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THE EFFECT OF CARDIAC CONDITIONING ON THE ANTICIPATORY EXERCISE AND RECOVERY HEART RATES OF YOUNG MEN

by
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A dissertation submitted in partial fulfillment
of the requirements for the degree of
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CHAPTER I

INTRODUCTION

Psychologists have utilized a variety of physiological measures to ascertain the behavior of organisms before undertaking a task. The tasks have been predominantly verbal and have involved a minimal energy expenditure. From these experimants the concepts of anxiety, emotion, motivation, arousal, and conditioning have emerged. Physiologists, conversely, have demonstrated prolonged and intensive interest in the response of the organism to physical activity demands. They have, however, concentrated primarily on response after the onset of exercise and have, with few exceptions, given changes in anticipation of exercise only passing notice. Consequently, the relation of anxiety, emotion, motivation, arousal, or conditioning to a minimal work demand or to an all-out maximal work effort has not been clearly demonstrated.

On the subjective side, instructors associated with competitive athletics have long recognized the importance of optimal motivation. This constitutes a critical area outside of which increases or decreases in motivation have deleterious effects upon performance. Beyond this clear cut definition, the mechanism involved is not well understood. Confusion stems from the wide range of individual differences and the distinct possibility that what constitutes optimal motivation may vary from sport to sport and even from time to time

within a sport.

Extensive physiological research has clarified the role of the motor cortex as the autonomic center of the forebrain. Pathways lead from the motor cortex through the hypothalmus to the medulla oblongata. These pathways provide the mechanism for emotional changes in heart rate and other aspects of left ventricular function. Psychosomatic diseases may also be explained in terms of this theory.

Increases in heart rate prior to and during the initial stages of adjustment to exercise have been noted in both animals and humans. In intact unanesthetized dogs, under conditions of submaximal exercise demands these excessive response patterns disappear after three or four trials. The human heart rate has been conditioned to different levels of static muscle contraction. The foregoing experimental results indicate a physiological mechanism by which motor cortical control over the cardiovascular response of animals may be exercised. Observations of the cardiovascular response of man suggest that the human cardiovascular system responds in a similar manner. The purpose of this study was to determine the initial levels and changes that occur in the heart rate response of young men before, during, and after a series of conditioning trials of minimal and maximal work intensity.

Hypotheses.

The hypotheses were that (1) cardiac conditioning to a minimal work output would result in decreased heart rates

prior to, during, and in recovery from the performance of a standard amount of work and (2) cardiac conditioning to an all-out work effort would result in increased heart rates prior to, during, and in recovery from the performance of maximal work per unit time. The first conditioning pattern might be considered more efficient; the second conditioning pattern might result in more work per unit time but at an increased heart rate.

Subsidiary hypotheses were that: (1) conditioning to a minimal or maximal work output would adversely affect subsequent adjustment to the opposite output, (2) the initial status of selected athletic categories would reflect habitual training patterns, and (3) the heart rate responses before, during, and after exercise might be attributable to personality variables. The last premise was based on the relation of anxiety and other types of conditioning.

Disinhibition.

Bannister (7) stressed the role mental excitement plays in aiding an athlete to endure the pain of physiological fatigue. Ikai and Steinhaus (59) used a gun shot, a shout, or hypnotism to reduce the gap between the "psychologic limit" imposed by the subject and his true "physiologic limit" in a test of maximal strength. The authors concluded that cultural factors contribute to a wide range of inhibitions that prevent the attainment of a true maximal performance. Strong emotion, motivation, and will power were cited as positive factors

aiding in disinhibition.

An earlier concept of inhibition was utilized by Hull (58) in his Performance Inhibition Theory. Kimble (67) and later Wasserman (115, 116) extended this Two Factor Theory of Inhibition into the realm of motor learning. More highly motivated subjects tolerated higher levels of reactive inhibition before succumbing to a conditioned resting tendency. Rasch and Morehouse (86) concluded that higher strength scores attributed to exercise programs were largely an acquisition of skill. Morehouse elaborated on these findings and proposed an inhibition theory of strength development. "It is probable that an individual in an untrained state possesses all of the physical requisites present in the trained state. What the individual acquires during training may be an increased ability to overcome the innate protective governor - inhibition." (80)

These views, although promulgated in slightly different contexts, appear at least in part to substantiate one another. Each emphasizes the role of motivation in performance. Morehouse's explanation of the difference between the trained and the untrained state does, however, appear somewhat extreme in the face of evidence of definite physiological change in a variety of organs and systems during intensive training (30, 49, 50, 106, 111). Hemingway (51) subscribes to a more balanced approach in his discussion of the physiological bases of training. Differentiation is made between skill learning and the development of endurance and strength. The former is described as being already within the grasp of the individual,

whereas the latter involves the extension and improvement of capabilities. The release of inhibitions would fit conveniently into the first category.

Level of arousal.

Considerable progress has been made during the past thirty years in the integration of the concepts of anxiety, emotion, and motivation through reference to the level of arousal (33, 34, 43, 79, 98). The level of arousal concerns the intensity of the behavioral response rather than the direction and consists of a continuum extending from deep sleep, through alert consciousness, to strong emotion. A subject's current position on the arousal continuum is determined by objective physiologic measures of heart rate, respiratory rate, blood pressure, skeletal muscle tension, EEG activation, and palmar skin conductance (98). Freeman (43) and Lansing, Schwartz, and Lindsley (73, 74) established an inverted "U" relationship between the level of arousal and reaction time. Stennett (109) observed a similar pattern in an auditory tracking task.

Although Schnore (99) and Lacey and Lacey (71) warn against using a single system to measure arousal because of individual differences in the reactivity of different systems, the heart rate was selected as the sole physiological measure of arousal and response to exercise in this investigation. This decision was based upon a firm foundation of experimental evidence. Consistency among various measures of response,

which included heart rate, was found by Reese and Dykman (87). Gantt, who refers to the level of arousal as the orienting reflex, considers the heart rate "the most significant index of the orienting reflex, showing a correlation among animals for different stimuli, and with motor components. Furthermore, heart rate can be measured precisely." (47). The latter comment is one of the most conclusive arguments in its favor.

The heart rate as a physiologic measure

Under experimental conditions which associate the level of arousal with response to physical activity, it is advantageous to have the same physiologic variable as a measure of both. Such equivalence of measures facilitates the valuation of the transition from rest to work. Rushmer (92) found the heart rate to be the most constant feature of left ventricular response to exercise. Maximum values in stroke volume were approached when animal and human subjects were resting in the recumbent position or immediately after the onset of even mild exercise (93). Stroke volume does not demonstrate a progressive increase with increasing work intensities. Increases, generally attributed to increased systolic ejection, are also restricted to approximately ten per cent (114) as compared to increases of 200 to 450 per cent attainable in heart rate.

The characteristic response of the heart rate to an unexpected exercise included sustained tachycardia which

began within two or three beats of the start (94). The response was even more rapid under experimental conditions in which the exercise was expected (96). Based upon data obtained in the steady state, the almost linear relation between heart rate and work intensity is widely accepted. Wahlund (113) provided an excellent resumé of the literature prior to 1948 and recent investigations by Berggren and Christensen (11), Astrand (3), and Wyndham, Strydom, Maritz, Morrison, and Potgeiter (117) substantiate the relationship. These studies have established a maximal heart rate in adults of 195 $\pm$ 10 beats per minute. In one of the few statistical treatments of the relationship, Taylor (111) obtained coefficients of correlation of 0.969 and 0.955 between heart rate and work load with two subjects exercised on a bicycle ergometer.

The prompt response of the heart rate to increases in work load was perceived by Lowsley (77) as early as 1911. Krogh and Lindhard (68) verified this finding and attributed its sensitivity to motor cortical innervation. The interrelated effects of load, rate, and duration of work upon heart rate were explored by Gillespie (50). A steep primary rise and slower secondary rise were observed with both being dependent upon the severity of the work. The cardiac response to exercise was so rapid that Asmussen (1) found the first pulse period after the beginning of work already shortened.

Initial overshoot and cardiac conditioning.

In his work with intact, unanesthetized dogs, Rushmer

(94) described their reaction to the turning on of the treadmill switch. A change in left ventricular performance occurred equal to that produced by running at three miles per hour on a five per cent grade. The change was so abrupt that measures of all parameters reacted during the next cardiac cycle. Gantt (47) has also commented on the brevity of the cardiac latency period.

In the initial stages of exercise, Rushmer's dogs demonstrated an overshoot in all parameters for ten to fifteen seconds, after which they reverted to a steady state at a lower level. Rushmer (96) concluded:

> The initial autonomic response occurs so rapidly that it cannot reflect the metabolic requirements of the tissues. If the cardiovascular adjustments were insufficient to meet the oxygen requirements of the body, the various parameters of left ventricular performance would increase progressively during the period of exercise. Instead, after an abrupt increase, the various parameters decline to a plateau. This sequence of events suggests that an excessive autonomic response is initially induced and then is modulated by various reflex mechanisms.

On the basis of a recent investigation in which a 12.9 miles per hour rate on an eighteen per cent grade was used (6), it is obvious that a three miles per hour rate on a five per cent grade is a decidedly minimal work load for a dog. This suggests that the excessive left ventricular response might be attributed to cardiac conditioning to habitual work levels much higher than the one assigned in the experiment. The stereotyped response pattern was called into play in anticipation of an unknown work demand. Such an hypothesis is supported by the elimination of the overshoot

after three of four bouts of exercise (96). The excessive autonomic response was thus eliminated through cardiac conditioning to minimal work demands in a recognizable situation.

Through the use of size-weight illusion, Jarrard (60) found visual cues of an apparently heavier object of the same weight increased muscle tension and reduced the number of lifts made to subjective exhaustion. The work was performed on a finger ergograph. His conclusion that perception of the amount of work to be done affects the performance of a task was in accord with previous research (13, 69). Since his subjects were lifting the same weight with increased muscle tension, this is a muscular overshoot comparable to the cardiac overshoot of Rushmer's dogs.

The elimination of an overshoot through cardiac conditioning raises the question whether such modifications through response to a minimal task will affect subsequent adaptation to a maximal task. A low heart rate, as postulated by Karvonen (64), or low muscle tension might be the most efficient adaptation to a given work load, but for a maximal output per unit time regardless of energy cost, the higher heart rate or muscle action potential might be advantageous. Support for such a premise appears in Hill's theory of two optimal speeds of muscular contraction (57): the one speed for maximal efficiency (work done/energy used) and the other for maximal power output (work done per unit time).

Level of anticipation and reactivity of heart rate in humans.

A high level of anticipation might well bear a linear relation to a maximal gross motor co-ordination task rather than the inverted "U" relation associated with maximal fine motor co-ordination tasks (43, 73, 74). H. G. Seashore (100) and R. H. Seashore (101, 102) have already demonstrated definite cleavages between gross and fine motor abilities on many other bases. Since the limiting factor physiologically is predominantly co-ordinative in the latter and a combination of speed of movement, strength, and endurance in the former, different effects from the level of anticipation appear feasible.

As early as 1913, Krogh and Lindhard (68) noted the extreme reactivity of the heart rate of athletes trained to sudden and violent exertions. Such training resulted in an especially abrupt rise in heart rate with the beginning of exercise. The relation of anticipation to vigorous physical activity is not well documented although incidental references are fairly common (95). Ramos and Reynaud (85) observed anticipatory increases in the heart rate of ten to twenty per cent of the basal rate in young men about to be exercised. When the anticipated exercise did not follow, the increases remained for two to three minutes.

Brouha and Heath (15) have provided the most comprehensive treatment of heart rate increases attributable to anticipation of exercise. The emotional effect of being tested medically or physically is discussed on the basis of experimental

results. A lower heart rate was evidenced by 20 per cent of the subjects during a rest period after a treadmill walk than before walking. Cardiotachometer heart rate readings of 170 subjects standing motionless on the treadmill just before an exhaustive run ranged from 82 to 165 beats per minute with a mean of 125 beats per minute. Non-athletic students and well-trained athletes both demonstrated the same phenomenon.

An attempt to assess the relationship of emotion and competitive sport was made by Johnson (61). Tests on heart rate, blood pressure, and psychogalvanic reflex were conducted on football players and wrestlers four to six days before a contest (T1), the day before (T2), a few hours before (T3), in the dressing room immediately before (T4), and fifteen minutes after (T5). The following mean heart rate values were obtained in the five test periods:

	Mean Heart Rate in Beats Per Minute				
	T1	T2	T3	T4	T5
Football (n=12)	70	72	74	78	90
Wrestling (n=21)	66	69	70	99	114

Although indicative of a gradual emotional build-up, these measures reflect a generalized concept of anticipation to the total game situation, which even in T4 is still somewhat remote in time. The most crucial measure of this would likely occur just as the athlete is about to enter the contest. Specific anticipation also takes place within the framework of a game. In football, such anticipation occurs before each play and would differ dependent upon the player's role in the play and his motivational involvement at that particular time.

Cardiac conditioning in humans.

Psychologists have been interested in the conditioning of the cardiac response since the turn of the century when Sherrington (103) reported a drop in the heart rate of dogs at the sound of the vibrator of an inductorium previously used to supply shock. Laboratory techniques involved the experimental development of anxiety through the use of visual or auditory stimuli as signals of shock to come. Two opposing results have been obtained from these experiments. Notterman, Schoenfeld, and Bersh (82) elicited a deceleration in the heart rate. Zeaman and Wegner (118) obtained heart rate acceleration in some subjects and heart rate deceleration in other subjects with the same experimental procedures. Deane and Zeaman (31) clarified the relation of anxiety of shock to come and heart rate changes by producing acceleration and deceleration of the heart rate in the same subjects through different experimental procedures. An acceleration of the heart rate preceded an expected shock, disappeared after the first shock, and was followed by a deceleration of the heart rate.

The physical activity demands of all the preceding studies were at the most minimal. Beier (10) was the first to use exercise as the unconditional stimulus for cardiac conditioning. Daily stability criteria were established for heart rate, blood pressure, and respiratory rate as the standard for comparison. A work intensity of 1,031 kilograms was sustained for one minute on a bicycle ergometer. Discussion of three case histories indicated blood pressure and heart rate

conditioning occurred in response to a buzzer signal for work, however, no supportive data were included. No conditioning of the respiratory response was evoked. Three training trials were sufficient to elicit the cardiovascular conditional response, however, the response became more intense and enduring with additional reinforcement.

Peters and Gantt (83) used three levels of muscular tension on a hand dynamometer to assess the relative effects of muscle tension and central nervous system excitation upon the heart rate. The conclusions, which supported the influence of central nervous system excitation, were used to refute the allegation that all conditioning was an artifact response (107). In a later study, Peters and Gantt (84) demonstrated heart rate conditioning to three different lights used to signify specific levels of muscle tension. From these and other experiments, Dykman and Gantt (35) and Gantt (47) conclude that the principles developed in salivary and motor conditioning are equally applicable to cardiac conditioning.

If the human cardiac response is conditioned to habitual work patterns, the trained performer or worker would have two gains above those attributed to motor learning and improved cardiovascular respiratory fitness. The two gains are (1) an efficient response to minimal work intensities and (2) a maximally powerful response to maximal work intensities. The first gain results from a lowered anticipatory heart rate and a reduction in the amount of overshoot. The second gain results from either increased anticipation or extreme reactivity in the

heart rate or possibly both. This is in essence the stereotyped concept of the experienced competitor who can husband his energy throughout most of a contest and yet attain a peak performance for intermittent crucial periods. Although unsubstantiated by objective data, the concept is firmly entrenched in the sports literature through centuries of subjective analysis.

The increased heart rate prior to exercise, the extreme reactivity of the heart rate in the initial stages of adjustment to physical activity, and the overshoot of the heart rate on exposure to an unexpected minimal work task cannot be accounted for on the basis of tissue demand. Such phenomena emanate from the motivational or emotional overtones of the expected task and occur in advance of or too quickly for the mediation of physiological requirements.

Neurophysiological experimentation.

Recent investigations in neurophysiology have related specific portions of the brain to autonomic response. Excellent reviews of the literature have been provided by Folkow (41, 42), Rushmer and Smith (95), and Bard (8). Discussion of the anatomical organization or neural mechanisms by which central nervous system control over the circulation is exercised is beyond the scope of this treatise. The motor cortical theory of cardiac control as described by Rushmer, Smith and Franklin (96), Rushmer and Smith (95), and Rushmer (92, 94) suggests a mechanism by which learning and conditioning can affect cardiac

regulation. In Russia, Bykov and his co-workers (16) have elaborated the dynamics of cerebral cortical control through the conditioning of virtually every autonomic system. Reese and Dykman (87) and Gantt (47) have reviewed the research pertinent to cardiovascular conditioning done in American laboratories. The present investigation focused this extensive body of psychological and physiological data upon the cardiac response of young men throughout a number of conditioning trials of minimal and maximal intensity. If the phenomena of heart rate anticipation, reactivity, and overshoot are demonstrable in these subjects and malleable to the processes of cardiac conditioning, it will strongly support the theory of motor cortical control. The mechanism of cardiovascular adjustment to exercise and its long range adaptation to habitual patterns of exercise might also be clarified. Such clarification would aid in the training of athletes for different sport situations, the preparation of workers for specific industrial tasks, and the improvement of the cardiovascular response of the general population to both emotional and physical activity demands. Cardiac conditioning also has implications for the treatment of cardiac neuroses (10, 66).

The 16 Personality Factor Test.

Anxiety, motivation, arousal, and cardiac conditioning in response to exercise demands might be expressions of the basic personality structure, past experiences, complex genetic differences, or various combinations of the three. For the

athlete, they might be attributable to the intensive training and competitive patterns imposed by a specific sport. A further possibility is the oft repeated thesis that certain personality types gravitate to particular sports.

A multitude of paper and pencil tests purport to measure either specific aspects of the personality or some of its broader dimensions. Some of these have shown high reliabilities when the co-operation of the subjects is assured. The Cattell 16 Personality Factor Test is the culmination of extensive theoretical and practical research (17, 19, 40). The test has been widely used in the study of occupational profiles (24, 25) including that of Olympic athletes (54). A comprehensive analysis is provided of a variety of dimensions along which individuals may differ. The personality description is based upon 16 bipolar source traits which have demonstrated consistency in a number of experimental and real life conditions (21, 23).

From the factor analysis loading pattern of the 16 first order factors, two major second order factors have been found (20). Scores may be ascertained on an adjustment versus anxiety scale and on an extroversion versus introversion scale through the weighted treatment of the appropriate first order factors. Although they present a diminished view of the personality factors operating in a particular situation, these second order factors might, on the basis of previous linkage of anxiety and some types of conditioning (62, 90), be useful in the prediction

of the amount of anticipatory heart rate and the degree of cardiac conditioning.

