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PROGRESS REPORT

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Principal investigator: Harry D. Olree, Ed. D.

Sponsoring institution: Harding College, Searcy, Arkansas

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This report covers Experiment III of five experiments to be conducted over a 24-month period beginning May 1, 1967. Experiment I revealed that running and riding a bicycle ergometer produced similar gains in physical fitness variables. In Experiment II the subjects exercising at a 180 heart rate made a greater improvement in physical fitness than did those exercising at a 140 or 160 heart rate. Three papers have been presented at scientific meetings in Little Rock, New Orleans, and St. Louis.

Experiment III was an investigation of the effects of variable length training sessions on physical fitness. The subjects who exercised sixty minutes per day made greater gains on specified components of physical fitness than did those who exercised twenty or forty minutes per day.

Experiment IV will begin September 1, 1968 and will be completed December 31, 1968. Three experimental groups will exercise on a bicycle ergometer at a 160 heart rate for twenty minutes per session. Group I will exercise three times per week, Group II six times per week and Group III twelve times per week.

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Methods of Achieving and Maintaining Physical Fitness for Prolonged Space Flight

Experiment III: An Investigation of the Effects of Variable Length Training Sessions on Physical Fitness in College Men

Harry Olree, Bob Corbin, and James Penrod
Harding College
Searcy, Arkansas

I. Introduction

Prolonged weightlessness during space flight might result in deterioration of fundamental cardiovascular-respiratory responses. There has been considerable concern that prolonged space flights might cause cardiovascular deconditioning, making the space crewman susceptible to syncope or circulatory collapse during re-entry or return to earth (1). One of the principal problems encountered with prolonged weightlessness is the hypotension which develops upon return to gravity due to the loss of the cardiovascular reflexes. Another problem of great concern to space officials is that of space fatigue. Astronauts have found even mild extra-vehicular activity to be very exhausting.

Lamb (2) states that prolonged bed rest results in physiological deconditioning, manifested by decreased plasma volume, decreased red blood cell mass, decreased red blood cell production with inactive bone marrows, increased resting heart rate, decreased exercise tolerance, decreased orthostatic tolerance, decreased coronary blood flow, increased storage of catecholamine products in the myocardium, decreased muscle mass and muscle tonus, increased nitrogen excretion, and increased calcium mobilization with increased calcium excretion. Several methods have been suggested to overcome various aspects of this problem. These include pressure cuffs, a centrifuge, acclimatization, an antigravity suit and exercise devices. Due to the weight and space requirements in space vehicles none of these appear to approach an ideal solution. To prevent or at least to minimize this deconditioning during prolonged space flights, further research needs to be undertaken.

Miller and Taylor found that increased physical fitness decreased deconditioning during two or three weeks of absolute bed rest (3) (4). It is generally assumed that anything which decreases deconditioning during bed rest will also decrease deconditioning during prolonged space flights. With the appointment of physicians and scientists as astronauts for the long-term manned space flights which are being planned, research is needed in the area of developing and maintaining optimal physical fitness.

The purpose of Experiment III was to determine which of three variable length training sessions, twenty, forty, or sixty minutes per day, would produce the greatest gain in physical fitness in college men.

II. Method

Subjects used in this study were twenty male college students who volunteered and had below average maximal oxygen uptake values as determined from the Balke Treadmill Test. (5) Baselines were determined on biochemical and physiological parameters by administering the following: (a) a medical examination, (b) a lean body mass determination, (c) an American Association for Health, Physical Education and Recreation battery test, (d) a treadmill test, (e) a bicycle ergometer test, and (f) an orthostatic tolerance test.

Each subject had a thorough medical examination, including a six lead EKG, a vital capacity test, a maximum breathing capacity test, and blood and urine analysis. The subjects were given the Balke Treadmill Test in which the speed of the belt was constant throughout the test at

90 meters per minute with an increment in grade of 1% per minute. Pulse rate and blood pressure (systolic and diastolic) were measured manually at one minute intervals throughout the test. The pulse rate was also telemetered to a Cardio-Tac for continuous observation and the test was terminated when the heart rate reached 180 beats per minute. During the last minute of the treadmill test, pulmonary ventilation was measured and expired air collected to determine the respiratory quotient, maximum oxygen consumption, and oxygen uptake per kilogram of body weight.

Blood samples were obtained by venipuncture, with the subject in a fasting state, just prior to and immediately after the treadmill test. The following determinations were made: lactic acid by the enzymatic method of Loomis (6); glucose by the method of Nelson (7) and Somogyi (8); total cholesterol by the procedure of Babson, Shapiro, and Phillips (9); total protein by the method of Reinholt (10); phospholipids by the method of Sunderman (11); triglycerides by the method of Van Handel and Zilversmitt (12); nitrogen by the method of Conway (13); sodium, potassium, and calcium on the Coleman flame photometer; serum glutamic oxalacetic transaminase by the method of Babson, Shapiro, Williams, and Phillips (14); creatine phosphokinase by the Sigma method (15); lactic acid dehydrogenase by the method of Babson and Phillips (16).

The subject's percent of body fat was determined by the body density method as described by Dill (17). An orthostatic tolerance test (18), the AAHPER Physical Fitness Test (19) and a bicycle ergometer test were given as part of the baseline evaluation.

