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ABSTRACT

The first phase of this study sought to determine: (1) the effects of exercise intensity when total work loads were similar; (2) the effects of duration when intensities were controlled; and (3) a possible intensity duration interaction. Subjects were 36 male college students. Frequency of exercise was similar for all subjects. The initial level of fitness was related to endurance changes recorded following the training program. The final phase of the study sought to determine the exercise perceived exertion relationship with special reference to the effects of training. The goal was the ability to determine the relationship between one's perception of exercise and his spontaneous physical activity. The subjects were the 36 young men and 18 older men involved in the training study. Another group of eight young men was also tested. Results showed that: (1) the Vamilmandelic Acid (VMA) values were variable; (2) the T-180 times increased for all subjects; and (3) the perceived exertion scores did not exhibit a strong trend. (Author/EK)

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FINAL REPORT

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A Study of the Relationship of the Intensity of Physical Exercise and the Length of Time Physical Exercise is Performed and its Effect on the Development and Maintenance of the Fitness of the Heart and Lungs.

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U.S. DEPARTMENT OF
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I. INTENSITY AND DURATION OF TRAINING AND THE DEVELOPMENT OF CARDIORESPIRATORY ENDURANCE

Physical activity has received considerable attention in the past decade due in part to its possible role in the prevention or treatment of coronary heart disease (9). This attention has shifted the focus of some exercise physiologists and medical researchers from maximal performance in athletics to optimal performance in the adult years. The increased attention accompanied a shift from the systems approach to physical training to the search for specific training parameters and a possible pharmacopoeia of exercise. Such a search naturally focused on the questions of possible minimal or optimal cardiorespiratory training stimuli, their arrangement, application and possible interaction. The training factors most frequently mentioned are exercise intensity, duration, frequency and initial level of fitness (6, 24, 29).

Studies dealing with exercise intensity have tended to indicate that the effects of training are directly related to the intensity of exercise (20, 28, 29). However, the increase of intensity usually corresponded with an increase in total work done in training. Therefore, the intensity studies seem confounded with a factor related to duration, total work or total energy expenditure. A recent exercise duration study concluded that improvements in fitness were noted most often in the group that trained for the longest period (8). However, an inspection of the data revealed that in certain important training criteria, such as the maximal oxygen intake, the oxygen pulse and the exercise heart rate, the changes favored those in the moderate duration group. Moreover, certain changes seemed to relate to the initial level of fitness and some even favored the short duration training group. The duration studies have also been confounded in that the longer duration of exercise also related to a greater total work load. Studies dealing with the frequency of training do not always agree (18, 23, 29), perhaps because of some of the problems already mentioned. Some studies indicate that two or three sessions per week are sufficient to elicit optimal training effects (18) while others argue for more frequent exposures (23, 29).

Shephard (29) reported that the main factor influencing training was the intensity of effort relative to the subject's initial aerobic power. It is possible that previous studies have underestimated the importance of the initial level of fitness in training studies.

Thus it seems that the previous research dealing with the factors associated with changes in cardiorespiratory endurance have been confounded. The studies have not been designed in such a way to separate the effects of intensity from those of duration, or the effects of intensity from those of initial fitness. Shephard's study utilized serial multiple regression analysis to determine the relative effects of the factors mentioned above. However, only one or two subjects were allocated to each of the possible combinations of intensity, duration or frequency of effort. Thus seventeen of the possible twenty-seven cells of the hypothetical 3 X 3 X 3 design included but one subject. Furthermore, due to the differential training frequencies used, true interaction effects could not be determined.

This study was undertaken to determine the effects of exercise intensity when total work loads were similar, to determine the effects of duration when intensities were controlled, and to determine a possible intensity-duration interaction. The frequency of exercise was similar for all subjects. The initial level of fitness was related to endurance changes recorded following the training program.

Methods

Thirty-six young male college students were randomly assigned to the cells of a 3 X 2 factorial design for a total of six subjects per cell. The design included three levels of intensity (training heart rates of 130, 150 and 170 beats per minute) and two levels of work duration (specified as total kilopond meters of work performed; 7500 and 15,000 kpm). The subjects received medical authorization to participate and were oriented to the tests and training procedures to be followed. The physical characteristics of the subjects are summarized in Table 1. Pretest data collection included a series of questions regarding previous activity patterns and athletic participation. None of the subjects were actively engaged in any intercollegiate athletics. All were requested to refrain from vigorous physical activity not included in the study. A daily questionnaire was utilized to check compliance with the request.

TABLE 1.--PHYSICAL CHARACTERISTICS OF SUBJECTS (N=36)

	Mean	Range
Age	19.5 yrs.	18 - 24
Height	5'9 3/4"	5'6" - 6'3"
Weight	162.4 lbs.	130 - 202

Testing.--Three tests were administered before and after the six week training program. They included the Astrand-Ryhming step test prediction of the maximal oxygen intake, the Balke treadmill test (T_{170}) and the Sjostrand physical working capacity test (PWC_{170}). The step test was administered according to the procedure developed for use by the United States Forest Service (26). The Balke test (2) involved a one percent increase in grade per minute and a rate of 3.5 miles per hour. The treadmill test was terminated when the heart rate reached 170 beats per minute. The PWC_{170} test (30) involved three work periods of 2 1/2 minutes each. The initial work load was 300 kpm/min. for all subjects except those who predicted an aerobic capacity above 48 ml/kg/min. in the step test. Those subjects began at 600 kpm/min. Work loads were increased 300 kpm/min. each work period. Test scores included predicted aerobic capacity (ml/kg/min.), time to 170 heart rate (T_{170}) and PWC_{170} scores (extrapolated from heart rates at three work loads) respectively. All tests were given in the order mentioned with sufficient rest to allow the heart rate to return to near the resting level.

Training.--Training was conducted on Monark bicycle ergometers. Subjects exercised at specified heart rate intensities until the designated work load was achieved. A subject in the 150 heart rate and 7500 kpm group would begin exercise at a level near that required to elicit the desired heart rate. The heart rate would be checked every other minute and the work-load adjusted if the heart rate was too high or too low. The work accomplished each minute would be recorded and the training session terminated when the work-load reached the 7500 kpm total. The pedalling rate was kept constant at 50 rpm with the aid of a metronome. Training continued for six weeks, three times per week for a total of eighteen training sessions. Testing and training were accomplished during the year 1969. Twenty-one subjects were trained in the winter quarter, twelve in the spring and three in the fall. Other subjects began the program but were excused for illness, injury or inconvenience. The same three tests were administered similarly at least two days after the final training session. Care was taken to insure similar testing conditions, including such items as time of testing, bicycle seat height, room temperature and clothing.

Adult Group.--A comparison group of eighteen adults was trained in a similar design. Characteristics of the adult group are included in Table 2. Modifications for this group included a more rigorous medical examination including an exercise electrocardiogram, two tests instead of three (the step test and the PWC_{170} test) and training intensities of 125, 145 and 165 beats per minute. The adult subjects were randomly assigned to one of the six cells of the 3 X 2 design for a total of three subjects per cell.

TABLE 2.--PHYSICAL CHARACTERISTICS OF ADULT SUBJECTS. (N=18)

	Mean	Range
Age	34.7 yrs.	29 - 39
Height	5'9 1/2"	5'4" - 6'2"
Weight	175.0 lbs.	155 - 201

Analysis of the Data.--Pre-post training test differences were analyzed for treatment and interaction effects via a 3 X 2 factorial analysis of variance (36). A separate analysis was performed for each test used. Pre-test scores on the three tests were correlated as were test differences. Test differences were also related to initial fitness level to determine the influence of fitness on training changes. It should be noted that the factorial design noted above does not provide for an inactive control group. This omission was justified on the grounds that previous control groups in this laboratory recorded little if any change on the ergometers and tests utilized in this investigation (18, 28).

Results

The pre-post test differences were analyzed via a 3 X 2 factorial analysis of variance.* Separate analyses were performed for each test procedure. A summary of the means and differences for the three test conditions appears in Table 3. A summary of the analysis of variance performed on the Astrand-Ryhming step test differences appears in Table 4. Summaries for the treadmill and bicycle tests appear in Tables 5 and 6 respectively.

The analyses fail to reveal significant treatment or interaction effects for any of the test conditions. To achieve significance the calculated F score would have to exceed 4.17 for one and thirty degrees of freedom and 3.32 for two and thirty degrees of freedom (36). These results were viewed with some surprise in view of the mean differences found in Table 3. Previous studies have indicated the importance of intensity (20, 28, 29) and duration (8, 29) of exercise in the development of cardiorespiratory endurance. Thus one might expect main effects or at least significant interaction effects. To understand these results it must be understood that in the case of exercise intensities, all groups performed exactly the same amount of total work. Thus the subjects in the 130-7500 cell exercised at a lower intensity but for a longer period than those in the 170-7500 group. The data suggested that the higher intensities yielded greater improvements; however, because of individual differences, the treatment effects did not achieve significance. Table 7 indicates the average training caloric expenditures for subjects in each cell of the experimental design. All subjects trained at a heart rate that averaged 150 beats/min. Thus duration effects must be interpreted in light of the equivalent intensity. One might conclude that none of the various intensity-duration combinations was better than any other, but this interpretation must await consideration of other factors.

The lack of a control group in this study makes analysis of changes difficult. In previous studies using subjects of similar age, height and weight, similar tests and training periods, active control groups (badminton and volleyball) showed changes of - .15 and 0.6 ml/kg/min. on the Astrand-Ryhming test and 2.67 and - 0.6 min. on the Balke test (18, 28). These controls were students in classes that met three times per week.

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*Statistical analyses performed at the University of Montana Computer Center.