Cattell's extensive treatment of physiological measures of neuroticism and anxiety (21, 25) and Been's establishment of some relationships between measures of personality traits and measures of physical fitness (9) suggested the possibility of determining the intercorrelations among psychological and physiological variables. Since the pilot study had uncovered major differences among different sports groups in heart rate response to exercise, there was the possibility that specific sports would have unique personality trait profiles.

CHAPTER II

METHODOLOGY

The subjects were volunteer, male, undergraduate students from the University of Michigan. The sample consisted of 20 non-varsity freshmen, and eight varsity or freshmen athletes from each of football, gymnastics, hockey, track distance events (880 yards, mile, and two mile), and track sprint events (100, 220, and 440 yards). A non-varsity subject was a student who had never won a letter or participated in any sport in either high school or college. A varsity or freshman athlete was a member of the appropriate university team during the preceding or current season.

The varsity subjects were placed in one of five different categories on the basis of their sport. A pilot study using two categories, one of non-varsity subjects and the other varsity subjects, uncovered considerable variability in anticipatory heart rate among different athletic groups. The conclusion was reached that varsity athletes did not constitute a homogeneous category. Consequently, the five sports were selected to represent individual and team, and endurance and sprint type events. The result was six experimental categories--non-varsity, football, gymnastics, hockey, distance running, and sprint running.

The age range of the non-varsity group was from 17 to 23 years with a mean age of 19 years. The age range of the varsity athlete group was from 17 to 24 years with a mean of 20 years.

Design of the experiment.

The influence of ordering--the effect of cardiac conditioning to either a minimal or a maximal work output on subsequent adjustment to the other level, was determined through a cross-over design (29). Group A performed four minimal trials on Day 1, a single minimal trial on Day 2, four maximal trials on Day 3, and a single maximal trial on Day 4. Group B followed the same basic pattern with a reverse ordering of the minimal and maximal trials. (See Table 1.)

The twenty non-varsity subjects were assigned randomly to Group A or Group B with equal numbers being maintained terminally in each group. The varsity athletes were separated into matched pairs within each sport on the basis of height, weight, and the position played or the event participated in. One of each pair was then assigned randomly to Group A and the other to Group B.

TABLE 1.--Experimental design.

Day	Group A	Group B
1	Minimal T1 Minimal T2 Minimal T3 Minimal T4	Maximal T1 Maximal T2 Maximal T3 Maximal T4
2	Minimal T5	Maximal T5
3	Maximal T1 Maximal T2 Maximal T3 Maximal T4	Minimal T1 Minimal T2 Minimal T3 Minimal T4
4	Maximal T5	Minimal T5

Note: The "T" stands for trial and the digit after the "T" refers to the number of the trial in the sequence from one to five.

Apparatus.

The exercise task was performed on an electrodynamic brake bicycle ergometer. The machine (Figure 1) was a modified version of the one described by Kelso and Hellebrandt (65). Throughout all experimental trials the load resistance was set at 0 ohms for the minimal trials and 10 ohms for the maximal trials. A three pole silent mercury switch controlled the flow of current around or through the 10 ohm resistor. Changes in the load resistance thus could be effected unknown to the subject.

Aside from affording opportunities for large muscle activities throughout a wide range of work intensities, this type of ergometer provides accurate measurement and simultaneous

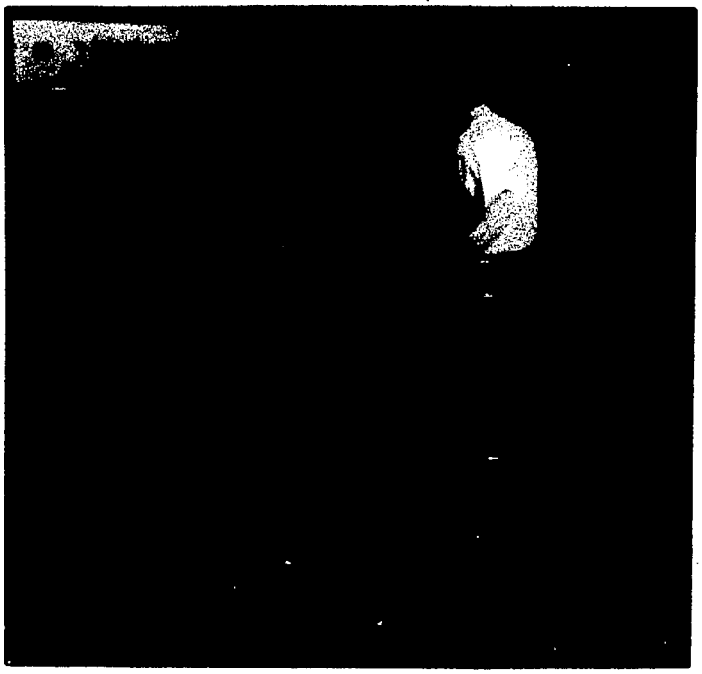


FIG. 1. A subject in the start position on the ergometer with ECG leads attached.

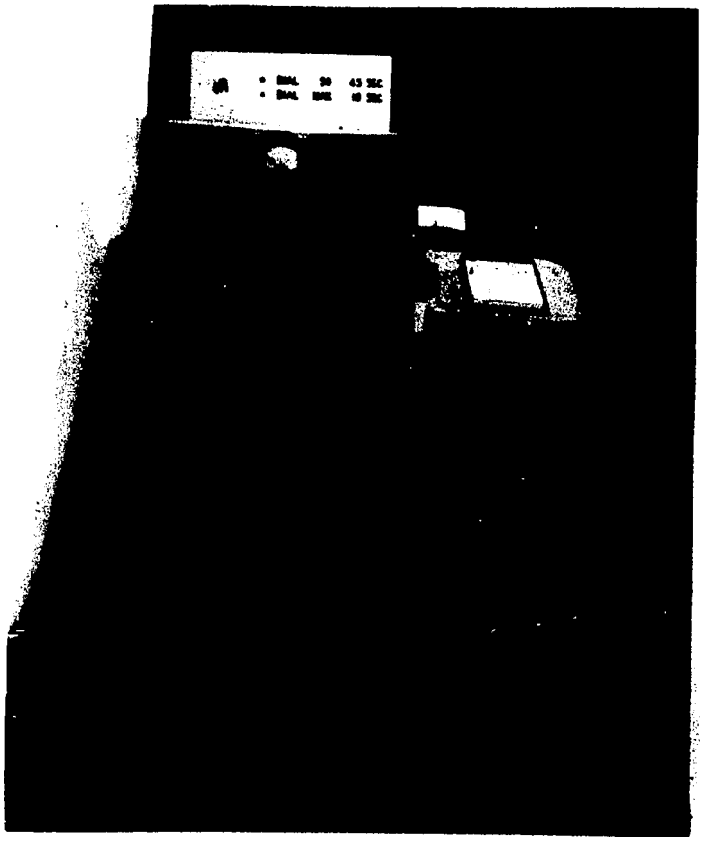


FIG. 2. The electrodynamic brake bicycle ergometer with control, instrument, and switch panels.

recording of the work output. The recording in revolutions per minute was made on a General Electric Speed Recorder mounted on the instrument panel immediately in front of a subject seated on the bicycle ergometer. The calibrated dial and recording paper provided the subject with instantaneous readings of his work output.

A control panel mounted above the instrument panel displayed a 6 volt buzzer and two different colored lights (Figure 2). Opposite each light appeared a description of the type and duration of the exercise associated with it. The buzzer provided an auditory signal of work to come, the immediate start of work, or the cessation of work. The colored lights provided a visual signal of a specific work pattern. A blue light indicated a dial reading of 50 was to be attained and held for a work period of 45 seconds. Since subjects in a pilot study yielded mean exercise heart rates of from 92 to 105, the work level used was classed as minimal. The 45 seconds provided a sufficient work period for the subject to reach a steady heart rate if he were going to do so at this work level. An amber light indicated to the subject that he was to reach his maximal pedalling rate as quickly as possible and attempt to hold it until the stop buzzer sounded. His rate of pedalling was constantly visible on the Speed Recorder. The ten seconds represented the approximate time period during which a maximal output could be attained and maintained. Some subjects would not reach their maximum output until eight or nine seconds and others would reach it earlier and begin to drop off in output

at this time. The buzzer and lights were controlled by a panel of switches situated behind a partition at the side of the ergometer (Figure 2). The wiring system was such that each light switch also activated the buzzer and simultaneous auditory and visual signals were presented to the subject.

Three types of signals were utilized. A warning signal ten seconds prior to the commencement of work consisted of the appropriate buzzer-light combination to provide for anticipation of a specific work load, a start signal to initiate work consisted of a repetition of this combination, and a stop signal to end work consisted of a buzzer. Each signal was wired into the margin marker of the Sanborn Twin-Viso Cardiette so that the exact timing of the signal was recorded and changes in work output and heart rate could be assessed in relation to them.

The recording of the heart rate was obtained by direct ECG leads from the exercising subject to Channel B of a Sanborn Twin-Viso Cardiette. The ECG disc electrodes were jellied and taped to the skin over the manubrium process, over the apex of the heart, and over the vertebral column in the region of the seventh dorsal (48). During the course of the experiment, it was found that for subjects with excessive amounts of body hair equally good tracings could be obtained by spanning the heart laterally with the two precordal electrodes and locating the ground electrode in any suitable locale dorsally.

A microswitch, attached to the bicycle frame, was depressed with each rotation of the pedal arm. The switch was

wired into a 1½ volt circuit and monitored on Channel A of the Sanborn. This provided work output readings in revolutions per minute simultaneously with heart rate readings and signal recordings.

Testing procedure.

The subjects did not exercise vigorously the day of a testing session. Trials were performed in isolation to avoid discussion or observation of the experimental procedure. The subjects were also cautioned not to talk about any aspect of the testing procedure outside of the laboratory.

a) Sitting heart rate. On each arrival for a testing session, the electrodes were attached, and the subject was seated in a chair. The subject remained seated quietly with a minimum of distractions for three minutes. The deflection of the Sanborn writing arm with each heart beat was observed during the latter portion of this time period for any deviations from a regular cardiac rhythm. If a steady rhythm was evidenced a reading was monitored that spanned a sequence of three beats. One subject in the pilot study (a gymnast), and one subject in this experiment (a sprinter), demonstrated cardiac arrhythmia. The readings for these subjects were extended to include the complete cycle of the arrhythmia and the average rate during the cycle was recorded. The subject then mounted the bicycle ergometer.

b) Pre-instruction heart rate. Once settled on the ergometer, the subject remained seated quitely for one minute

after which a three beat reading was replicated as in Section a).

c) Test instruction. The regulations governing pedalling included: (1) the starting position half a revolution from the microswitch, (2) the maintenance of a seated position during pedalling, and (3) the removal of the feet from the pedals on the stop signal. The instrument panel, control, and signal system were all explained and the test procedure for the first trial outlined.

Prior to each of the five maximal trials, the low, mean, and high Speed Recorder readings achieved by previous subjects in the individual's category were supplied to the subject for motivational purposes. The maximal trial was described to the subject as an all-out maximal performance comparable to a 100-yard dash. The term minimal was not associated with the 50 revolutions per minute trial. The subject was instructed to hold the Speed Recorder needle on 50 revolutions per minute for 45 seconds. In reality, none of the subjects had any advance cues as to how light or strenuous either work pattern might be since they were not permitted to pedal before their first trial. If the load resistance had been reversed, the all-out maximal revolutions in 10 seconds would have been less strenuous than the 50 revolutions per minute in 45 seconds. Subjects, therefore, had no forewarning of the load resistance, nor did they know that it could be changed by the operator.

The experimental hypotheses were not divulged to the subjects. The experiment was explained as an assessment of heart rate and work output at different rates of pedalling. The warning signal was described as a preliminary notice of work to come and subjects were not aware that their heart rate was being monitored during the anticipatory period.

On Day 1 and Day 3, the initial trial instructions referred only to a single trial. It was not until the recovery rates for the first trial had been completed that the rest periods and additional trial sequences were explained. Rest periods of one minute were allowed between each of the minimal trials and eight minutes between each of the maximal trials.

d) Heart rate and work output readings. During minimal T1 and minimal T5, the heart rate was recorded continuously from two seconds before the warning signal, throughout the anticipatory period, until five seconds after the start signal. Two-second readings were then taken at the following time periods from the start signal: 7 to 9 seconds, 11 to 13 seconds, 15 to 17 seconds, 19 to 21 seconds, 23 to 25 seconds, 31 to 33 seconds, 37 to 39 seconds, and 43 to 45 seconds. A two-second recovery heart rate reading was taken from 60 to 62 seconds after the stop signal.

During minimal T2, T3 and T4, the heart rate was sampled with two-second readings prior to the warning signal and the start signal. Exercise readings were taken from 10 to 12 seconds, 25 to 27 seconds, and 43 to 45 seconds. A recovery rate was taken as in minimal T1 and T5.

During maximal T1 and maximal T5, the heart rate was recorded continuously from two seconds before the warning signal, throughout the ten second anticipatory period, throughout the ten second exercise period, and for three seconds after the stop signal. Two-second heart rate readings were taken from 5 to 7 seconds, 9 to 11 seconds, 13 to 15 seconds, 30 to 32 seconds, and from 60 to 62 seconds after the stop signal. The purpose of the heart rate readings immediately after the cessation of exercise was to determine the peak heart rate attained as a result of the maximal work effort of short duration. The data from the pilot study indicated that peak heart rates would be reached from one to ten seconds after the subject stopped pedalling. This peak heart rate was arbitrarily termed peak exercise heart rate and the 30 second and 60 second readings after exercise were termed recovery heart rates.

During maximal T2, T3, and T4, the heart rate was sampled with two-second readings prior to the warning signal and the start signal. A four-second reading was run from eight seconds after the start signal to two seconds after the stop signal and a recovery heart rate reading was taken from 60 to 62 seconds after the end of exercise.

Since the minimal pattern consisted of a standardized work output of 50 revolutions per minute on the Speed Recorder Dial, each trial was merely checked to insure that no major discrepancies in pedalling rate had occurred. The majority of riders were able to hold the rate steady between 48 and 52 revolutions per minute. The work output on the maximal trials

was monitored along with the heart rate throughout the ten second exercise period for T1 and T5. For T2, T3, and T4, the terminal work output was assessed from the recording made from eight to ten seconds after the start signal.

All two-second heart rate readings were reported in beats per minute by measuring the linear distance encompassed by two cardiac cycles (Figure 3). The linear distance was converted to a rate per minute on the basis of a paper speed of 5.2 centimeters per second. With the exception of the first pedal revolution which was used to indicate initial speed of movement, all subsequent revolutions were handled in pairs in the same manner as the heart rate readings. The grouping of two cycles or revolutions increased the precision of the measure. The objectivity of this method was determined by a coefficient of correlation between the readings made by two technicians on rates ranging from 80 to 160 beats per minute. A coefficient of correlation of 0.99 was obtained. The majority of the variation was introduced above heart rates of 140 beats per minute (Appendix A).

The mean heart rates for all anticipatory periods and for the maximal exercise period and the mean work output for the maximal exercise period were obtained by counting the number of complete cardiac or sprocket cycles and partial cycles to the nearest sixth. The total of these for the ten second period was multiplied by six to convert it into beats or revolutions per minute.

The mean heart rate in beats per minute was obtained for each 15 second portion of the 45 second minimal exercise

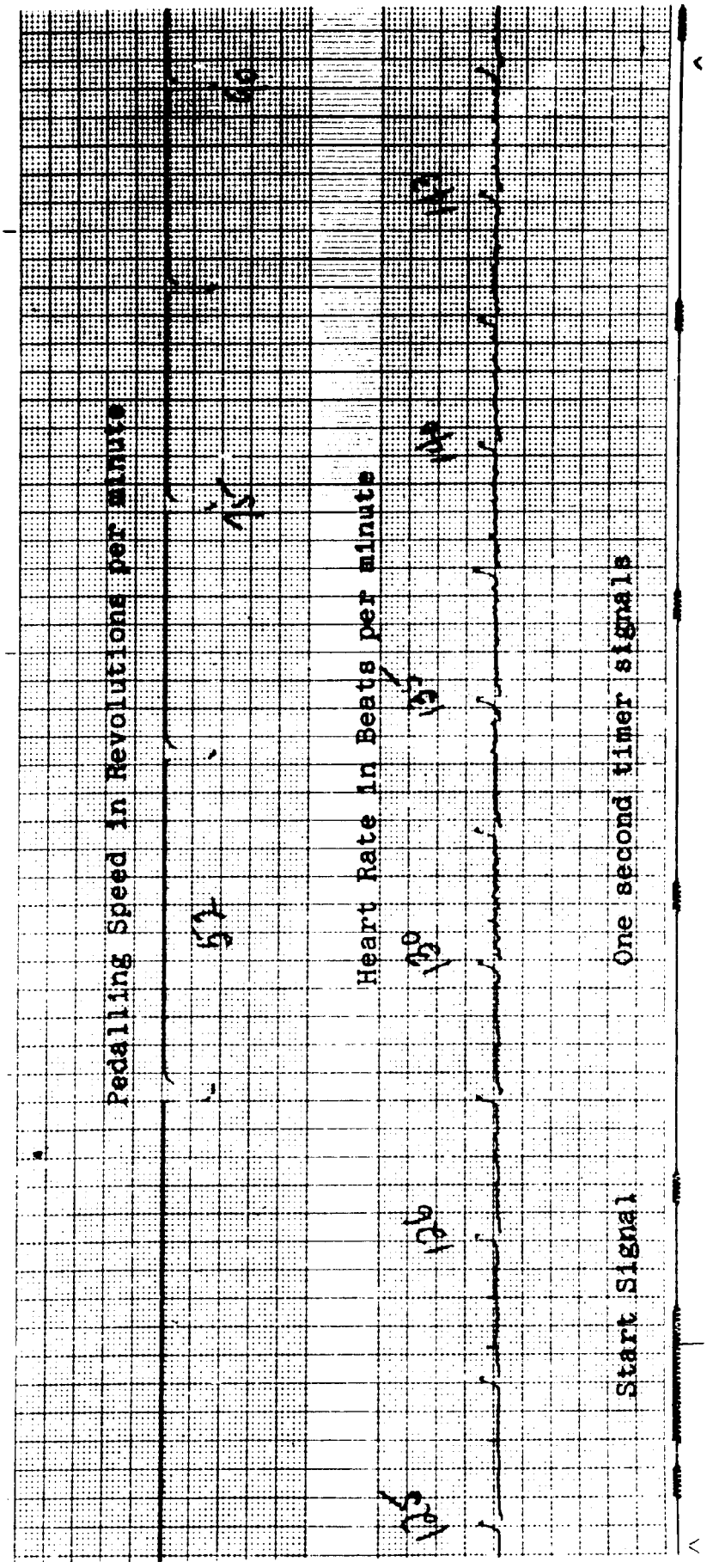


FIG. 3. The work output and heart rate recordings obtained during a maximal trial.

period by averaging the two second readings obtained in that portion. The mean heart rate for the 45 second exercise period was determined by taking the mean of the means for the three portions. This mean minimal exercise heart rate had a coefficient of correlation of 0.983 with the mean heart rate obtained by monitoring the total 45 second exercise period and extrapolating the number of complete and partial cardiac cycles to beats per minute. After each experimental trial series, the raw scores were transferred from the Sanborn Permapaper to the individual data sheets (Appendix B).

e) Demographic data. On the first day, prior to the administration of the 16 Personality Factor Test, the following demographic data were obtained and recorded on the individual data sheet:

(1) Date of birth.