By using a table of random numbers the twenty subjects were divided into four groups of five each. Three of the groups followed a prescribed training program on a bicycle ergometer five days per week for ten weeks.

The daily training period consisted of a five minute warmup with the work load adjusted to produce a heart rate of 120-130 beats per minute, followed immediately by a work load adjustment to produce a heart rate of 180 beats per minute for each group.

Group I exercised for twenty minutes per day, Group II forty minutes per day, and Group III sixty minutes per day. A research assistant checked the heart rate each minute during exercise and adjusted the work load when necessary to maintain the desired heart rate. If during any workout the subject was not able to maintain the prescribed pedalling speed the workload was reduced until the speed could be maintained and the subject completed the workout at this level. This resulted in some of the subjects working at less than a 180 heart rate. The average workout heart rate for each subject is given in Table XIII. Group IV served as the control group and engaged in their normal daily schedule without participating in an exercise program.

During the seventh week of training the physical capacity of each subject was assessed by administering the bicycle ergometer test as follows. The subject exercised for three minutes at 300 kilopond meters per minute. At the beginning of each minute thereafter, the workload was increased by 75 kpm. When the heart rate reached 180 beats per minute the test was terminated. Gas samples were collected during the third, fifth, eighth, and each of the last three minutes of exercise to obtain oxygen consumption data. The heart rate, blood pressure, and respiration rate were measured each minute of the test as well as three minutes pretest and ten minutes posttest.

At the end of the ten weeks each subject's physical fitness was again evaluated to determine the effectiveness of the different length training sessions. Indexes of physical fitness which were investigated included resting heart rate, blood volume, plasma volume, red blood cell mass, red blood cell production, exercise tolerance, orthostatic tolerance, lean body mass, maximal oxygen consumption, maximal oxygen uptake per kilogram of body weight, and the AAHPER scores. Measurements were made on several biochemical and physiological parameters to determine the nature and extent of any change which took place as a result of the physical training.

III. Results

The average age, height, and weight for each group prior to the beginning of the ten weeks of training are given in Table I.

Table I

Mean Age, Height, and Weight of Subjects

Group	Age (Yr.)	Height (Cm.)	Weight (Kg.)
I - 20 Min.	20.80	177.80	78.420
II - 40 Min.	21.75	175.00	71.375
III - 60 Min.	21.20	177.20	76.400
IV - Control	21.80	170.60	78.840
All	21.37	175.16	76.516

The mean pre-training, post-training, and difference values for the variables investigated are presented in Tables VI-XII inclusive.

Prior to beginning the experiment the decision was made to make comparisons between the first and last tests for each group. The following model was used for the analysis of variance:

$Y_{ijkl} = \mu + A_i + B_{j(i)} + C_k + E_{l(ijk)}$, where A represents the groups and is considered fixed, B represents the subjects and is considered random, and C represents the tests and is considered fixed.

Table II

Anova Table

Source	Df	E(ms)	F
Total	N-1		
(A) Groups	n-1	(1) $\sigma E^2 + q\sigma B(A)^2 + pq\sigma A^2$	1/2
B(A) Subjects in Groups	n(p-1)	(2) $\sigma E^2 + q\sigma B(A)^2$	
C Tests	(q-1)	(3) $\sigma E^2 + \sigma (B(A)C)^2\ np\sigma C^2$	3/5
AC Groups, Tests Interaction	(n-1)(q-1)	(4) $\sigma E^2 + \sigma (B(A))C^2 + p\sigma AC^2$	4/5
(B(A))C Subjects in Groups, Tests Interaction	n(p-1)q-1)	(5) $\sigma E^2 + \sigma (B(A))C^2$	

In the Anova Table (N) is the total number of observations, 38 for the treadmill variables and 57 for the variables obtained from the bicycle test. The number of groups (n) is four in both analyses. Originally there were five subjects in each group. However, during the experiment subject number six who was working for 40 minutes per day was forced to drop out. Thus there are five subjects (p) in Groups I, III, IV and four subjects in Group II. The number of tests (q) is two for treadmill data and three for bicycle variables.

A. Analysis of all Variables Except Those Obtained From the Bicycle Tests

The following results were obtained from the analysis of all the variables except those obtained from the three bicycle tests.

There was no significant change in any of the groups in Vital Capacity, Maximum Breathing Capacity, or the AAHPER Mean Percentile.

The group-time interaction for time on the treadmill was significant at the $p=.01$ level. Comparisons within groups showed significant increases at the $p=.001$ level in all exercise groups with no change in the controls.

Systolic Blood Pressure at Rest did not change significantly in any of the groups. Diastolic Blood Pressure at Rest did not change in any of the exercise groups but there was a significant ($p=.05$) decrease in the control group. Heart Rate at Rest decreased at the $p=.05$ level in Groups I (20 minutes) and III (60 minutes), and at the $p=.001$ level in Group II (40 minutes). The controls did not change.

The Maximal Pulmonary Ventilation at BTPS increased significantly at the $p=.001$ level in Group II and at the $p=.01$ level in Groups I and III. There was no significant change in the control group.

The group-time interaction for CO_2 was significant at the $p=.05$ level. Comparisons within groups showed a significant increase at the $p=.001$ level in Groups II and III, and at the $p=.01$ level in Group I. The controls did not change.