TABLE 3.--SUMMARY OF MEAN PRE-TEST, POST-TEST AND DIFFERENCE SCORES FOR THE THREE TEST CONDITIONS

		130			150			170		
	Test	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif
7500	AR ml/kg/min	41.5	44.7	3.2	40.4	49.0	8.6	46.1	52.2	6.1
	TM (sec)	530	605	75	485	595	110	612	717	105
	PWC_{170} (kpm)	1005	1053	48	917	1087	170	1105	1300	195
15,000	AR	43.3	45.9	2.6	44.0	46.2	2.2	44.6	49.3	4.7
	TM	482	552	70	520	687	167	483	630	147
	PWC	912	1080	168	1007	1167	160	933	1018	85

TABLE 4.--SUMMARY OF ANALYSIS FOR ASTRAND RYHMING STEP TEST DIFFERENCES

Source of Variation	SS	df	MS	F
D	70.28	1	70.28	2.015
I	51.21	2	25.61	0.734
I x D	58.92	2	29.46	0.845
Within cell	1046.00	30	34.87	
Total	1226.41	35		

D=Duration, I=Intensity

TABLE 5.--SUMMARY OF ANALYSIS FOR BALKE TREADMILL TEST DIFFERENCES

D	87.11	1	87.11	1.447
I	293.39	2	146.70	2.437
I x D	62.05	2	31.03	0.516
Within cell	1805.67	30	60.19	
Total	2248.22	35		

TABLE 6.--SUMMARY OF ANALYSIS FOR PWC_{170} TEST DIFFERENCES

D	0.00	1	0.00	0.00
I	193.65	2	96.82	0.212
I x D	797.90	2	398.95	0.872
Within cell	13728.67	30	457.62	
Total	14720.22	35		

An intensity-duration interaction had been hypothesized at the outset of this investigation. It is possible that such an effect, or main treatment effects may have been confounded by other aspects of the study, including the specific tests used, possible learning or habituation effects or the initial fitness of the subjects. It is likely that all of these factors are involved in some manner, however, randomization was utilized to attempt to minimize such influences.

Testing procedures: The search for an adequate test of cardiorespiratory endurance has long been in progress. Most physiologists agree that the best available measure of fitness or C-R endurance is the maximal oxygen intake or aerobic capacity test. This test was not used in the present investigation since it is relatively insensitive to minor changes in fitness. In a previous experiment using similar subjects, training intensities and durations, the maximal oxygen intake measure was the only test that did not indicate changes in fitness (18). However, experience with the tests that were used in this study indicate that they are somewhat task-specific, that is they relate specifically to previous exercise habits or experiences. The three tests used were compared to reveal the extent to which they agreed. Table 8 illustrates several test comparisons including the relationships among the tests before training, the relationships among test differences and the relationship of initial fitness scores with the magnitude of change. It is interesting to note that the pre-test correlation coefficients for the three test comparisons are significant but low (r's=.42 to .48). This suggests that the tests measure some uncommon factors. It also raises questions regarding studies that rely on but one measure (29) of fitness.

TABLE 7.--CALORIES EXPENDED DURING TRAINING

	Intensity		
	130 H.R.	150	170
7500 kpm	100*	100	100
15,000 kpm	200	200	200

*Total calories consumed during a single training period.

Even more suprising was the comparison of differences (Table 8). When the test differences were related none of the resulting correlation coefficients were found to be significant. Hence it appears that differences on one test were not related to those measured on another test. It should be noted that the relationship of test differences may be confounded by differential training effects and the previous level of fitness.

Learning, training and performance.--The rather recent realization of the learning and habituation effects on performance test scores has resulted from some recent findings regarding the learning of autonomic responses (21, 25). The complexity of the topic is outlined in a recent paper published by Sharkey and Dayries (27). The discussion suggests that the training itself may reinforce heart rate changes that are essentially independent of actual physiological alterations due to training. Hence some of the changes noted in the performance tests, particularly those tests that are similar to the

TABLE 8.--COMPARISON OF FITNESS TEST SCORES AND DIFFERENCES BETWEEN PRE AND POST TEST DIFFERENCES

Pre Test Scores			Pre Post Differences			Pre Score and Differences		
Comparison		**r**	**Comparison**		**r**	**Comparison**		**r**
$T_1 - T_2$	=	.443**	$D_1 - D_2$	=	.223	$T_1 - D_1$	=	-.206
$T_1 - T_3$	=	.424**	$D_1 - D_3$	=	.168	$T_2 - D_2$	=	-.374*
$T_2 - T_3$	=	.484**	$D_2 - D_3$	=	.092	$T_3 - D_3$	=	-.539**

T_1 = AR step test, T_2 = Balke test, T_3 = PWC test. D = Difference of pre-post test.

*Significant at .05 level.

**Significant at .01 level.

training procedure, may be related to learning, habituation, reduction of anxiety or reduced hypothalmic arousal.

Initial fitness level.--Shephard (29) published data that related training changes to the initial fitness of the subjects. The resulting relationships (Table 8) agree that the magnitude of change is inversely related to the initial level of fitness. In the bicycle ergometer test, the test that corresponded closely to the method of training, the relationship of initial fitness level to degree of change was highly significant ($r = -.539$). Failure to adequately account for this factor in previous experiments of this type may have resulted in erroneous conclusions. It is certainly possible that the somewhat higher fitness level of the subjects in the 170-7500 group (Table 3) may have tended to depress the amount of change possible due to training.

It is perhaps true that matching or covariance procedures could be used to remove the influence just noted. However, matching on level of fitness could not account for other unexplored influences such as hereditary limits, dietary advantages, previous exercise experiences (influencing perception of exercise and perhaps influencing autonomic heart rate control). Several statistical methods of adjustment are currently being attempted in hopes that some of these influences may be specified, controlled or accounted for in this type of investigation. To date, however, none has advanced beyond the level of an a posteriori guess.

Adult comparison group.--In order to test the generality of the above findings, an adult comparison group was trained simultaneously. Eighteen adult men (29-39 years of age) were trained in a similar design. The training was modified to include intensities of 125, 145, and 165 heart rates. The total work or duration dimension remained the same. The adults received a comprehensive medical examination including an exercise electrocardiogram, cholesterol and blood pressure analyses. Volunteers with coronary heart disease risk factors were excluded from participation. Testing was modified to include only the Astrand-Ryhming and PWC_{170} tests. The PWC test began at 300 kpm for all subjects. The physical characteristics of the adult subjects are found in Table 2. The mean pre-post and difference scores are summarized in Table 9.

The results of the 3 x 2 analysis are included in Tables 10 and 11. To achieve significance the calculated F score would have to exceed 4.75 for one and twelve degrees of freedom and 3.89 for two and twelve degrees of freedom (36). The step test analysis yielded highly significant interaction effects. The duration effects were also significant at the .02 level. The analysis of the bicycle data did not reveal significant differences. Both tests indicated that fitness changes were related to exercise intensity. The highly significant interaction found in the step test analysis suggests that high exercise intensities yield optimal training benefits when combined with moderate exercise durations.

TABLE 9.--SUMMARY OF MEAN PRE-TEST, POST-TEST AND DIFFERENCE SCORES FOR THE ADULT GROUP

		125			145			165		
		Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif
7500	AR	36.4	36.1	-0.3	36.9	39.2	2.3	37.3	43.1	5.8
	PWC_{170}	1213	1233	20	1153	1303	150	1253	1519	266
15,000	AR	36.7	45.9	9.2	35.7	41.7	6.0	40.1	43.6	3.5
	PWC_{170}	1103	1296	193	1200	1300	100	1133	1343	210

TABLE 10.--SUMMARY OF ANALYSIS FOR ADULT ASTRAND-RYHMING TEST DIFFERENCES

Source of Variation	SS	df	MS	F
D	57.96	1	57.96	9.128*
I	0.66	2	.33	.050
I x D	103.85	2	51.93	8.178**
Within cell	76.21	12	6.35	
Total	238.68	17		

*Significant at .02 level.
**Significant at .01 level.

TABLE 11.--SUMMARY OF ANALYSIS FOR ADULT PWC_{170} TEST DIFFERENCES

Source of Variation	SS	df	MS	F
D	0.00	1	0.00	.00
I	614.77	2	307.34	1.186
I x D	869.56	2	434.78	1.678
Within cell	3110.00	12	259.17	
Total	4594.33	17		

The adult training program was less intense and it yielded lower differences. However, direct comparison of the fitness scores for adults and young men is not advised since the step test scores were corrected for age (1) due to the reduction in maximal heart rate with age. The reduced heart rate with age accounts for the relatively higher PWC_{170} scores in the adult group. The corrected step test scores offer the most valid measure for comparing the two age groups. Those scores suggest that the older subjects were indeed less fit.

Discussion.--It seems reasonable to assume that training has its effect, at least in part, by its stimulation of changes within the active muscle fibers (13, 14, 17). The importance of exercise intensity or duration rests in the fact that both stimulate increased metabolism within the cell. When the increase exceeds the typical, it seems to stimulate adjustments that allow larger expenditures in the future. High exercise intensities call on many muscle fibers to contract in an all or none fashion. Exercise of long duration eventually may do the same since some of the contracting fibers will fatigue and others will take their place or join them. Thus it seems possible that both intensity and duration may be involved in stimulating changes in fitness. Excessive intensity may result in a rapid fatigue, without adequately stimulating aerobic metabolism. Exercise of long duration requires a relatively low intensity. The results of this study did not statistically support specific intensity, duration or interaction effects. However, fitness changes were noted and possible reasons for lack of significant differences have been discussed.

