J. Smith, and completed by Alton E. Prince, PhD, for the USAF. Technical contract monitor for NASA was Paul A. Lachance, PhD. The research effort of the Department of Research of the Miami Valley Hospital, was accomplished under Contract AF 33 (657)- 11716. Bernard J. Katchman, PhD, and George M. Homer, PhD, were technical contract administrators, and Robert E. Zipf, MD, Director of Research, had overall contractual responsibility.

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This technical report has been reviewed and is approved.

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ABSTRACT

Eight human male volunteers participated in two 6-week simulated aerospace studies. During this time the subjects wore an unpressurized MA-10 pressure suit for 16 consecutive days and ate a 4-day cycle diet composed of precooked freeze dehydrated foods or a matched 4-day cycle diet composed of fresh foods. The food was served at room temperature. Each diet was comprised of about 330 g of carbohydrate, 95 g of crude protein, 87 g of fat, and 2500 kcal per day. The diets were organoleptically acceptable and efficiently utilized. Only minimal weight changes were observed. Metabolic balances showed adequate adjustment to the diets; all subjects were in positive balance for nitrogen and for the major inorganic constituents. The wearing of the MA-10 pressure suit did not affect protein or caloric requirements but water intake did increase significantly by 17%. There were no significant changes in blood pressure or oral temperature. All other clinical measurements were in the normal range of clinical values. All subjects maintained excellent health throughout all the test periods.

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SECTION I

INTRODUCTION

A series of experiments have been designed to determine the nutritional requirements of man under simulated aerospace conditions. Although the nutritional requirements of man in an aerospace environment cannot be determined completely until space systems for long term flight are available, data obtained under simulated aerospace conditions may serve as a basis for a more definitive approach than is possible with data extant to our evaluation of the biochemical and physiological effects of aerospace stress.

In a previous study (1) 4 untrained human subjects were confined in a controlled activity facility (CAF)* and ate a metabolic diet. Neither the 6-week confinement nor the wearing of an unpressurized MA-10 pressure suit** continuously for 14 days had any effect upon the measured biochemical and physiological parameters.

In this study 8 human subjects were confined in the CAF for 6 weeks and wore an unpressurized MA-10 pressure suit for 16 days. They ate an experimental metabolic diet made up of precooked freeze dehydrated foods or a matched metabolic diet of fresh foods. Selected biochemical and physiological parameters were measured to evaluate the nutritional requirements and general health status of the subjects.

SECTION II

METHODS

Two separate 6-week experiments were carried out during which 8 human male subjects were confined to the CAF. Each of these individuals was selected after extensive medical, psychiatric, and microbiological examinations. The physical characteristics of these subjects are listed in table I.

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* The controlled activity facility (CAF) at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, was used to provide the simulated aerospace conditions.

** The MA-10 pressure suits were furnished for these experiments by the Manned Spacecraft Center, NASA, Houston, Texas.

Each subject was required to adhere to a controlled activity schedule designed to provide work, exercise, total relaxation, and sleep. The activity schedule is shown in table II. Psychological testing was carried out each day and consisted of the following tests: Vigilance Performance, Transposition of Numeric Symbols, Time Estimation Cost Tolerance, and Complex Coordination. The 5BX plan or a treadmill was used during the exercise periods. Blood pressure measurements were taken after the first exercise period each day. Blood pressure and oral temperature were taken each morning before the subjects left their beds and oral temperature was taken each night before bedtime. The 24-hour urine collection period ended at each morning void. Body weights were taken each morning after voiding. Oral hygiene was limited to a gingival stimulator and an abrasive gum in experiment 1, and the Oral B electric toothbrush used with distilled water and a gingival stimulator in experiment 2. Face and hand hygiene was accomplished by use of wet and dry paper wipes. The Whirlpool windup vacuum razor was available for shaving or trimming the beard. During free time, the subjects watched television, read, or worked on handicraft projects. Newspapers, current magazines, and mail were supplied daily. The men were monitored 24 hours a day and were examined daily by a physician.

The experimental design is shown in table III. This experimental design provides for pairs of subjects to participate in a particular sequence of diets and wearing the MA-10 pressure suits. Each subject wore the MA-10 pressure suit for 16 consecutive days and ate either the control diet or the experimental diet. The suits were ventilated by pumping filtered atmospheric air through the suits at a rate of 200 to 280 cubic liters per minute.

The metabolic diets served in these experiments were composed of either fresh foods (tables IV-VII) or precooked freeze dehydrated foods (tables VIII-XI). Each metabolic diet was designed to provide 4 meals per day in 4-day cycles; 16 different meals of fresh foods and an equal number of meals of precooked freeze dehydrated foods were served. All meals were served at room temperature. From the calculated compositions, the fresh and dehydrated food (3) diets were to provide 324 g of carbohydrate, 103 g of protein, and 88 g of fat for a daily caloric intake of about 2500 kcal. After the first experiment was completed, the overall food analysis was found to be 336.9 g of carbohydrate, 86.9 g of protein, and 98.9 g of fat for the fresh food diet, and 328.1 g of carbohydrate, 92.5 g of protein, and 88.4 g of fat for the dehydrated food diet. For the second experiment, the fresh food diet was modified to increase protein and decrease fat as follows: diet 1, meal C - 27 g of whole egg and 6 g of sugar added to chocolate pudding; meals A and D - 5 g of butter subtracted; diet 2, meal B - 27 g of whole egg added to vanilla pudding recipe; diet 3, meal B - 5 g of butter subtracted; meal C - 6 g of sugar added to butterscotch pudding recipe; diet 4, meal B - 27 g of whole egg and 6 g of sugar added to and 2 g of butter subtracted from banana pudding recipe.

The metabolic diet as well as the adjusted diets (tables IV-XI) were randomly sampled and analyzed at least two times during each 6-week experiment. These analyses included determinations for moisture (4), nitrogen (5,6), fat (7), fiber (cellulose) (8), ash (9), energy (10), calcium (11), phosphorus (12), sodium and potassium (13), and chloride (14). The amount of carbohydrate was calculated as the difference between total sample weight and the sum of the weights of moisture, protein, fat, fiber, and ash (15). Water was consumed ad libitum and the individual intake of water was accurately measured. The amount of metabolic water produced from the combustion of food was calculated by the method of Consolazio (16).

Fasting blood samples were drawn from each subject twice a week. A complete blood count was performed and included white blood cell count, differential smear, and microhematocrit (17), and total eosinophil count (18). Each blood sample was also analyzed for hemoglobin (19), glucose (20), creatinine (21), calcium (22), chloride (23), sodium (24), and phosphorus (25).

Twenty-four hour urine samples were collected and the volume, *p*H, specific gravity, qualitative albumin, total solids, and moisture content (26) determined. The daily urine samples were pooled into either 48-hour or 96-hour specimens and the following chemical analyses were performed: total nitrogen (5,6), calcium (27), phosphorus (12), sodium (13), chloride (14), total energy (10), and creatinine (28). All samples were stored in a refrigerator during collection and then frozen until analyzed.

Individual fecal samples were collected in plastic bags and stored in a deep-freeze as received. Individual samples were pooled into at least 4-day samples. The pooled samples were weighed, homogenized with water and sulfuric acid, dried overnight in a forced air oven at 105 to 110°C, and stored in an air tight container until analyzed. The following analyses were performed: moisture (4), total nitrogen (5,6), total fat (7), fiber (8), ash (9), calcium (11,27), phosphorus (12), sodium and potassium (13), and total energy (10). Nitrogen in food, fecal, and urinary samples in experiment 1 was analyzed by a Kjeldahl method. In experiment 2 the nitrogen in food, feces, and urine was analyzed by means of the nitrogen analyzer (6). Fecal and food nitrogen obtained by either method is acceptable. However, when certain urine samples were rerun by the Kjeldahl method they were found to be in the order of 10% lower than the analyzer method. Unfortunately it was not possible to rerun all the urine samples and therefore the data presented is that obtained with the nitrogen analyzer. The nitrogen analyzer is an instrument which utilizes the Dumas methof for nitrogen, a method used extensively by organic chemists. In this method, organic and inorganic nitrogen are converted to nitrogen gas. Carbon dioxide is trapped in alkali; long chain carbon compounds that produce methane instead of carbon dioxide will give high values because methane is not soluble in alkali. Although the urinary nitrogen data presented here are likely to be about 10% too high, they have been used in the calculation of the balances.