The Maximal Oxygen Uptake had a significant group-time interaction at the $p=.05$ level. Within group comparisons showed all exercise groups had increased at the $p=.001$ level with no change in the controls.

The Maximal O_2/kgbw•min. from the treadmill test showed a significant group time interaction ($p=.05$). Within group comparisons revealed Groups II and III had increased at the $p=.001$ level and Group I at the $p=.01$ level. Group IV showed no change.

Neither the RQ nor the Lean Body Mass (Percent Fat) changed significantly in any of the groups.

There were no changes in Hemoglobin or in Hematocrit in any of the groups. The Red Blood Cell level increased ($p=.05$) in Group III. The level of Reticulocytes showed a significant decrease at the p=.05 level in Group I. Group III showed a significant decrease in Red Cell Volume at the p=.05 level, in Plasma Volume at the p=.01 level and in Total Blood Volume at the p=.01 level. There was no change in the other groups for these variables.

Blood samples were taken from each subject before and immediately after each treadmill test. In the analysis samples taken before Test I and Test II were evaluated, then samples taken after Test I and Test II.

Glucose Before (the treadmill test) and After (the treadmill test) showed no significant changes in any of the groups.

Group II showed a significant decrease at the p=.05 level for SGOT Before. The other groups did not change. There were no significant changes in any of the groups in SGOT After.

Lactic Acid Before showed no changes. Lactic Acid After had an increase in Group II at the p=.05 level. The other groups did not change.

The only change in Total Cholesterol Before and After was an increase in Group I at the p=.05 level in the Before analysis.

There were no changes in any of the groups in Phospholipids Before. Analysis of Phospholipids After revealed a significant increase in Group I at the p=.01 level and no changes in the other groups.

Sodium Before showed significant increases at the p=.01 level in Groups II, III and IV. Group I did not change. For Sodium After, Group I did not change, Group II increased at the p=.05 level, Group III increased at the p=.01 level and Group IV increased at the p=.001 level.

There was no change in any of the groups for Triglycerides Before or After.

Potassium Before showed no significant changes. Group III increased at the p=.01 level in Potassium After. The other groups did not change.

The group-time interaction for Proteins Before was significant at the p=.05 level. Within group comparisons revealed increases in Group II (p=.05) and Group IV (p=.001). Groups I and III did not change. Proteins After also showed increases in Groups II and IV at the p=.01 and p=.001 levels respectively. There were no changes in the other groups.

Creatine Phosphokinase Before and After and Nitrogen Before and After showed no significant changes in any of the groups.

Calcium Before and After had significant group-time interactions (p=.01). Comparisons within groups showed decreases at the p=.001 level in all groups in both the Before and After analyses.

B. <u>Analysis of the Variables Investigated by the Bicycle Tests</u>

The Length of Time on the Bike until the subject reached a 180 heart rate had a significant group-time interaction (p=.001). However, comparisons between times one and three within each group showed significant increases at the p=.001 level in Groups I, II, and III with no change in Group IV.

Systolic Blood Pressure at Rest, Systolic Blood Pressure for the Last Minute of Work and Diastolic Blood Pressure at Rest showed no significant changes. Diastolic Blood Pressure for the Last Minute of Work had decreases at the p=.001 level in Group I, at the p=.01 level in Group III, and at the p=.05 level in Group IV. Group II did not change significantly.

Heart Rate at Rest showed a significant decrease between Test I and Test III in Group III at the p=.05 level. There was no change in the other groups. Heart Rate at the Last Minute of Work did not change significantly.

The Pulmonary Ventilation at BTPS ($\dot{V}_E$) at the 8th minute of work decreased at the p=.05 level in Groups I and III. Groups II and IV did not change. The $\dot{V}_E$ at the last minute of work showed an increase in

Group III at the $p=.05$ level and no changes in the other groups.

Only Group III showed a change between Test I and Test III for CO_2 at the 8th minute. It decreased at the $p=.01$ level. The CO_2 during the last minute group-time interaction was significant at the $p=.05$ level. The within group comparisons showed that all groups increased. Group I changed at the $p=.01$ level, Group II at the $p=.01$ level, Group III at the $p=.001$ level, and Group IV at the $p=.05$ level.

Oxygen Uptake at the 8th minute showed no significant changes. Maximal O_2 Uptake had a group-time interaction significant at the $p=.05$ level. The within group comparisons revealed increases at the $p=.001$ level in Groups I and III, at the $p=.01$ level in Group II, and no change in Group IV.

There was no change indicated in O_2/kgbw•min. at the 8th minute in any of the groups. The O_2/kgbw•min. during the last minute had a group-time interaction significant at the $p=.01$ level. The comparisons showed changes in all groups. Groups I and III increased at the $p=.001$ level, Group II increased at the $p=.01$ level, and Group IV increased at the $p=.05$ level.

The RQ at the 8th minute of work showed a significant decrease in Group III at the $p=.001$ level and no change in the other groups. The RQ at the last minute of work showed no significant changes between Test I and Test III.

The Heart Rate during the last minute of work minus the 3rd minute Recovery Heart Rate showed significant increases in Group II ($p=.05$) and Group III ($p=.001$). Groups I and IV did not change.