The magnitude of the differences for each group in each test were ranked and compared as a final attempt to uncover differential effects of training. The sum of the ranks on the three tests (Figure 1) indicate that the low intensity programs were inferior to those of higher intensity. At higher intensities the lower workload (7500 kpm) seemed to elicit greater differences. In the case of the adult subjects (Figure 2) the sum of the ranks for the two tests indicate that changes relate to intensity at the 7500 duration level. At the higher duration level the higher intensities do not seem to elicit larger changes in fitness.

The ambiguity of the results cited illustrates the need for a new approach to the problem. It has become evident that more sophisticated experimental designs are needed. These designs must be utilized in conjunction with very precise schemes for the prescription of exercise dosage. They must include ample subjects, more precise information regarding level of cardiorespiratory endurance and better measures of fitness changes (for suggestions see Sharkey and Dayries, 27).

The implications of research of this sort to the question of the importance of physical activity for cardiovascular health are still not clear. It is still too early to support the optimistic suggestions advanced by Bouchard et al. (6). They have suggested that a daily exercise program of but three minutes duration, using at least fifty percent of the maximal oxygen intake will increase cardiopulmonary capacity. This point may well be defensible. However, the title of their article relates that amount of exercise to the prevention of cardiovascular diseases. As pointed out by Fox and Haskell (9), such statements cannot be defended on the basis of the available evidence.

Conclusions

The training intensity, as defined by the exercise heart rate, did not significantly influence the extent of training changes when the total work load was held constant. The duration of training, as defined by the total amount of work performed, did not significantly influence the extent of training changes when the intensity of training was held constant. Intensity and duration of training did

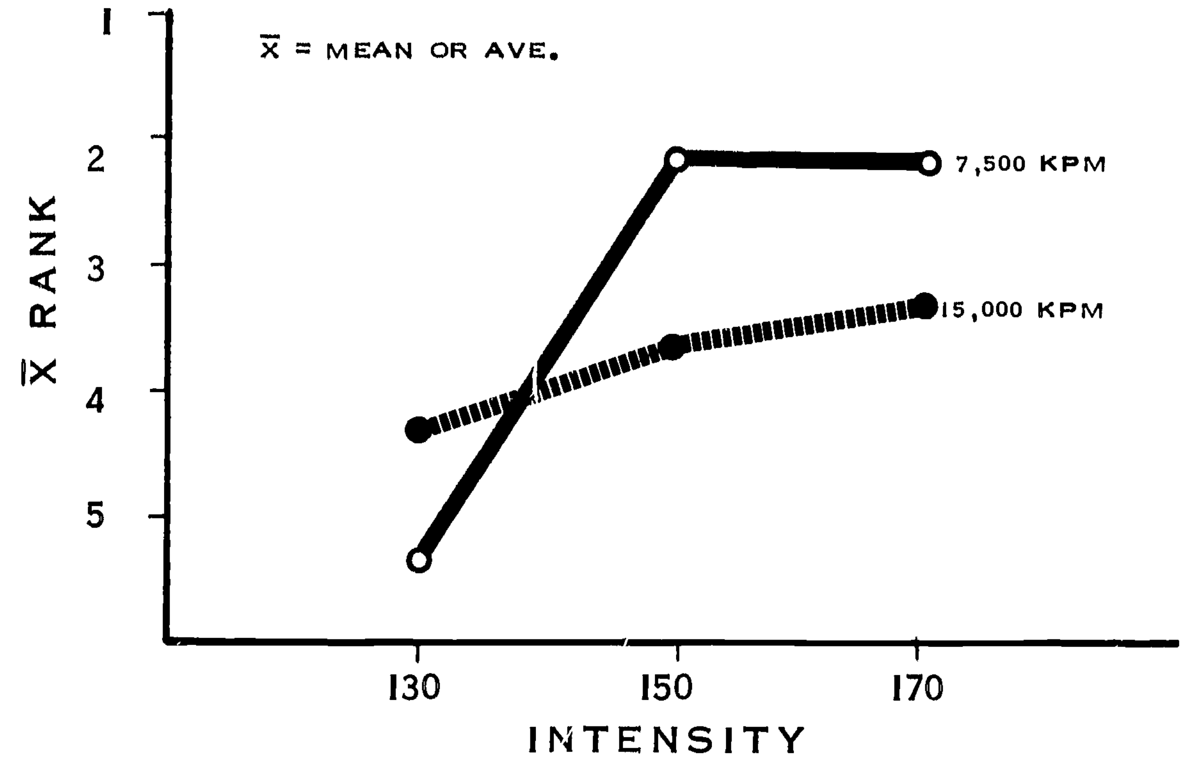

FIGURE I
AVERAGE IMPROVEMENT ON THREE TESTS
AS INDICATED BY RANKS (YOUNG S's)

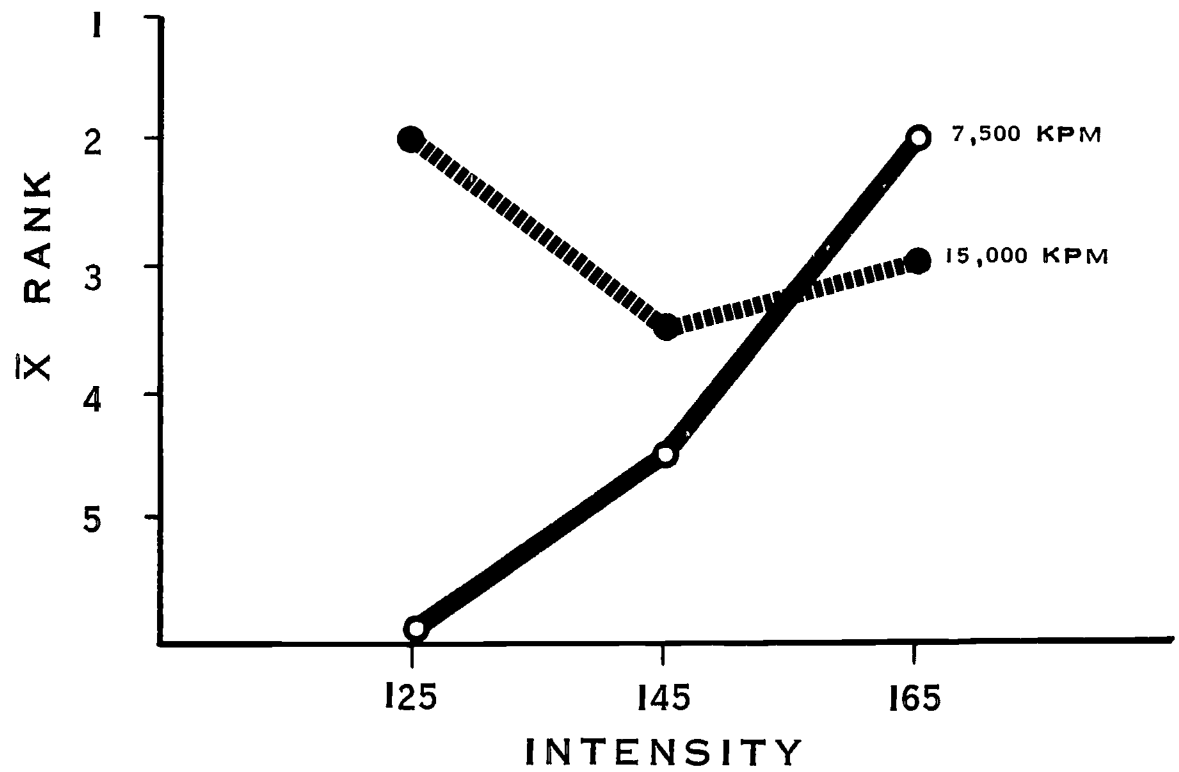

FIGURE 2
AVERAGE IMPROVEMENT ON TWO TESTS
AS INDICATED BY RANK (ADULT S's)

interact to produce significantly different training changes.

In spite of the possible confounding effect of differential training programs, the previous level of fitness yielded a highly significant negative correlation when compared with the extent of changes due to training and testing on the bicycle ergometer. The cardiorespiratory endurance tests used are related but they seem to measure different aspects of changes due to training.

II. THE EFFECTS OF TRAINING ON THE PERCEPTION OF EXERCISE

Borg (3, 4, 5) has established the psychophysical relationship of physical exertion to perception. He has developed and tested a rating scale suitable for the subjective evaluation or perception of the degree of exertion. Borg's perceived exertion scale was utilized in conjunction with the training study previously summarized in order to evaluate the effect of training on perceived exertion.

Investigations on animals and humans have established the validity of so-called training effects. The physiological alterations due to training are well documented. However, physical educators have begun to realize that the alteration of the physiological system does not insure concommitant psycho-social changes that relate to continued physical activity. The rationale underlying the requirement of physical education at the secondary or college level assumes that exposure to the activity will somehow prompt individuals to seek out physical activity in the future. Literature regarding the validity of this assumption for humans is scarce indeed (15).

The perceptual process may well be related to the desire to participate in physical activity. Perception of an event is related to the stimuli accompanying the event, previous experiences with similar stimuli and the physiological state of the organism. The present concern with perceived exertion and training was predicated on the assumption that the events of training could alter one or all of the factors involved.

The purpose of this phase of the study was to further study the exercise-perceived exertion relationship with special reference to the effects of training. The investigation included:

a. A determination of the pulse rate--perceived exertion relationship on several ergometers.
b. The effects of training on perceived exertion.
c. The effects of training on catecholamine excretion during exercise.
d. The effects of training on preferred exertion.
e. The relationship of perceived exertion to measures of physiological stress.