TABLE I

PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

Subject No.	Age	Weight		Height	
		kg	lb	cm	in
9	26	61.4	135	174	68
10	22	83.6	184	175	69
11	20	68.2	150	176	69
12	21	81.8	180	179	70
13	22	75.0	165	176	69
14	21	59.5	131	174	68
15	22	75.0	165	174	68
16	22	64.1	141	166	65

TABLE II

DAILY ACTIVITY SCHEDULE

Time	Activity
0645-0730	Wake, void, personal hygiene, oral temperature
0730-0815	Meal A
0815-0830	Housekeeping
0830-1000	Psychological testing
1000-1030	Biological samples
1030-1100	Free time, physiological measurements, exercises
1100-1130	Free time
1130-1215	Meal B
1215-1230	Free time
1230-1400	Psychological testing
1400-1530	Free time
1530-1615	Meal C
1615-1800	Free time
1800-1945	Exercises
1945-2000	Housekeeping
2000-2045	Meal D
2045-2300	Free time, personal hygiene, oral temperature
2300	Lights out

TABLE III

EXPERIMENTAL DESIGN

Subject No.	Days				
	4	16	4	16	2
9, 13	Control diet* no suit	Control diet suit‡	Exptl. diet† no suit	Exptl. diet no suit	Control diet no suit
10, 14	Control diet no suit	Control diet no suit	Exptl. diet no suit	Exptl. diet suit	Control diet no suit
11, 15	Exptl. diet no suit	Exptl. diet suit	Control diet no suit	Control diet no suit	Control diet no suit
12, 16	Exptl. diet no suit	Exptl. diet no suit	Control diet no suit	Control diet suit	Control diet no suit

* Control diet was composed of fresh foods served at room temperature.

† Experimental diet was composed of precooked freeze dehydrated foods reconstituted with water and served at room temperature.

‡ MA-10 pressure suit.

TABLE IV

FRESH FOOD METABOLIC DIET 1*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grapefruit juice	185.0	20.50	0.90	0.20
	Sugar frosted flakes	25.0	22.38	1.13	0.04
	Half and Half	30.0	1.30	0.90	3.00
	Beef and vegetables	80.0	2.42	18.92	4.32
	Toast	12.0	6.30	1.04	0.37
	Butter	8.0	0.00	0.00	6.40
	Banana cube	22.5	13.44	2.52	5.64
	Apricots	72.0	12.84	0.36	0.06
		434.5	79.18	25.77	20.03
Meal B	Corn chowder	201.0	37.38	5.59	4.78
	Peanut butter sandwich	38.0	13.13	6.70	10.13
	Beef	40.0	0.00	11.74	2.68
	Potato	80.0	15.28	1.60	0.08
	Butter	3.0	0.00	0.00	2.40
	Pound cake	20.0	13.83	0.78	4.50
		382.0	79.62	26.41	24.57
Meal C	Chicken sandwich	37.0	9.06	6.25	0.34
	Canadian bacon	28.0	3.82	7.90	5.35
	Toast	39.0	20.10	3.38	1.18
	Butter	5.0	0.00	0.00	4.00
	Chocolate pudding	267.0	48.00	7.25	10.56
		376.0	80.98	24.78	21.43
Meal D	Roast beef	67.0	0.00	19.51	4.46
	Toast	37.0	19.00	3.20	1.12
	Butter	15.0	0.00	0.00	12.00
	Pineapple cake	92.0	40.30	3.78	5.64
	Fruit cocktail	90.0	16.75	0.23	0.31
	Tea and sugar	186.0	7.70	0.40	0.00
		487.0	83.75	27.12	23.53
Daily total		1679.5	323.53	104.08	89.56
Total calories		2517			

* Values calculated from Bowes and Church (2).

TABLE V

FRESH FOOD METABOLIC DIET 2*

		Weight g	CHO g	Protein g	Fat g
Meal A	Orange-grapefruit juice	176.0	18.68	1.05	0.08
	Sugar frosted flakes	20.0	17.90	0.90	0.03
	Skimmed milk	120.0	5.60	3.96	0.10
	Fried chicken leg	45.0	1.69	11.80	5.96
	Cheese sandwich	34.0	6.50	6.68	7.43
	Brownies	39.0	21.66	1.71	7.79
	Tea and sugar	186.0	7.70	0.40	0.00
		620.0	79.73	26.50	21.39
Meal B	Beef and gravy	106.0	10.38	16.45	6.62
	Potato salad	72.0	10.91	5.66	12.95
	Cinnamon toast	22.0	9.30	1.04	3.57
	Apricots	150.0	26.75	0.75	0.13
	Vanilla pudding	86.0	25.20	2.03	0.05
		436.0	82.54	25.93	23.32
Meal C	Orange juice	172.0	18.80	1.30	trace
	Tuna salad	85.0	3.40	19.10	10.83
	Mushroom soup	297.0	11.40	3.45	11.55
	Toast	12.0	6.30	1.04	0.37
	Applesauce	210.0	43.75	0.35	0.53
		776.0	83.65	25.24	23.28
Meal D	All Star cereal	25.0	22.38	1.30	0.05
	Skimmed milk	60.0	2.80	1.98	0.18
	Beef sandwich	37.0	3.02	9.59	2.15
	Creamed carrots	108.0	7.90	1.80	4.50
	Toast	37.0	19.00	3.20	1.12
	Butter	6.0	0.00	0.00	4.80
	Cocoa	188.0	30.70	5.24	5.09
		461.0	85.80	23.11	17.89
Daily total		2293.0	331.72	100.78	85.88
Total calories		2503			

* Values calculated from Bowes and Church (2).

TABLE VI

FRESH FOOD METABOLIC DIET 3*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grape juice	100.0	18.28	0.39	trace
	Sugar frosted flakes	10.0	8.95	0.45	0.02
	Skimmed milk	30.0	1.40	0.99	0.03
	Toast	12.0	6.30	1.04	0.37
	Butter	5.0	0.00	0.00	4.00
	Salmon salad	141.0	6.00	20.49	19.38
	Fruit compote	153.0	32.25	0.73	0.18
	Tea and sugar	186.0	7.70	0.40	0.00
		637.0	80.88	24.49	23.98
Meal B	Orange-pineapple juice	183.0	21.96	0.99	0.08
	Spaghetti and meat	95.0	5.65	10.00	9.52
	Beef sandwich	45.0	3.02	9.59	8.55
	Date cake	84.0	46.54	3.68	7.58
		407.0	77.17	24.26	25.73
Meal C	Grapefruit juice	185.0	20.50	0.90	0.20
	Hard cooked egg	54.0	0.30	6.90	5.50
	Broiled bacon	7.0	0.20	1.80	4.40
	Chicken and vegetables	94.0	3.78	15.65	0.45
	Butterscotch pudding	164.0	55.40	4.30	9.50
		504.0	80.18	29.55	20.05
Meal D	Potato soup	251.0	28.67	4.45	6.40
	Shrimp	60.0	0.00	16.00	0.80
	Pineapple cubes	35.0	20.90	4.10	8.40
	Gingerbread	50.0	34.88	2.44	4.12
		396.0	84.45	26.99	19.72
Daily total		1944.0	322.68	105.29	89.48
Total calories		2517			

* Values calculated from Bowes and Church (2).

TABLE VII

FRESH FOOD METABOLIC DIET 4*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grape juice	140 0	25.59	0.54	trace
	Sausage	70.0	2.35	19.83	17.11
	Toast	39.0	20.10	3.38	1.18
	Cocoa	188.0	30.70	5.24	5.09
		437.0	78.74	28.99	23.38
Meal B	Chicken salad	119.0	2.87	22.57	14.72
	Creamed green beans	143.0	7.70	2.40	4.20
	Banana pudding	220.0	57.90	4.66	1.80
	Tea	186.0	7.70	0.40	0.00
		668.0	76.17	30.03	20.72
Meal C	Blended apple-pineapple juice	390.0	51.00	0.85	0.22
	Ham and applesauce	58.0	10.07	7.95	3.07
	Peanut butter sandwich	38.0	13.13	6.70	10.13
	Potato salad	72.0	10.91	5.66	12.95
		558.0	85.11	21.16	26.37
Meal D	Grape juice	140.0	25.59	0.54	trace
	Pea soup	192.0	23.25	6.30	4.03
	Chicken and gravy	203.0	13.83	15.78	14.00
	Apricots	105.0	18.70	0.52	0.09
		640.0	81.37	23.14	18.12
Daily total		2303.0	321.39	103.32	88.59
Total calories		2496			

* Values calculated from Bowes and Church (2).

TABLE VIII

FREEZE DEHYDRATED FOOD METABOLIC DIET 1*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grapefruit juice	175.0	18.9	1.00	trace
	Apricot cereal cubes	37.0	25.5	3.10	6.10
	Toast	9.5	4.7	1.60	2.70
	Beef and vegetables	109.5	6.9	14.30	2.00
	Banana cube	37.5	22.4	4.20	9.40
		368.5	78.4	24.20	20.20
Meal B	Corn chowder	196.0	37.0	4.90	9.40
	Peanut butter sandwich	27.5	8.1	8.50	9.20
	Beef bites	14.0	2.0	10.40	0.40
	Potato chip blocks	32.3	20.5	5.17	6.79
	Pound cake	14.5	7.8	1.20	4.00
		284.3	75.4	30.17	29.79
Meal C	Chicken sandwich	14.5	3.8	8.50	0.90
	Bacon squares	15.0	1.9	7.90	3.50
	Toasted bread cubes	35.5	21.1	5.30	7.40
	Chocolate pudding	182.0	54.7	2.70	9.20
		247.0	81.5	24.40	21.00
Meal D	Roast beef	111.0	2.4	18.50	3.60
	Toast	19.0	9.4	3.20	5.40
	Pineapple fruitcake	78.8	44.3	5.00	15.40
	Fruit cocktail	106.0	20.5	0.60	trace
	Tea	148.0	7.7	0.10	trace
		462.8	84.3	27.40	24.40
Daily total		1362.6	319.6	106.17	95.39
Total calories		2562			

* Values calculated from Bowes and Church (2).