The Diastolic Blood Pressure during the last minute of work minus the Recovery Diastolic Blood Pressure at the 3rd minute showed a decrease in Group III at the $p=.001$ level with no change in the other groups. Maximum Systolic Blood Pressure minus Recovery Systolic Blood Pressure at the 3rd minute showed no significant changes.

IV. Summary

Fifty-two variables which were considered to be indexes of physical fitness were investigated. A significant increase from the pre-training value to the post-training value was considered to indicate improvement in fitness in thirty-one of the variables. Table III presents those variables along with the significant changes which were found.

Table III

Variables in Which a Significant Increase Indicates Improvement in Physical Fitness

Variable	I 20 Min.	II 40 Min.	III 60 Min.	IV Control
Vital Capacity				
Maximum Breathing Capacity				
Pullups				
Situps			.01	
Standing Broad Jump				
Softball Throw				
Mean AAHPER Percentile				
Time on Treadmill to 180 H.R.	.001	.001	.001	
Maximal Pulmonary Ventilation (TM)	.01	.001	.01	
Tidal Volume (TM)		.05		
Carbon Dioxide (TM)	.01	.001	.001	
Maximal Oxygen Uptake (TM)	.001	.001	.001	
Oxygen per Pulse (TM)	.001	.001	.001	
Max. O_2/kgbw·min. (TM)	.01	.001	.001	
Hemoglobin				
Hematocrit				
Red Blood Cells			.05	
Reticulocytes				
Red Cell Volume				
Plasma Volume				
Total Blood Volume				
Lactic Acid (After TM Test)		.05		
Time on Bicycle to 180 H.R.	.001	.001	.001	
Maximal Pulmonary Ventilation (Bike)			.05	
Tidal Volume at 180 H.R. (Bike)	.01	.05		
Carbon Dioxide at 180 H.R. (Bike)	.01	.01	.001	.05
Maximal Oxygen Uptake (Bike)	.001	.01	.001	
Oxygen per Pulse at 8th Minute (Bike)	.05		.001	
Oxygen per Pulse at 180 H.R. (Bike)	.001	.01	.001	
O_2/kgbw at 180 H.R. (Bike)	.001	.01	.001	.05
180 H.R. Minus Recovery H.R. at 3rd min. (Bike)		.05	.001	

A significant decrease was considered to indicate improved physical fitness in twenty-one of the variables. These variables and the level of significance for the changes which were found are presented in Table IV.

Table IV

Variables in Which a Significant Decrease Indicates Improvement in Physical Fitness

Variable	I 20 Min.	II 40 Min.	III 60 Min.	IV Control
Weight				
Shuttle Run				
50-yd. Dash				
600-yd. Run	.05			
Systolic Blood Pressure at 180 H.R. (TM)				
Diastolic Blood Pressure at 180 H.R. (TM)	.001	.05	.001	.01
Resting Heart Rate	.05	.001	.05	
Ventilation/Oxygen at 180 H.R. (TM)				
Percent of Body Fat				
Resting, Fasting Cholesterol				
Resting, Fasting Phospholipids				
Resting, Fasting Triglycerides				
Systolic Blood Pressure at 180 H.R. (Bike)				
Diastolic Blood Pressure at 180 H.R. (Bike)	.001		.01	.05
Ventilation at 8th Min. (Bike)	.05		.05	
Tidal Volume at 8th Min. (Bike)				
Carbon Dioxide at 8th Min. (Bike)			.01	
Oxygen at 8th Min. (Bike)				
O_2/kgbw•min. at 8th Min. (Bike)				
Ventilation/Oxygen at 8th Min. (Bike)			.05	
Ventilation/Oxygen at 180 H.R. (Bike)	.01		.05	

Table V gives a summary of the significant changes which indicate an increase in physical fitness.

Table V

Summary of Significant Changes Indicating An Increase in Physical Fitness

Group	Level of Significance			
	.05	.01	.001	Total
I - 20 Min.	4	6	9	19
II - 40 Min.	5	4	8	17
III - 60 Min.	6	4	13	23
IV - Control	3	1	0	4

The data in Table V indicates that Group III, those subjects who exercised for sixty minutes per day, five days per week for ten weeks at a 180 heart rate, made the greatest gains in physical fitness. They had a significant change at the p=.05 level or higher on twenty-three of the fifty-two variables considered to be indexes of physical fitness. The groups which exercised twenty minutes per day, forty minutes per day, and the control group had 19, 17, and 4 significant changes respectively.

The maximal O_2 uptake, as measured by the treadmill test, increased over one-half liter per minute for each of the three exercise groups and only .06 liter for the control group. (Table VI) The maximal O_2/kgbw•min. increased 20% for the twenty minute group, 25% for the forty minute group, and 23% for the sixty minute group. The control group did not have a significant increase.

When the bicycle test was used to measure the maximal O_2/kgbw•min. the three exercise groups had the following changes (Table XI): the twenty minute group increased from 30.98 ml. to 37.70 ml., 22%; the forty minute group increased from 34.85 ml. to 40.78 ml., 17%; and the sixty minute group increased from 31.86 ml. to 40.88 ml., 28%.