(2) Height in inches to the nearest inch.

(3) Weight in pounds to the nearest pound.

(4) Category and where appropriate position or event.

(5) Order (Group A or Group B).

f) The 16 Personality Factor Test. The subjects were given the Form A of the test individually. The test booklet was presented to the subject and he was instructed to read the introduction. The purpose of the test was cited as an effort to assess through self-report the inherent qualities within the individual that contributed to the physiological differences in heart rate and work output that might be demonstrated on the bicycle ergometer. A plea was made for

co-operation since erroneous answers would provide misleading results. The subjects were assured that the results would be completely confidential, that a master scoring system provided composite scores, and that their names would never be linked to any of the data.

The individual responses marked on the answer sheet were hand scored by master score sheets into the raw scores for each of the 16 personality factors. These raw score values were entered on the individual data sheets (Appendix B). The raw scores were converted into sten scores for male college students. The conversion was a prerequisite for the calculation of the second order factors of anxiety and introversion (20, 23).

The sten scores as used by Cattell have a mean of 5.5. One standard deviation spans the sten range from 4.5 to 6.5 and this arbitrarily is called "average." Sten scores of 4 or 7 and beyond are considered to deviate from the average. Each sten score from 1 through 10 is assigned a ½ standard deviation interval. The sten table thus covers a range of five standard deviations. Sten scores are necessary for the determination of the second order factors and norms are available on previous studies of male university students. Consequently, conversion to more traditional standard or sigma scores was not warranted.

Treatment of data.

Based upon the proposed statistical analysis of the data, an IBM punch card code was devised (Appendix C). The

demographic data, the raw scores of the 16 Personality Factor Test, the second order factors of anxiety and introversion, and the heart rate and work output readings from the five minimal trials and five maximal trials resulted in 111 variables for each subject. Seven IBM cards were required to handle the data for each subject.

CHAPTER III

PRESENTATION AND ANALYSIS OF DATA

The primary hypothesis was that cardiac conditioning to specific work intensities provides for an appropriate heart rate response prior to and in the initial stages of adjustment to work. The hypothesis was tested through the statistical analyses of five measures associated with the minimal work task. Heart rate in the chair, mean anticipatory heart rate, mean exercise heart rate, peak exercise heart rate, and recovery heart rate were selected as the measures most significant to the assessment of the subjects' response to the minimal work load. The time of the peak exercise heart rate, mean work output, peak work output, and time of peak work output were added to the previous five measures for the analysis of the maximal work load. The standardization of work output at 50 revolutions per minute for all subjects during the minimal trials made its inclusion in the analysis of these trials unnecessary.

All statistical analyses were performed with the data arranged in twelve cells on the basis of category-order subgroups (Table 2). The category-order subgroups were established in the initial design of the study. The pilot study suggested the possibility of an ordering effect. The cross-over design (29) was adopted to analyze any possible effect of order in the presentation of the two work intensities. The orders

consisted of Group A, who performed a minimal-maximal sequence of trials, and Group B, who performed a maximal-minimal sequence of trials. The division of each of the six categories into two order subgroups provided 12 cells. A cell, therefore, contained the statistics of ten non-varsity subjects of a particular order, or four varsity subjects of a particular category-order.

TABLE 2.--Subject distribution in the category-order subgroup cells.

Group	Category						
	Non-varsity	Football	Gymnast	Hockey	Distance	Sprints	Overall
A Order Min-Max	10	4	4	4	4	4	30
B Order Max-Min	10	4	4	4	4	4	30
Total	20	8	8	8	8	8	60

The category-order subgroups facilitated the determination of differences in the initial status of the subjects and in the amount and direction of conditioning that was attributable to previous athletic training patterns and/or group personality traits. The initial status of the subjects was based upon their response to minimal T1 and maximal T1 (see page 37). The amount

and direction of conditioning induced by the experimental trials was assessed by subtracting minimal T5 from minimal T1 and by subtracting maximal T1 from maximal T5. The order of the subtraction was based upon the expected direction of change (see page 49).

The mean and variance for each category-order subgroup cell was determined for the initial status of each variable. The pooled within cell variance was calculated and used to compute the 95 and 99 per cent confidence limits. The amount of conditioning was determined by assessing the amount and direction of change from T1 to T5 for each subject. The category-order subgroup cell means and variances for the amount of conditioning were obtained for all variables. The pooled within cell variance was determined and used for the calculation of the 95 and 99 per cent confidence limits.

The same statistical analysis was performed for the 16 Personality Factors and the two second order factors of anxiety and introversion with the exception that the cells were collapsed across orders. Six cells remained based upon the subjects' categories. The rationale of this procedure was that the subjects were assigned to Group A and Group B randomly for the analysis of differences in the amount of conditioning attributable to an ordering effect. Since no such change was to be expected in measures of basic personality structure, an analysis of the initial status of category-order subgroup cells would merely reflect sampling error due to the small sample size. The collapsing of the category-order subgroup cell into

categories also provided increased stability because of the doubled sample size.

The two major categories of non-varsity and varsity subjects and the orders of group A and Group B were analyzed for differences between means at the 95 and 99 per cent level of confidence. This analysis was performed on each of the 14 measures for initial status and for amount of conditioning (see page 47, Table 6).

A correlation matrix and a factor analysis with a varimax rotation was programmed for the 16 personality variables and six physiologic variables selected from minimal T1 and maximal T1. The two second order factors of anxiety and introversion (see page 16) were included in the correlation matrix but excluded from the factor analysis. The overall sample means were used in the determination of the correlation matrix and the factor analysis. The composition of the overall sample places limitations upon the generalizations that can be drawn from these analyses.

In all tables and appendices, means, confidence limits, and standard deviations are given in beats per minute for heart rate, revolutions per minute for work output, and in seconds from the work signal for time of peak exercise heart rate and time of peak work output. Variances are in these units squared. The peak exercise heart rate values greater than ten seconds indicate that the peak rate was attained after cessation of work.

Initial status.

Although the establishment of initial status was not germane to the testing of the experimental hypothesis, it does clarify the point of departure. It also presents the possibility that if the experimental hypotheses are substantiated, it will reflect, at least for the athletes, the influence of long term cardiac conditioning to habitual training patterns or possibly basic genetic or physical differences.

The category-order subgroup means in age, height, weight, and heart rate in chair are in Table 3. The category-order subgroup means for heart rate in the chair were taken from the readings obtained the first time the subject was tested. This first heart rate in chair reading was taken prior to any experimental instructions. It occurred prior to minimal T1 for Group A and prior to maximal T1 for Group B.

The major category deviations from the overall means were reduced considerably by the contribution of the category mean to the overall mean. The purpose of the listings is to present an overview of the inter-category comparisons.

Major category deviations from the overall means were as follows:

1. Non-varsity category mean age was one year younger and mean heart rate in chair was ten beats higher.
2. Football category mean height was three inches taller and mean weight was 44 pounds heavier.
3. Gymnastic category mean height was three inches shorter and mean weight was 21 pounds lighter.

4. Hockey category mean age was one year older.

5. Distance runner category mean weight was 17 pounds lighter and mean heart rate was ten beats lower.

6. Sprint runner category means did not deviate.

TABLE 3.--Initial status of category-order subgroups in terms of mean age, height, weight, and heart rate in chair prior to experimental instructions.

	Non-vars.	Foot-ball	Gym-nast	Hockey	Dis-tance	Sprints	Overall
Age (years)							
A.	19.0	19.5	20.5	20.8	20.0	20.2	19.9
B	18.0	19.8	18.8	20.5	20.5	19.8	19.5
C	18.5	19.6	19.6	20.6	20.2	20.0	19.7
Height (ins.)							
A.	70.6	73.8	67.5	70.8	69.2	71.8	70.6
B	70.0	72.2	67.7	70.8	70.8	70.8	70.3
C	70.3	73.0	67.6	70.8	70.0	71.2	70.4
Weight (lbs.)							
A	160	215	139	166	144	162	164
B	158	200	147	168	150	164	163
C	159	208	143	167	147	163	164
Heart Rate Chair (beats per minute)							
A	74	76	65	65	62	68	70
B	86	69	62	66	59	62	71
C	80	73	64	66	60	65	70

Legend: A - Group A (minimal-maximal sequence)
B - Group B (maximal-minimal sequence)
C - Category

Major differences between Group A and Group B in the same category were as follows:

1. Non-varsity category. Group A mean age was one year older and mean heart rate in chair, 12 beats

slower.

2. Football category. Group A mean height was 1.6 inches taller, mean weight 15 pounds heavier, and mean heart rate in chair seven beats higher.
3. Gymnastic category. Group A mean age was 1.7 years older, and mean weight was eight pounds lighter.
4. Hockey category. No major deviations.
5. Distance runner category. Group A mean height was 1.6 inches shorter and mean weight six pounds lighter.
6. Sprint runner category. Group A mean heart rate was six beats higher.
7. Overall sample. No major deviations.

These category and category-order differences in demographic characteristics give some indication of the success of the random and matched sampling techniques. Since weight correlated 0.56 with the mean work output in maximal T1 and 0.66 with the mean work output in maximal T5, this variable is of interpretative value in the explanation of the response to the maximal trials.

The 12 cell variances and the pooled within cell variance for the five variables measured in minimal T1 and the nine variables measured in maximal T1 are in Appendix D. The 95 and 99 per cent confidence limits for the overall means were determined for each of the 14 variables (Tables 4 and 5). The category-order subgroup and marginal means for the five minimal T1 and five minimal T5 measures

TABLE 4.--The 95 and 99 per cent confidence limits for the overall means minimal T1

Measures	Minimal T1	
	95%	99%
Heart rate in chair	68.2 to 74.5	67.1 to 75.5
Mean anticipatory heart rate	80.0 to 86.4	79.0 to 87.4
Mean exercise heart rate	97.9 to 103.6	97.0 to 104.5
Peak exercise heart rate	107.1 to 113.3	106.3 to 114.4
Recovery heart rate	72.1 to 78.7	71.0 to 79.9

TABLE 5.--The 95 and 99 per cent confidence limits for the overall means maximal T1

Measures	Maximal T1	
	95%	99%
Heart rate in chair	65.1 to 70.9	64.1 to 71.8
Mean anticipatory heart rate	86.5 to 93.5	85.3 to 94.7
Mean exercise heart rate	116.8 to 123.0	115.8 to 124.0
Peak exercise heart rate	145.8 to 152.9	144.6 to 154.0
Time peak heart rate	13.3 to 15.0	13.1 to 15.3
Recovery heart rate	93.7 to 101.6	92.4 to 102.9
Mean work output	94.6 to 100.8	92.9 to 101.9
Peak work output	122.2 to 130.6	120.9 to 132.0
Time peak work output	8.5 to 9.1	8.4 to 9.2

Note: Heart rates are in beats per minute. Work outputs are in revolutions per minute. Time of peak heart rate and peak work output is in seconds from the start signal.

and for the nine maximal T1 and nine maximal T5 measures are in Table 6 and Table 7. The cell means of minimal T1 and maximal T1 that are significantly different from the overall mean at the one per cent level are indicated by an asterisk.

Since the confidence limits were based upon the pooled within cell variance of the overall sample, the scores of extreme categories would tend to influence the overall mean in the direction of the extreme category. This is especially true of the non-varsity category scores which contribute so heavily numerically to the overall mean. Consequently, this constituted a very conservative criterion for the measurement of the digression of category means. The primary statistical analyses were made of the changes between T1 and T5 for each work intensity. No statistical analyses were made of the raw score responses to T5 minimal or maximal. These means are included in Table 6 and Table 7 merely to give an overview of the pre- and post-experimental status of each category-order subgroup cell in mean raw score values. In assessing pre-experimental levels of the heart rate in chair, the minimal T1 value of Group A should be compared to the maximal T1 value of Group B. This is the only point at which the heart rates of the two groups were directly comparable.

Although considerable between-cell variability was evidenced in response to minimal T1 and maximal T1, even between orders within a single category, several clear-cut category trends still emerged (Tables 6 and 7). The non-varsity subjects tended to have mean heart rates above the 99 per cent confidence

TABLE 6.--Cell means for the category-order subgroups and the marginal totals for minimal T1 and minimal T5.

	Minimal T1							Minimal T5						
	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart rate in chair														
A	74	76*	65*	65*	62*	68	70	70	64	62	67	57	65	65
B	81*	70	77*	72	58*	66*	73	78	72	77	65	65	62	71
C	78*	73	71	69	60*	68	71	74	68	70	66	61	63	68
Mean anticipatory heart rate														
A	93*	100*	76*	70*	76*	86	85	76	77	64	66	63	78	72
B	89*	79	81	79	70*	78*	82	86	75	73	72	63	69	76
C	91*	88*	78*	74*	73*	82	83	81	76	70	69	63	74	74
Mean exercise heart rate														
A	110*	111*	94*	91*	98	102	103	98	87	86	84	85	93	91
B	107*	98	94*	95*	91*	100	99	101	90	94	88	83	86	92
C	108*	104	94*	93*	94*	101	101	99	88	90	85	84	89	91
Peak exercise heart rate														
A.	122*	119*	102*	98*	106	112	112	105	97	94	92	96	100	99
B	116*	106	102*	105*	100*	107	108	108	97	100	100	91	95	100
C	119*	113	102*	102*	103*	109	110	106	97	97	96	93	98	99

TABLE 6.--(Continued)

	Minimal T1							Minimal T5						
	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
60 second recovery heart rate														
A	81*	88*	71	7[illegible]*	63*	60*	74	74	68	64	67	63	64	68
B	[illegible]*	75	75	76	62*	66*	7[illegible]	86	78	69	73	60	68	75
C	8[illegible]*	81*	73	73	62*	63*	75	80	73	66	7[illegible]	61	66	71

*Indicates a cell mean significantly different from the overall sample mean at the one per cent level.

Legend: A - Group A
B - Group B
C - Total category

Note: T5 trials are not analyzed statistically.

TABLE 7.--Cell means for the category-order subgroups and the marginal totals for maximal T1 and maximal T5.

	Maximal T1							Maximal T5						
	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart rate in chair														
A	68	71	65	61*	59*	61*	65	71	70	65	63	60	73	68
B	86*	69	62*	66	59*	62*	71	88	61	75	72	62	65	74
C	77*	70	63*	63*	59*	62*	68	80	65	70	68	61	69	71
Mean anticipatory heart rate														
A	93	96*	80	74*	82*	93	88	90	108	87	71	81	112	91
B	105*	88	78*	88	85	91	92	101	87	84	86	77	89	90
C	99*	92	79*	81*	84*	92	90	95	98	86	78	79	101	91
Mean exercise heart rate														
A	125*	124	116	100*	112*	122	118	124	133	113	107	114	134	121
B	134*	119	104*	120	112*	122	122	132	135	112	119	111	119	1122
C	130*	121	110*	110*	112*	122	120	128	129	112	113	113	126	122
Peak exercise heart rate														
A	157*	152	150	126*	136*	148	147	158	165	146	141	133	158	152
B	165*	147	133*	148	143*	152	151	165	154	144	155	139	151	154
C	161*	150	142*	137*	139*	150	149	162	160	146	148	136	155	153
60 second recovery heart rate														
A	94	107*	96	81*	74*	105*	93	105	124	100	86	80	113	102
B	116*	108*	96	92	85*	97	102	113	108	100	107	84	100	104
C	105*	108*	96	86*	80*	101	98	109	116	100	96	82	107	103

TABLE 7.--(Continued)

	Maximal T1							Maximal T5						
	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Time peak heart rate (seconds)														
A	13	14	16*	14	14	14	14	13	16	18	16	14	12	14
B	15	14	14	13	15	15	14	16	16	15	16	16	15	16
C	14	14	15	14	14	14	14	15	15	16	16	15	14	15
Mean work output														
A	95	112*	95	96	81*	96	96	103	125	105	105	96	110	107
B	94	112*	90*	105*	99	103*	99	104	124	104	122	106	111	110
C	95	112*	92*	100	90*	99	97	103	124	104	113	101	111	108
Peak work output														
A	123	143*	126	119*	105*	129	124	129	150	133	135	120	144	134
B	124	142*	115*	136*	130	133*	129	135	150	129	147	133	141	138
C	124	143*	120*	128	117*	131	126	132	150	131	141	127	143	136
Time peak work output (seconds)														
A	9	8	9	8	8	9	9	7	7	8	8	9	8	8
B	9	8	9	9	9	9	9	8	7	8	8	8	8	8
C	9	8	9	9	9	9	9	8	7	8	8	8	8	8

*Indicates a cell mean significantly different from the overall mean at the one per cent level.

Legend: A - Group A
B - Group B
C - Total category

limits for the overall means in all responses to both minimal and maximal trials. The Group A football players demonstrated a similar pattern and both groups of football players had high mean and peak work outputs in the maximal trial. The gymnasts, hockey players, and distance runners tended toward mean heart rates below the 99 per cent confidence limits in response to both the minimal and maximal trials. The sprinters had low heart rates in the chair prior to both trials and low recovery heart rates after the minimal trial.

Table 8 contains the difference between the mean of the non-varsity subjects and the mean of the varsity subjects ffom the other five categories for each variable. The difference between the means was obtained by subtracting the varsity mean from the non-varsity mean and the Group B mean from the Group A mean. Significance differences are designated at the one and five per cent levels. Significant differences occurred between the two groups in all heart rate measures associated with both work loads. In every instance the non-varsity subjects had the higher heart rate. No significant differences were evidenced in the time of the peak exercise heart rate, the mean work output, the peak work output, or the time of the peak work output.

The difference in means between Group A and Group B for all variables are in Table 9. The difference between means was obtained by subtracting the Group B mean from the Group A mean. The 60-second recovery heart rate after the maximal trial demonstrated an ordering effect significant at

TABLE 8.--The differences between the means for the non-varsity subjects and the means for the varsity subjects for minimal Tl and maximal Tl

	Minimal Tl	Maximal Tl
	Difference Between Means	Difference Between Means
Heart rate in chair	9.42**	13.60**
Mean anticipatory heart rate	11.78**	13.35**
Mean exercise heart rate	11.40**	14.68**
Peak exercise heart rate	13.32**	17.43**
60 second recovery heart rate	14.48**	12.02**
Time peak heart rate		0.23
Mean work output		-3.87
Peak work output		-4.25
Time peak work output		0.40

**Indicates a significant difference at the one per cent level.

Note: The difference between the means was obtained by subtracting the mean of the varsity subjects (N=40) from the mean of the non-varsity subjects (N=20).

