THE RELATIONSHIP BETWEEN RESTING HEART RATE AND WORKING HEART RATE DURING THE ASTRAND-RHYMING SUBMAXIMAL BICYCLE TEST

by

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INTRODUCTION

Cardiovascular fitness as defined by maximal oxygen uptake can be determined accurately, but the method is somewhat time consuming and therefore not practical for use with large groups. Elaborate equipment is needed and a high degree of cooperation is required from the subject. Maximal tests generally determine subjects at a maximal level when: 1) irregularities in ECG's become increasingly present, 2) the subject experiences pain sufficient to terminate activity, or 3) the point of exhaustion is reached. Physicians, coaches and other professionals often do not have the facilities or time available for using maximal testing methods. For these reasons a more convenient method is preferred. A submaximal test is that more convenient method. A submaximal test: 1) can often be completed in a fraction of the time it would take for a maximal test, 2) does not require as elaborate and expensive equipment as a maximal test and 3) can be done without taking the subject to the point of pain or exhaustion.

One of the most commonly used measures of cardiovascular efficiency during work is the Astrand-Rhyming submaximal bicycle ergometer test. It has been established that a linear relationship exists between heart rate (HR) and oxygen uptake (VO2) (Astrand & Rhyming, 1954). As HR increases, VO2 will also increase at a rate consistant with that of the HR. The Astrand and Rhyming test is based on that linear relationship. By determining the HR at a set workload the Astrand-Rhyming test predicts maximal VO2. These predictions are based on averages from previous testing results in which actual maximal VO2 values were determined by means of a maximal treadmill or bicycle test. The submaximal bicycle test of Astrand & Rhyming is one of the easiest and most highly regarded techniques available for the estimation of maximal oxygen uptake from submaximal workloads.

The results of the Astrand-Rhyming test are derived from the stabilized HR of a subject after 5-6 minutes work at a set workload. Studies have shown that aerobic training programs produce a lowering of resting HR and the HR during the same absolute workload (Pollock, 1975; Knehr, 1942). Heart rates are lowered because an increase in the strength of the heart muscle allows more blood to be pumped with each contraction.

A suspect area of the Astrand-Rhyming test lies in the lack of attention to resting HR (R). The test uses the steady-state HR (S) value of a subject at a set workload to predict a maximum VO2 value. Using the point of origin (which is an assumed R of 60 bts/min) and its assigned average VO2 value, and the S and its assigned average VO2 value, a line is extrapolated to the predicted maximal HR and its assigned average VO2 value, which in this case would be the maximal VO2. The slope between the assumed R and the measure S of the subject will determine the cardiovascular fitness rating of that individual. An acute slope would suggest poor cardiovascular (C-V) fitness whereas a relatively flat slope would project a high C-V fitness rating since it shows a relatively small increase in HR (or VO2) with increases in workload. Indirectly, the Astrand-Rhyming test considers the change in one's HR from rest to work (D); however, this range is based on the assumed value of 60 bts/min for R. It is possible that a subject with a R lower than the assumed value may achieve a higher fitness rating than deserved, and the true slope of D would be rising faster than the one projected by the Astrand-Rhyming prediction method. Perhaps rather than assessing fitness strictly by means of an attained S, the Astrand-Rhyming test should consider the individual's D. As the test is presently conducted, there is no consideration of the extent of HR increase (D) during the test. Thus, an individual may have a high S, which would mean a low fitness rating. Yet it is possible for this individual to have the same D as the person with a low S who earned a high fitness rating. The present investigation will attempt to determine if the Astrand-Rhyming submaximal bicycle ergometer test, by not considering the R, is biased in favor of individuals with a low resting HR.

PURPOSE OF THE STUDY

The purpose of the present investigation is to determine if differences in resting heart rate levels are important in the interpretation of working heart rate.

NEED FOR THE STUDY

The Astrand-Rhyming submaximal bicycle ergometer test is based on certain premises (Maritz, 1961). The first of these premises is that heart rate is a linear function of VO2. That is, as the VO2 increases so does HR in a consistant manner. The second premise is that the deviations of individual maximum heart rates from the mean maximum for the population are small. Astrand (1954), stated that the subjects used in calculating 'aerobic capacity' nomograms were well-trained. The third premise, as explained by Maritz (1961), is that all the individual straight lines representing the relationship between HR and VO2 have a common point of 60 bts/min for men, which, as previously mentioned, was established by use of a well-trained population.