Table XIV presents the average work load for each subject for the first and tenth week. The mean increase for each of the exercising groups was as follows: Group I, 252 kpm/min.; Group II, 325 kpm/min.; and Group III, 423 kpm/min. This represents a 29% increase for Group I, a 37% increase for Group II, and a 57% increase for Group III. However, Group III started at a significantly lower work load and would normally be expected to make a greater gain than either of the other groups.

Although the group which exercised sixty minutes per day made the greatest gains in the specified physical fitness variables, they did not improve a great deal more than did the group which exercised only twenty minutes per day. Based on the analysis of the data and after consultation with the NASA Technical Monitor the conclusion was reached that the slightly greater gain in physical fitness did not justify the extra forty minutes of work each day. Although most of the subjects were able to maintain the 180 heart rate, one in the forty minute group and one in the sixty minute group worked at a considerably lower heart rate. Since the working heart rate declines with age and improved fitness the astronauts could not be expected to maintain a 180 heart rate for more than a very few minutes. There would be exceptions.

Based on the first three experiments the decision was made to train on the bicycle ergometer at a 160 heart rate in Experiment IV. The length of the training sessions will be twenty minutes with the number of sessions varying for the three exercise groups. Group I will exercise three times per week, Group II six times per week, and Group III twice per day or twelve times per week.

Table VI

Respiratory Data Obtained from the Balke Treadmill Test

Variable		I 20 Minutes	II 40 Minutes	III 60 Minutes	IV Control
Vital Capacity (l)	Pre	4.98	4.98	4.68	4.66
	Post	5.10	5.18	4.64	4.76
	Difference	.12	.20	- .04	.10
Maximum Breathing Capacity (l)	Pre	181.6	177.2	186.6	167.6
	Post	190.2	180.5	181.4	166.0
	Difference	8.6	3.3	- 5.2	- 1.6
Respiratory Rate During MBC Test (min.)	Pre	178.8	143.8	168.0	147.0
	Post	178.2	165.8	183.6	157.6
	Difference	- .6	22.0	15.6	10.6
Tidal Volume During MBC Test (l)	Pre	1.04	1.25	1.12	1.14
	Post	1.10	1.10	.98	1.06
	Difference	.06	- .15	- .14	- .08
$\dot{V}_E$ (Maximal Pulmonary Ventilation) BTPS (l)	Pre	73.48	88.58	87.46	97.22
	Post	94.18	121.12	108.92	103.06
	Difference	20.70	32.54	21.46	5.84
Respiratory Rate at $\dot{V}_E$ (min.)	Pre	28.6	36.5	36.8	39.2
	Post	34.8	43.8	46.0	40.4
	Difference	6.2	7.3	9.2	1.2
Tidal Volume at $\dot{V}_E$ (l)	Pre	2.58	2.45	2.36	2.50
	Post	2.76	2.80	2.44	2.60
	Difference	.18	.35	.08	.10
Carbon Dioxide at $\dot{V}_E$ (l)	Pre	2.132	2.260	2.366	2.604
	Post	2.568	3.055	2.850	2.606
	Difference	.436	.795	.484	.002
Maximal Oxygen Uptake (l)	Pre	2.380	2.398	2.406	2.680
	Post	2.920	3.078	3.008	2.740
	Difference	.540	.680	.602	.060
Oxygen per Pulse at $\dot{V}_E$ (ml)	Pre	13.04	13.15	13.22	14.88
	Post	16.18	17.10	16.70	15.24
	Difference	3.14	3.95	3.48	.36
Max. O_2/kgbw·min. (ml)	Pre	31.10	34.00	31.98	34.22
	Post	37.44	42.60	39.36	34.90
	Difference	6.34	8.60	7.38	.68
$\dot{V}_E/O_2$ (l)	Pre	30.86	37.00	36.20	36.02
	Post	32.60	39.28	36.26	37.30
	Difference	1.74	2.28	.06	1.28
RQ at 180 Heart Rate	Pre	.8936	.9265	.9842	.9702
	Post	.8822	.9932	.9432	.9486
	Difference	- .0114	.0667	- .0410	- .0216