TABLE 9.--The differences between the means for Group A subjects and the means for Group B subjects for minimal T1 and maximal T1.

	Minimal T1	Maximal T1
	Difference Between Means	Difference Between Means
Heart rate in chair	-3.50	-5.77
Mean anticipatory heart rate	3.47	-4.34
Mean exercise heart rate	3.90	-3.51
Peak exercise heart rate	4.10	-4.07
60-second recovery heart rate	-3.24	-9.10*
Time peak heart rate		-0.34
Mean work output		-3.67
Peak work output		-4.80
Time peak work output		-0.08

**Indicates a significant difference at the five per cent level.

Note: The difference between means was obtained by subtracting the Group B mean from the Group A mean.

the five per cent level. Group B showed a slower recovery rate and therefore a higher mean group value. There were no other significant ordering effects. All measures associated with the maximal trial and heart rate in chair and recovery heart rate associated with the minimal trial did, however, show a consistent trend toward higher mean values in Group B. The three measures concerned directly with the anticipation or performance of the minimal work, anticipatory, mean, and peak exercise heart rate, were higher in Group A.

Experimental conditioning.

The amount of conditioning was determined by subtracting minimal T5 from minimal T1 and by subtracting maximal T1 from maximal T5. The changes from T1 to T5 were determined for each subject and for each variable. The 95 and 99 per cent confidence limits were based upon the pooled within cell variance (Appendix E). The differences between the overall mean in T1 and the overall sample mean in T5 for all 14 variables are in Table 10. The assessment of changes from minimal T1 to minimal T5 in the overall sample shows no significant change in the heart rate in the chair. All other measures were lower in T5 than in T1 significant at the one per cent level for the mean anticipatory heart rate, the mean exercise heart rate, and the peak exercise heart rate and at the five per cent level for the recovery heart rate.

TABLE 10.--The means for the differences between minimal T1 and minimal T5 (T1 minus T5) and between maximal T1 and maximal T5 (T5 minus T1).

	Minimal Difference Between Means	Maximal Difference Between Means
Heart rate in chair	2.883	3.083**
Pre-warning heart rate	5.650**	2.683
Mean anticipatory heart rate	9.383**	0.550
Peak anticipatory heart rate	11.100**	-0.267
Mean exercise heart rate	9.283**	2.300
Peak exercise heart rate	10.867**	3.733*
60 second recovery heart rate	3.967*	5.600
Time peak heart rate		0.800
Mean work output		10.850*
Peak work output		9.817**
Time peak work output		-1.017**

*Indicates a significant difference at the five per cent level.

**Indicates a significant difference at the one per cent level.

Note: For each subject in the minimal trials T5 scores were subtracted from T1 scores, summed and averaged. In maximal trials, T1 scores were subtracted from T5 scores.

In the maximal trials, the heart rate in the chair, the mean work output, and the peak work output were all significantly higher in T5 than T1 at the one per cent level of significance. The time of the peak work output was earlier in the work period significant at the same level. At the five per cent level of significance the peak exercise heart rate was higher in T5 than in T1.

Table 11 provides the difference between the means for the non-varsity and varsity subjects in the change from T1 to T5 in both minimal and maximal trials. The mean change from T1 to T5 was determined for the non-varsity and varsity subjects for each of the 14 variables. The varsity mean was then subtracted from the non-varsity mean in each instance. The 95 and 99 per cent confidence limits were calculated from the pooled within cell variance of the amount of change. There were no significant differences between these two groups in the amount of change that occurred between T1 and T5 in either minimal or maximal trials. Varsity subjects did, however, tend to condition less to the minimal trials and more to the maximal trials than did the non-varsity subjects.

The differences in the amount of conditioning (see page 34) to the minimal and maximal trials that was attributable to an ordering effect are displayed in Table 12. The mean change from T1 to T5 was determined for Group A (minimal-maximal order) and for Group B (maximal-minimal order). The Group B mean was then subtracted from the Group A mean for each of the 14 variables. The 95 and 99 per cent confidence

TABLE 11.--The differences between means for non-varsity subjects and varsity subjects in amount of change from minimal T5 to minimal T5 and from maximal T1 to maximal T5.

	Minimal Differences Between Means	Maximal Differences Between Means
Heart rate in chair	+0.652	-0.350
Mean anticipatory heart rate	+1.450	-6.450
Peak anticipatory heart rate	+3.375	-6.200
Mean exercise heart rate	-0.350	-3.975
Peak exercise heart rate	-2.975	-4.625
Time peak heart rate		-0.175
60 second recovery heart rate	+1.925	-6.300
Mean work output		-3.375
Peak work output		-1.825
Time peak work output		-0.500

Note: To assess the amount of conditioning minimal T5 measures were subtracted from minimal T1 measures and maximal T1 measures were subtracted from maximal T5 measures. The mean amount of change for varsity subjects was subtracted from the mean amount of change for non-varsity subjects for each variable. There were no significant differences.

TABLE 12.--The differences between the means for Group A subjects and Group B subjects in amount of change from minimal T1 to minimal T5 and from maximal T1 to maximal T5.

	Minimal Differences Between Means	Maximal Differences Between Means
Heart rate in chair	2.567	-0.300
Mean anticipatory heart rate	7.367*	5.633
Mean exercise heart rate	5.633**	3.800
Peak exercise heart rate	5.267*	1.800
Time peak heart rate		-0.660
60 second recovery heart rate	3.667	6.866
Mean work output		0.233
Peak work output		0.700
Time peak work output		-0.167

*Indicates a significant difference at the five per cent level.

**Indicates a significant difference at the one per cent level.

Note: To assess the amount of conditioning minimal T5 scores were subtracted from minimal T1 measures and maximal T1 scores were subtracted from maximal T5 measures. The mean amount of change for Group B was subtracted from the mean amount of change for Group A for each variable.

limits were calculated from the pooled within cell variance of the amount of change. The Group A difference between means from T1 and T5 in the minimal trials was higher than Group B mean difference significant at the one per cent level for mean exercise heart rate and at the five per cent level for mean anticipatory heart rate and peak exercise heart rate. There were no significant ordering effects associated with the maximal trials, although Group A demonstrated a greater amount of change from T1 to T5 in all measures except the time of peak exercise heart rate.

The means for the category-order subgroup cell differences between T1 and T5 for each of the 14 measures are in Table 13 and Table 14. The variances and the pooled within cell variance for the same measures are in Appendix E. In the minimal trials, some variability was evidenced among category-order subgroup means in the amount and direction of the conditioning of the heart rate in the chair and in recovery. The mean cell differences for all other category-order subgroup cells were positive indicating higher values in minimal T1 than minimal T5 for these measures (see page 35).

In the maximal trials, mean work output, the peak work output, and the time of the peak work output of the maximal trial showed consistency in the direction of change for all category-order subgroups. The output values were positive indicating higher values for all cells in maximal T5 than maximal T1. The time of peak work output was negative indicating an earlier attainment of the peak in T5. The heart

TABLE 13.--The means for the differences between minimal T1 and minimal T5 (T5 minus T1) for each category-order subgroup cell and for the overall sample.

	Non-Varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart Rate in Chair							
A	3.6	12.5*	3.0	-2.0*	5.2	3.5	4.2
B	3.0	-1.2	0.0	7.5*	-6.5*	4.8	1.6
C	3.3	5.6	1.5	2.8	-0.6	4.1	2.9
Mean Anticipatory Heart Rate							
AA	16.9*	20.0*	10.0	4.8*	12.5	8.5	13.1
B	3.8*	3.8*	6.0	6.8	7.2	9.5	5.7
C	10.4	11.9	8.0	5.8	9.9	9.0	9.4
Mean Exercise Heart Rate							
A	12.6*	24.5*	7.2	6.5	12.2*	8.8	12.1
B	5.5*	7.8	0.8*	6.5	8.2	11.5	6.5
C	9.0	16.1*	4.0*	6.5	10.2	10.1	9.3
Peak Exercise Heart Rate							
A	17.0*	22.0*	7.8	6.5*	10.8	11.8	13.5
B	8.7	9.2	2.0*	7.8	9.0	12.0	8.2
C	12.8	15.6*	4.9*	7.1*	9.9	11.9	10.9
Recovery Heart Rate							
A	6.7	19.8*	7.5	3.0	0.5	-4.0*	5.8
B	3.8	-2.5*	6.2	3.2	1.5	-2.0*	2.1
C	5.2	8.6	6.9	3.1	1.0	-3.0*	4.0

*Indicates a significant difference at the one per cent level. between a cell mean and the overall mean.

TABLE 14.--The means for the differences between maximal T1 and maximal T5 (T1 minus T5) for each category-order subgroup cell and for the overall sample

	Non-Varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart Rate in Chair							
A	3.0	-1.2	0.2	2.5	1.5	11.5*	2.9
B	2.7	-8.5**	13.8*	6.5	2.2	3.5	3.2
C	2.8	-4.9*	7.0*	4.5	1.9	7.5*	3.1
Mean Anticipatory Heart Rate							
A	-3.4	12.0*	7.0*	-3.0	-1.5	19.2*	3.4
B	-4.1	-1.2	6.2*	-2.0	-8.0*	-1.8	-2.3
C	-3.8	5.4	6.6*	-2.5	-4.8	8.8*	0.6
Mean Exercise Heart Rate							
A	1.4	9.5*	-3.0*	7.2*	2.5	11.8*	4.2
B	-2.1	5.5	7.8*	-1.2	-1.2	-2.5*	0.4
C	-0.4	7.5*	2.4	3.0	0.6	4.6	2.3
Peak Exercise Heart Rate							
A	1.0	12.5*	-3.8*	15.2*	-2.5*	10.8*	4.6
B	0.3	7.5	11.2*	7.0	-4.0*	-1.2*	2.8
C	0.6	10.0*	3.8	11.1*	-3.2*	4.8	3.7
Time Peak Exercise Heart Rate							
A	-0.1	2.5*	1.5	1.5	-0.2*	-1.8*	0.4
B	1.6	1.8	1.0	1.0	0.8	0.0	1.1
C	0.8	2.1*	1.2	1.2	0.5	-1.8*	0.8
Recovery Heart Rate							
A	11.2	16.5	5.0	4.8	5.8	7.8	9.0
B	-2.7	0.8	5.0	15.0	-1.2	3.5	2.2
C	4.2	8.5	5.0	9.9	2.2	5.6	5.6
Mean Work Output							
A	8.0	13.0	10.0	9.2	15.2*	14.8*	11.0
B	9.2	11.5	14.2*	16.8*	7.0*	8.0	10.7
C	8.6	12.2	12.1	13.0	11.1	11.4	10.8
Peak Work Output							
A	6.2*	7.2	6.8	16.0*	15.5*	15.2*	10.2
B	11.0	7.5	14.0*	10.8	3.0*	8.2	9.5
C	8.6	7.4	10.4	13.4*	9.2	11.8	9.8
Time Peak Work Output							
A	-1.9*	-1.8*	-1.0	0.2*	0.2*	-1.2	-1.1
B	-0.8	-0.5*	-1.5	-1.0	-1.0	-1.0	-0.9
C	-1.4	-1.1	-1.2	-0.4	-0.4*	-1.1	-1.0

*Indicates a significant difference at the one per cent level between a cell mean and the overall mean.

rate measures associated with the maximal trial varied considerably among cells in both amount and direction of conditioning. The deviations among cells in the pattern of conditioning were clarified by the same technique used in the assessment of cell deviations in initial status (see page 42). The category-order subgroup cell means significantly different from the overall mean at one per cent level were determined (Tables 13 and 14). All differences cited as significant in the following paragraphs will be at the one per cent level of significance.

In their response to the minimal trials, the non-varsity and football category mean differences showed significantly greater amounts of conditioning for mean anticipatory, mean exercise, and peak exercise heart rate in Group A and significantly less in mean anticipatory heart rate in Group B. The Group B non-varsity mean also showed a significantly low level of conditioning in mean exercise heart rate. The mean for the recovery heart rate of the Group A football players showed a significantly greater decrease, as did the mean exercise heart rate cell mean of the Group A distance runners. The Group B gymnasts' and the Group A hockey players' cell means showed significantly less conditioning than the overall mean in several measures--mean and peak exercise heart rates for the gymnasts and mean anticipatory and peak exercise heart rate for the hockey players. The cell means for gymnasts and hockey players tended toward low levels of conditioning in both categories and all measures. The recovery heart rate cell

means of the Group B football players and both groups of sprinters demonstrated a negative conditioning pattern.

The football players' cell means showed the same significantly high levels of conditioning in response to the maximal trials as they had in response to the minimal trials. Cell means for mean anticipatory, mean exercise, and peak exercise heart rates, and the time of peak exercise heart rate, and work output were all significantly high for the Group A football players.

Although the cell means for hockey players indicated negative conditioning in anticipation of the maximal trials, their cell means showed significantly higher levels of conditioning than the overall mean in mean and peak exercise heart rate, and peak work output and lower in the time of peak work output. Group B hockey player cell mean demonstrated significantly high levels of conditioning in the time of the peak heart rate and mean work output.

The Group A sprinter cell means followed the same pattern as the football and hockey player cell means with significantly high levels of conditioning in mean anticipatory, mean exercise, and peak exercise heart rate, and in mean and peak work output. The time of peak exercise heart rate showed negative conditioning.

The cell means for Group A gymnasts, Group A and B distance runners, and Group B sprinters tended to indicate significantly lower levels of conditioning than the overall means and in many cases negative patterns were displayed.

The Group A gymnasts had a significantly high mean in mean anticipatory heart rate. Significantly low levels of conditioning were evidenced by the cell means of the Group A gymnasts in mean and peak exercise heart rates; the Group A distance runnegs in peak exercise heart rate and time of peak work output; the Group B distance runners in mean work output; and Group B sprinters in mean and peak exercise heart rates.

Figure 4 depicts the overall means for each of the five measures used in the statistical analysis of the minimal trials. These have been supplemented by the means for heart rate on the ergometer, the peak anticipatory heart rate, the terminal anticipatory heart rate, and the terminal exercise heart rate. The overall means for minimal T1 and minimal T5 have been plotted. Figure 5 presents the means for the nine measures associated with the maximal trials. Additional means here include the four means ased to supplement the portrayal of the minimal trials and the mean for the 30-second recovery heart rate. The mean and peak work output means are also shown. The change in the order of the peak, mean, and terminal exercise heart rate plots from Figure 4 to Figure 5 depict a difference in the time sequence of attainment of each measure. In the minimal trials, the peak occurred within the first ten seconds. In the maximal trials, the peak occurred after the cessation of work. The purpose of displaying the means graphically was to present a concise picture of the general pattern of experimental change which occurred in response to the two work intensities.