TABLE IX

FREEZE DEHYDRATED FOOD METABOLIC DIET 2*

		Weight g	CHO g	Protein g	Fat g
Meal A	Orange-grapefruit juice	175.0	18.8	1.20	trace
	Sugar frosted flakes	120.8	31.3	3.40	0.10
	Chicken bites	19.0	1.1	11.80	4.10
	Cheese sandwich	18.5	3.6	8.00	5.40
	Brownies	31.0	14.4	2.40	11.80
	Tea	8.0	7.7	0.10	trace
		372.3	76.9	26.90	21.40
Meal B	Beef and gravy	120.0	8.8	18.60	4.30
	Potato salad	81.5	8.1	6.00	9.80
	Cinnamon toast	11.4	7.0	1.10	2.80
	Apricot pudding	210.0	61.4	1.30	4.90
		422.9	85.3	27.00	21 80
Meal C	Orange juice	175.0	18.8	1.30	trace
	Tuna salad	79.5	3.3	19.50	11.60
	Mushroom soup	203.0	20.0	2.60	8.60
	Toast	9.5	4.7	1.60	2.70
	Applesauce	168.0	40.5	0.30	0.20
		635.0	87.3	25.30	23.10
Meal D	All Star cereal	108.0	18.7	3.50	0.20
	Beef sandwich	16.8	3.6	9.50	2.50
	Toasted bread cubes	35.5	20.1	5.30	7.40
	Carrots in cream sauce	99.0	7.9	1.80	4.10
	Cocoa	182.0	31.8	3.10	5.10
		441.3	82.1	23.20	19.30
Daily total		1871.5	331.6	102.40	85.60
Total calories		2506			

* Values calculated from Bowes and Church (2).

TABLE X

FREEZE DEHYDRATED FOOD METABOLIC DIET 3*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grape juice	181.0	25.7	0.5	trace
	Strawberry cereal cubes	36.0	24.5	3.3	6.20
	Toast	9.5	4.7	1.6	2.70
	Salmon salad	123.0	0.7	19.2	16.60
	Peaches	104.0	17.9	1.0	trace
	Tea	148.0	7.7	0.1	trace
		601.5	81.2	25.7	25.50
Meal B	Orange-pineapple juice	179.0	23.1	1.0	trace
	Spaghetti and meat	105.0	6.2	9.9	2.90
	Beef sandwich	16.8	3.6	9.5	2.50
	Date fruitcake	73.6	46.5	3.2	8.90
		374.4	79.4	23.6	14.30
Meal C	Grapefruit juice	175.0	18.8	1.3	trace
	Bacon and egg bites	26.0	1.1	8.9	15.00
	Chicken and vegetables	109.0	3 7	17.6	1.40
	Butterscotch pudding	182.0	58.2	1.2	1.80
		492.0	81.8	29.0	24.20
Meal D	Potato soup	188.0	34.3	2.8	8.20
	Shrimp cocktail	86.0	9.6	15.4	1.60
	Pineapple cubes	35.0	20.9	4.1	8.40
	Gingerbread	31.0	18.0	1.8	6.70
		341.0	82.8	24.6	24.90
Daily total		1808.9	325.2	102.9	88.90
Total calories		2513			

* Values calculated from Bowes and Church (2).

TABLE XI

FREEZE DEHYDRATED FOOD METABOLIC DIET 4*

		Weight g	CHO g	Protein g	Fat g
Meal A	Grape juice	181.0	25.9	0.5	trace
	Sausage	124.0	2.8	20.9	13.10
	Toasted bread cubes	35.5	20.1	5.3	7.40
	Cocoa	42.0	31.8	3.1	5.10
		382.5	80 6	29.8	25.60
Meal B	Chicken salad	126.0	0.7	23.8	15.80
	Green beans in cream sauce	99.0	7.5	2.0	3.80
	Banana pudding	210.0	64.1	0.5	2.60
	Tea	148.0	7.7	0.1	trace
		583.0	80.0	26.4	22.20
Meal C	Pineapple juice mix	182.0	26.5	0.6	trace
	Apple juice mix	180.0	25.2	0.1	trace
	Ham and applesauce	80.0	9.4	9.1	3.90
	Peanut butter sandwich	27.5	8.1	8.5	9.20
	Potato salad	81.5	8.1	6.0	9.80
		551.0	77.3	24.3	22.90
Meal D	Grape juice	181.0	25.7	0.5	trace
	Pea soup	189.0	28.9	6.8	8.50
	Chicken and gravy	109.0	8.6	12.6	1.10
	Apricot cubes	32.5	18.7	4.0	8.30
		511.5	81.9	23.9	17.90
Daily total		2028.0	319.8	104.4	88.60
Total calories		2494			

* Values calculated from Bowes and Church (2).

TABLE XII

MEAL EVALUATION FORM

Name ______________________________ Date ______________

Rate each item with the number that best indicates your taste.

9 - Like Extremely
8 - Like Very Much
7 - Like Moderately
6 - Like Slightly
5 - Neither Like Nor Dislike
4 - Dislike Slightly
3 - Dislike Moderately
2 - Dislike Very Much
1 - Dislike Extremely

FOOD	SCORE	Do Not Mark in These Spaces
Grapefruit sections		
Egg		
Toast		
Strawberry jelly		
Coffee and sugar		

Additional Comments: ______________________________

Meal evaluation forms were completed by each subject after every meal to determine the organoleptic quality of the food. Acceptability of the food was assessed by using a 9-point graduated hedonic scale (table XII).

SECTION III

RESULTS

The average composition of the 4-day cycle diets fed in each experiment is shown in table XIII where DD designates precooked freeze dehydrated food diet and FD designates the fresh food diet. The DD1 (expt. 1) and DD2 (expt. 2) prepared from the experimental precooked freeze dehydrated foods agree in composition within experimental error. As pointed out before, FD1 was lower in protein and higher in fat than DD1 and adjustments were made so that FD2 did match DD2. This is seen in table XIII. The metabolizable caloric intake per day from carbohydrate, fat, and protein is 2530 kcal for experiment 1 and 2490 kcal for experiment 2, when calculated (29) from the data in table XIII. These results compare favorably with the calculated values shown in tables IV through XI where the average for experiment 1 is 2515 kcal. The experimentally determined metabolizable caloric intake obtained from bomb calorimetry of food, feces, and urine are shown in table XIV. The overall average of 2448 kcal is in excellent agreement with the calculated value of 2509 kcal obtained from the data in table XIII. Table XIV also shows that both the experimental and fresh food diets were highly digestible; the combined subject average was 95.8%. There were no differences among the subjects, between the diets when the subjects were wearing unpressurized MA-10 pressure suits with respect to digestibility or metabolizable calories.

The acceptabilities of the individual food items of the 4-day cycle fresh food diet and 4-day cycle experimental diet are shown in tables XV and XVI, respectively. The mean and standard deviations of the 8 subjects' acceptability ratings for each food item have been computed. There are 15 fresh food items and 33 precooked freeze dehydrated food items that were rated lower than 7 (like moderately). However, if one allows for individual variation of 2 standard deviations around a mean rating (95% confidence interval), then there are only 2 fresh food items (pea soup and creamed carrots) that rate less than 7. Similarly, 4 precooked freeze dehydrated items were rated less than 7; these were muchroom soup, creamed carrots, pea soup, and creamed green beans. Note that upon the basis of mean rating above there are a total of 48 items rated less than 7 and this number is reduced to a total of 6 when individual variations are taken into account. This is due to the very large coefficients of variance for those food items rated less than 7. A good example is the food item ham and applesauce, table XVI, diet 4 rated 5.5±2.3. The coefficient of variance is about 50%; the actual ratings are 2, 3, 4, 6, 6, 7, 8, 8. The mean value of 5.5 obviously is not a reliable index of acceptability except for ratings well below or well above 7. In most cases, the higher the rating the smaller the coefficient of variance. A more detailed statistical analysis of the data is presented elsewhere (30). It was shown that 5 precooked freeze dehydrated food items and 1 fresh food item became less acceptable with time. Seven precooked freeze dehydrated food items and 3 fresh food items increased in acceptability with time. Thus, there is no substantial practical effect of monotony. Table XVII is a comination of the acceptabilities of the metabolic diets by meal as well as their overall averages. Of the 16 meals served with fresh food items, 3 were rated less than 7, and of the 16 meals served with the experimental food items, 8 were rated less than 7. The overall average acceptabilities of the fresh food diet and the experimental food diet are rated 7. Overall, the food was rated acceptable.