Table VII

Cardiovascular Data Obtained from the Balke Treadmill Test

Variable		20 Minutes	40 Minutes	60 Minutes	Control
Systolic Blood Pressure at Rest	Pre	128	122	128	128
	Post	129	129	131	131
	Difference	1	7	3	3
Systolic Blood Pressure at 180 H.R.	Pre	182	164	183	187
	Post	190	188	202	196
	Difference	8	24	19	9
Diastolic Blood Pressure at Rest	Pre	80	86	88	83
	Post	83	80	85	76
	Difference	3	- 6	- 3	- 7
Diastolic Blood Pressure at 180 H.R.	Pre	70	65	66	69
	Post	60	60	56	62
	Difference	- 10	- 5	- 10	- 7
Heart Rate at Rest	Pre	88.8	86.0	78.4	76.0
	Post	75.2	60.5	67.2	72.0
	Difference	- 13.6	- 25.5	- 11.2	- 4.0
Heart Rate at Work	Pre	182.4	182.5	182.0	180.0
	Post	180.4	180.0	180.0	180.0
	Difference	- 2.0	- 2.5	- 2.0	.0
Hemoglobin	Pre	16.26	15.32	15.78	15.60
	Post	16.22	15.82	15.58	15.82
	Difference	- .04	.50	- .20	.22
Hematocrit	Pre	48.3	46.8	47.5	46.8
	Post	49.4	47.6	46.8	47.0
	Difference	1.1	.8	- .7	.2
Red Blood Cells (millions)	Pre	4.940	4.848	4.586	4.858
	Post	5.070	5.245	5.096	4.790
	Difference	.130	.397	.510	- .068
Reticulocytes (%)	Pre	1.02	.88	.52	.86
	Post	.44	.65	.78	.64
	Difference	- .58	- .23	.26	- .22
Red Cell Volume (ml)	Pre	2602.6	2390.8	2693.0	2398.4
	Post	2540.2	2483.5	2349.0	2358.8
	Difference	- 62.4	92.7	- 344.0	- 39.6
Plasma Volume (ml)	Pre	3400.4	3180.2	3496.8	3248.8
	Post	3140.6	3242.2	3100.0	3100.4
	Difference	- 259.8	62.0	- 396.8	- 148.4
Total Blood Volume (ml)	Pre	6003.0	5571.0	6187.8	5647.2
	Post	5680.6	5725.8	5449.0	5459.2
	Difference	- 322.4	154.8	- 738.8	- 188.0

Table VIII

Blood Chemistry Data in
Resting, Fasting State

Variable		20 Minutes	40 Minutes	60 Minutes	Control
Glucose (mg%)	Pre	79.80	78.95	89.48	78.96
	Post	86.68	85.98	86.56	86.72
	Difference	6.88	7.03	- 2.92	7.76
SGOT (Sigma Units)	Pre	24.28	26.85	24.00	21.86
	Post	23.30	20.15	20.02	23.72
	Difference	- .98	- 6.70	- 3.98	1.86
Lactic Acid (mg%)	Pre	10.98	12.90	11.46	10.24
	Post	12.18	11.45	9.38	7.42
	Difference	1.20	- 1.45	- 2.08	- 2.82
Total Cholesterol (mg%)	Pre	141.0	179.8	180.8	172.8
	Post	177.8	155.0	160.0	173.4
	Difference	36.8	- 24.8	- 20.8	.6
Phospholipids (mg%)	Pre	181.8	214.5	199.6	203.4
	Post	200.6	212.2	209.6	211.8
	Difference	18.8	- 2.3	10.0	8.4
Sodium (m Eq/L)	Pre	140.22	129.68	131.30	132.60
	Post	140.76	140.42	141.38	143.50
	Difference	.54	10.74	10.08	10.90
Potassium (m Eq/L)	Pre	4.36	3.90	4.50	4.62
	Post	5.04	4.60	4.96	4.84
	Difference	.68	.70	.46	.22
Protein (gr%)	Pre	7.642	7.718	7.586	7.442
	Post	7.784	8.198	7.616	8.358
	Difference	.142	.480	.030	.916
Creatine Phosphokinase (Sigma Units)	Pre	9.44	7.90	4.04	8.30
	Post	7.10	4.65	5.28	6.12
	Difference	- 2.34	- 3.25	1.24	- 2.18
Nitrogen (mg%)	Pre	11.28	13.75	11.38	11.66
	Post	11.42	11.02	12.06	12.96
	Difference	.14	- 2.73	.68	1.30
Calcium (mg%)	Pre	11.14	11.30	10.92	10.62
	Post	9.76	8.85	8.06	8.62
	Difference	- 1.38	- 2.45	- 2.86	- 2.00
Triglycerides (mg%)	Pre	40.0	72.2	56.4	84.0
	Post	67.4	81.2	78.8	105.0
	Difference	27.4	9.0	22.4	21.0

Table IX

Blood Chemistry Data Immediately
After Maximal Work Task

Variable		20 Minutes	40 Minutes	60 Minutes	Control
Glucose (mg%)	Pre	89.04	82.95	82.64	85.56
	Post	81.96	81.88	83.32	82.36
	Difference	- 7.08	- 1.07	.68	- 3.20
SGOT (Sigma Units)	Pre	25.98	27.32	24.60	24.36
	Post	23.28	23.48	21.92	24.70
	Difference	- 2.70	- 3.84	- 2.68	.34
Lactic Acid (mg%)	Pre	28.52	31.32	36.72	42.30
	Post	34.26	42.72	40.84	39.32
	Difference	5.74	11.40	4.12	- 2.98
Total Cholesterol (mg%)	Pre	152.8	180.2	190.2	187.4
	Post	170.0	158.8	169.2	181.4
	Difference	17.2	- 21.4	- 21.0	- 6.0
Phospholipids (mg%)	Pre	187.0	226.0	214.4	218.6
	Post	226.0	235.5	218.0	222.2
	Difference	39.0	9.5	3.6	3.6
Sodium (m Eq/L)	Pre	138.32	131.12	132.48	130.50
	Post	139.90	140.38	142.78	143.80
	Difference	1.58	9.26	10.30	13.30
Potassium (m Eq/L)	Pre	4.56	4.42	4.36	4.78
	Post	5.12	5.02	5.46	5.22
	Difference	.56	.60	1.10	.44
Protein (gr%)	Pre	7.790	7.928	7.776	7.766
	Post	8.218	8.855	8.176	8.958
	Difference	.428	.927	.400	1.192
Creatine Phosphokinase (Sigma Units)	Pre	5.06	6.90	6.86	5.84
	Post	6.36	10.45	7.26	5.70
	Difference	1.30	3.55	.40	- .14
Nitrogen (mg%)	Pre	11.66	13.50	11.98	11.86
	Post	11.04	10.90	12.30	12.76
	Difference	- .62	- 2.60	.32	.90
Calcium (mg%)	Pre	11.04	11.65	11.54	11.40
	Post	9.80	9.30	8.48	8.68
	Difference	- 1.24	- 2.35	- 3.06	- 2.72
Triglycerides (mg%)	Pre	49.2	82.0	59.8	87.4
	Post	72.6	80.8	74.4	104.6
	Difference	23.4	- 1.2	14.6	17.2