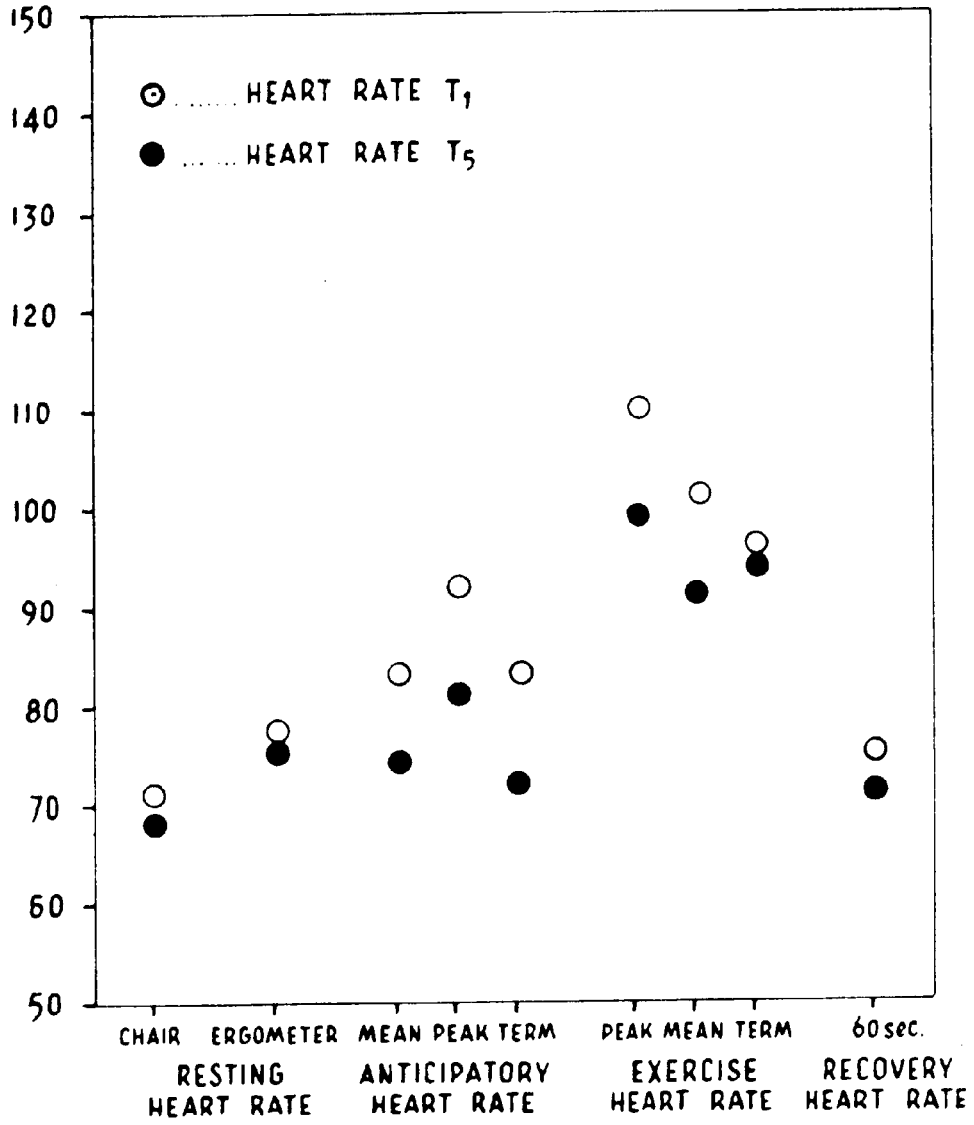


FIG. 4 THE HEART RATE MEANS IN BEATS PER MINUTE FOR THE MEASURES ASSOCIATED WITH MINIMAL T_1 AND MINIMAL T_5

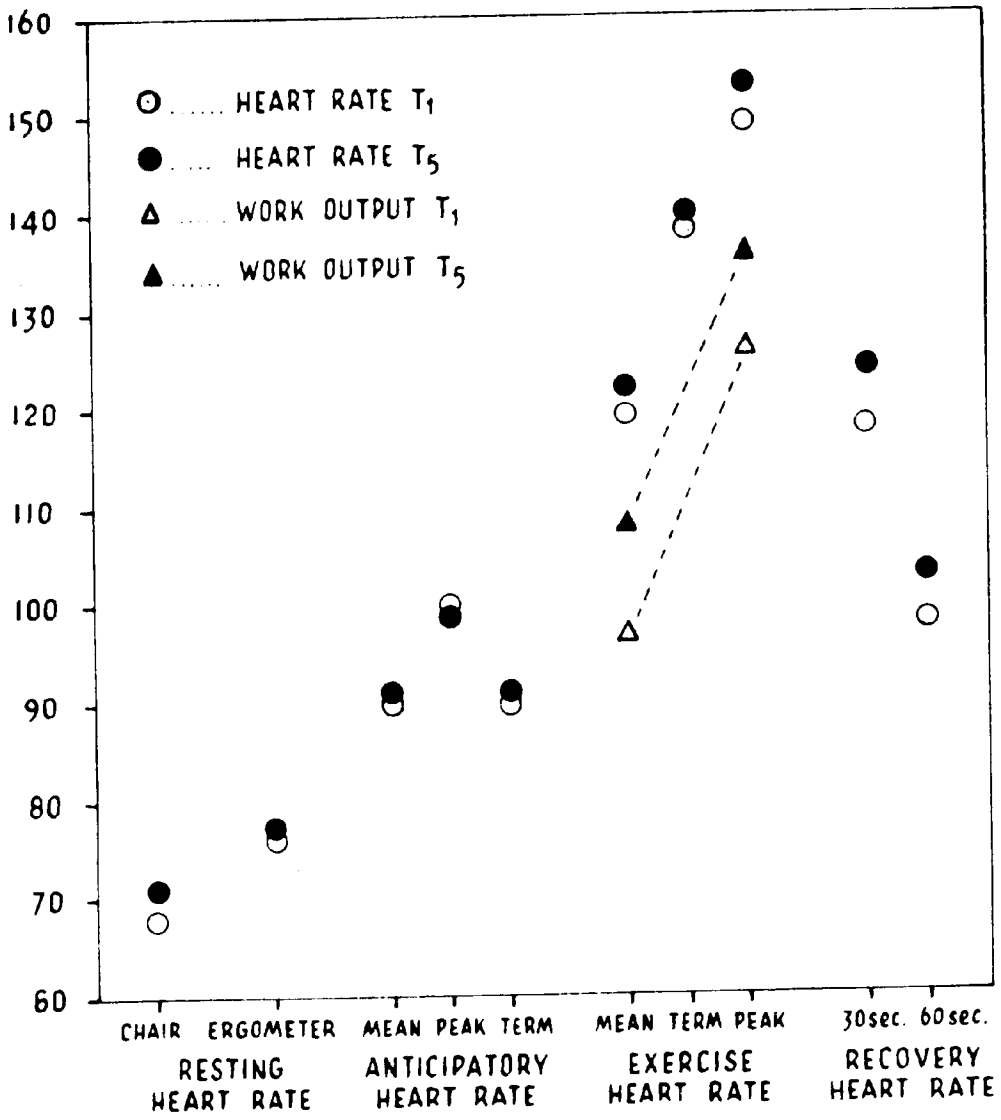


FIG. 5 THE OVERALL SAMPLE HEART RATE AND WORK OUTPUT MEANS IN BEATS OR REVOLUTIONS PER MINUTE FOR THE MEASURES ASSOCIATED WITH MAXIMAL T_1 AND MAXIMAL T_5.

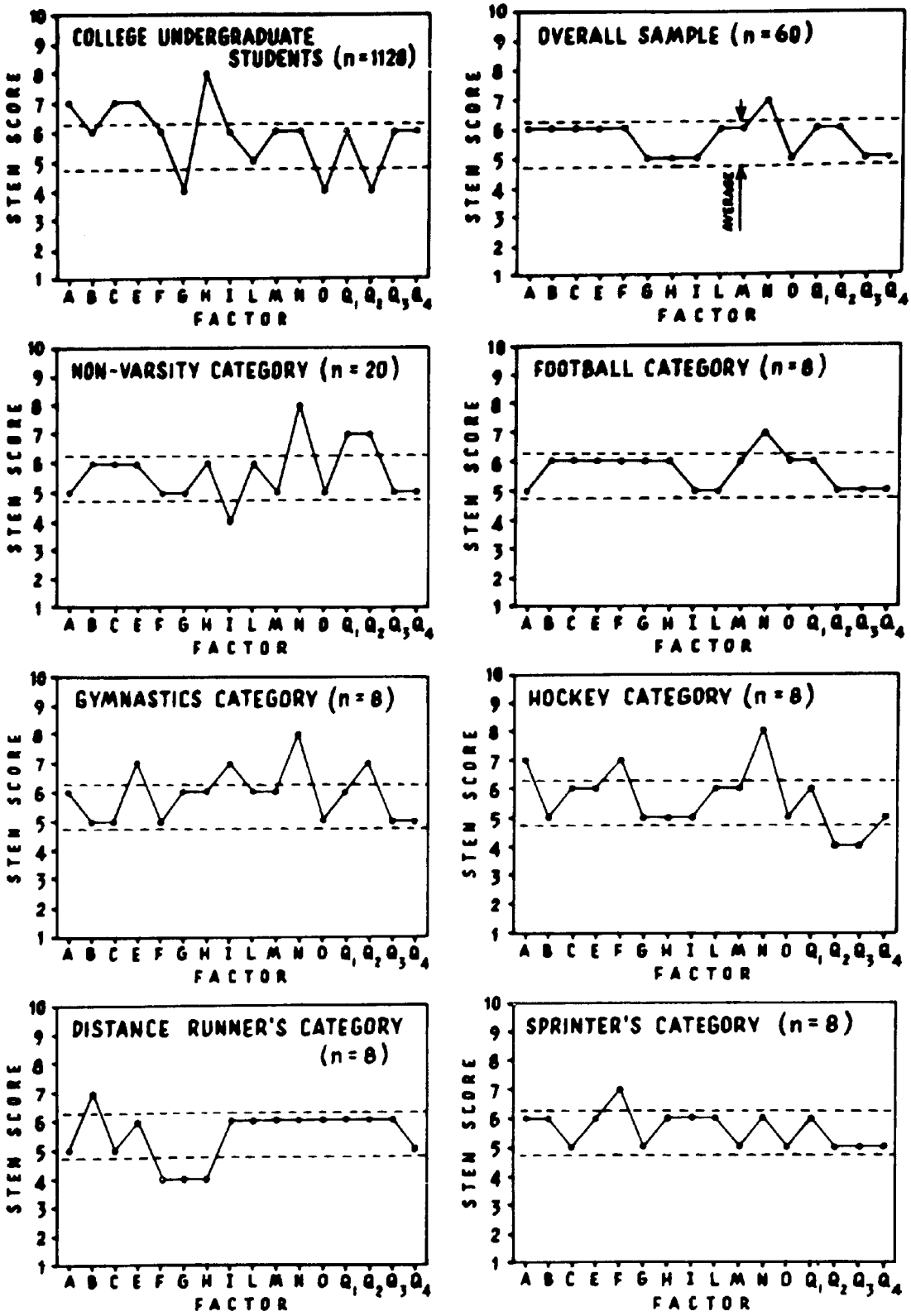


FIG.6 THE MEAN STEN PROFILES FOR THE 16 PERSONALITY FACTOR TEST

The 16 Personality Factor Test

To assess deviations from previous studies of university populations, the mean trait scores were transferred into sten scores for each category and for the overall sample. The mean sten profiles for the six categories, the overall sample, and that of 1128 male Pennsylvania State College students were plotted (Figure 6). The present sample approximated the University of Illinois sample of 364 cases upon which the stens were constructed more closely than the Pennsylvania group. N was the only factor that deviated beyond the one sigma range around the mean. The Michigan sample scored higher toward the "sophisticated, polished, and shrewd" pole of the trait than did the original subjects. A summary of the category deviations from the one sigma range and the appropriate pole description are included in Table 15.

The category and overall means for the 16 primary personality factors and the two second order factors are contained in Table 16. The variance for each category and the pooled within category standard deviation for the overall sample for each of the 18 personality variables are in Appendix F.

The 95 and 99 per cent confidence limits were determined for the overall sample (Table 17). Category means which deviate above or below the 99 per cent confidence limits are designated separately in Tables 13 and 14. As with the physiologic variables, this technique constituted a conservative estimate and merely indicates gross divergencies.

TABLE 15.--Category deviations beyond the one sigma range in the 16 personality factors with the appropriate pole description.

Category	Factor	Sten	Pole Description
Non-varsity	I	4	Tough, realistic
	N	8	Sophisticated, polished
	Q1	7	Experimenting, critical
	Q2	7	Self-sufficient, resourceful
Football	N	7	Sophisticated, polished
Gymnastics	E	7	Dominant, aggressive
	I	7	Sensitive, effeminate
	N	8	Sophisticated, polished
	Q2	7	Self-sufficient, resourceful
Hockey	A	7	Warm, sociable
	F	7	Enthusiastic, talkative
	N	8	Sophisticated, polished
	Q2	7	Self-sufficient, resourceful
	Q3	7	Controlled, exact
Distance	B	7	Bright, intelligent
	F	4	Glum, silent
	G	4	Casual, undependable
	H	4	Timid, shy
Sprinters	F	7	Enthusiastic, talkative

Note: The deviations displayed here were obtained from the sten profiles plotted in Figure 6.

TABLE 16.--The category and overall means in raw scores for the 16 primary personality factors and for the second order factors of anxiety and introversion.

Category Factor	Non-varsity	Football	Gymnastics	Hockey	Distance	Sprinters	Overall S.D.
A	7.8	8.4	9.1	11.2*	8.2	8.8	8.7
B	9.4	8.8	8.2	7.8*	10.0*	8.6	8.9
C	18.0	18.1	16.9	18.6*	16.2*	16.9	17.5
E	15.6	15.8	16.8	14.8	15.2	15.6	15.6
F	13.7	15.0	13.9	17.1*	12.2*	16.9	14.6
G	11.3	12.9*	12.9*	12.4	9.9*	10.6	11.6
H	13.2	12.0	13.6	11.1	7.5*	13.4	12.1
I	6.3*	8.2	10.6*	9.0	9.9*	10.1*	8.5
L	8.0	6.6	7.5	7.6	8.0	8.8	7.8
M	10.0	11.1	11.1	12.1*	10.8	10.5	10.8
N	12.1	10.6	11.5	11.5	10.4	10.1*	11.2
O	8.6	10.4	9.4	9.1	10.0	9.2	9.3
Q1	11.8	9.9	11.0	9.8	10.0	10.6	10.8
Q2	11.5*	8.4*	11.8*	7.2*	10.5	9.0	10.1
Q3	9.4	8.6	9.0	8.1*	9.5	9.0	9.0
Q4	11.1	12.1	10.8	12.5	12.4	12.2	11.7
Anx.	46.8	51.0	49.8	49.9	52.4	49.8	49.3
Intro.	47.2	44.5	45.4	39.2*	51.1*	40.9*	45.2

*Indicates a significant difference at the one per cent level between a cell mean and the overall mean.

TABLE 17.--The 95 and 99 per cent confidence limits in raw scores for overall means for each trait of the 16 Personality Factor Test and the two-second order factors.

Factor	Confidence Limits	
	95 per cent	99 per cent
A	7.8 to 9.6	7.5 to 9.9
B	8.4 to 9.4	8.2 to 9.6
C	16.9 to 18.3	16.6 to 18.5
E	14.5 to 16.6	14.2 to 17.0
F	13.6 to 15.6	13.3 to 15.9
G	10.8 to 12.3	10.6 to 12.6
H	10.9 to 13.3	10.4 to 13.7
I	7.8 to 9.2	7.6 to 9.4
L	6.8 to 8.8	6.5 to 9.1
M	9.9 to 11.6	9.6 to 11.9
N	10.6 to 11.9	10.4 to 12.2
O	8.3 to 10.2	8.0 to 10.5
Q1	9.9 to 11.6	9.7 to 11.8
Q2	9.3 to 10.9	9.0 to 11.2
Q3	8.4 to 9.7	8.1 to 10.0
Q4	10.6 to 12.7	10.3 to 13.1
Anxiety	46.4 to 52.2	45.4 to 53.2
Introversion	42.9 to 47.5	42.1 to 48.3

Each of the categories had distinctive scoring patterns and deviated from the group norms on some of the factors. Consequently if the 16 Personality Factor Test does measure real personality traits, then each category has a unique personality profile. The digression of a category mean beyond the 99 per cent confidence limits of the overall mean does not suggest that the category has the descriptive qualities associated with that pole. Rather, it suggests that subjects in that category tend toward these qualities more than the overall sample or categories that do not digress.

The bipolar technique of handling trait scores utilizes the antonym of the high score to describe the low score (Figure 7). A category mean score above the 99 per cent confidence limits is Factor + and below is Factor -. Only factors which are beyond the 99 per cent confidence limits of the overall sample will be mentioned in the subsequent paragraphs. The summary statements of the category digressions will merely cite in quotation marks the pole description toward which the category has digressed. The factor and its sign loading will be included immediately afterward in parentheses. The standard deviation is given to indicate the dispersion of the category scores around the category mean.

Partly because of their greater sample size and consequently increased weight in the determination of the statistics for the overall sample, the non-varsity category demonstrated little divergence. The non-varsity category was "tough and realistic" (I-) and "self-sufficient and resourceful" (Q2+).

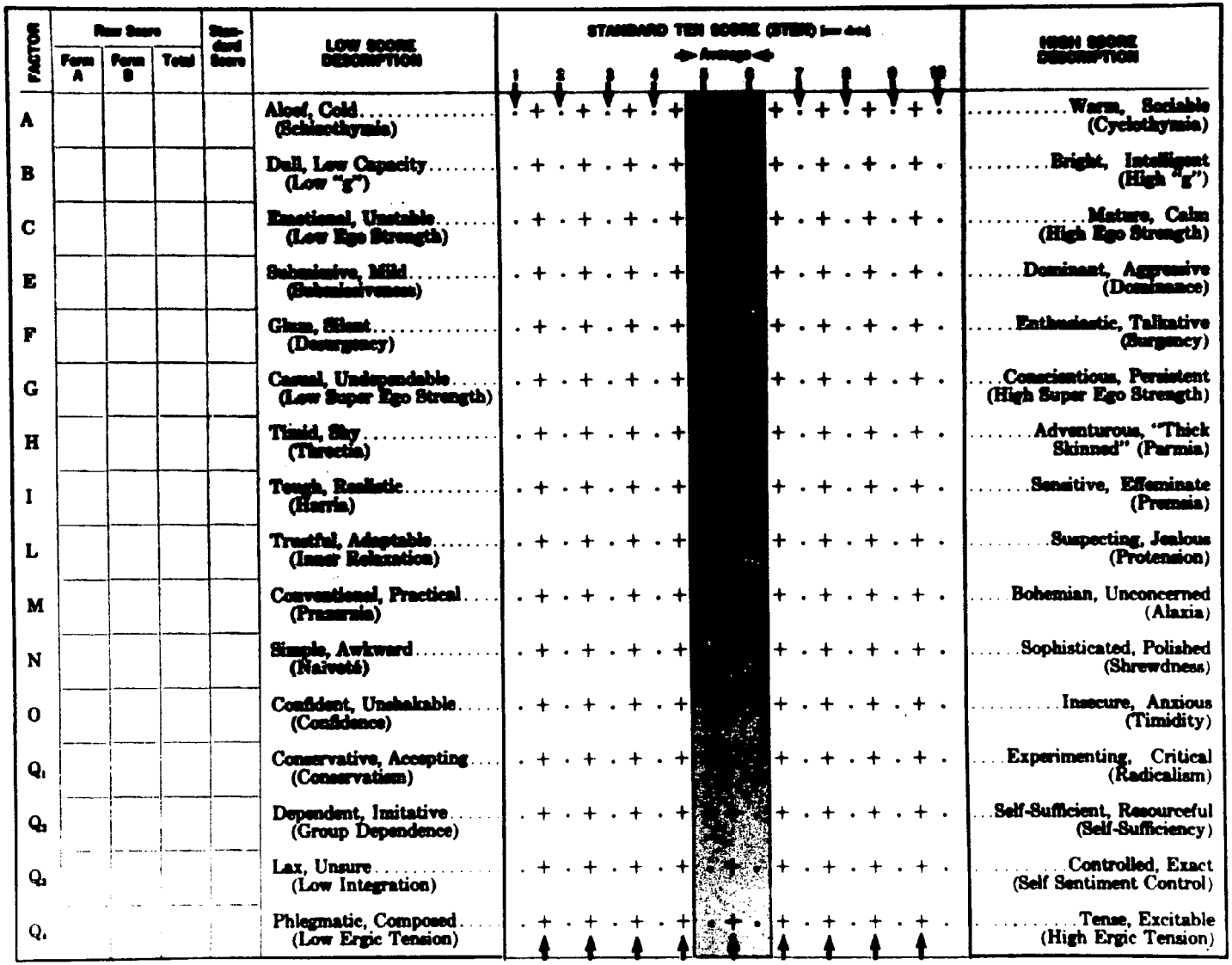


FIG. 7. The bipolar trait descriptions for the 16 primary personality factors.

The standard deviation was 2.20 scores for Factor I and 3.63 scores for Factor Q2.

The members of the varsity football team were "conscientious and persistent" (G+) and "dependent and imitative" (Q2-). The standard deviation was 2.53 scores for Factor G and 2.39 scores for Factor Q2.

The gymnasts were "conscientious and persistent" (G+), "sensitive and effeminate" (I+), and "self-sufficient and resourceful" (Q2+). The standard deviation was 3.67 scores for Factor G, 2.44 scores for Factor I, and 4.06 scores for Factor Q2.

The scores for the hockey players deviated beyond the 99 per cent confidence limits of the overall sample in seven of the 18 factors. The hockey players were "warm and sociable" (A+), of "lesser general intelligence" (B-), "mature and calm" (C+), "enthusiastic and talkative" (F+), "bohemian and unconcerned" (M+), "dependent and imitative" (Q2-), and "extroverted" (low on second order factor of introversion). The standard deviations were 3.90 scores for Factor A, 1.48 scores for Factor F, 3.65 scores for Factor M, 2.05 scores for Factor Q2, and 9.58 scores for the second order factor of introversion.