Heart rate determinations are subject to individual random variation due to error or difficulty in measurement and intra-individual variation. A straight line fitted through two points, one of which is an assumed value (60 bts/min at 'zero' levels of VO2)[1] and the other subject to individual variations, may need more consideration than is given by the Astrand-Rhyming bicycle test.

A possible problem in the Astrand-Rhyming test lies in the assumed resting HR levels. With the assumed level for resting HR, the D levels would appear to be linearly related on the Astrand-Rhyming nomograms. This, however, may not be the case. An S value of 128 bts/min would produce a D of 68 bts/min when using the assumed R of 60 bts/min. Yet with a true R of 54 bts/min the true D would be 74 bts/min. The widespread use of this test makes the concern for accuracy greater. In many instances, the Astrand-Rhyming test is used by doctors to measure

1. 'Zero' levels of VO2 refers to the amount of oxygen consumed at resting metabolism.

fitness levels of the cardiovascular system and in turn for rehabilitory exercise prescriptions. Often times such a submaximal test is used due to fear of possible injury to the subject during a maximal test. In these cases the submaximal test is commonly used to predict maximum levels of VO2. Complications in exercise prescription could come about due to the great variability in such a submaximal method.

HYPOTHESIS

A discrepency will exist when measuring physiological response to a workload by the steady-state heart rate as opposed to the increase in heart rate above resting heart rate. In the cases where the discrepency is evident, results in the Astrand-Rhyming test, based upon steady-state heart rate, will be biased to favor those with a lower resting heart rate.

LIMITATIONS

A factor which may limit the interpretation of this study should be noted:

Actual VO2 max was not determined, so actual values are not available to test predictive ability of the Astrand-Rhyming test or the increase in HR (D). The study can only investigate if there are deviations between fitness as judged by a lower S and fitness as judged by a smaller D.

DELIMITATIONS

Generalizations from the results of this study are restricted by the following factors:

1. The subject group included males and females between the ages of 18 and 28 years.
2. This study delimited to 82 volunteer students enrolled at Kansas State University during the spring semester 1982.

DEFINITION OF TERMS

The following list of terms need to be understood to comprehend the main ideas presented in this paper.

<u>Heart Rate (HR)</u>

1. Resting (R)
   - beats per minute determined at the lowest possible level of activity.
2. Working (S)
   a. maximal -beats per minute determined at the highest possible level of activity (usually established at the peak of a maximal effort just prior to the point of exhaustion).
   b. submaximal -beats per minute determined at a level of work effort below that of maximal.

<u>Kilopond Meter (kpm)</u>

1 kpm is the force acting on the mass of 1 kg at normal acceleration of gravity. Kilopond meter is a unit of work and one way of expressing the workload on a bicycle ergometer.

Chapter 2

REVIEW OF LITERATURE

This chapter presents a review of pertinent literature related to: 1) maximaum oxygen uptake, 2) estimation of maximum oxygen uptake, 3) the effect of cardiovascular training on the heart rate and 4) the role of resting heart rate in the Astrand-Rhyming nomogram.

MAXIMUM OXYGEN UPTAKE AS A MEASURE OF CARDIOVASCULAR FITNESS

It has been stated by Astrand and Rodahl (1977) that exercises which involve large muscle groups for a period of one minute or longer show performance and maximum oxygen uptake (max V02) are linearly related. No one can attain top results in such exercises without a high aerobic power. A high max V02 indicates a greater amount of efficiency of the cardiovascular system. A high oxygen consumption capability would mean a greater availability of oxygen to working muscles and a greater capacity of the muscles to utilize oxygen. This in turn would mean that for two individuals performing at the same workload, the one with the greater max V02 would accomplish the work at a lower percentage of maximal abilities than the individual with the lower max V02. This ability to do work at a lower percentage of one's maximum V02 may be expressed as cardiovascular efficiency or fitness.

The work of Hill (1950) has demonstrated that there is an upper limit to the capacity of the combined respiratory and cardiovascular system to transport oxygen to the muscles. A direct measurement of the maximum V02 can be made while a person performs steadily increasing workloads which will eventually result in a plateau in oxygen consumption in spite of increases in workload. During a max V02 test, expired gases are collected and analyzed to determine the amount of oxygen used by the subject.