Table X

Values for AAHPER Items, Weight, Body Fat
and Time on the Treadmill and Bicycle

Variable		20 Minutes	40 Minutes	60 Minutes	Control
Pullups	Pre	5.4	5.0	3.8	2.8
	Post	5.6	5.0	4.0	3.0
	Difference	.2	.0	.2	.2
Situps	Pre	48.8	43.2	37.2	38.2
	Post	54.0	53.2	52.2	41.0
	Difference	5.2	10.0	15.0	2.8
Shuttle Run (sec.)	Pre	9.62	10.00	9.56	9.90
	Post	9.70	10.18	9.72	9.72
	Difference	.08	.18	.16	- .18
Standing Broad Jump (in.)	Pre	85.4	81.5	84.8	83.8
	Post	85.8	81.8	82.6	85.2
	Difference	.4	.3	- 2.2	1.4
50-yd. Dash (sec)	Pre	6.54	6.68	6.70	6.78
	Post	6.80	6.95	6.82	7.14
	Difference	.26	.27	.12	.36
Softball Throw (ft.)	Pre	167.4	162.8	173.8	170.6
	Post	160.0	160.5	171.8	163.0
	Difference	- 7.4	- 2.3	- 2.0	- 7.6
600-yd. Run (sec.)	Pre	113.4	113.5	115.6	128.6
	Post	107.2	112.8	110.4	132.0
	Difference	- 6.2	- .7	- 5.2	3.4
Mean AAHPER %tile	Pre	48.62	39.80	44.42	37.92
	Post	47.98	38.30	45.20	35.20
	Difference	- .64	- 1.50	.78	- 2.72
Time on Treadmill to 180 H.R. (min.)	Pre	11.80	14.25	12.80	13.60
	Post	16.20	18.75	17.80	14.40
	Difference	4.40	4.50	5.00	.80
Time on Bicycle to 180 H.R. (min.)	Pre	11.8	13.0	11.8	13.0
	Post	15.6	16.2	16.4	13.4
	Difference	3.8	3.2	4.6	.4
Weight (kg)	Pre	78.64	71.90	77.72	78.60
	Post	78.24	73.05	76.86	76.94
	Difference	- .40	1.15	- .86	- 1.66
Body Fat (%)	Pre	16.12	12.48	15.88	17.32
	Post	15.62	12.75	14.84	16.58
	Difference	- .50	.27	- 1.04	- .74

Table XI

Respiratory Data Obtained from
a Modified NASA Bicycle Test

Variable		I 20 Minutes	II 40 Minutes	III 60 Minutes	IV Control
Pul. Vent. at 8th Min. BTPS (l)	Pre Post Difference	56.4 50.2 - 6.2	54.2 53.5 - .7	57.4 49.8 - 7.6	60.8 62.0 1.2
$\dot{V}_E$ (Maximal Pulmonary Ventilation BTPS) (l)	Pre Post Difference	83.6 87.8 4.2	94.2 103.0 8.8	89.2 102.2 13.0	99.0 109.0 10.0
Tidal Volume at 8th Min. (l)	Pre Post Difference	2.00 2.12 .12	1.90 1.80 - .10	1.74 1.68 - .06	2.08 2.06 - .02
Tidal Volume at $\dot{V}_E$ (l)	Pre Post Difference	2.30 2.76 .46	2.25 2.60 .35	2.18 2.44 .26	2.56 2.74 .18
Carbon Dioxide at 8th Min. (l)	Pre Post Difference	1.726 1.606 - .120	1.695 1.590 - .105	1.730 1.548 - .182	1.788 1.798 .010
Carbon Dioxide at $\dot{V}_E$ (l)	Pre Post Difference	2.524 3.090 .566	2.728 3.332 .604	2.626 3.246 .620	2.760 3.100 .340
Oxygen Uptake at 8th Min. (l)	Pre Post Difference	1.752 1.694 - .058	1.750 1.710 - .040	1.714 1.718 .004	1.762 1.750 - .012
Maximal Oxygen Uptake (l)	Pre Post Difference	2.378 2.916 .538	2.478 2.925 .447	2.428 3.108 .680	2.442 2.678 .236
Oxygen per Pulse at 8th Min. (ml)	Pre Post Difference	11.16 12.32 1.16	12.20 12.68 .48	11.00 13.44 2.44	12.44 13.38 .94
Oxygen per Pulse at $\dot{V}_E$ (ml)	Pre Post Difference	13.18 16.16 2.98	13.72 16.28 2.56	13.50 17.26 3.76	13.50 14.88 1.38
O_2/kgbw·min. at 8th Min. (ml)	Pre Post Difference	23.34 22.30 - 1.04	24.45 23.52 - .93	22.26 22.64 .38	22.68 22.94 .26
Max. O_2/kgbw·min. (ml)	Pre Post Difference	30.98 37.70 6.72	34.85 40.78 5.93	31.86 40.88 9.02	31.60 35.16 3.56

Table XI (Cont.)