Table XVIII shows the average intake of energy and crude protein as related to initial body weight. It is seen that with one exception the weight changes were minimal. More subjects lost weight than gained weight. The kilocalories per day per kilogram of body weight of caloric intake was plotted versus weight change, and a linear relationship was found. These data show that under conditions of the experiments a 70 kg man would require an average of 2700 kcal of energy to be in weight balance. Subject 14 should have gained weight and the weight loss for subject 11 seems larger than is to be expected. Crude protein intakes are all greater than the 1.0 g per day per kilogram of body weight which is recommended by the Food and Nutritional Board, Nutritional Research Council (31).

Table XIX shows the balance of water intake and water output. The data are grouped to indicate experimental condition. The average balance for each condition is FD, 1801±256 ml; FDS, 1452±390 ml; DD, 1113±280 ml; and DDS, 1320±344 ml. Six combinations of these conditions were compared by Student's t-test for significance of their differences. The balance was significantly greater (99% level of confidence) when the subjects ate the fresh food diet than when they ate the experimental food diet. There is no reason for the water balance to be greater for the fresh food diet. The water balance represents the amount of water lost through evaporation from the skin and lungs assuming no body weight changes. The magnitude depends upon caloric intake, the work done, the relative humidity, and temperature of the environment (32). Since the caloric intake, relative humidity, and environmental temperature were constant, these differences probably reflect differences in daily activity on the two diets; the subjects were less active on the experimental diet than on the fresh food diet. Comparisons had to be made among groups of subjects because each subject ate both diets and wore the suit. The FDS and DDS are greater than DD by 339 ml and 207 ml, respectively. Wearing the pressure suit increased the water balance. However, due to the large individual variations, these increases have a probability of only 70% (about 1 standard deviation).

Nitrogen balance and digestibility are shown in table XX. The digestibility of both diets by all subjects is high; the overall average of 91.9% shows that the absorption of nitrogen from the diets is good. The balances show 3 values that are inconsistent with the slight weight losses shown by these subjects and their overall well being; the negative balances of 2.4, 3.3, and 1.6 reflect unusually high experimental urine outputs. These are probably due to the fact that nitrogen analyzer values were too high. There are no significant differences in the balances among the conditions as shown in table XX.

Digestibilities of fat, ash, and fiber are shown in tables XXI through XXIII. Absorption of fat from both diets is very high (97.8% of the ingested diet). Ash, which represents the total mineral content of the diet is absorbed extremely well in both diets (86.3%). The high digestibility of fiber, 86%, is rather surprising. Until it is determined whether this is an artifact which arises from the analytical procedure or due to bacterial action in the intestine, it is not feasible to consider this high digestibility as indicative of a high absorption. There are no significant changes in the digestibility of fat, ash, and fiber among the conditions as shown in tables XXI through XXIII.

The balances and digestibilities of sodium, potassium, calcium, and the chloride balance are shown in tables XXIV through XXVIII. The sodium, potassium, and phosphorus digestibilities are high, showing excellent absorption of these mineral elements. The balances are positive and there are no significant differences among the conditions. The calcium digestibilities are low as is to be expected. However, subject 15 shows an unusually low digestibility of 12%. For this reason he is the only subject who was not in positive balance for calcium. There are no significant changes in either digestibility or balances among the conditions. The overall chloride balance is positive by about 0.2 g per day. Of interest is the fact that subjects 9 through 12 were in negative balance while on the fresh food diet which contained only 9.29 g of chloride as sodium chloride. These subjects obviously were on much higher chloride intakes before the experiment began which explains the negative balance. These data show that in some individual cases it may take more than 16 days to bring about a metabolic balance with respect to chloride especially when the metabolic diet is very much lower in intake than the usual intake patterns. Table XXIX is a summary of the hematological examinations that were made on each subject. The mean values of the hematocrit, white blood cell count, and total eosinophil count, percent of granulocytes, lymphocytes, and monocytes for each subject were in the normal range.

Blood and urine chemistries are summarized in tables XXX through XXXII. The mean values for the parameters for each subject as shown in the tables are in the normal range of clinical values.

Blood pressure and oral temperatures are shown in tables XXXIII and XXXIV. The systolic-diastolic readings before and after exercise are shown as averages of each test period. There were no readings taken while the subjects were wearing the unpressurized MA-10 pressure suit. Blood pressure readings were all in the normal range of clinical values before and after exercise. There were no significant changes due either to diet type or the wearing of the unpressurized MA-10 pressure suit. The oral temperature readings both in the a.m. and p.m. are tabulated as averages for each test period. The p.m. readings were always higher than the a.m. readings, as is to be expected. All the values are in the normal range of clinical values.

Table XXXV is a summary of the defecation patterns of the subjects. The pattern for each subject is consistent over the whole test period. There were no changes caused by diet type or wearing of the unpressurized MA-10 pressure suit.

The fecal and urinary outputs of water and solids are summarized in tables XXXVI and XXXVII. The tables are averaged to show total output, water, and solids for feces and urine in grams and grams per day for each subject. At the bottom of each table is the average per man as grams (total) and grams per day. The average output of feces per man is 71.2 g per 24 hours; of this 48.9 g are water and 22.3 g are solids. The average output of urine per day is 1490 g per 24 hours; of this 1433 g are water and 87.2 g are solids. These data for urine were calculated from the daily specific gravity and daily urine volumes of each subject.

A summary of waste management parameters is shown in table XXXIX. The average input and output of the 8 subjects as grams per man day are shown as well certain ratios of these input and output parameters. In a closed ecological system, as in a space cabin, 86.5% of the total input is to be recovered as waste; of this about 15% are solids and 85% are liquid. The liquid output is roughly half in the urine and half in the environment; the amount in the feces is negligible. The insensible water output, 1415 g per day, is higher than normal because the subjects wore MA-10 pressure suits which caused increased insensible water output. The urinary output is considerably larger than the obligatory output of about 10 times the solids output. This extra urinary water reflects the large amount of water ingested by the subjects. Such large volumes are not obligatory. The obligatory intake is about 1500 g per day of which 1000 g are attributed to insensible water requirements and the remainder to solubilize urinary solids.

SECTION IV

DISCUSSION

The experimental aerospace diet composed of precooked freeze dehydrated foods consisting of about 330 g of carbohydrate, 95 g of crude protein, 87 g of fat, and 2500 kcal of metabolizable energy was found to be adequate under the conditions of stress imposed upon the subjects in these experiments. The experimental diet of precooked freeze dehydrated food was found to be as digestible and to be as highly absorbed as a matched metabolic diet of fresh foods. The weight gains or losses exhibited by the subjects with respect to the caloric intake were independent of diet and were minimal in nature. The metabolic balances obtained from the subjects while on the experimental diet were not different from those obtained when the subjects were on the fresh food diet. All balances were essentially positive. All the subjects maintained overall health as evidenced by the fact that physiological and biochemical parameters measured throughout the tests were all in the normal range for clinical values.

The organoleptic rating of the experimental food diet was acceptable and was (overall rating was 7) equal to that for the fresh food diet. Although the food was served at room temperatures it was well tolerated. Monotony was not a great factor in lowering food ratings. Obviously there was a large enough variety in the 4 meals per day, 4-day cycle diet to limit to a large extent the effect of monotony. There were more experimental foods that were not unacceptable than fresh foods. These were mainly creamed foods which were unacceptable mainly because they were served at room temperature. The total number of these unacceptable foods was so small as to make insignificant the quantitative differences between the two diets.

Welch, et al. (33) have reported an increase in the water requirements of human subjects wearing a pressure suit at 5 psi and 100% oxygen atmosphere. They reported a 20% increase in water intake, an 11% decrease in water loss in urine and feces, and an increase of 47% in water available for evaporation from the skin and lungs due to wearing a pressure suit. The results reported herein are similar to those of Welch, et al.(33). There was a decrease in urine water of 9%, an increase in water intake of 17%, and an increase in water available for evaporation through the skin and lungs of 44%.

In summary, wearing of the unpressurized MA-10 pressure suit for 16 days did not affect the energy or protein requirements but did affect the water requirements of these 8 subjects. The 4-day cycle diet of precooked freeze dehydrated foods and a matching diet of fresh foods were adequate and efficiently utilized by all the subjects. There were no significant changes in the physiological, biochemical, or nutritional measurements.