The ultimate goal of this phase of the project is to be able to determine the relationship between one's perception of exercise and his spontaneous physical activity (see Appendix B). Earlier experiments in this laboratory (31,37) have indicated that the stress response to exercise and training seems to be a function of the emotional response to the exercise, including perhaps uncertainty or fear. Continued exposure to the exercise situation allows a diminished stress response (as measured by the urinary excretion of 17-ketogenic steroids, end products of adrenal cortical hormone secretion). The diminished stress response occurs in spite of an increased work-load. The rationale involved here is that as one's perception of physical effort is altered via training, the emotional threat imposed by the effort will diminish. Hence the individual may feel more willing or eager to undertake a higher level of spontaneous activity. A given level of exertion would not be unfamiliar and would not impose a threat.

Method

The subjects for this phase of the project included the 36 young men and 18 older men involved in the training study. Another group of eight young men were tested and trained for the evaluation of the relationship between stress measures and perceived exertion.

The perceived exertion rating scale used was that devised by Borg (3). The subject was asked to respond to the question: How does the exercise feel? Numerical estimations were selected from the 21 available responses. The odd scale values from 3 to 19 were defined in succession by the terms: 3 extremely light, 5 very light, 7 light, 9 fairly light, 11 neither light nor difficult, 13 fairly difficult, 15 difficult, 17 very difficult, 19 extremely difficult. During the step test the subject was asked to rate the exertion at the beginning of the fourth minute of the test. During the treadmill test the subject was asked to respond to the exertion question at heart rates of 120, 140 and 160 beats per minute. During the bicycle test the subject responded to the question during the last half minute of each 2 1/2 minute work period. Preferred exertion scores were also gathered via a similar scaling procedure.

This phase of the investigation should be considered in several sections. The pre-training perceived exertion scores were evaluated on the three ergometers. The relationship of the pulse rate to the perceived exertion score was compared on each ergometer, The changes in perceived exertion were related to fitness changes following the six week training program. The relationship of perceived exertion to emotional manifestations (stress) were compared before, during and after training.

The final aspect of the study involved eight young men of college age. These subjects were not actively engaged in any competitive athletic programs. They were tested and trained on the motor driven treadmill. Testing and training involved progressive treadmill walks to a heart rate of 180 beats per minute (T_{180}). Heart rates were monitored with a Tektronix Physiological Monitor. Perceived exertion questions were asked during the sixth minute of exercise. Following a one week orientation that involved two T_{180} treadmill walks and orientation to the urine collection procedures, the subjects underwent control tests and then a five week training program. Training was conducted on a M-W-F schedule. Urine samples for the estimation of catecholamine production (using Sunderman's method for the estimation of urinary vanilmandelic acid, 33) were collected following each Wednesday treadmill walk. The Wednesday T_{180} time was increased by thirty seconds per day for the Friday and Monday walks to insure an adequate training stimulus.

Results

Pulse rate and perceived exertion.--Borg (3, 4, 5) and Frankenhaeuser et al. (10) have reported data suggesting a linear relationship between heart rate and therefore work load and perceived exertion. The pre-test data for the 36 young subjects support such a conclusion. Figure 3 presents the relationship for the three ergometers. The linear relationship suggested by the bicycle ergometer data and the close agreement shown by the treadmill and step test data indicate the remarkable degree to which the perceived exertion scores follow heart rate increases. This should not come as any surprise because it has been established that oxygen needs are a linear function of exercise intensity and that the heart rate is the major determinate of the cardiac output response to exercise. The relatively close agreement of heart rate and perceived exertion scores on different ergometers was not expected. However, since all three ergometers involve work with the legs there is probably some degree of perceptual overlap involving stimuli, previous experience and physiological conditions. One might not necessarily work with the arms to fit the data presented in Figure 3. Borg (5) has suggested that the perception of exertion experienced by a forest worker seems to influence (or relate to) field performance as much as the working capacity estimated from physiological variables. The data just presented would tend to offer tangible support for such a contention. Borg goes on to say that the resources of mental energy, motivation and ability to tolerate heavy physical strain and stress also seem to be of great importance. It is clear that the ability to tolerate heavy physical strain and the resource of mental energy could be influenced by physical conditioning and additional experiences with the stimuli involved.

Training and perceived exertion.--The changes in perceived exertion scores are presented in Tables 12 and 13 in a 3 x 2 table corresponding to the cardiorespiratory endurance changes noted in Tables 3 and 9. The positive changes represent lower post-test ratings. The step test and bicycle ratings should be considered in relation to the same work load while the treadmill scores should be considered in relation to the same heart rate, but generally a higher work load. The treadmill difference relates to the reading taken with a 160 heart rate, the bicycle score relates to the reading taken at the end of the last work level. The step test and bicycle data show generally consistent improvements in perceived exertion. The treadmill data, based on readings taken at the same heart rate, did not show equivalent improvement. This suggests that the heart rate-perceived exertion relationship did not change greatly during the six week training period. The step test data for

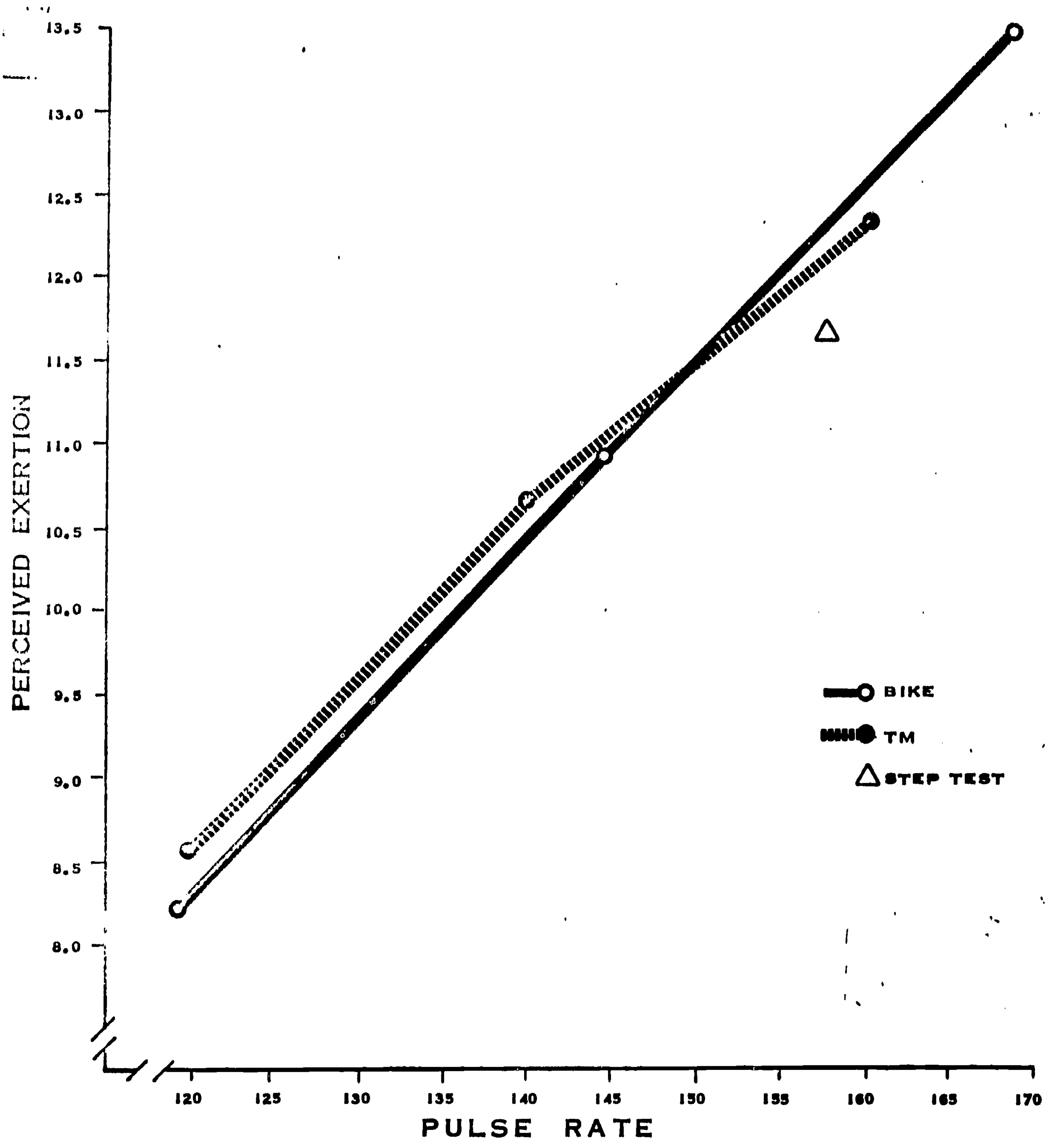

FIGURE 3
PULSE RATE AND PERCEIVED EXERTION
ON THREE ERGOMETERS

the young men did not exhibit any relationship with intensity or duration of training. The equivalent data for the older subjects (Table 13) suggested that changes were related to intensity unless the duration was excessive. The bicycle changes for the young men seemed related to intensity, as did those for the adult subjects. It might be expected that the bicycle ratings would be more influenced by the bicycle training. In fact, the lack of change in rating for the subjects in the low intensity groups was rather consistent. This could be interpreted in light of the training procedure. Subjects in the low intensity groups were not exposed to the higher resistances during training. Therefore, in spite of any training changes, they would have little experience with the resistances encountered in the second and third work period of the bicycle test.

TABLE 12.--PRE-POST TEST DIFFERENCES IN PERCEIVED EXERTION SCORES (N=36 Young Men)

		Intensity		
		130	150	170
	AR	2.0	1.7	1.0
7500	TM	0.5*	-1.1	0.3
	PWC	0.5**	2.7	2.0
Duration				
	AR	1.9	2.7	1.1
15,000	TM	1.1	0.7	1.1
	PWC	0.3	2.0	1.7

*For 160 heart rate rating.
**For rating taken at end of last work level.