Like the hockey players, the scores of the distance runners varied considerably from the overall sample. The distance runners were "bright and intelligent" (B+), "emotional and unstable" (C-), "glum and silent" (F-), "casual and undependable" (G-), "timid and shy" (H-), "sensitive and effeminate" (I+), and "introverted" (high on the second order

factor of introversion). The standard deviations were 2.07 scores for Factor B, 2.96 scores for Factor C, 3.24 scores for Factor F, 2.23 scores for Factor G, 2.98 scores for Factor H, 3.00 scores for Factor I, and 6.38 scores for introversion.

The scores for the sprinters suggested that they tended to be "sensitive and effeminate" (I+), "simple and awkward" (N-), and "extroverted" (low on second order factor of introversion). The standard deviation was 2.75 scores for Factor I, 2.75 scores for Factor N, and 6.08 scores for the second order factor of introversion.

The correlation matrix.

Appendix G contains the correlation matrix for the 18 psychological variables and for the six variables selected to represent the subjects' physiological response to the minimal and maximal trials. Heart rate in the chair, mean anticipatory heart rate, and mean exercise heart rate were selected from the minimal trial variables. Mean anticipatory heart rate, peak exercise heart rate, and mean work output were selected from the maximal trial variables. All six measures were taken from the subjects' response to T1. The correlation matrix was based upon the data from the overall sample. Because of the unique composition of the overall sample--20 non-varsity subjects, and 40 athletes, this limits the generalizations that can be made. The purpose of this portion of the analysis was, however, merely exploratory.

As expected, very few intercorrelations among the primary factors of 16 Personality Factor Test were statistically significant. Of the 120 correlations, 15 were significant at the five per cent level and 14 at one per cent level (32). The correlations significantly different from zero varied from -0.396 between Factors Q3 and Q4 to 0.562 between Factors L and Q4.

Cattell (21, 25) weighted and combined factors Q4+, Q+, L+, C-, and Q3- to form the second order factor of anxiety and factors A-, F-, H-, M+, and Q2+ to form the second order factor of introversion. The correlations, indicated in parentheses in the following sentences, between the 16 primary personality factors and the second order factors of anxiety and introversion tend to substantiate Cattell's analysis. Factors C (-0.498), H (-0.316), L (0.631), O (0.754), Q3 (-0.618), and Q4 (0.782) had correlations with the second order factor of anxiety significant at the one per cent level. Factors A (-0.652), E (-0.417), F (-0.747), H (-0.608), and Q2 (0.458) had correlations with second order factor of introversion significant at the one per cent level.

Significant correlations at the one per cent level between psychological variables and physiological variables were exceedingly rare. Factor I correlated -0.336 with mean exercise heart rate minimal T1, -0.300 with mean anticipatory heart rate maximal T1, and -0.415 with peak exercise heart rate maximal T1. Factor Q1 had a correlation of 0.309 with peak exercise heart rate maximal T1.

The intercorrelations among the physiological variables, with the exception of mean work output maximal T1, were all moderately high and positive. The highest were between mean anticipatory heart rate and mean exercise heart rate in response to the minimal trial (0.841) and between mean anticipatory heart rate and peak exercise heart rate in response to the maximal trial (0.647). The lowest correlation was 0.271 between heart rate in chair minimal T1 and peak exercise heart rate maximal T1. The only statistically significant correlation with mean work output maximal T1 was 0.401 with peak exercise heart rate maximal T1.

The factor analysis with varimax rotation.

The data from the overall sample for the 16 primary personality factors and the same six physiological factors that were used in the correlation matrix (heart rate in chair, mean anticipatory heart rate, and mean exercise heart rate associated with minimal T1 and mean anticipatory heart rate, peak exercise heart rate, and mean work output associated with maximal T1) were included in the factor analysis. The program for factor analysis was adapted from the GMR-270 program for the IBM 704. There was no weighting of variables and the number of iterations was limited to 25. The proportion of the variation in the correlation to be accounted for by the factors was 1.00. The program went through 22 iterations in the determination of eight factors (Appendix H). The factor loadings for each variable were squared and summed for each factor.

The sum of the squares for the factor was then divided into each squared factor loading to determine the proportion of variation attributed to it (Appendix I).

Factor I was highly related to four heart rate measures and moderately to the fifth. The factor loadings were 0.922 for mean anticipatory heart rate minimal T1, 0.921 for mean exercise heart rate minimal T1, 0.611 for heart rate in chair minimal T1, 0.582 for mean anticipatory heart rate maximal T1, and 0.388 for peak exercise heart rate maximal T1. These five variables account for 0.91 of the variance of this factor.

Factor II was Cattell's second order factor of anxiety. The moderate to high factor loadings were 0.653 for variable L, 0.574 for variable O, -0.500 for variable Q3, and 0.891 for variable Q4. The four variables explained 0.84 of the variance of factor II.

The loadings on factor III followed a pattern similar to Cattell's second order factor of introversion. The moderate to high correlations with factor III were -0.281 for variable A, -0.714 for variable E, -0.599 for variable (F), and -0.544 for variable H. Variable A was included despite its relatively low correlation because its contribution to the variance of this factor was the next highest (0.0480) and was necessary to raise the variance accounted for to 0.81.

Factor IV was predominantly composed of variable Q2. The factor loading was 0.811 and it accounted for 0.52 of the variance. Variables Q1 and F with factor loadings of 0.333 and -0.399 respectively raised the proportion of variance

accounted for up to 0.73. Factor V had a high negative relationship to variable N. The correlation of variable N to factor V was -0.960 and it explained 0.65 of the factor variance.

The three measures associated with the maximal trial load on factor VI. Mean anticipatory heart rate had a factor loading of 0.416, peak exercise heart rate of 0.786, and mean work output of 0.661. These three variables accounted for 0.79 of the variance of factor VI.

Variables B (-0.441), C (0.475), and G (0.453) were moderately related to factor VII. They explained 0.65 of the variance of the factor. Factor VIII was moderately related to variable M and weakly related to variable A. The factor loading was 0.564 for M and -0.261 for A. Variable M accounted for 0.54 of the factor's variance and variable A supplemented this with a 0.12.

Results

1. Initial status in physiologic variables. Compared to the overall means the category means showed the football players were taller and heavier, the gymnasts were shorter, and the gymnasts and distance runners were lighter. The non-varsity subjects and the football players tended toward higher mean heart rate values for all measures associated with both minimal Tl and maximal Tl. Unlike the non-varsity category, the football category had high mean and peak work output means in maximal Tl. The gymnasts, hockey players, and distance

runners tended toward low mean heart rate values in response to both work intensities. The sprinters had low resting values, low recovery values after the minimal trial, and average exercise rates in response to both work intensities.

The non-varsity subjects had higher heart rate means in all responses to minimal T1 and maximal T1 than the varsity mean. The difference was significant at the one per cent level.

The 60-second recovery heart rate after maximal T1 was the only ordering effect significant at the five per cent level. Group A had a lower mean rate than Group B.

2. Amount of conditioning in physiologic variables. The means of all variables associated with the minimal trials, except heart rate in chair, were significantly lower in T5 than T1. The difference was significant at the one per cent level for mean anticipatory, mean exercise, and peak exercise heart rates, and at the five per cent level of significance for the 60-second recovery heart rate.

In response to the maximal trials, heart rate in chair, mean work output, and peak work output were significantly higher in T5 than T1 at the five per cent level. The time of peak work output was significantly earlier in the exercise period in T5 than in T1 at the one per cent level.

There were no significant differences in the amount of conditioning of non-varsity as compared to varsity subjects in response to either the minimal or maximal trials.

An ordering effect was evidenced in response to the minimal trials between the minimal-maximal sequence presented

to Group A and the maximal-minimal sequence presented to Group B. The difference between the means of the measures for minimal T1 and the means of the measures for minimal T5 (T1 minus T5) were positive for both groups. However Group A had a greater difference between the means than did Group B, significant at the one per cent level for mean exercise heart rate and at the five per cent level for mean anticipatory and peak exercise heart rates.

The maximal trial measures did not demonstrate a significant ordering effect, although Group A showed a greater amount of increase in the means of all measures from maximal T1 to maximal T5 than did Group B.

Conditioning to minimal trials.

The general trends in the conditioning patterns of the category-order subgroup cell means compared to the overall sample means were: (a) Minimal-maximal order. The Group A non-varsity and Group A football cell means (T1 minus T5) showed significantly high levels of cnnditioning. The Group A hockey cell mean showed a significantly low level of conditioning. Significance was at the one per cent level. (b) Maximal-minimal order. The Group B gymnasts had significantly low levels of conditioning at the one per cent level.

Conditioning to maximal trials.

The general trends in the conditioning patterns of the category-order subgroup cell means compared to the overall

sample means were: (a) Minimal-maximal order. The Group A football and Group A sprint cell means showed significantly high levels of conditioning. The Group A non-varsity, the Group A gymnastics, and the Group A distance cell means showed significantly low levels of conditioning. The Group A distance, and sprint cell means showed significantly high increases in mean and peak work output and the Group A hockey cell mean had a significantly high increase in peak work output. The Group A non-varsity cell mean had a significantly low increase in peak work output. Significance was at the one per cent level. (b) Maximal-minimal order. The Group B gymnastic cell mean showed significantly high increases in heart rate conditioning and in mean and peak work output. The Group B hockey cell mean had significantly high and the Group B non-varsity, distance, and sprint cell means had significantly low levels of heart rate conditioning. The distance runners' cell mean showed a low increase in mean and peak work outputs. Significance was at the one per cent level. The Group B hockey cell mean showed significantly high increase in mean work output. The Group B non-varsity, distance and sprint cell means showed significantly low levels of heart rate conditioning and the distance cell mean had a low increase in mean and peak work outputs. Significance was at the one per cent level.

3. Personality variables.. If the Cattell 16 Personality Factor Test does measure valid personality traits, then each category displayed a distinctive personality profile.

Each category had mean raw score values for specific traits that deviated beyond the 99 per cent confidence limits for the overall sample and unique sten profiles. The overall sample closely approximated the sten profile of the original Illinois sample of college men with the exception of factor N. The means of the 60 Michigan students tested in this study deviated toward the "sophisticated, polished" pole of this trait.

4. Correlation matrix of psychological and physiological variables. The intercorrelations among the 16 primary personality factors varied from moderate positive (+0.562) to moderate negative (-0.396). Twenty-nine of the 120 intercorrelations were significant at the five per cent level or higher.

The correlations between the 16 primary factors and the second order factors of anxiety and interversion tended to substantiate the existence of these second order factors.

The statistically significant correlations between psychological variables and physiological variables were rare. Factor I had low negative correlations ranging from -0.231 to -0.415 with the five heart rate measures. Factor Q1 correlated 0.309 with peak exercise heart rate maximal T1. Since none of these are of strong predictive value (75), the personality variables as measured by this test on this sample did not play an important role in the explanation of the physiologic response of the subjects to the exercise trials.

The intercorrelations among the heart rate measures were moderately high and positive. The range of coefficients of correlation was from 0.841 between mean anticipatory and mean exercise heart rate minimal T1 to 0.271 between heart rate in chair minimal T1 and peak exercise heart rate maximal T1. Peak exercise heart rate maximal T1 had the only statistically significant correlation with mean work output (0.401).

5. Factor Analysis. The factor analysis of the 16 primary personality variables and the five heart rate and one work output variables resulted in eight factors. Four of the factors were readily identifiable. Factor I consisted of the three heart rate measures associated with minimal T1 with some contribution from the two heart rate measures associated with maximal T1. Factors II and III were basically Cattell's second order factors of anxiety and introversion. The two heart rate measures of maximal T1 and the mean work output maximal T1 accounted for most of the variance of factor VI. Factor VII had moderate correlations with variables B, C, and G. The other three factors were predominantly composed of a single trait from the 16 primary personality variables. Most of the variance of factor IV was accounted for by variable Q2, factor V by variable N, and factor VIII by variable M.

CHAPTER IV

DISCUSSION

The cardiovascular system at rest and during exercise responds to multiple and diverse controls. Sympathetic and parasympathetic nerves of the autonomic nervous system maintain the restinglevels of the various parameters. At rest the vagal tone is dominant. Pressoreceptors, sensitive to stretch, are located in the carotid sinus, the aortic sinus, the walls of the venae cavae, and the walls of the heart chambers. Impulses relayed from these nerve endings are mediated by the bulbar cardiovascular center in the medulla oblongata. The autonomic nervous system controls are augmented during exercise by secretions from the adrenal glands (55,56), increased blood temperature, rise in carbon dioxide content and fall in oxygen content of the blood, and reflexes originating in the contracting muscles (5). Cardiovascular effects have been elicited from the hypothalmus and the motor cortex. Investigators have traced pathways from the motor cortex to the hypothalmus and then on the medulla oblongata (37, 38, 39). These vasodilator fibers appear to be separate from the vasoconstrictor center in the medulla (91, 94, 95, 96).

Rushmer, Smith, and Franklin (96) hypothesized from their data, that auditory or visual stimuli or anticipation of exercise can evoke a barrage of impulses from the motor

cortex to the hypothalmus which subsequently involves the medullary centers of cardiac control. The medullary centers activate the accelerator nerves and inhibit vagal tone. Greater contractile tension and more complete systolic ejection are achieved through sympathetic impulses to the atrial and ventricular myocardium. Respiratory activity and blood flow to the appropriate skeletal muscles are simultaneously increased. The barrage of impulses may precede or accompany the nerve impulses which initiate the skeletal muscle contractions. Preceding impulses would result in anticipatory increases in left ventricular function whereas accompanying impulses would result in an initial autonomic response too rapid to reflect tissue demands.

As with Rushmer's dogs, the human subjects responded to the unknown minimal work intensity with increased heart rate in anticipation and an overshoot in the heart rate during the initial stages of adjustment to the exercise. During minimal T1 the peak exercise heart rate was attained 12 seconds after the start buzzer. A steady state was invariably reached at a lower heart rate before the termination of work after 45 seconds. This sequence of events is explained in terms of complex cardiovascular reflex mechanisms, possibly pressoreceptors and chemoreceptors (96), which moderate the excessive autonomic response on the basis of tissue demands actually incurred by the activity. Subjects in all categories reduced their anticipatory heart rates and virtually eliminated the initial overshoot after the five conditioning trials.

If executing the same amount of work at a lower heart rate is accepted as a more efficient performance (51), all subjects gained in efficiency during the five minimal trials. A cross-sectional analysis of categories indicates a similar increase in efficiency accruing from habitual endurance training. Gymnasts and distance runners had lower mean heart rates in performing a standardized amount of work than did any of the other categories. In the armed forces, industry, or athletics, when efficiency of performance is either necessary or desirable, the participants should be adequately conditioned to the work patterns and acquainted with the cues required to recognize the situation. Changes in equipment, procedures, or work intensities are likely to result in at least a temporary loss of efficiency. Where recovery or terminal heart rates are used to assess cardiovascular condition, such as in the one minute step test, subjects must be given sufficient trials to become conditioned to the actual physiological demands of the test. In the absence of such training trials, the results will strongly reflect anticipatory levels.

The effect of anticipatory heart rate levels upon a maximal performance of short duration was obscured by a diversity of factors. Body weight, cardiovascular fitness, motivation, emotionality, habitual training patterns, and possibly total body or leg strength all appear to have some influence on the relationship. To clearly delineate the role of each would necessitate a more comprehensive study in which more variables were controlled.

Under the present controls, mean and peak work outputs and peak exercise heart rate increased significantly from maximal T1 to maximal T5. The time of the peak work output was also significantly earlier in the work period. The improvements in work output were, however, secured by a variety of different means. A few, particularly distance runners, merely operated more efficiently and performed more work at the same heart rate values. The higher peak exercise heart rates demonstrated by the majority were attained by (1) increased anticipatory heart rates, (2) low anticipatory heart rates followed by a rapid increase in heart rate during the initial stages of adjustment to exercise, and (3) a gradual increase in heart rate during exercise probably in response to tissue demands which culminated in a peak exercise heart rate as long as 10 to 12 seconds after the cessation of work. Football players and sprinters tended to follow the first pattern, hockey players the second pattern, and distance runners the third pattern. The non-varsity subjects and gymnasts did not show as definite a response pattern as the other categories.

Although the difference was not statistically significant, the means for heart rate in chair, mean anticipatory heart rate, mean exercise heart rate, and recovery heart rate all increased during the five maximal trials. As has been already suggested, habitual training patterns were strongly evidenced in the responses to the maximal trials. The non-varsity, football, and sprint category means were high for

anticipatory heart rate initially and the latter two categories tended to hold or increase their levels. The hockey players utilized a high reactivity of heart rate response after the start of exercise rather than anticipation throughout all maximal trials. Neither the experimental conditioning nor the habitual training patterns clarify the relationship between level of anticipation and work output as being either linear or inverted "U." The clear-cut establishment of this relationship would require the experimental manipulation of the anticipatory rates of the same subject through a wide range of values and the correlation of these values with work output.

Anticipatory increases in heart rate ranged from approximately 20 to 100 per cent of resting levels. These percentages are far in excess of the 10 to 20 per cent increase reported by Ramos and Reynaud (85). They closely approximate the results obtained by Brouha and Heath (15) prior to an all-out treadmill run. The percentage increase is in reality a misleading statistic because of its dependence on the resting level. An increase of 100 per cent might refer to a distance runner's anticipatory increase from 45 beats per minute to 90 beats per minute or a non-varsity student's anticipatory increase from 80 beats per minute to 160 beats per minute. Numerically, the greatest anticipatory increase in heart rate was 70 beats. A football player recorded this increase going from 60 beats per minute in the chair to 130 beats per minute in anticipation. Several hockey players demonstrated extreme

reactivity of heart rate response with the onset of activity. Increases of 49 and 56 beats were registered by two players from the cardiac cycle immediately before the work signal to the cardiac cycle immediately after the work signal. The increases were from 73 to 122 beats per minute and from 89 to 145 beats per minute. These increases are too great and too fast to reflect tissue demand. The heart rate actually dropped during subsequent cardiac cycles and then began a secondary rise. The secondary rise was gradual and progressive up to the peak exercise heart rate and would appear to be in response to tissue demands.

The initial status and conditioning patterns of the various categories suggest classification into sprint type and endurance type groupings. The football players and sprinters would be assigned to the sprint group and the gymnasts and distance runners to the endurance group. The hockey players and non-varsity subjects did not display either attribute clearly or displayed some attributes of each. The majority of the varsity subjects thus showed the effects of habitual training in one direction only. They could demonstrate an efficient response or an all-out maximal response but not both. The conclusion that long term training in making one type of response must interfere with the successful demonstration of the opposite response is contraindicated by the conditioning and terminal response patterns of some track men and some gymnasts. A few track athletes had undergone previous training in the opposite type of event to the one in

which they were presently competing. These track men demonstrated a low anticipatory heart rate and an efficient response to minimal T5 and a high anticipatory heart rate and a maximal output response to maximal T5. Two gymnasts who participated in the rope climb and tumbling as well as in the longer endurance type routines on the side horse, horizontal bar, parallel bars, still rings, and trampoline, had similar responses.