TABLE XIII

AVERAGE COMPOSITION OF DIETS

Constituent*	DD1**	FD1	DD2	FD2
Total weight	1770	2055	1791	2043
Moisture	1231	1506	1246	1508
Dry weight	539.3	549.4	544.1	538.6
Protein	92.5	86.9	96.9	97.5
Fat	88.4	98.9	85.2	88.8
Carbohydrate	328.1	336.9	334.0	324.2
Fiber	9.7	7.0	8.2	9.4
Ash	20.6	19.7	19.8	18.6
Phosphorus	1.73	1.73	1.73	1.61
Chloride	10.47	9.29	10.47	9.29
Calcium	0.81	0.79	0.68	0.93
Sodium	3.95	4.20	4.68	4.58
Potassium	3.28	3.25	3.73	4.22

* grams per day; average of 4 cycle diets

** DD and FD denote precooked freeze dehydrated diets and fresh food diets; 1 and 2 refer to the two different experiments.

TABLE XIV

ENERGY BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake cal	Undigested in feces cal	Digest-ible cal	Excreted in urine cal	Metabo-lizable cal	Coefficient of apparent digestibility %
Fresh diet suit	9	2760	117	2643	118	2525	95.8
	12	2760	171	2589	129	2460	93.8
	13	2624	116	2508	109	2399	95.6
	16	2624	70	2554	112	2442	97.3
Fresh diet no suit	10	2760	121	2639	125	2514	95.6
	11	2760	126	2634	123	2511	95.4
	14	2624	77	2547	113	2434	97.1
	15	2624	111	2513	109	2404	95.8
Experimental diet no suit	9	2696	126	2570	124	2446	95.3
	12	2696	82	2614	127	2487	97.0
	13	2633	111	2522	107	2415	95.8
	16	2633	138	2495	114	2381	94.8
Experimental diet suit	10	2696	83	2613	122	2491	96.9
	11	2696	101	2595	118	2477	96.3
	14	2633	117	2516	112	2404	95.6
	15	2633	135	2498	114	2384	94.9
			Subject Averages				
	9	2728	122	2606	121	2485	95.5
	10	2728	102	2626	124	2502	96.3
	11	2728	114	2614	121	2493	95.8
	12	2728	127	2601	128	2473	95.3
	13	2629	114	2515	108	2407	95.7
	14	2629	97	2532	113	2419	96.3
	15	2629	123	2506	112	2394	95.3
	16	2629	104	2526	113	2412	96.0
			Combined Subject Averages				
		2679	113	2566	118	2448	95.8

TABLE XV

SUMMARY OF ACCEPTABILITIES OF FRESH FOOD DIETS

Diet 1	Mean	±S.D.	Diet 2	Mean	±S.D.
Grapefruit juice	7.10	±1.50	Orange grapefruit juice	7.90	±0.99
Sugar frosted flakes	7.60	±0.07	Sugar frosted flakes	7.30	±0.71
Toast and butter	7.90	±1.00	Fried chicken	7.00	±0.75
Beef and vegetables	6.90	±1.00	Cheese sandwich	7.40	±1.06
Banana cubes	5.80	±0.90	Brownies	8.60	±0.74
Apricots	8.30	±0.95	Tea and sugar	7.90	±0.64
Corn chowder	4.80	±1.50	Beef and gravy	5.00	±2.30
Peanut butter sandwich	7.90	±0.83	Potato salad	6.50	±1.85
Roast beef	7.90	±0.99	Cinnamon toast	7.50	±1.41
Potato and butter	7.30	±1.50	Orange juice	8.30	±0.89
Pound cake	8.90	±0.35	Tuna salad	6.60	±2.10
Chicken sandwich	8.00	±0.53	Toast and butter	7.90	±1.24
Canadian bacon	8.50	±0.75	Applesauce	7.60	±0.74
Chocolate pudding	7.25	±1.40	Mushroom soup	6.00	±1.93
Pineapple cake	8.40	±0.50	All Star cereal	7.60	±0.74
Fruit cocktail	8.60	±0.52	Beef sandwich	7.75	±0.70
Tea and sugar	7.90	±0.64	Creamed carrots	3.75	±1.22
			Cocoa	8.00	±1.15
			Vanilla pudding	6.00	±1.60
			Apricots	8.25	±0.85

TABLE XV, continued

Diet 3	Mean	±S.D.	Diet 4	Mean	±S.D.
Orange juice	7.62	±0.74	Grape juice	7.5	±0.75
Sugar frosted flakes	7.50	±0.54	Sausage	7.4	±0.74
Toast and butter	7.40	±1.00	Toast and butter	7.3	±1.04
Salmon salad	4.40	±2.50	Cocoa	7.9	±0.83
Fruit compote	8.30	±0.70	Chicken salad	7.9	±0.99
Tea and sugar	7.60	±0.91	Creamed green beans	5.8	±1.58
Orange pineapple juice	7.90	±0.64	Banana pudding	6.5	±1.19
Spaghetti and meat	7.60	±0.91	Tea and sugar	7.6	±0.78
Beef sandwich	7.90	±0.64	Blended juices	7.8	±0.71
Date cake	7.90	±0.84	Peanut butter sandwich	7.8	±1.04
Grapefruit juice	7.00	±1.67	Potato soup	7.0	±1.60
Chicken and vegetables	7.30	±1.04	Pea soup	3.4	±1.50
Butterscotch pudding	8.30	±0.89	Chicken and gravy	3.9	±1.80
Potato soup	4.80	±2.30	Apricots	8.1	±0.64
Shrimp	4.80	±2.20	Canadian bacon	8.1	±0.99
Pineapple cubes	6.90	±0.99	Applesauce	7.5	±0.76
Gingerbread	8.10	±0.64			
Hard cooked egg	7.60	±0.74			
Broiled bacon	7.90	±0.83			

TABLE XVI

SUMMARY OF ACCEPTABILITIES OF PRECOOKED FREEZE DEHYDRATED FOOD DIETS

Diet 1	Mean	±S.D.	Diet 2	Mean	±S.D.
Grapefruit juice	6.3	±1.50	Orange grapefruit juice	7.3	±1.05
Apricot cereal	5.4	±1.50	Sugar frosted flakes	6.8	±0.89
Toast	6.3	±1.70	Chicken bites	6.4	±0.92
Beef and vegetables	6.3	±1.70	Cheese sandwich	6.8	±0.83
Banana cubes	6.0	±1.70	Brownies	8.0	±0.76
Toast bread cubes	7.3	±1.40	Tea	7.3	±0.46
Corn chowder	3.3	±2.10	Beef and gravy	7.5	±1.07
Peanut butter sandwich	7.8	±1.00	Potato salad	5.9	±1.95
Beef bites	6.3	±1.00	Cinnamon toast	7.8	±1.17
Potato chip block	5.1	±1.90	Orange juice	7.9	±1.45
Pound cake	7.7	±0.88	Tuna salad	6.8	±2.24
Chicken sandwich	6.8	±0.88	Toast	6.4	±1.85
Bacon squares	7.7	±1.40	Applesauce	7.0	±1.20
Chocolate pudding	7.9	±1.80	Mushroom soup	2.8	±2.00
Pineapple fruitcake	7.9	±1.40	All Star cereal	7.1	±1.35
Fruitcocktail	7.8	±1.00	Beef sandwich	7.1	±0.83
Tea	7.6	±0.75	Creamed carrots	2.0	±1.80
			Cocoa	7.9	±0.64
			Toast bread cubes	7.1	±1.55
			Apricot pudding	6.6	±1.20

TABLE XVI, continued

Diet 3	Mean	±S.D.	Diet 4	Mean	±S.D.
Grape juice	7.4	±0.52	Grape juice	7.4	±0.51
Strawberry cereal cubes	6.3	±1.39	Sausage	6.4	±0.53
Toast	6.4	±1.76	Toast bread cubes	6.9	±0.99
Salmon salad	5.5	±1.77	Cocoa	7.8	±0.71
Peaches	7.8	±0.70	Chicken salad	6.4	±1.50
Tea	7.5	±0.76	Creamed green beans	3.5	±1.70
Orange pineapple juice	7.9	±0.64	Banana pudding	6.8	±2.01
Spaghetti and meat	7.6	±0.91	Tea	7.9	±0.68
Beef sandwich	6.8	±1.16	Blended juices	7.6	±0.92
Date fruitcake	8.1	±0.84	Peanut butter sandwich	8.1	±0.98
Grapefruit juice	7.3	±0.88	Potato salad	5.9	±2.15
Chicken and vegetables	7.1	±1.10	Pea soup	4.1	±1.50
Butterscotch pudding	7.9	±1.35	Chicken and gravy	6.1	±1.07
Potato soup	4.5	±1.85	Apricot cubes	6.8	±1.04
Shrimp	6.8	±1.75	Ham and applesauce	5.5	±2.27
Pineapple cubes	7.3	±1.03			
Gingerbread	7.9	±0.99			
Bacon and egg bites	7.1	±0.99			