In their study regarding manifest anxiety and physical fitness, Franks and Jette (12) noted that training should be of such intensity that subjects can adjust to it psychologically. Subjects who trained three times per week exhibited a reduction in manifest anxiety while subjects in a five day program did not. While this phase of the present study did not deal with anxiety, it is interesting to note the effects of activity on a more generalized aspect involving perception. The results of the present investigation suggest that perceived exertion changes are related to changes in physical fitness and that the relationship of perceptual change to training intensity is most clearly indicated when measured on an ergometer identical to that used for training. This does not suggest that the perceptual changes are closely related to the actual physiological changes that may have been taking place. The data only seems to indicate that a psychophysical tool such as a simple rating scale seems to serve as an indicator for the numerous stimuli, impressions and associations that are affected daily in a training program.

TABLE 13.--PRE-POST TEST DIFFERENCES IN PERCEIVED EXERTION SCORES (N=18 Adult Men)

Duration		Intensity 125	Intensity 145	Intensity 165
7500	AR	-0.3	3.0	2.3
	PWC	-1.3*	2.0	1.3
15,000	AR	0.0	3.3	-0.7
	PWC	0.3	1.7	1.7

*For rating taken at end of last work level.

Training and preferred exertion.--Preferred exertion scores were obtained (using scale illustrated in Table 14) at the third work level on the bike. The post-training differences are pictured in Tables 14 and 15. The intent here was to determine if training altered the individuals preferred training level. The data suggests a general decrease in preferred exertion scores at a set level of work. Hence a higher level of work could be tolerated at the same preference level. The adult subjects in the low intensity and duration cell exhibited an increase in preferred exertion. Thus the training did not allow them to prefer a higher training work-load. It should be noted that these subjects trained at a level far below the work-load at which the preferred exertion question was asked (900 kpm for all adult subjects).

While these results suggest a slight effect on preferred exertion responses, they should not be interpreted as evidence of behavioral changes. Also, the scores are obviously confounded by previous exercise experiences and level of fitness. Finally, since the preferred question was always asked following the perceived scaling, we noticed a very direct relationship between the responses on the two questions. The preferred scale was used to gather experience for future attempts that might relate the preference to actual spontaneous behavior.

TABLE 14.--CHANGES IN PREFERRED EXERTION SCORES FOR YOUNG SUBJECTS (N=36)

	Intensity		
	130	150	170
7500	-1/6	-1	-1/6
Duration			
15,000	-1	-1	0

Preferred Exertion*

1. Much below
2. Below
3. Somewhat below
4. About right
5. Somewhat above
6. Above
7. Much above

TABLE 15.--CHANGES IN PREFERRED EXERTION SCORES FOR ADULT SUBJECTS (N=18)

	Intensity		
	125	145	165
7500	+2/3	-1	-1 2/3
Duration			
15,000	-1/3	-1/3	-1/3

*How does this exercise feel in relation to that you would prefer to engage in for fitness training. NOTE: A negative change indicates a desire to train at a higher level.

Perceived exertion, stress and the effects of training.--The perceived exertion score represents a verbalized impression of the exercise. This sort of perceptual response has been studied for a wide variety of stimuli. Stevens (32) has shown that psychophysical relationships of this sort can usually be described as a power function with the exponent dependent on the particular stimuli. Physical effort stimuli have been found to exhibit exponents ranging from 1.1 to 1.7 (32). Thus the relationship of the stimulus magnitude to the estimated or perceived magnitude would exhibit a rising curve. Experience with the literature regarding physiological stress (defined as any of the magnitude of stimuli that result in increased secretion of ACTH from anterior pituitary gland: usually measured via indirect methods such as urinary excretion of 17-ketogenic steroids, 37) indicates that some of the same stimuli elicit adrenocortical responses characterized by similar fast rising curves (34).

Hence it was hypothesized that the perceptual response to exercise was mediated via the hypothalmus. Training and familiarity with exercise would tend to reduce the emotional aspects of the involvement and reduce both the stress and the perceptual responses. It has been reasonably well established that exercise, by itself, need not be a stressor (16, 31, 34, 37). The data in this study indicated a general decline in perceived exertion scores with training. Steadman and Sharkey (31) and then Whiddon et al. (37) have shown that adrenocortical activity declines with training, even in the face of increased work-loads. This data is summarized in Figure 4. Figure 5 suggests some ways in which training might influence perception and stress responses.

Since the hypothalmus is also involved in the activation of the adrenal medulla via the sympathetic nervous system, it was decided to determine the relationships of adrenomedullary secretions to exercise, perception and training. Frankenhaeuser et al. (10) studied the relationship of catecholamine excretion to exercise and also to perceived exertion as measured by the Borg (3) scale. Their data confirmed the linear relationship of exercise intensity to perceived exertion already noted in this study. When they related exercise work-load to catecholamine excretion they found that both adrenaline and noradrenaline exhibited power function relationships in that a calculated exponent would be above 1.0. The noradrenaline increase was explained as a result of the cardiovascular regulating system. They suggested that the adrenaline increase was due to the degree of mental stress or unpleasantness associated with the effort. They concluded that the adrenaline increase was at least partly associated with the subjective reaction accompanying heavy physical work, rather than being elicited by the work itself.

These interesting conclusions suggested further studies involving the effects of training on catecholamine excretion. For this phase of the project eight young college men were tested and then trained for five

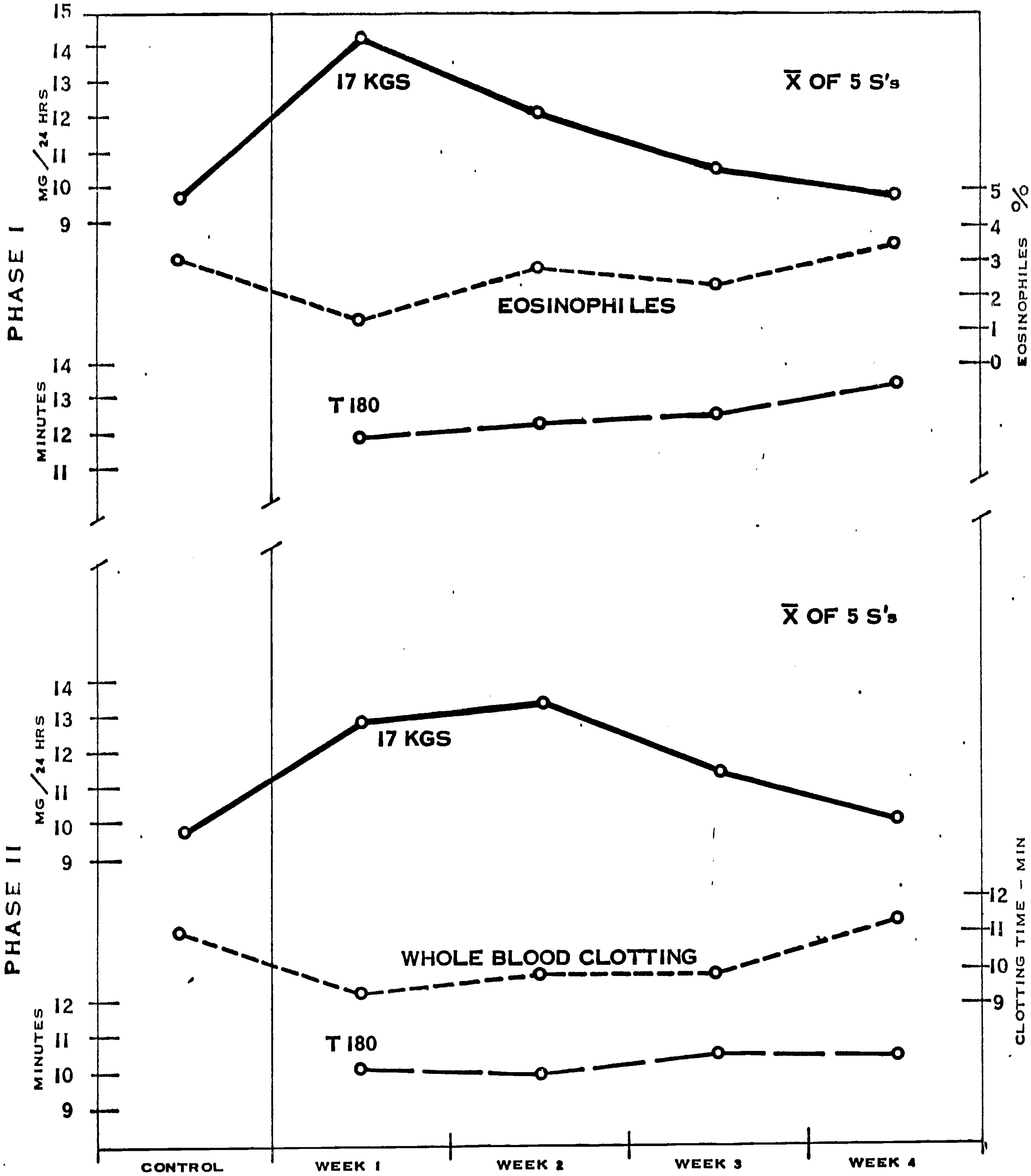

FIGURE 4 MEAN WEEKLY RESPONSES OF 17–KETOGENIC STEROIDS, T 180 TREADMILL TIMES AND EOSINOPHILES OR WHOLE BLOOD CLOTTING TIMES.