Respiratory Data Obtained from
a Modified NASA Bicycle Test

Variable		I 20 Minutes	II 40 Minutes	III 60 Minutes	IV Control
Pulmonary Ventilation/Oxygen at 8th Min. (1)	Pre Post Difference	31.96 29.92 - 2.04	31.05 31.20 .15	33.44 28.92 - 4.52	34.36 35.68 1.32
Pulmonary Ventilation/O_2 at 180 H.R. (1)	Pre Post Difference	35.66 30.38 - 5.28	37.80 35.32 - 2.48	36.42 32.84 - 3.58	39.72 40.68 .96
RQ at 8th Minute	Pre Post Difference	.9832 .9490 - .0342	.9692 .9282 - .0410	1.0116 .8996 - .1120	1.0142 1.0358 .0216
RQ at 180 Heart Rate	Pre Post Difference	1.0652 1.0562 - .0090	1.0972 1.1365 .0393	1.0816 1.0306 - .0510	1.1262 1.1654 .0392
Respiratory Rate at 8th Minute	Pre Post Difference	29.0 24.4 - 4.6	28.5 29.5 - 1.0	32.8 29.6 - 3.2	30.8 31.6 .8
Respiratory Rate at 180 H.R. (min.)	Pre Post Difference	37.2 32.0 - 5.2	41.5 40.0 - 1.5	40.6 43.4 2.8	38.0 39.6 1.6

Table XII

Cardiovascular Data Obtained from
a Modified NASA Bicycle Test

Variable		I 20 Minutes	II 40 Minutes	III 60 Minutes	IV Control
Systolic Blood Pressure at Rest	Pre	126	121	125	127
	Post	128	120	124	123
	Difference	2	- 1	- 1	- 4
Systolic Blood Pressure at 180 Heart Rate	Pre	179	172	179	182
	Post	177	171	181	192
	Difference	- 2	- 1	2	10
Systolic Blood Pressure at 3rd Min. of Recovery	Pre	140	136	147	150
	Post	149	149	156	150
	Difference	9	13	9	0
Diastolic Blood Pressure at Rest	Pre	81	74	78	78
	Post	79	76	72	72
	Difference	- 2	2	- 6	- 6
Diastolic Blood Pressure at 180 Heart Rate	Pre	68	61	67	69
	Post	56	55	56	62
	Difference	-12	- 6	- 11	- 7
Diastolic Blood Pressure at 3rd Min. of Recovery	Pre	71	66	66	70
	Post	66	64	70	68
	Difference	- 5	- 2	4	- 2
Heart Rate at Rest	Pre	73.6	80.0	85.6	89.6
	Post	79.2	74.0	71.2	78.4
	Difference	5.6	- 6.0	- 14.4	- 11.2
Heart Rate at Work	Pre	180.4	180.5	180.0	180.8
	Post	180.4	180.0	180.0	180.0
	Difference	.0	- .5	.0	- .8
Heart Rate at 3rd Minute of Recovery	Pre	118.4	122.0	120.0	116.8
	Post	110.4	110.0	101.6	112.8
	Difference	- 8.0	- 12.0	- 18.4	- 4.0

Table XIII

Average Heart Rate During Workouts

Group	Subject Number	Beats Per Minute
	01	177.6
Group I	02	179.2
20 Min.	03	180.0
	04	176.8
	05	180.4
	Mean	178.8
	06	Dropped from Program - Illness
Group II	07	175.6
40 Min.	08	179.2
	09	177.6
	10	166.4
	Mean	174.8
	11	161.6
Group III	12	178.4
60 Min.	13	179.6
	14	179.2
	15	180.0
	Mean	175.6
	Overall Mean	176.4

Table XIV

Difference in Work Load From First Through Tenth Week

	Subject Number	Average Work Load First Week kpm/min.*	Average Work Load Tenth Week kpm/min.*	Difference kpm/min.*
	01	660	1020	360
Group I	02	945	1005	60
20 Min.	03	765	975	210
	04	1095	1500	405
	05	900	1125	225
	Mean	873	1125	252
	06	Dropped from Program Due to Illness		
Group II	07	936	1155	219
40 Min.	08	930	1275	345
	09	810	1185	375
	10	795	1155	360
	Mean	868	1193	325
	11	720	1125	405
Group III	12	735	1395	660
60 Min.	13	780	1020	240
	14	645	1125	480
	15	825	1155	330
	Mean	741	1164	423
	Overall Mean	827	1161	333

* kpm = kilopond meter; 1 kp is the force acting on the mass of 1 kg at normal acceleration of gravity; 100 k_{pm} per minute = 723 foot-pounds per minute = 16.35 watts.

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