The conclusion is that the response patterns are developed by the training. When the training is properly directed to the attainment of both a sprint and endurance type response, the participant can learn to make the appropriate response in recognizable situations within the limits of his innate capacities. In almost all sports activities it is advantageous for a participant to operate efficiently and maximally. Of vital importance is the fatiguing effect of a long period of anticipation of endurance or sprint events. This lack of emotional control, usually associated with inexperienced athletes but not unknown even among world class performers, may leave the competitor exhausted before he starts.

The overall sample mean for mean anticipatory heart rate was 83 beats per minute before minimal T1 and 90 beats per minute before maximal T1. After the five conditioning trials for each work intensity, the mean had decreased to 74 beats per minute prior to minimal T5 and had risen slightly to 91 beats per minute prior to maximal T5. Recognizable auditory and visual stimuli were then associated with specific work

demands. Consequently, motor cortical control of the cardiovascular response prepares the organism for the appropriate response in anticipation of the onset of physical activity and during the initial stages of adjustment to physical activity.

The height of the anticipatory levels and the amount of overshoot associated with minimal T1 suggests that when the subject cannot recognize any cues in an impending work situation he tends to prepare for a maximal response. The amount of threat perceived in the situation by the subject is undoubtedly a major influence on the levels. Genetically the maximal response pattern in anticipation of an unknown physical demand has survival implications. If adequate preparation for fight or flight is a matter of life or death, it is preferable to overestimate rather than underestimate. In athletic contests which call for a maximal output, a performance goal supplants the survival goal. It is possible that immediately prior to a short duration, all-out performance, the anticipatory level is indicative of motivational involvement. Certainly, the peak exercise heart rate attained appears to be a reliable and valid measure of the amount of effort expended. Therefore, subjects who did not reach moderately high levels might be credited with submaximal performance. This should hold valid regardless of the resting level since this can be obliterated by a high anticipatory increase. The submaximal performance could result from lack of motivation or from inhibition of output arising from past experiences or

habitual training.

The statistical significance of the ordering effect on all measures associated with the minimal trials resulted from greater conditioning gains in the minimal-maximal sequence than in the maximal-minimal sequence. The Group A subjects who received the minimal-maximal sequence started with slightly higher response patterns to minimal T1 and concluded with slightly lower response patterns to minimal T5 than did Group B who had already undergone conditioning to the five maximal trials.

The ordering effect on the response to the maximal trials was not statistically significant. Group A did, however, start at maximal T1 with lower means in all measures and make greater conditioning gains so that in maximal T5 the means were almost identical.

The conclusion was that conditioning to the minimal trials had an inhibitory effect on the first maximal trial although not of statistical significance. The conditioning to the maximal trials provided a frame of reference which made "50 revolutions per minute for 45 seconds" appear less demanding. Group B, therefore, had less overshoot and a more efficient performance in minimal T1. In reality this was an erroneous assumption for if the resistance had been maintained at the same level, this task would have been maximal. In a pilot study, in which minimal and maximal trials were presented in random order after a neutral 10 second warning signal, the preceding trial strongly influenced the anticipation of and

initial response to the next trial.

The Cattell 16 Personality Factor Test was based on extensive research, involved statistical analysis, and clinical validation (40). The results of the correlation matrix and the factor analysis obtained in the present study tend to support many of its underlying assumptions. If valid personality traits are adequately measured by this test, then the six categories represented in this study have different personality profiles. The direction of this causal relationship was not investigated. Alternatives are: (1) certain personality traits predispose individuals to participate in or not to participate in specific sports, (2) participation or non-participation in specific sports develops certain personality traits, (3) reciprocal causality in which each interacts with the other, and (4) a spurious relationship in which some third variable has causative power over both the development of the personality trait and the participation or the non-participation in a specific sport. A wider and larger sampling of specific sports groups from other than college populations and stratification of the groups into the number of years of intensive training would be of some assistance in clarifying the direction of causality.

The measures used on these subjects in this experimental design did not provide predictive relationships between the psychological factors and the physiological factors. The normalcy of the population studied resulted in but moderate gradations and ranges in all variables. Predictive relation-

ships might emerge in the study of extreme populations selected on the basis of either psychological or physiological grounds.

Six physiolcgical variables were included in the correlation matrix and the factor analysis. In the factor analysis, the three measures associated with the minimal trials, heart rate in chair, mean anticipatory heart rate, and mean exercise heart rate, and the three measures associated with the maximal trials, mean anticipatory heart rate, peak exercise heart rate, and mean work output, did not cluster separately into clearly definable factors. The interdependence of all the heart rate factors was indicated by the partial loadings of the two heart rate measures associated with the maximal trial, with the three heart rate measures associated with the minimal trial, and with mean work output. The intercorrelations among the physiologic variables substantiate this interrelationship. It is apparent that resting and anticipatory heart rates have some impact upon mean exercise, peak exercise, and recovery heart rates. This dependence is particularly true when the rates are associated with standardized minimal work intensities. This substantiates the findings of Cogswell, Henderson, and Berryman (28) and Elbel, Reid, and Ormond (36). These investigators found significant correlations between the pre-exercise and post exercise recovery pulse rate associated with the Harvard Step Test.

Fulton (44) credits the "recognition of the frontal lobe as the primary autonomic center of the forebrain" of vital significance in providing a sound physiologic basis for

psychosomatic medicine. Beier (10) cites cardiac conditioning as having a direct bearing on cardiac neuroses. The experimental evidence beginning with Bykov and culminating in the Symposium on Central Nervous System Control of Circulation (8, 42, 47, 87) has indicated the pathways over which motor cortical control of the cardiovascular response can be exercised. The heart rate conditioning patterns produced experimentally in this study show that the human cardiac response can be readily conditioned to both minimal and maximal work intensities even in non-directive circumstances. The initial status and amount of conditioning demonstrated by specific sports groups reflects the influence of intensive, long term training patterns. The major conclusion of the study is that the human cardiovascular response can be conditioned to make an efficient response to minimal work intensities and a maximal response to all-out work intensities. This has applications for psychosomatic medicine and for the training of the armed forces, industrial workers, and athletes.

CHAPTER V

SUMMARY AND CONCLUSION

Summary

The anticipatory, exercise, and recovery heart rates and work output of 60 young men were recorded during cardiac conditioning trials to minimal and maximal work loads. The hypothesis tested was that cardiac conditioning to known work demands would provide an efficient heart rate response to minimal work intensities and a maximal heart rate response to maximal work intensities.

The hypothesis was based primarily on Rushmer's theory (92, 93, 94) of motor cortical control of the left ventricular response prior to and in the initial stages of adjustment to exercise. The concept of cardiac conditioning to exercise emanates from the works of Beier (10), Peters and Gantt (83, 84), and Reese and Dykman (87). A. V. Hill's discussion of maximally efficient and maximally powerful skeletal muscle contractions (57) suggested the possibility of conditioning the heart rate to two work intensities. The cross-over design was used to test the subsidiary hypothesis that conditioning to a minimal or maximal work intensity would adversely affect subsequent adjustment to the other.

The sample was stratified into a non-varsity category of 20 subjects and five varsity categories of eight subjects

each. The varsity categories consisted of eight athletes from each of football, gymnastics, hockey, distance running, and sprint running.

The subjects performed five minimal and five maximal exercise trials on an electrodynamic brake bicycle ergometer (65). The heart rate and work output were monitored on a Sanborn Twin-Viso Cardiette, Model 60. The work intensity and duration were indicated by an auditory and visual signal system.

The 16 Personality Factor Test (19) was administered to all subjects. The individual responses were hand scored into raw scores for the 16 primary factors. The raw scores were transferred into sten scores and the second order factors of anxiety and introversion were determined. The mean sten profiles were plotted for each category.

The data were punched into IBM cards and analyzed by a program in the IBM 704 electronic computer. All analyses were made with the data arranged in 12 category-order subgroup cells. Means and variances were determined for each cell for five variables associated with the minimal trial and the nine variables associated with the maximal trial, and for each category for the raw scores of the 18 psychological variables. The means, pooled within cell variance, and 95 and 99 per cent confidence limits were calculated for the overall sample. All statistics were computed for the initial status and the degree of conditioning. The initial status was represented by minimal T1 and maximal T1. The degree

of conditioning was represented by the difference between T1 and T5 in both work intensities.

The mean sten profiles of each category and the overall sample were compared to previous profiles of university students. Digressions of the category mean raw scores for each of the 18 personality variables beyond the 99 per cent confidence limits for the overall means were determined.

The interrelationships among the 16 primary personality factors, the two second order factors, the three heart rate measures and one work output measure associated with the maximal trial were assessed by a correlation matrix. The 16 primary personality variables and the six physiological variables were factor analyzed by varimax rotation. Twenty-two iterations resulted in eight factors which accounted for all the variance among variables.

Conclusions

The following conclusions are warranted:

1. The anticipatory, exercise, and recovery heart rate of young men performing a standardized amount of minimal work are decreased through a series of five conditioning trials. Since the major decreases occur in anticipation of and during initial adjustment to work before tissue demands could be registered, this appears to support the motor cortical theory of cardiac control.
2. Mean and peak work outputs and the peak exercise heart rate of young men were increased through a series of five conditioning trials, although in isolated cases, particularly

endurance athletes, decreases were noted.

3. The human heart rate conditions rapidly to a known and recognizable work task of either minimal or maximal intensity and prepares the organism for the appropriate response.
4. The human heart rate response in anticipation of and in the initial stages of adjustment to an unknown exercise demand tends to prepare the organism for a maximal response.
5. The level of heart rate anticipation and the reactivity of the heart rate to the onset of maximal exercise are strongly influenced by habitual training patterns.
6. Regular and prolonged training in making an exclusively efficient or exclusively maximal response impedes the preparation of the organism for the opposite response. Individuals can, however, be trained to respond successfully to each.
7. The order in which the minimal and maximal trials were presented resulted in significant differences in the means. Conditioning to the five minimal trials resulted in lower work outputs and lower peak heart rates during the first maximal trial than when the maximal trial occurred first. Thus, conditioning to the five minimal trials interferred with subsequent adjustment to a maximal output response. Conversely, conditioning to the five maximal trials resulted in lowered anticipatory, exercise, and recovery heart rates in response to the first minimal trial than

when the minimal trials were performed first. Apparently, even though there were no real cues to the intensity of the minimal trial, it "appeared" less demanding after conditioning to the maximal trials.

8. The non-varsity subjects had higher heart rates than the varsity subjects in all measures associated with both minimal and maximal trials. Therefore, in both minimal and maximal trials the non-varsity subjects did a comparable amount of work less efficiently.
9. If the 16 Personality Factor Test does measure valid personality traits, then each of the six categories has a unique personality profile.
10. The coefficients of correlation between the psychologic and physiologic variables were of a low order.
11. The mean exercise heart rate during work of minimal intensity may be predicted from the mean anticipatory heart rate.
12. The peak heart rate resulting from an all-out maximal work output of short duration is reached after the end of work.

APPENDIX A

The means and standard deviations for the readings of 2 cardiac cycles at different heart rates.

Reading	Number	Mean Heart Rate	Standard Deviation
1	5	81.8	.447 beats / minute
2	5	98.6	.548
3	5	104.0	.707
4	5	133.0	.707
5	5	151.8	1.100

Note: Five different technicians read each of the five heart rate readings independently of each other.

APPENDIX B

NAME_____ DATE OF BIRTH_____ GROUP_____

CATEGORY_____ HEIGHT_____(inches) WEIGHT_____(lbs.)

Minimal Trials	T1	T2	T3	T4	T5
RESTING MEASURES					
In Chair					
On Ergometer					
ANTICIPATORY MEASURES					
Peak H.R.					
Time of Peak					
Mean H.R.					
Terminal H.R.					
EXERCISE MEASURES					
Peak H.R.					
Time of Peak					
Mean H.R.					
Terminal H.R.					
RECOVERY MEASURE					
60 Seconds					
WORK MEASURE					
Mean Output					

16 Personality Factor	Raw score	Sten score
A		
B		
C		
E		
F		
G		
H		
I		
L		
M		
N		
O		
Q1		
Q2		
Q3		
Q4		
Anxiety		
Introversion		

Heart Rate		
R1		
R2		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
18		
22		
26		
30		
34		
42		
48		
54		
115		

Maximal Trials	T1	T2	T3	T4	T5
RESTING MEASURES					
In chair					
On ergometer					
ANTICIPATORY MEASURES					
Peak H.R.					
Time of Peak					
Mean H.R.					
Terminal H.R.					
EXERCISE MEASURES					
Peak H.R.					
Time of Peak					
Mean H.R.					
Terminal					
RECOVERY MEASURES					
30 seconds					
60 seconds					
WORK MEASURES					
Mean Output					
Peak Output					
Time of Peak					

	HEART RATE		WORK OUTPUT		
R1					
R2					
A1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11			11		
12			12		
13			13		
14			14		
15			15		
16			16		
17			17		
18			18		
19			19		
20			20		
21					
22					
26					
30					
34					
50					
80					

APPENDIX C

PHYSICAL EDUCATION - MEN

Project: 61

Title: The effect of cardiac conditioning on anticipatory, exercise, and recovery heart rates of young men.

Re: Punch card code

	Column Number	Item	Code
Card #1	1-3	Study Number	61
		Card Number	Actual Number
	4	Category	1 - Non-varsity
			2 - football
			3 - gymnastics
			4 - hockey
			5 - track-distance
			6 - track-sprint
	5	Strata	1 - A (Min-Max)
			2 - B (Max-Min)
	6	Name	Single digit actual number in matched pairs
	7-8	Age	in actual years
	9-10	Height	in inches
	11-13	Weight	in pounds
	14-45	16 Personality Factor	Raw scores
	14-15	A	
	16-17	B	
	18-19	C	

	20-21	E	
	22-23	F	
	24-25	G	
	26-27	H	
	28-29	I	
	30-31	L	
	32-33	M	
	34-35	N	
	36-37	O	
	38-39	Q1	
	40-41	Q2	
	42-43	Q3	
	44-45	Q4	
		Second Order Factors	
	46-47	Anxiety	Total Score
	48-49	Introversion	Total Score
Card #2	1-13	Basic Demographic Data	
	14-54	Minimal Trial #1	
	14-16	H.R. in chair	actual beats/min
	17-19	H.R. on ergometer	
	20-22	H.R. pre warning signal	
	23-25	H.R. peak anticipatory	
	26	Time of peak	
	27-29	H.R. mean anticipatory	
	30-32	H.R. terminal anticipatory	
	33-35	H.R. peak exercise	
	36-37	Time of peak	

	38-40	H.R. mean exercise
	41-43	H.R. terminal exercise
	44-46	H.R. recovery
	47-49	H.R. mean 0-15 sec.
	50-52	H.R. mean 16-30 sec.
	53-55	H.R. mean 31-45 sec.
Card #3	1-13	Basic demographis data
	14-25	Minimal Trial #2
	14-16	H.R. pre warning signal
	17-19	H.R. terminal anticipatory
	20-22	H.R. mean exercise
	23-25	H.R. recovery
	26-37	Minimal Trial #3
	26-28	H.R. pre warning signal
	29-31	H.R. terminal anticipatory
	32-34	H.R. mean exercise
	35-37	H.R. recovery
	38-49	Minimal Trial #4
	38-40	H.R. pre warning signal
	41-43	H.R. terminal anticipatory
	44-46	H.R. mean exercise
	47-49	H.R. recovery
Card #4	1-13	Basic demographic data
		Punch Trial #5 on Card #4 identical to #1 in Card 2

Card #5	1-13	Basic demographic data
	14-59	Maximal Trial #1
	14-16	H.R. in chair
	17-19	H.R. on ergometer
	20-22	H.R. pre warning signal
	23-25	H.R. peak anticipatory
	26	Time of peak
	27-29	H.R. mean anticipatory
	30-32	H.R. terminal anticipatory
	33-35	H.R. peak exercise
	36-37	Time of peak
	38-39	Rate of Increase
	40-42	H.R. mean exercise
	43-45	H.R. terminal exercise
	46-48	H.R. 2 seconds after start of exercise
	49-51	H.R. recovery 30 sec.
	52-54	H.R. recovery 60 sec.
	55-57	Peak output
	58-59	Time of peak
	60-62	Rate of increase work output
	63-65	Mean work output
Card #6	1-13	Basic demographic data
	14-28	Maximal Trial #2
	14-16	H.R. pre warning signal
	17-19	H.R. terminal anticipatory
	20-22	H.R. terminal exercise

	23-25	H.R. recovery 60 seconds
	26-28	Peak output
	29-42	Maximal Trial #3
	29-31	H.R. pre warning signal
	32-34	H.R. terminal anticipatory
	35-37	H.R. terminal exercise
	38-40	H.R. recovery 60 seconds
	41-43	Peak output
	44-58	Maximal Trial #4
	44-46	H.R. pre warning signal
	47-49	H.R. terminal anticipatory
	50-52	H.R. terminal exercise
	53-55	H.R. recovery 60 seconds
	56-58	Peak output
Card #7	1-13	Basic Demographis Data
	14-59	Maximal Trial #5
		Punch Trial #5 on Card #7 identical to Trial #1 on Card #5

RE: STATISTICAL TREATMENT - 704 Program

CARDS: #1, #2, #4, #5, and #7

MINIMAL WORK OUTPUT ON CARDS 2 (T1) and 4 (T5)	CARD #2 minus #4 CODE
X1 Heart rate in chair (T1-T5)	14-16
X2 Heart rate mean anticipatory (T1-T5)	27-29
X3 Heart rate mean exercise (T1-T5)	38-40
X4 Heart rate peak exercise (T1-T5)	33-35
X5 Heart rate recovery (T1-T5)	44-46

MAXMMAL WORK OUTPUT CN CARDS 7 (T5) and 5 (T1)	CARD #7 minus #5 CODE
X6 Heart rate in chair (T5-T1)	14-16
X7 Heart rate mean anticipatory (T5-T1)	27-29
X8 Heart rate mean exercise (T5-T1)	40-42
X9 Heart rate peak exercise (T5-T1)	33-35
X10 Time of peak heart rate (T5-T1)	36-37
X11 Heart rate 60 second recovery (T5-T1)	52-54
X12 Mean work output (T5-T1)	63-65
X13 Peak work output (T5-T1)	55-57
X14 Time of peak work (T5-T1)	58-59

CORRELATION MATRIX AND FACTOR ANALYSIS

Item	Card	Column		Measure
16 P.F.Test	#1	14-15	X1	
		16-17	X2	
		18-19	X3	
		20-21	X4	
		22-23	X5	
		24-25	X6	
		26-27	X7	
		28-29	X8	
		30-31	X9	
		32-33	X10	
		34-35	X11	
		36-37	X12	
		38-39	X13	
		40-41	X14	
		42-43	X15	
		44-45	X16	
		46-47	X17	
		48-49	X18	
Minimal Work	#2	14-16	X19	heart rate in chair
		27-29	X20	mean anticipatory heart rate
		38-40	X21	mean exercise heart rate
Maximal Work	#5	27-29	X22	mean antic heart rate
		33-35	X23	peak exercise heart rate
		63-65	X24	mean work output

APPENDIX D

Category-order subgroup cell variances for minimal T1 and pooled within cell variance for the overall sample.