TABLE XVII

ACCEPTABILITIES OF MEALS AND METABOLIC DIETS

Meal	Metabolic diet 1		2		3		4		Average	
	FD	DD	FD	DD	FD	DD	FD	DD	FD	DD
A	7.0	6.0	7.6	7.1	7.1	7.0	7.7	7.3	7.35	6.85
B	7.1	6.0	6.7	7.1	7.8	7.6	7.0	6.2	7.15	6.73
C	7.8	7.3	7.1	6.2	7.6	7.2	7.6	6.8	7.53	6.88
D	8.0	7.5	6.9	6.3	6.1	6.7	5.9	6.1	6.73	6.65
Overall acceptability									7.19	6.78
Overall food acceptability									7.0	

TABLE XVIII

AVERAGE NUTRIENT INTAKE AS RELATED TO BODY WEIGHT

Subject No.	Body weight, kg			Caloric intake		Protein intake	
	Initial	Final kg	Change	kcal/day	kcal/day/kg body wt	g/day	g/day/kg body wt
9	59.1	61.9	+ 2.8	2730	46.2	89.7	1.52
10	86.8	82.1	- 4.7	2730	31.5	89.7	1.03
11	71.2	68.4	- 2.8	2730	38.3	89.7	1.26
12	79.7	77.8	- 1.9	2730	34.3	89.7	1.13
13	73.6	71.8	- 1.8	2630	35.7	97.2	1.32
14	60.9	60.9	0.0	2630	43.2	97.2	1.60
15	69.9	69.5	- 0.4	2630	37.6	97.2	1.39
16	65.4	66.4	+ 1.0	2630	40.2	97.2	1.49

TABLE XIX

WATER BALANCE

Condition	Subject No.	Average daily intake: Dietary	Ad lib	Metabolic	Total	Average daily output: Urine*	Feces	Total	Balance** difference
		ml/24 hr				ml/24 hr			ml/24 hr
Control diet suit	9	1507	882	343	2732	1390	25	1415	1317
	12	1507	1993	343	3843	1844	40	1884	1959
	13	1505	1226	310	3041	1445	90	1535	1506
	16	1505	858	310	2673	1602	46	1648	1025
Control diet no suit	10	1507	1413	343	3263	1043	42	1085	2178
	11	1507	1875	343	3725	1929	49	1978	1747
	14	1505	1139	310	2954	1272	35	1307	1647
	15	1505	1353	310	3168	1484	51	1535	1633
Experimental diet no suit	9	1231	710	329	2270	1389	40	1429	841
	12	1231	2802	329	4362	2825	38	2863	1499
	13	1245	1183	311	2739	1665	75	1740	999
	16	1245	1248	311	2804	1634	57	1691	1113
Experimental diet suit	10	1231	1035	329	2595	1240	25	1265	1330
	11	1231	974	329	2534	1164	43	1207	1327
	14	1245	613	311	2169	1234	44	1278	891
	15	1245	1344	311	2900	1118	49	1167	1733
				Subject averages					
	9	1369	796	336	2501	1390	33	1423	1078
	10	1369	1224	336	2929	1142	34	1176	1753
	11	1369	1425	336	3130	1547	46	1593	1537
	12	1369	2397	336	4102	2335	39	2374	1728
	13	1375	1205	311	2910	1555	83	1638	1272
	14	1375	876	311	2581	1253	40	1293	1288
	15	1375	1348	311	3053	1301	50	1351	1702
	16	1375	1053	311	2758	1618	53	1671	1087
				Combined subject averages					
		1372	1290	324	2995	1518	47	1565	1430

* Uncorrected for total solids.

** Represents water lost through evaporation via skin and through respiration when body weight does not change.

TABLE XX

NITROGEN BALANCES AND DIGESTIBILITIES

Condition	Subject No.	Intake	Excretion g/24hr			Balance g/24hr	Coefficient of apparent digestibility %
			Feces	Urine	Total		
Control diet suit	9	13.9	1.1	10.4	11.5	2.4	92.1
	12	13.9	1.6	12.9	14.5	- 0.6	88.5
	13	15.6	1.4	13.5	14.9	0.7	91.0
	16	15.6	1.0	15.4	16.4	- 0.8	93.6
Control diet no suit	10	13.9	1.1	11.3	12.4	1.5	92.1
	11	13.9	1.1	12.7	13.8	0.1	92.1
	14	15.6	.8	14.9	15.7	- 0.1	94.9
	15	15.6	1.5	16.5	18.0	- 2.4	90.4
Experimental diet no suit	9	14.8	1.2	12.0	13.2	1.6	91.9
	12	14.8	1.2	14.6	15.8	- 1.0	91.9
	13	15.5	1.3	14.5	15.8	- 0.3	91.6
	16	15.5	1.4	14.4	15.8	- 0.3	91.0
Experimental diet suit	10	14.8	.8	13.9	14.7	0.1	94.6
	11	14.8	1.4	12.0	13.4	1.4	90.5
	14	15.5	1.1	17.7	18.8	- 3.3	92.9
	15	15.5	1.3	15.1	16.4	- 1.6	91.6
				Subject averages			
	9	14.4	1.2	11.2	12.4	2.0	93.0
	10	14.4	1.0	12.6	13.6	0.8	93.1
	11	14.4	1.3	12.4	13.7	0.7	91.0
	12	14.4	1.4	13.8	15.2	- 0.8	90.3
	13	15.6	1.4	14.0	15.4	0.2	91.0
	14	15.6	1.0	16.3	17.3	- 1.7	93.6
	15	15.6	1.4	15.8	17.2	- 1.6	91.0
	16	15.6	1.2	14.9	16.1	- 0.5	92.3
				Combined subject averages			
		15.0	1.2	13.9	15.1	- 0.1	91.9

TABLE XXI

FAT DIGESTIBILITY

Condition	Subject No.	Intake g/24 hr	Excretion in feces g/24 hr	Coefficient of apparent digestibility %
Control diet suit	9	98.9	2.5	97.5
	12	98.9	2.6	97.4
	13	88.8	1.3	98.5
	16	88.8	1.0	98.9
Control diet no suit	10	98.9	2.5	97.5
	11	98.9	1.9	98.1
	14	88.8	1.1	98.8
	15	88.8	1.7	98.1
Experimental diet no suit	9	88.4	1.8	98.0
	12	88.4	1.7	98.1
	13	85.2	2.6	96.9
	16	85.2	3.1	96.4
Experimental diet suit	10	88.4	1.4	98.4
	11	88.4	1.7	98.1
	14	85.2	1.9	97.8
	15	85.2	2.1	97.5
		Subject averages		
	9	93.7	2.2	97.7
	10	93.7	2.0	97.9
	11	93.7	1.8	98.1
	12	93.7	2.2	97.7
	13	87.0	2.0	97.7
	14	87.0	1.5	98.3
	15	87.0	1.9	97.8
	16	87.0	2.1	97.6
		Combined subject averages		
		90.4	2.0	97.8

TABLE XXII

ASH DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion in feces g/24hr	Coefficient of apparent digestibility %
Control diet suit	9	19.7	2.6	86.8
	12	19.7	3.6	81.7
	13	18.6	2.7	85.5
	16	18.6	1.6	91.4
Control diet no suit	10	19.7	2.8	85.8
	11	19.7	3.1	84.3
	14	18.6	2.9	84.4
	15	18.6	3.2	82.8
Experimental diet no suit	9	20.6	3.4	83.5
	12	20.6	3.3	84.0
	13	19.8	2.4	87.9
	16	19.8	2.9	85.4
Experimental diet suit	10	20.6	2.5	87.9
	11	20.6	3.8	81.6
	14	19.8	2.7	86.4
	15	19.8	2.7	86.4
		Subject Averages		
	9	20.2	3.0	85.1
	10	20.2	2.7	86.6
	11	20.2	3.5	82.7
	12	20.2	3.5	82.7
	13	19.2	2.6	86.5
	14	19.2	2.8	85.4
	15	19.2	3.0	84.4
	16	19.2	2.3	88.0
		Combined Subject Averages		
		19.7	2.7	86.3

TABLE XXIII

FIBER DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion in feces g/24hr	Coefficient of apparent digestibility %
Control diet suit	9	7.0	0.8	88.6
	12	7.0	1.5	78.6
	13	9.4	2.9	69.1
	16	9.4	0.7	92.6
Control diet no suit	10	7.0	1.1	84.3
	11	7.0	1.2	82.9
	14	9.4	0.8	91.5
	15	9.4	1.3	86.2
Experimental diet no suit	9	9.7	1.1	88.7
	12	9.7	1.0	89.7
	13	8.2	0.9	89.0
	16	8.2	1.2	85.4
Experimental diet suit	10	9.7	1.0	89.7
	11	9.7	1.2	87.6
	14	8.2	0.9	89.0
	15	8.2	0.9	89.0
		Subject Averages		
	9	8.4	1.0	88.1
	10	8.4	1.1	86.9
	11	8.4	1.2	85.7
	12	8.4	1.3	84.5
	13	8.8	1.9	78.4
	14	8.8	0.9	89.8
	15	8.8	1.1	87.5
	16	8.8	1.0	88.6
		Combined Subject Averages		
		8.6	1.2	86.0