It has been found that there is a positive correlation between HR and V02 (Hermansen, 1970; Teraskinna, 1966; Margaria, 1965; Rowell, 1964; Maritz, 1961; and Astrand & Rhyming, 1954). The responses of HR and V02 have been shown to increase in a linear fashion in response to increasing workloads. This linear relationship remains strong until max V02 is reached (Astrand & Rodahl, 1977; Maritz, 1961; Taylor, 1955; and Astrand & Rhyming, 1954), where further increases in workload do not change V02. The energy for the increased work output beyond the plateau in oxygen consumption is provided by anaerobic pathways. As workload increases so does HR up until maximum HR. Maximal oxygen uptake and maximal HR occur at the same or very nearly the same point (Sinning, 1975).

ESTIMATING MAXIMAL OXYGEN UPTAKE

Maxiaml tests can determine max V02 with accuracy, but the methods are time consuming and require complicated equipment.

For these reasons, maximal tests are not practical for use with large populations. When working with large numbers to be tested, it is generally easier to use a submaximal test to predict a max VO2 rather than do a maximal test. Submaximal tests do not take subjects to the point of exhaustion, they lessen time needed for test administration and they do not expose subjects to pain of exhaustion or, in cases where heart disease is suspected, the possible danger of high activity levels. For all these reasons, a submaximal test is of great value in determining cardiovascular fitness.

During submaximal exercise, VO2 increases during the first minutes of exercise, to a steady-state where the VO2 corresponds to the demands of the tissues. The slow increase in VO2 at the beginning of exercise is explained by the sluggish adjustment of respiration and circulation. A steady-state condition denotes a work situation where oxygen uptake equals the oxygen requirement of the tissues. In laboratory experiments, methods of producing standard workloads have included running on a treadmill, working on a bicycle ergometer and using a step test (Astrand & Rodahl, 1977).

There are several reasons why the bicycle ergometer is a preferred instrument for use in determining max VO2. The bicycle can easily be set to a precise workload which is repeatable from subject to subject. The cost is relatively inexpensive and the bicycle is easily moved from place to place without consideration of electric power. Any subject is capable of riding a stationary bicycle with no previous instruction.

Basing estimation on the steady-state HR after 5-6 minutes of work, the submaximal tests rely on the linear relationship between HR increases and VO2 (this has been determined by information obtained through maximal testing). The slope of the line from the points of resting HR (R) and steady-state HR (S) indicates cardiovascular fitness. The slope of this line can change with the state of physical training. A fit person is able to transport the same amount of oxygen at a lower HR than an unfit person (Fletcher, 1979; Astrand & Rodahl, 1977; and Taylor, 1955). Thus a fit person will have a lower S at a particular workload than an unfit person. This would produce a HR vs workload plot with a smaller slope than that of the unfit person.

On the basis of this VO2-HR relationship, it is possible to predict an individual's max VO2 by the HR response to a submaximal workload. Previous testing results at various workloads were used to establish average VO2 values for each workload. A subject's HR response to a set workload allows for a prediction of maximum workload to be made through extrapolation of the HR-workload line to the predicted maximum HR. This predicted maximal workload value is then converted, by use of the previously determined averages, into a predicted max VO2 value.

When Astrand and Rhyming developed a nomogram for calculating maximal aerobic capacity, they projected a submaximal HR response into a maximal VO2 value. Astrand and Rhyming collected data from a group of healthy, well-trained male and female subjects. These subjects were tested for max VO2 on a treadmill and the HR and VO2 values obtained were compared to submaximal tests: 1) step test, 2) treadmill and 3) bicycle.

From this data, norms were established so that one may simply look at the nomogram for the appropriate workload and body weight and find a prediction of a max V02 value from a submaximal HR response.

There are limitations to prediction of max V02. An investigation by Williams (1975) revealed a low estimated reliability for the Astrand-Rhyming submaximal bicycle ergometer test for a single trial (.64). It was found that a total of three trials over three days was needed to estimate reliability above .80 and six trials were needed to estimate reliability above .90. Rowell (1964) studied the predictability of max V02 in groups of normal men. Prediction of max V02 was made from HR and V02 at a single submaximal workload by use of the nomogram of Astrand and Rhyming (1954). This method underestimated actual max V02 by approximately 27% ml/02/min before training and by approximately 14% ml/02/min after 2½-3 months of physical training in a previously sedentary group. Max V02 was determined on a treadmill. The nomogram also underestimated endurance athletes by approximately 5.6% ml/02/min.