Category	Non-Varsity	Foot-ball	Gymnas-tics	Hockey	Dis-tance	Sprints	Overall
Measure							
Chair HR	167.88	197.67	40.67	112.67	88.67	180.33	
	243.12	44.25	38.92	286.33	92.92	64.33	149.08
$\bar{x}$ Antic HR	210.68	310.00	17.58	112.91	63.00	443.58	
	88.71	132.67	134.25	36.92	89.67	171.00	150.30
$\bar{x}$ Exer HR	152.18	202.92	63.00	132.92	83.00	192.91	
	91.39	141.67	156.25	49.33	12.67	146.67	119.02
Peak Exer HR	187.73	252.25	104.67	132.67	68.25	123.33	
	129.38	151.58	240.92	32.67	18.00	259.58	145.92
Recovery HR	156.49	320.25	51.58	308.25	12.92	104.92	
	328.71	54.00	56.25	48.92	51.00	152.67	163.07

Category-order subgroup cell variances for maximal T1 and pooled within cell variance for the overall sample.

Category	Non-Varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Measure							
Chair HR	99.38	34.92	4.67	34.92	68.67	184.92	
	311.12	2.92	255.00	11.67	80.92	84.25	123.87
$\bar{x}$ Antic HR	203.88	150.25	125.58	74.25	305.00	188.25	
	242.68	88.67	112.67	229.67	256.67	76.00	184.14
$\bar{x}$ Exer HR	95.07	101.67	144.92	55.00	157.58	32.25	
	279.07	106.92	138.67	296.67	54.92	41.66	140.65
Peak Exer HR	259.11	20.33	376.92	103.33	332.25	168.25	
	179.88	31.58	156.25	406.00	22.67	36.67	185.50
Time Peak HR	11.12	48.00	0.00	19.67	5.33	5.67	
	7.29	5.33	5.33	4.91	14.67	14.67	10.62
Recovery HR	206.44	198.25	182.33	257.33	317.58	150.25	
	206.67	70.92	476.33	432.25	314.92	82.92	232.56
Mean WO	105.96	50.67	147.58	321.67	287.58	571.66	
	95.17	118.25	53.67	362.25	120.92	79.33	169.52
Peak WO	149.96	94.92	216.67	236.25	646.67	888.92	
	198.22	78.00	81.33	479.00	248.25	140.00	259.53
Time Peak WO	.667	1.667	.667	5.583	.333	.667	
	.400	3.000	.250	0.000	.667	.917	1.060

APPENDIX E

Category-order subgroup variances and overall sample pooled within cell variance for minimal T1 minus minimal T5.

Non-Varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart Rate in Chair						
157.16	443.67	115.44	304.67	12.92	188.33	0.00
145.56	88.92	342.00	141.67	47.00	24.25	0.00
0.00	0.00	0.00	0.00	0.00	0.00	163.58
Mean Anticipatory Heart Rate						
234.10	440.67	18.00	30.92	25.67	189.67	0.00
40.84	20.25	132.00	9.58	61.58	69.67	0.00
0.00	0.00	0.00	0.00	0.00	0.00	113.84
Mean Exercise Heart Rate						
67.16	312.33	21.58	19.67	44.25	168.25	0.00
30.06	77.58	16.25	5.67	48.92	53.67	0.00
0.00	0.00	0.00	0.00	0.00	0.00	66.25
Peak Exercise Heart Rate						
82.89	455.33	39.58	35.00	38.92	169.58	0.00
41.57	202.92	75.33	2.92	60.67	69.33	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.57
Recovery Heart Rate						
171.57	543.25	131.67	332.00	115.67	40.00	0.00
144.84	211.67	262.25	72.25	11.67	208.67	0.00
0.00	0.00	0.00	0.00	0.00	0.00	179.29

Category-order subgroup variances and overall sample pooled within cell variance for maximal T5 minus maximal T1.

Non-Varsity	Football	Gymnastics	Hockey	Distance	Sprints	Overall
Heart Rate in Chair						
140.00	54.25	38.92	40.33	33.67	69.67	0.00
244.68	89.67	72.92	161.67	52.25	163.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	120.56
Mean Anticipatory Heart Rate						
281.38	592.67	116.67	42.67	145.67	62.25	0.00
541.66	132.92	28.25	194.67	123.33	57.58	0.00
0.00	0.00	0.00	0.00	0.00	0.00	247.74
Mean Exercise Heart Rate						
315.60	223.00	224.00	36.92	201.67	44.25	0.00
252.10	94.33	54.92	129.58	142.92	17.67	0.00
0.00	0.00	0.00	0.00	0.00	0.00	179.56
Peak Exercise Heart Rate						
258.89	249.67	76.25	44.92	57.00	44.92	0.00
154.68	219.00	32.92	44.67	258.00	9.58	0.00
0.00	0.00	0.00	0.00	0.00	0.00	142.32
Time of Peak Exercise Heart Rate						
3.88	19.67	35.67	19.67	10.92	4.92	0.00
7.82	6.92	14.67	4.92	39.58	10.67	0.00
0.00	0.00	0.00	0.00	0.00	0.00	12.67
Recovery Heart Rate						
436.18	820.33	136.67	376.92	310.92	146.25	0.00
298.23	90.92	124.67	423.33	163.58	23.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	3009.61
Mean Work Output						
66.89	55.33	140.67	38.92	48.92	276.92	0.00
26.62	80.33	172.92	118.25	21.33	66.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	81.18
Peak Work Output						
109.96	32.25	77.58	133.33	243.00	305.58	0.00
24.89	38.33	176.67	49.58	8.00	14.25	0.00
0.00	0.00	0.00	0.00	0.00	0.00	92.73
Time Peak Work Output						
0.99	2.92	2.00	3.58	0.92	1.58	0.00
1.51	3.67	0.33	3.33	1.33	3.33	0.00
0.00	0.00	0.00	0.00	0.00	0.00	1.90

APPENDIX F

Category cell variances and the pooled within category variance of the overall sample for the 16 Personality Factor Test and the 2 second order factors.

Factor	Non-Varsity	Foot-ball	Gym.	Hockey	Dist.	Sprint	Overall
A	8.48	13.41	8.12	15.07	10.50	17.07	11.28
B	3.94	4.98	3.36	2.21	4.29	5.13	3.96
C	7.90	5.27	8.98	4.84	9.79	6.98	7.29
E	20.67	6.79	14.50	23.93	9.64	11.70	15.92
F	21.90	26.00	10.70	3.27	10.50	3.27	14.66
G	11.27	6.41	13.55	4.55	4.98	6.27	8.58
H	25.08	10.86	37.98	20.98	8.86	20.84	21.71
I	4.85	13.07	5.98	7.43	8.98	7.55	7.29
L	15.10	5.12	18.29	17.41	16.57	13.36	14.13
M	9.58	13.27	3.55	13.27	6.21	24.86	11.28
N	5.78	1.98	10.57	4.86	11.70	7.55	6.76
O	13.73	5.12	17.41	8.98	18.86	11.07	12.81
Q1	12.41	4.98	13.71	10.22	5.71	7.13	9.79
Q2	13.21	5.70	16.50	4.22	6.29	7.43	9.85
Q3	10.79	6.84	4.57	4.12	4.57	4.00	6.91
Q4	19.78	48.70	25.07	12.00	20.84	5.92	16.32
Anx.	171.22	48.29	112.21	58.12	181.98	117.64	127.69
Int.	108.56	68.00	82.55	91.64	40.70	36.98	79.56

APPENDIX G

Correlation matrix for 16 personality factors, two second order factors of anxiety and introversion and three physiologic factors associated with each of minimal V_1 and maximal V_1

		16 Personality Factor Test															2nd Order		Minimal V_1			Maximal V_1		
	Variables	A	B	C	E	F	G	H	I	L	M	N	O	Q_1	Q	Q_3	Q_4	Anx	Intro	WR Chair	V Antic	V Exer	V Antic	Peak Ex.	V WO
	Factor																								
16 Personality Factor Test	A	1.000																							
	B	-0.074	1.000																						
	C	0.002	-0.147	1.000																					
	E	0.201	-0.047	0.015	1.000																				
	F	0.260	-0.203	0.116	0.398	1.000																			
	G	-0.106	-0.214	0.212	-0.284	-0.030	1.000																		
	H	0.152	-0.171	0.193	0.459	0.317	0.081	1.000																	
	I	-0.010	-0.046	-0.376	0.061	0.115	-0.176	0.062	1.000																
	L	-0.095	-0.043	-0.176	0.143	0.121	-0.241	-0.148	0.060	1.000															
	M	-0.072	-0.043	-0.129	-0.002	-0.093	-0.080	0.010	0.267	0.253	1.000														
	N	0.095	0.032	0.328	0.129	0.133	0.007	0.238	-0.263	-0.046	-0.101	1.000													
	O	-0.000	-0.239	-0.403	-0.235	-0.107	-0.356	-0.231	0.324	0.318	0.086	-0.252	1.000												
	Q_1	-0.018	0.106	-0.213	0.152	-0.093	-0.179	0.113	-0.018	0.111	-0.094	0.110	-0.049	1.000											
	Q_2	-0.098	0.030	-0.165	0.014	-0.192	-0.156	-0.146	-0.365	0.235	-0.098	-0.145	0.052	0.241	1.000										
	Q_3	-0.092	0.141	0.094	-0.046	-0.176	0.080	0.024	-0.054	-0.126	-0.244	0.029	-0.294	0.076	0.050	1.000									
	Q_4	-0.936	0.010	-0.266	-0.033	0.024	-0.192	-0.134	0.344	0.662	0.231	-0.006	0.489	0.059	0.019	-0.196	1.000								
2nd Order	Anxiety	0.004	-0.111	-0.498	-0.081	0.02	-0.199	-0.116	0.110	0.631	0.242	-0.160	0.754	0.052	0.055	-0.618	0.782	1.000							
	Introversion	-0.652	0.180	-0.132	-0.417	-0.747	-0.305	-0.608	-0.051	0.129	0.236	-0.266	0.175	0.045	0.458	0.065	0.193	0.154	1.000						
Physiological Measures	Chair Min 1	-0.068	0.032	0.167	-0.025	-0.054	0.065	-0.091	-0.231	0.167	-0.158	-0.025	0.193	0.068	0.205	-0.118	0.165	0.067	0.135	1.000					
	V Antic HR Min 1	-0.109	0.058	0.229	-0.005	0.015	0.112	0.043	-0.249	0.169	-0.251	-0.016	0.041	-0.025	0.044	0.013	0.057	-0.025	0.001	0.539	1.000				
	V Exer HR Min 1	-0.141	0.093	0.209	-0.046	-0.11	0.043	-0.034	-0.136	0.305	-0.265	0.075	0.015	-0.013	0.004	0.090	0.164	-0.022	0.041	0.647	0.841	1.000			
	V Antic HR Max 1	-0.112	0.098	0.118	-0.071	-0.24	-0.130	-0.047	-0.100	-0.112	-0.215	0.073	0.022	0.187	0.195	0.098	0.087	-0.068	0.203	0.365	0.566	0.532	1.000		
	Peak Ex 1 HR Max 1	-0.111	0.180	0.117	0.039	-0.168	-0.028	0.030	-0.415	-0.169	-0.236	0.118	-0.298	0.309	0.198	0.058	0.032	-0.170	0.127	0.271	0.336	0.474	0.647	1.000	
	V WO Max 1	0.260	0.005	0.031	0.195	0.220	0.111	0.065	-0.188	-0.112	-0.045	-0.003	-0.097	0.126	-0.174	-0.276	0.070	-0.031	-0.286	0.070	0.046	0.062	0.151	0.401	1.000

APPENDIX H

Factor analysis with varimax rotation of 16 personality factors and three physiologic variables associated with each of minimal T1 and maximal T1

	FACTORS							
	1	2	3	4	5	6	7	8
A	0.157	-0.012	0.281	0.150	0.025	-0.096	-0.049	0.261
B	-0.081	0.077	-0.148	-0.015	0.059	-0.130	0.441	-0.088
C	-0.262	0.283	0.032	0.145	0.324	-0.016	-0.475	-0.138
E	0.022	0.018	0.774	-0.067	0.088	-0.082	0.109	-0.050
F	0.046	-0.084	0.599	0.399	0.078	0.087	-0.124	0.190
G	-0.047	0.220	-0.212	0.178	-0.019	-0.003	-0.453	0.049
H	0.011	0.294	0.544	0.061	0.199	-0.005	-0.129	-0.120
I	0.285	-0.052	0.167	0.070	-0.283	0.330	0.293	-0.089
L	-0.038	-0.653	0.187	-0.252	0.004	0.202	0.006	-0.102
M	0.275	-0.256	0.030	0.088	-0.278	0.068	-0.026	-0.564
N	-0.007	0.025	0.093	0.056	0.960	-0.045	-0.016	0.050
O	-0.029	-0.574	-0.209	-0.065	-0.225	0.153	-0.133	0.215
Q1	0.044	-0.078	0.122	-0.333	0.268	-0.277	0.268	0.053
Q2	-0.060	-0.041	-0.053	-0.811	-0.096	-0.047	0.038	0.046
Q3	-0.059	0.500	-0.147	-0.070	0.066	0.002	0.183	0.065
Q4	-0.086	-0.891	-0.078	0.057	0.009	-0.068	0.114	-0.062
HR Ch	-0.611	-0.183	0.001	-0.170	-0.021	-0.081	-0.152	0.096
HR Ant	-0.922	-0.007	0.069	-0.018	-0.046	-0.025	-0.071	0.046
$\bar{x}$ Ex HR	-0.921	-0.047	-0.082	0.043	0.063	-0.140	0.033	0.001
HR Ant	-0.582	0.010	-0.129	-0.184	0.066	-0.416	0.117	-0.005
Pk ExHR	-0.388	0.085	-0.050	-0.184	0.127	-0.786	0.076	-0.069
x WO	0.018	-0.057	0.223	0.250	-0.078	-0.661	-0.113	0.173

APPENDIX I

The squared factor loadings for the 16 Personality Factors and the three physiological variables associated with each of minimal T1 and maximal T1.

Physiology Variables		FACTORS 1	2	3	4	5	6	7	8
Personality	A	.025	.000	.079	.023	.001	.009	.002	.068
	B	.007	.006	.022	.000	.003	.017	.194	.008
	C	.051	.080	.001	.021	.105	.000	.226	.018
	E	.000	.000	.599	.004	.008	.007	.012	.003
	F	.002	.007	.359	.159	.006	.008	.015	.036
	G	.002	.048	.045	.032	.000	.000	.205	.002
	H	.000	.086	.296	.004	.040	.000	.017	.014
	I	.081	.003	.028	.005	.080	.109	.086	.008
	L	.001	.426	.035	.064	.000	.041	.000	.010
	M	.076	.065	.001	.008	.077	.005	.001	.318
	N	.000	.000	.009	.003	.922	.002	.000	.003
	O	.001	.329	.044	.004	.051	.023	.018	.046
	Q1	.002	.006	.015	.111	.072	.077	.072	.003
	Q2	.004	.002	.003	.658	.009	.002	.001	.002
	Q3	.003	.250	.022	.005	.004	.000	.033	.004
	Q4	.007	.794	.006	.003	.000	.005	.013	.004
Min T1	HR Ch	.373	.033	.000	.029	.000	.007	.023	.009
	HR Ant	.850	.000	.005	.000	.002	.000	.005	.002
	HR Ex	.848	.002	.007	.002	.004	.020	.001	.000
Max T1	HR Ant	.339	.000	.017	.034	.004	.173	.014	.000
	HR Ex	.151	.007	.002	.034	.016	.618	.006	.005
	$\bar{x}$ WC	.000	.003	.050	.063	.006	.437	.013	.030
$\sum$ Squares		2.823	2.147	1.645	1.266	1.410	1.560	.957	.594

The proportion of the variance of each of the eight factors attributable to each of the 22 variables.

Variables		FACTORS							
		1	2	3	4	5	6	7	8
Personality	A	.0088	.0000	.0480	.0182	.0007	.0058	.0021	.1145
	B	.0025	.0027	.0133	.0000	.0021	.0109	.2027	.0135
	C	.0180	.0372	.0006	.0166	.0745	.0000	.2362	.0320
	E	.0000	.0000	.3641	.0032	.0057	.0045	.0125	.0051
	F	.0007	.0032	.2182	.1256	.0043	.0051	.0156	.0606
	G	.0007	.0223	.0274	.0253	.0000	.0000	.2142	.0034
	H	.0000	.0400	.1799	.0032	.0284	.0000	.0176	.0236
	I	.0287	.0013	.0170	.0039	.0567	.0699	.0899	.0135
	L	.0003	.1984	.0213	.0506	.0000	.0263	.0000	.0168
	M	.0027	.0302	.0006	.0063	.0546	.0032	.0010	.5354
	N	.0000	.0000	.0055	.0024	.6539	.0012	.0000	.0051
	O	.0003	.1532	.0267	.0032	.0362	.0147	.0188	.0774
	Q1	.0007	.0027	.0091	.0877	.0511	.0493	.0752	.0052
	Q2	.0014	.0009	.0018	.5197	.0064	.0013	.0010	.0034
	Q3	.0011	.1164	.0134	.0039	.0028	.0000	.0345	.0067
	Q4	.0025	.3698	.0036	.0024	.0000	.0032	.0136	.0067
Physiology	HR ch	.1321	.0153	.0000	.0229	.0000	.0045	.0240	.0152
Max Tl Min Tl	HR Ant	.3011	.0000	.0030	.0000	.0014	.0000	.0052	.0034
	HR Ex	.3004	.0009	.0043	.0016	.0028	.0128	.0010	.0000
	HR Ant	.1201	.0000	.0103	.0269	.0028	.1109	.0146	.0000
	HR Ex	.0535	.0032	.0012	.0269	.0113	.3962	.0063	.0084
	% WO	.0000	.0013	.0304	.0498	.0043	.2801	.0136	.0505

Note: The squared factor loading for each variable was divided into the sum of the squared factor loadings for the factor.

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