TABLE XXIV

SODIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion g/24hr Feces	Urine	Total	Balance g/24hr	Coefficient of apparent digestibility %
Control diet	9	4.20	0.02	3.78	3.80	0.40	99.5
suit	12	4.20	0.03	4.03	4.06	0.14	99.3
	13	4.55	0.004	3.73	3.73	0.82	99.9
	16	4.55	0.003	4.00	4.00	0.55	99.9
Control diet	10	4.20	0.02	3.65	3.67	0.53	99.5
no suit	11	4.20	0.02	3.93	3.95	0.25	99.5
	14	4.55	0.003	3.80	3.80	0.75	99.9
	15	4.55	0.004	4.03	4.03	0.52	99.9
Experimental diet	9	4.00	0.02	3.70	3.72	0.28	99.5
no suit	12	4.00	0.02	3.30	3.32	0.68	99.5
	13	4.66	0.005	4.50	4.51	0.15	99.9
	16	4.66	0.006	4.53	4.54	0.12	99.9
Experimental diet	10	4.00	0.01	3.50	3.51	0.49	99.8
suit	11	4.00	0.02	3.18	3.20	0.80	99.5
	14	4.66	0.003	4.30	4.30	0.36	99.9
	15	4.66	0.004	4.65	4.65	0.01	99.9
			Subject averages				
	9	4.10	0.02	3.74	3.76	0.34	99.5
	10	4.10	0.02	3.58	3.60	0.50	99.5
	11	4.10	0.02	3.56	3.58	0.52	99.5
	12	4.10	0.03	3.67	3.70	0.40	99.3
	13	4.61	0.005	4.12	4.13	0.48	99.9
	14	4.61	0.003	4.05	4.05	0.56	99.9
	15	4.61	0.004	4.34	4.34	0.27	99.9
	16	4.61	0.005	4.27	4.28	0.33	99.9
			Combined subject averages				
		4.36	0.01	3.92	3.93	0.43	99.8

TABLE XXV

POTASSIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion g/24hr Feces	Urine	Total	Balance g/24hr	Coefficient of apparent digestibility %
Control diet suit	9	3.30	0.25	2.55	2.80	0.50	92.4
	12	3.30	0.45	2.55	3.00	0.30	86.4
	13	4.21	0.75	2.43	3.18	1.03	82.3
	16	4.21	0.48	2.83	3.31	0.90	88.6
Control diet no suit	10	3.30	0.39	2.50	2.89	0.41	88.2
	11	3.30	0.23	2.63	2.86	0.44	93.0
	14	4.21	0.42	2.48	2.90	1.31	90.0
	15	4.21	0.56	2.68	3.24	0.97	86.7
Experimental diet no suit	9	3.30	0.27	2.48	2.75	0.55	91.8
	12	3.30	0.34	2.48	2.82	0.48	89.7
	13	3.71	0.69	2.80	3.49	0.22	81.4
	16	3.71	0.57	2.75	3.32	0.39	84.6
Experimental diet suit	10	3.30	0.27	2.50	2.77	0.53	91.8
	11	3.30	0.18	2.38	2.56	0.74	94.5
	14	3.71	0.52	2.80	3.32	0.39	86.0
	15	3.71	0.53	2.93	3.46	0.25	85.7
Subject Averages							
	9	3.30	0.26	2.52	2.78	0.52	92.1
	10	3.30	0.33	2.50	2.83	0.47	90.0
	11	3.30	0.21	2.51	2.72	0.58	93.6
	12	3.30	0.40	2.52	2.92	0.38	87.9
	13	3.96	0.72	2.62	3.34	0.62	81.8
	14	3.96	0.47	2.64	3.11	0.85	88.1
	15	3.96	0.55	2.81	3.36	0.60	86.1
	16	3.96	0.53	2.79	3.32	0.64	86.6
Combined Subject Averages							
		3.63	0.43	2.61	3.04	0.59	88.2

TABLE XXVI

CALCIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion g/24hr			Balance g/24hr	Coefficient of apparent digestibility %
			Feces	Urine	Total		
Control diet suit	9	0.79	0.52	0.20	0.72	0.07	34.2
	12	0.79	0.47	0.25	0.72	0.07	40.5
	13	0.93	0.55	0.20	0.75	0.18	40.9
	16	0.93	0.45	0.19	0.64	0.29	51.6
Control diet no suit	10	0.79	0.55	0.21	0.76	0.03	30.4
	11	0.79	0.35	0.25	0.60	0.19	55.7
	14	0.93	0.54	0.17	0.71	0.88	41.9
	15	0.93	0.79	0.19	0.98	-0.05	15.1
Experimental diet no suit	9	0.81	0.51	0.24	0.75	0.06	37.0
	12	0.81	0.53	0.18	0.71	0.10	34.6
	13	0.68	0.43	0.18	0.61	0.07	36.8
	16	0.68	0.55	0.20	0.75	-0.07	19.1
Experimental diet suit	10	0.81	0.20	0.23	0.43	0.38	75.3
	11	0.81	0.48	0.21	0.68	0.13	42.0
	14	0.68	0.56	0.18	0.74	-0.06	17.6
	15	0.68	0.63	0.16	0.79	-0.11	7.4
		Subject Averages					
	9	0.80	0.52	0.22	0.74	0.06	35.0
	10	0.80	0.38	0.22	0.60	0.20	52.5
	11	0.80	0.41	0.23	0.64	0.16	48.8
	12	0.80	0.50	0.22	0.72	0.08	37.5
	13	0.81	0.49	0.19	0.68	0.13	39.5
	14	0.81	0.55	0.18	0.73	0.08	32.1
	15	0.81	0.71	0.18	0.89	-0.08	12.3
	16	0.81	0.50	0.20	0.70	0.11	38.3
		Combined Subject Averages					
		0.81	0.51	0.21	0.72	0.09	37.0

TABLE XXVII

PHOSPHORUS BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion g/24 hr Feces	Excretion g/24 hr Urine	Excretion g/24 hr Total	Balance g/24hr	Coefficient of apparent digestibility %
Control diet suit	9	1.73	0.39	1.05	1.44	0.29	77.5
	12	1.73	0.53	1.29	1.82	- 0.09	69.4
	13	1.61	0.33	1.09	1.42	0.19	79.5
	16	1.61	0.28	1.01	1.29	0.32	82.6
Control diet no suit	10	1.73	0.40	1.11	1.51	0.22	76.9
	11	1.73	0.40	1.17	1.57	0.16	76.9
	14	1.61	0.40	0.92	1.32	0.29	75.2
	15	1.61	0.45	1.02	1.47	0.14	72.0
Experimental diet no suit	9	1.77	0.50	0.98	1.48	0.29	71.8
	12	1.77	0.29	1.08	1.37	0.40	83.6
	13	1.73	0.30	1.26	1.56	0.17	82.7
	16	1.73	0.48	1.06	1.54	0.19	72.3
Experimental diet suit	10	1.77	0.42	0.93	1.35	0.42	76.3
	11	1.77	0.45	1.06	1.51	0.16	74.6
	14	1.73	0.39	1.17	1.56	0.17	77.5
	15	1.73	0.40	1.23	1.63	0.10	76.9
Subject averages							
	9	1.75	0.45	1.02	1.47	0.28	74.3
	10	1.75	0.41	1.02	1.43	0.32	76.6
	11	1.75	0.43	1.12	1.55	0.20	75.4
	12	1.75	0.41	1.19	1.60	0.15	76.6
	13	1.67	0.32	1.18	1.50	0.17	80.8
	14	1.67	0.40	1.05	1.45	0.22	76.0
	15	1.67	0.43	1.13	1.56	0.11	74.3
	16	1.67	0.38	1.04	1.42	0.25	77.2
Combined subject averages							
		1.71	0.40	1.11	1.51	0.20	78.4

TABLE XXVIII

CHLORIDE BALANCE

Condition	Subject No.	Intake g/24 hr	Excretion in urine g/24hr	Balance g/24hr
Control diet suit	9	9.29	11.95	- 2.66
	12	9.29	11.28	- 1.99
	13	9.29	8.91	0.38
	16	9.29	8.25	1.04
Control diet no suit	10	9.29	10.29	- 1.00
	11	9.29	11.04	- 1.75
	14	9.29	9.24	0.05
	15	9.29	7.50	1.79
Experimental diet no suit	9	10.47	10.19	0.28
	12	10.47	10.33	0.14
	13	10.47	7.55	2.92
	16	10.47	9.92	0.55
Experimental diet suit	10	10.47	9.79	0.68
	11	10.47	10.23	0.24
	14	10.47	8.94	1.53
	15	10.47	9.69	0.78
		Subject averages		
	9	9.88	11.07	- 1.19
	10	9.88	10.04	- 0.16
	11	9.88	10.63	- 0.75
	12	9.88	10.81	- 0.93
	13	9.88	8.23	1.65
	14	9.88	9.09	0.79
	15	9.88	8.60	1.28
	16	9.88	9.09	0.79
		Combined subject averages		
		9.88	9.69	0.19