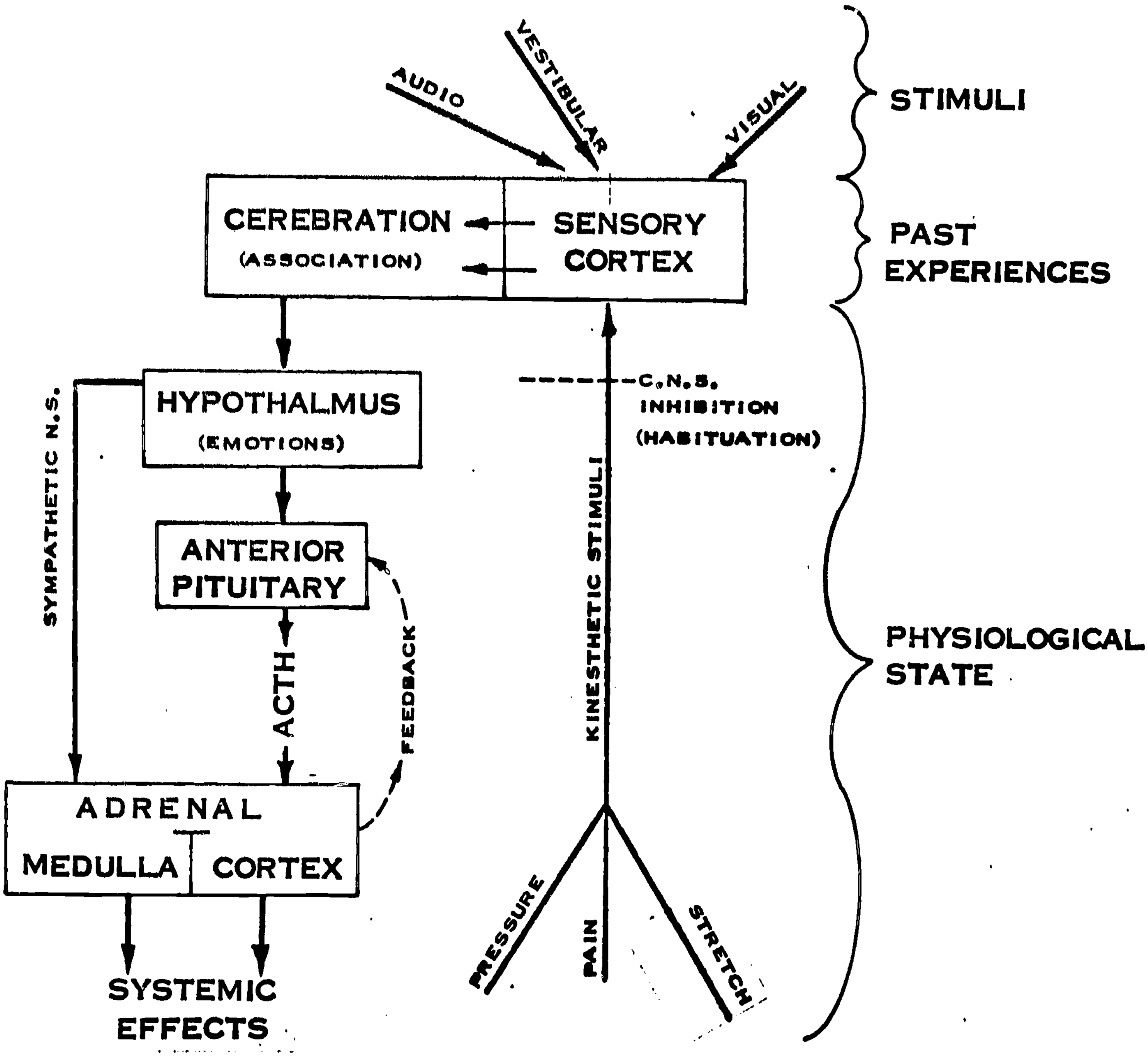

FIGURE 5 Possible Exercise, Perception and Neuroendocrine Relationships

weeks. Perceived exertion was determined at the start of the sixth minute of the T180 treadmill walk. Vanilmandelic acid (VMA) was measured from three hour post-exercise urine samples for the estimation of urinary catecholamine excretion (33, 22). The data for this aspect of the study is included in Figure 6.

Results

The raw data for this phase of the study is included in Appendix G. The data presented in Figure 6 represents the mean VMA, T_{180} and perceived exertion (minute 6) scores for five of the eight subjects. Failure to urinate, illness and methodological problems precluded the use of the data for the remaining three subjects. The VMA values were quite variable and should be inspected before conclusions are drawn. The figure illustrates the trend, an increase above control levels and a gradual return over a period of several weeks. The T_{180} times increased for all subjects. The mean increase amounted to three minutes and fifteen seconds. The perceived exertion scores did not exhibit a strong trend. It was unfortunate that the perceptual score was recorded in the sixth minute. While this time period was almost half way into the work test at the beginning of training, the improvement in training soon relegated that measure to a relatively early portion of the test. This factor may account for the rather variable response obtained in this phase, in contrast to the more predictable perceptual responses measured in the factorial training design.

Discussion

Based on results reported by Karki (19) and Frankenhaeuser et al. (10) it was hypothesized that the total VMA, composed of adrenaline and noradrenaline, would increase with work. As training increased and allowed a greater work-load but the same terminal heart rate, it was further hypothesized that the total VMA would tend to decrease, indicating a decrease in the adrenalin or mental stress aspect of the work test. No change in noradrenaline was considered likely since the terminal heart rate remained the same. The general trend of the VMA data confirm the above hypotheses. However, as might be expected with tests involving three hour urine collection periods on free ranging college students, other factors undoubtedly elicited some degree of mental stress or unpleasantness. One subject was a member of a string quartet involved in a series of concerts. A sample taken close to a concert date was elevated considerably above others in the series. This subject became ill near the end of the five week training period and was dropped from the study. Another subject evidenced a large increase in the third week of training. No explanation was found for that score. It must be noted, however, that subjects sometimes complained of colds and that the sensation of weakness may have elicited an increased adrenaline excretion. It was unfortunate that the technique used did not allow the separation of adrenaline and noradrenaline.

Karki (19) reported that exhausting exercise provoked a 25 fold increase in the adrenaline excretion with but a 17 fold increase in noradrenaline.

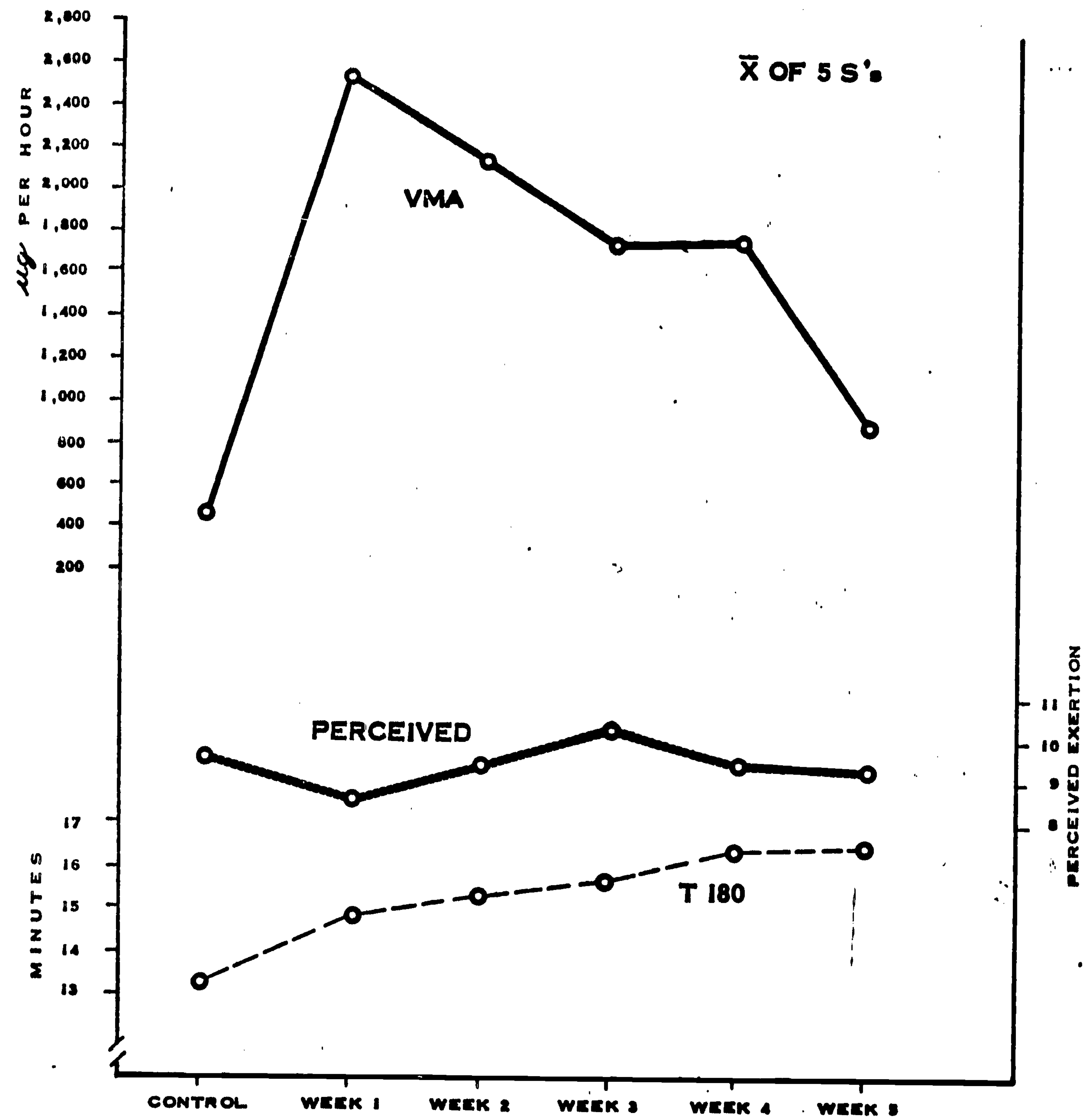

FIGURE 6
MEAN WEEKLY RESPONSES OF VMA,
T 180 AND PERCEIVED EXERTION

Frankenhaeuser et al. (11) reported a consistent relationship between adrenaline release and the degree of mental stress or unpleasantness. The pattern of VMA excretion found in this study seems to agree with the data for 17-ketogenic steroid excretion found in Figure 5, and reported by Whiddon et al. (37) and Steadman and Sharkey (31). It supports the contention that the T_{180} test is perceived as a threat at first. Continued exposure to the task results in a degree of familiarity that is evidenced in the conduct of the subjects, adrenal cortical secretions and adrenal medulla secretions. Since the hypothalmus is involved in the stimulation of both the cortex and medulla, it is not surprising that the patterns of response seem related. Figure 6 summarizes some ways in which exercise and perception may be related to adrenal response and also to the effects of training. This attempt to fit the facts and hypotheses into a model should not be interpreted literally. The results of this small study should not be generalized until techniques are improved and the sample size increased. However, the results do not detract from the model as conceived. The model also attempts to relate ways in which training may also alter the perception of exercise via an influence on the stimuli, past experience and the physiological state.