TABLE XXIX

SUMMARY OF HEMATOLOGICAL ANALYSES

Subject	Hematocrit vol. %	White Blood cells mm3	Total Eosinophils mm3	Granulocytes %	Lymphocytes %	Monocytes %
9	43	4952	134	48	52	0.0
10	43	5981	99	50	49	1.0
11	42	5720	100	48	51	1.0
12	44	5558	110	57	42	1.0
13	43	8125	133	49	50	1.0
14	47	7625	149	42	57	1.0
15	41	6821	230	46	53	1.0
16	46	5161	96	43	56	1.0

TABLE XXX

BLOOD CHEMISTRY, INORGANIC CONSTITUENTS

Subject	Calcium mg/100 ml	Sodium mEq/l	Potassium mEq/l	Phosphorus mg/100 ml	Chloride mEq/l
9	10.2	147	4.5	3.7	103
10	10.2	145	4.5	3.7	103
11	9.9	146	4.5	3.7	103
12	9.8	147	4.5	3.6	102
13	10.1	146	4.6	2.8	105
14	10.0	146	4.5	2.8	103
15	9.9	147	4.6	3.0	103
16	10.3	144	4.5	2.9	104

TABLE XXXI

BLOOD CHEMISTRY, ORGANIC CONSTITUENTS

Subject	Glucose mg/100 ml	Creatinine mg/100 ml	Hemoglobin gm/100 ml
9	76	1.5	14.1
10	76	1.5	14.3
11	76	1.5	14.6
12	74	1.6	15.3
13	76	1.5	15.1
14	75	1.7	15.4
15	77	1.5	14.3
15	73	1.5	14.6

TABLE XXXII

SUMMARY OF CHEMICAL ANALYSES ON URINE

Subject	*p*H Daily Averages	Creatinine g/24hr
9	6.07	1.95
10	6.10	2.33
11	6.02	2.04
12	6.07	2.30
13	6.05	2.09
14	6.14	1.83
15	5.98	2.03
16	6.50	1.92

TABLE XXXIII

BLOOD PRESSURE

Experimental period	Blood pressure, systolic/diastolic							
	Subject							
	9	10	11	12	13	14	15	16
4 days - before exercise	91/59	118/79	103/60	111/78	121/78	114/68	122/83	101/66
after exercise	155/68	197/57	143/75	172/66	174/82	158/86	175/94	144/80
16 days - before exercise	suit	122/69	suit	108/65	suit	120/70	suit	117/69
after exercise	suit	197/68	suit	172/66	suit	148/73	suit	125/58
4 days - before exercise	98/63	116/66	88/59	109/68	123/69	102/72	122/69	115/75
after exercise	148/78	194/70	129/79	137/80	178/73	154/79	148/83	119/59
16 days - before exercise	98/66	suit	94/63	suit	109/75	suit	116/76	suit
after exercise	152/77	suit	134/81	suit	141/66	suit	136/74	suit
2 days	101/79	130/86	97/67	126/83	120/88	100/78	110/78	100/70

TABLE XXXIV

ORAL TEMPERATURE

Experimental period	Oral temperature, degrees Fahrenheit							
	Subject							
	9	10	11	12	13	14	15	16
4 days - morning	96.6	97.3	96.7	96.7	96.7	96.6	97.1	97.1
evening	97.3	97.8	97.1	98.1	97.2	97.6	98.0	97.4
16 days - morning	96.5	97.5	97.1	96.8	97.1	97.3	97.4	97.2
evening	97.5	98.1	97.6	97.9	97.5	97.8	97.7	97.6
4 days - morning	97.0	97.6	97.2	96.9	97.2	96.6	97.4	97.5
evening	97.5	97.9	98.0	97.6	97.9	97.6	97.9	97.3
16 days - morning	97.2	97.3	97.2	96.9	96.7	96.9	97.3	97.3
evening	97.6	97.8	97.9	97.9	97.8	97.7	97.7	97.7
2 days - morning	97.0	97.2	97.1	97.2	96.2	97.1	97.5	97.1
evening	97.8	97.5	97.7	97.9	97.6	97.8	98.0	97.6

TABLE XXXV

DEFECATION PATTERNS

Fecal collection days	Subjects							
	9	10	11	12	13	14	15	16
1	x		x		xx		x	x
2	x	x		xx	xx			x
3	x	x	x		xx	x	x	x
4	x	x		xx	x	x		x
5	x	x	x	x	x	x	x	x
6	x			x	x	x		x
7	x	x	x		xx	x	x	x
8			x	x	x	x		
9	x			x	x		x	x
10	x	x	x		xx	x		x
11	x	x	x	x	x	x	x	x
12				x	xx	x		
13	x			x				x
14	x	x	x		x	x		x
15	x	x	x		x		x	x
16				x	x	x	x	
17	x		x		xx	x		x
18	x	x	x	xx	xx	x	x	
19	x	x			xxx	xx	x	
20	x			xx	x		x	x
21	x		x	x	x	x		x
22					xx		x	x
23		x	x	x	xx			x
24	xx		x	x	xx		x	
25			x		x	x		x
26	x			xx	x	x		x
27	x		x		xx	x	x	
28	x	x		x	xx		x	x
29	x				x			x
30				xx	x		x	x
31	x		x	x	xxx	xx		x
32	xx			xx	x	x		x
33	x				x		x	x
34	x		x	x	xx	x		x
35		x		x	xx	x	x	xx
36	xx	x	x	xx	xx	x	x	x

TABLE XXXVI

FECAL OUTPUT, WATER AND SOLIDS

Subject	Total output		Water output		Solid output	
	g	g/24 hr	g	g/24 hr	g	g/24 hr
9	2000	55.6	1183	32.9	817	22.7
10	1925	53.5	1234	34.3	691	19.2
11	2315	64.3	1503	41.8	812	22.5
12	2775	77.1	1849	51.4	926	25.7
13	3853	107.0	3004	83.5	849	23.5
14	2207	61.3	1514	42.1	693	19.2
15	2733	75.9	1845	51.3	888	24.6
16	2683	74.5	1941	53.9	742	20.6
Average per man						
	2561	71.2	1759	48.9	802	22.3

TABLE XXXVII

URINARY OUTPUT, WATER AND SOLIDS

Subject	Total output		Water output		Solid output	
	g	g/24 hr	g	g/24 hr	g	g/24 hr
9	54,999	1309	52,597	1252	2402	57.2
10	46,393	1104	43,826	1046	2452	58.4
11	98,343	2342	95,826	2282	2517	59.9
12	65,858	1568	63,284	1507	2574	61.3
13	62,445	1486	60,201	1433	2244	53.4
14	51,665	1230	49,275	1173	2390	56.9
15	54,403	1295	52,080	1240	2333	55.3
16	66,488	1583	6417	1528	2312	55.0
Average per man						
	62,574	1490	60,173	1433	2402	57.2

TABLE XXXVIII

WASTE MANAGEMENT

	Input		Output
Water, g/man day			
Dietary	1373		
Ad libitum	1200		
Metabolic	324		
Urine			1433
Feces			48.9
Insensible water*			
	2897		2896.9
Solids, g/man day			
Dietary	543		
Urine			57.2
Feces			22.3
	543		79.5
Ratio (output/input), %			
Total weight		86.5	
Solids		14.6	
Insensible water/total water		48.8	
Urinary water/total water		49.5	
Feces/total weight		2.10	

* Water lost to environment via lungs and skin assuming a constant weight.

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13. ABSTRACT
Eight human male volunteers participated in two 6-week simulated aerospace studies. During this time the subjects wore an unpressurized MA-10 pressure suit for 16 consecutive days and ate a 4-day cycle diet composed of precooked freeze dehydrated foods or a matched 4-day cycle diet composed of fresh foods. The food was served at room temperature. Each diet was comprised of about 330 g of carbohydrate, 95 g of crude protein, 87 g of fat, and 2500 kcal per day. The diets were organoleptically acceptable and efficiently utilized. Only minimal weight changes were observed. Metabolic balances showed adequate adjustment to the diets; all subjects were in positive balance for nitrogen and for the major inorganic constituents. The wearing of the MA-10 pressure suit did not affect protein or caloric requirements but water intake did increase significantly by 17%. There were no significant changes in blood pressure or oral temperature. All other clinical measurements were in the normal range of clinical values. All subjects maintained excellent health throughout all the test periods.

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Precooked frozen foods						
Confinement						
Nutritional balance						
Simulated aerospace environments						
Physiological measurement						
Biochemical measurement						