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APPENDIX A

MAINTENANCE OF OPTIMAL FITNESS

The original study plan called for a limited investigation of the frequency of exercise required to maintain the fitness achieved in the training study. Plans called for the utilization of the training scheme that proved to be most efficient in the training study. The data summarized in the training portion of the study illustrate that no intensity-duration scheme proved statistically superior to any other. Hence this portion of the project could not be carried out according to original plans.

It was also suggested that a level of fitness could be described as optimal (for an age group) and that the maintenance schedule could be related to that standard. While any attempt to generalize such a definition is subject to considerable discussion, it was hoped that the definition could be tied in with information relating physical activity and cardiovascular health. Data in these studies indicate that health benefits may be obtained from very brief activity (6), about 100 calories of activity (9) or from at least 300 calories of physical activity daily. While the decision regarding optimal fitness is really a personal one, and is still in need of further support, it can be noted that the subjects in the present training study consumed either 100 or 200 calories per training session. The higher calorie work-out would insure greater fat metabolism and weight control benefits unless the exercise was of high intensity. The proportion of fat metabolized during exercise is inversely related to exercise intensity. However, the importance of such fat metabolism in the prevention of heart disease is still undecided (9).

APPENDIX B

TRAINING AND SPONTANEOUS ACTIVITY

The original study plan called for an analysis of the effects of training on spontaneous physical activity. Subjects in the training study were to be observed following their participation. Spontaneous activity was to be related to the intensity and duration of training. However, it was impossible to carry out such an analysis on the young college men involved in training. Other factors made efforts to complete this phase impossible. Some of the subjects scheduled more physical education classes after training but often the classes were scheduled to fulfill requirements for physical education credit. Many of the subjects became involved in intramural activities but some were required to do so for fraternity teams. Hence few of the men remained available for truly spontaneous activity. Time consuming seasonal activities (eg. full day of skiing, once per week) also confounded the question.

The adult subjects, on the other hand, were not required to participate in classes or intramurals. However, only 11 of 18 remained available for follow-up. Of the eleven available, six engage regularly and voluntarily in a twice weekly recreational program entitled "Physiological Fitness and Weight Control" (see below). Of the remaining five, three engage regularly (at least twice weekly) in skiing, volleyball, jogging, tennis, golf or a combination of the activities mentioned. Two of the subjects do not exercise regularly. Of the nine active adults, five were equally active before training, four were not.

Other attempts to study the spontaneous exertion question are currently in progress. After conducting several voluntary jogging programs on campus we are beginning to follow-up the training exposure to see how many now participate on their own and the extent of their physical activity. During the past quarter we have been experimenting with a novel approach to physical activity for adults (Physiological Fitness and Weight Control). This program has been made available to all men and women faculty, staff and graduate students on a voluntary, come when you can basis. The program concept allows the adults to make their own decisions regarding the type and extent of physical activity. Posters, printed information and personal conversations are used to acquaint the participants with the facts upon which to make decisions. Physical fitness tests are administered to those who ask to take them, also body weight and per cent body fat can be calculated and weight control or weight reduction attempts can be measured. Sport skill instruction is available if requested. Available indoor activities include volleyball, badminton, basketball, gymnastics, weight lifting, jogging, circuit training excercises, miscellaneous games and swimming. Personal swimming instruction is also made available. Participation at this voluntary program has averaged 45 at each Tuesday or Thursday session. About one in five avail themselves of the fitness testing and body composition predictions. We hope to follow-up the participants and a comparable sample of non-participants to determine their exercise habits following their experiences with the program.

Other attempts to learn more about why people decide to engage in regular physical activity are planned. One approach will involve sports skill instruction for adults. A program of tennis instruction will be provided and spontaneous participation will be investigated at intervals following the termination of the instruction.

A sample of the "Physical Activity History Interview" is included.

HUMAN PERFORMANCE LAB
PHYSICAL ACTIVITY HISTORY INTERVIEW

NAME______________________________ DATE______________________________

1. Did you ever participate in vigorous sports and games? YES NO

2. Are you still participating in vigorous sports and games? YES NO

3. What sports did (or do) you play?______________________________

____

4. When did you stop participating?______________________________

5. Why did you stop participating?______________________________

____

6. Do you feel that you get enough physical activity without engaging in other activities and sports? YES NO

7. In what way?______________________________

8. Where did you learn to play the sports in which you participate (ed)?__________

____

9. In what geographic area were you born and raised?______________________________

10. Did you grow up in a rural or urban area? Rural Urban

11. Did you attend summer camp as a youngster? YES NO

12. Did you enjoy participation in athletic events as a youngster? YES NO

13. Did you (or do you) belong to any club or organization which promotes activity or provides facilities for participation? YES NO

14. What clubs or organizations?______________________________

15. Did you participate regularly in a high school program of physical activity? YES NO

16. Were you a member of any high school athletic team? YES NO

17. What team or teams?______________________________

18. Were you a member of any high school intramural teams? YES NO

19. Did you receive any honors or recognition for participation? YES NO

20. What type honor or recognition?______________________________

21. Did you participate regularly in physical activity in college? YES NO

22. Were you a member of a college athletic team? YES NO

23. What team or teams? ____________________

24. Were you a member of any college intramural teams? YES NO

25. What team or teams? ____________________

26. Did you receive any honors or recognition for participation? YES NO

27. What type honor or recognition? ____________________

28. Did you participate in any type of exercise program with the military service? YES NO

29. What kind of exercise program? ____________________

30. Did your parents participate in sports? YES NO

31. Do they still participate? YES NO

32. Did your parents encourage your participation in vigorous activity? YES NO

33. Do other members of your family (brothers and sisters) participate? YES NO

34. Do you encourage your children to participate in activity? YES NO

35. Do most of your friends participate in the activities you enjoy? YES NO

36. Do you enjoy being a spectator at sport events? YES NO

37. Would you rather participate than watch? YES NO

38. Is the image of an athlete a desirable one for you? YES NO

39. What kind of image do you have of an athlete? ____________________

____

40. Do you enjoy competing with others? YES NO

41. Do you enjoy competing with yourself and trying to improve your own performance? YES NO

42. Do you enjoy competing with yourself or with others more? ____________________

43. Do you have the desire to excel when you participate? YES NO

44. Do you enjoy the challenge of new and difficult techniques and the thrill of their mastery? YES NO

45. Do you find the feeling of physical fatigue resulting from strenuous activity a pleasant one? YES NO

46. Do you (or did you) get a feeling of well-being from participation? YES NO

(For those individuals who are still actively participating)

1. Have you always been physically active? YES NO
2. When did you learn to play the activities you now enjoy?____________

____

3. Where did you learn the skills and techniques?____________
4. What physical activities do you participate in during the winter?____________

____

5. How often and for what length of time do you participate in these?____________

____

6. What physical activities do you participate in during the summer?____________

____

7. How often and for what length of time do you participate in these?____________

____

8. How long have you engaged in these activities?____________

____

9. Do you find that you feel any different when you miss getting your regular activity? YES NO
10. In what way do you feel different? (less energetic, tense can't sleep, etc,)____________

____

11. Why do you continue to make time in your busy schedule for regular physical activity?____________
12. Do you enjoy the companionship of like-minded individuals who also enjoy participation in sports? YES NO
13. Would you say you are more or less active now than you were a year ago at this time? More______ Less______ Same______
14. Why do you think this is so?____________

____

15. What sport or game would you like to learn?____________

____

Average Week

	M	T	W	TH	F	SAT	SUN
Hours Activity	____	____	____	____	____	____	____
How Active	____	____	____	____	____	____	____

Note - Mild activity does not involve heavy breathing, perspiration, etc.

Moderate activity does not lead to excessive fatigue.

Vigorous activity involves rapid and deep breathing, rapid pulse rate, perspiration and considerable fatigue.

APPENDIX C

ALTERED RESEARCH METHODS

The original study plan called for an additional dimension in the training study. Continuous and intermittent training patterns were to be included in the factorial design. This procedure was followed with the first twenty-four subjects (young men) trained. The data did not indicate differential effects due to the continuous or intermittent programs. Furthermore, since the extra dimension required extra subjects, it was decided to omit that aspect of the design from the analysis. All other subjects trained continuously.

Another reason for omitting that phase of the analysis was the additional group of adult subjects that were not included in the initial study plan. The adult subjects were far more difficult to obtain and to maintain on the strict training schedule demanded by the research design. Extensive pre-training medical examinations were required. Some subjects were found to be unfit for participation, some decided to drop-out when they were randomly assigned to an undesirable training scheme, some became ill late in the training program and some attended irregularly and had to be omitted from the analysis. Other programs involving adult subjects have found similar rates of attrition (Pennsylvania State University, Public Health Study).

These problems and the amount of time necessary to personally train each subject limited the total participation in the study and hindered the completion of the aspects mentioned in Appendices A and B. However, unlike other studies, the training programs were carried out precisely according to the plan. Thus each subject trained at the required intensity and duration and for the required number of sessions. This author has observed larger projects where the extent of participation was far from that presented in the methods section.

APPENDIX D

TEST SCORES ON THREE ERGOMETERS (N=36 Young Men)

I.D.*	A-R Step Test (ml/kg/min) Pre	Post	Dif	Treadmill Test (sec.) Pre	Post	Dif	Bicycle Test (PWC_{170}) Pre	Post	Dif
351	37.6	41.6	4.0	490	740	250	820	930	110
352	40.0	47.1	7.1	630	640	10	810	1100	290
353	47.5	43.8	-3.7	500	540	40	850	1080	230
354	34.3	43.1	8.8	230	410	180	590	890	300
355	51.5	48.5	-3.0	380	380	0	1310	1210	-100
356	48.6	50.8	2.2	660	600	- 60	1090	1270	180
551	37.6	38.1	0.5	520	730	210	1200	1420	220
552	47.1	53.7	6.6	660	840	180	1190	1100	- 90
553	45.1	51.0	5.9	400	580	180	850	1060	210
554	38.7	45.5	6.8	470	550	80	800	1060	260
555	50.6	52.4	1.8	650	750	100	1120	1220	100
556	44.7	36.1	-8.6	420	670	250	880	1140	260
751	51.3	53.0	1.7	540	610	70	13[illegible]	1100	-200
752	37.8	37.8	0.0	480	530	50	900	900	00
753	51.3	56.1	5.2	360	580	220	530	630	100
754	42.9	52.4	9.5	500	660	160	1020	1060	40
755	40.3	48.4	8.1	520	710	190	920	1220	300
756	44.0	47.9	3.9	500	690	190	930	1220	270

APPENDIX D (Continued)

I.D.*	A-R Step Test (ml/kg/min)			Treadmill Test (sec.)			Bicycle Test (PWC_{170})		
	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif
371	40.7	47.5	6.8	660	730	70	810	710	-100
372	41.6	39.2	-2.4	650	650	0	1410	1590	180
373	37.2	41.8	4.6	360	540	180	780	990	210
374	41.9	53.5	11.6	490	550	60	900	1020	120
375	41.8	41.8	0.0	510	570	60	800	950	150
376	45.8	44.2	-1.6	510	590	80	1330	1060	-270
571	34.1	36.7	2.6	320	380	60	840	1000	160
572	39.2	44.9	5.7	330	500	170	800	900	100
573	35.9	48.6	12.7	450	620	170	780	1190	410
574	44.4	55.7	11.3	590	740	150	1170	1250	80
575	48.8	53.7	4.9	710	790	80	750	1120	370
576	39.8	53.9	14.1	510	540	30	1160	1060	-100
771	44.0	52.4	8.4	540	600	60	880	1420	540
772	45.1	48.6	3.5	720	750	30	1080	1130	50
773	53.0	50.2	-2.8	660	690	30	1200	1060	140
774	48.8	71.9	23.1	630	840	210	1400	1000	-400
775	45.3	48.6	3.3	570	720	150	1060	1350	290
776	40.5	41.8	1.3	550	700	150	1010	1560	550

*I.D. Code: 3, 5 or 7 refer to intensity (130, 150, 170).
Second digit, 7 or 5 refers to duration (7500 or 15,000).
Third digit refers to number of subjects in cell.

APPENDIX E

TEST SCORES AND PERCEIVED EXERTION DATA (N=18 Adults)

	A-R Step Test (ml/kg/min)			A-R Perceived			Bicycle Test (PWC170)			Bicycle Perceived		
I.D.	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif
271	37.3	38.5	1.2	12	13	-1	1400	1400	0	13	17	-4
272	38.5	37.3	-1.2	12	12	0	1310	1370	60	13	13	0
273	33.5	32.7	-0.8	13	13	0	930	930	0	13	13	0
471	36.2	39.6	3.4	12	8	4	1050	1260	210	15	13	2
472	37.3	39.6	2.3	13	10	3	1060	1210	150	14	12	2
473	37.3	38.6	1.3	13	11	2	1350	1440	90	15	13	2
671	35.4	41.0	5.6	9	7	2	860	1460	600	13	10	3
672	36.4	40.4	4.0	13	9	4	1250	1250	0	13	13	0
673	40.2	48.0	7.8	9	8	1	1650	1850	200	12	11	1
251	31.2	36.7	5.5	11	13	-2	770	880	110	15	16	-1
252	40.4	52.6	12.2	11	11	0	1400	1480	80	13	11	2
253	38.6	48.4	9.8	13	11	2	1140	1530	390	15	15	0
451	32.7	38.3	5.6	14	11	3	1120	1230	110	17	15	2
452	33.5	36.4	2.9	13	9	4	880	970	90	11	10	1
453	41.0	50.5	9.5	12	9	3	1600	1500	-100	13	11	2
651	40.8	45.6	4.8	12	12	0	1070	1170	100	14	13	1
652	37.3	42.9	5.6	9	10	-1	1260	1450	190	10	9	1
653	42.1	42.1	0.0	10	11	-1	1070	1410	340	13	10	3

APPENDIX F

PERCEIVED EXERTION CHANGES ON THREE ERGOMETERS (N=36 Young Men)

	A-R Step Test			Treadmill Test			Bicycle Test			Preferred Exertion (bicycle		
I.D.	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif	Pre	Post	Dif
371	9	9	0	10	11	-1	13	13	13	9	6	[illegible]
372	12	10	2	13	13	0	11	11	0	6	4	2
373	13	12	1	12	13	-1	14	13	1	5	5	0
374	13	11	2	13	12	1	15	13	2	4	4	0
375	16	12	4	15	13	2	20	16	4	7	6	1
376	9	6	3/2	10	8	2/.05	9	13	-4/.05	3	5	-2
571	12	12	0	6	8	-2	12	8	4	4	3	1
572	12	13	-1	13	15	-2	18	13	5	6	6	0
573	15	12	3	13	17	-4	20	15	5	7	4	3
574	7	8	-1	11	13	-2	12	11	1	4	4	0
575	12	7	5	13	12	1	16	15	1	6	5	1
576	11	7	4/1.7	13	11	2/-1.1	11	11	0/2.7	4	3	1
771	10	8	2	12	11	1	12	8	4	[illegible]	2	0
772	11	9	2	13	9	4	11	9	2	2	2	0
773	7	7	0	11	12	-1	3	13	0	4	4	0
774	10	12	-2	11	15	-4	13	13	0	3	5	-2
775	13	9	4	15	13	2	15	11	4	5	3	2
776	11	11	0/1.0	13	13	0/0.3	13	11	2/2.0	5	4	1

APPENDIX F (Continued)

I.D.	A-R Step Test Pre	A-R Step Test Post	A-R Step Test Dif	Treadmill Test Pre	Treadmill Test Post	Treadmill Test Dif	Bicycle Test Pre	Bicycle Test Post	Bicycle Test Dif	Preferred Exertion (bicycle) Pre	Preferred Exertion (bicycle) Post	Preferred Exertion (bicycle) Dif
351	12	12	0	14	15	-1	14	12	2	5	3	2
352	11	11	0	11	11	0	9	13	-4	3	3	0
353	11	8	3	12	10	2	13	10	3	4	3	1
354	13	12	1	15	15	0	17	17	0	6	6	0
355	11	8	3	15	11	4	12	13	-1	4	4	0
356	13	9	4	13	11	2	15	13	2	4	5	-1
551	9	10	-1	10	12	-2	12	10	2	4	2	2
552	11	8	3	13	17	-4	12	12	0	4	4	0
553	13	9	4	11	8	3	13	13	0	4	4	0
554	11	11	0	9	11	-2	13	9	4	4	2	2
555	12	7	5	14	13	1	17	15	2	6	5	1
556	13	8	5	13	13	0	16	12	4	5	4	1
751	8	10	-2	12	13	-1	15	14	1	4	5	-1
752	13	11	2	13	13	0	13	13	0	4	5	-1
753	9	7	2	13	9	4	18	15	3	4	3	1
754	13	11	2	13	11	2	14	11	3	4	3	1
755	13	12	1	13	14	-1	15	14	1	4	4	0
756	12	10	2	13	10	3	10	8	2	2	2	0

APPENDIX G

CATECHOLAMINE EXCRETION (VMA), T_{180} TIMES AND PERCEIVED EXERTION SCORES (N=5)

S		Control	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
1	VMA (mg)	0.0	3470	5901	2860	7072	2590
	T_{180} (min.)	14:20	17:10	18:30	18:00	19:50	19:50
	P.E.	11	11	11	11	9	9
2	VMA	72	5121	8285	3790	2795	1948
	T_{180}	15:50	17:30	15:10	15:30	16:00	15:40
	P.E.	5	5	7	7	7	7
3	VMA	1370	6835	7011	1712	7844	1998
	T_{180}	10:30	12:00	13:30	14:30	13:30	14:20
	P.E.	11	9	9	11	9	11
4	VMA	1034	5699	4322	8002	6335	1721
	T_{180}	12:20	14:00	14:20	15:20	16:50	16:50
	P.E.	9	11	9	11	11	9
5	VMA	3957	2740	6911	11,209	2534	3975
	T_{180}	13:10	13:20	14:50	15:20	15:30	16:00
	P.E.	12	7	11	11	11	10
	VMA	1287	4773	6486	5515	5316	2446

VMA = Total ug (for 3 hour collection); T_{180} = minutes and seconds.