This may be partially explained by a study by Hermansen where maximal and submaximal tests were compared on the treadmill and bicycle. Hermansen (1970) found when comparing cardiac outputs during the treadmill and bicycle exercise, oxygen uptake and cardiac output were higher during maximal uphill running. However, at a given submaximal oxygen uptake the mean value for heart rate was 6-10 bts/min higher on the bicycle than on the treadmill. Glassford (1965) also found submaximal HR values on the bicycle ergometer to be higher than on the treadmill, producing lower mean max V02 ratings when compared to treadmill results. The higher heart rate values on the bicycle may be responsible for the underestimation of max VO2 when using the nomogram.

THE EFFECT OF CARDIOVASCULAR TRAINING ON HEART RATE

The heart rate cannot be pushed beyond a certain maximum (Taylor, 1955; and Knehr, 1942). The capacity for supplying oxygen to the tissues is also finite. Yet it is a common observation that exercise repeatedly carried out leads to improved performance. The rate of an individual's improvement depends on the subject's initial state and how vigorous the training is (Pollock, 1975; and Knehr, 1942). In a study conducted by Pollock (1975), subjects were introduced to exercise regimens of different intensities. In all exercise groups improvements were found in max VO2 and in work capacity. It was also found that max HR values during the same absolute workload were lowered by 3-4%. Similar results were found by Pollock (1972), Cureton (1969), Pollock (1969) and Corbin (1968).

Resting

Cardiovascular training may be attributed with a lowering in resting HR of approximately 5 bts/min. This was determined as a result of an investigation conducted by Knehr (1942). In this investiagtion a group of male subjects followed a training regimen of middle-distance running for six months. At the end of that time it was found that the training produced a lowering in resting heart rate. This lowering is due to strengthening of the heart muscle, in particular the left ventricle (Faulkner, 1971; Hermansen, 1970; and Karvonen, 1957). Cardiac output (Q) is the product of HR and stroke volume (SV) (Q = HR x SV). The increased strength of the heart muxcle increases the capabilities of its stroke volume. In other words, more blood can be pumped during each beat. Thus cardiac output can remain constant with fewer beats per minute.

Brouha (1962) states that through training the heart becomes more efficient. The stroke volume and cardiac output are increased by the ability of the heart to empty itself more completly during systole. '...the heart rate becomes slower as training progresses. Slower heart rates are observed even at rest and it is not exceptional for the resting pulse to be reduced by 10-20 beats per minute between the beginning and the end of a training period.'

<u>Working</u>

Experiments were conducted that introduced subjects to intensive training regimens. These exhausting experiments, which were characterized by a mounting oxygen debt, found approximately a 60% increase in work capability due to the cardiovascular training. There was an increase in tolerance for lactate along with a 6-7% increase in oxygen transported to the tissues during work (Brouha, 1962). The increase in ability to do work is generally attributed to a more economical organization of bodily functions. In the case of decrease in HR and increase in SV, the ability of the heart to move more blood through the system in fewer beats makes the availability of oxygen to the tissues also increase. Thus a more fit person will be able to supply the needs of the tissues in fewer heart beats.

In summary, it should be noted that cardiovascular training does have a lowering effect on heart rate, both at rest and work.

The improvement was found to be more dramatic for the working heart rate than for the resting heart rate (Pollock, 1975; Hermansen, 1970; and Brouha, 1962), suggesting an increase in efficiency through training.

THE ROLE OF RESTING HEART RATE IN ASTRAND AND RHYMING'S NOMOGRAM FOR PREDICTION OF MAX VO2 DURING SUBMAXIMAL TESTING

The nomogram, by Astrand and Rhyming, and its accompanying tables are set up in such a way that the lower the S for a set workload, the higher the predicted max VO2. In order to use the tables one simply finds the appropriate column for workload used and then one finds the point where the individual's S intersects with that column. That point of intersection will give a predicted max VO2 in liters/minute. Under the same workload, a wide range of predicted max VO2 values is possible. A high S will predict a low max VO2 and a low S will predict a high max VO2.

These tables are set up from data collected by Astrand and Rhyming. In this data collection, subjects performed to maximum on the treadmill or the bicycle ergometer. These values were then compared to submaximal test values for HR and VO2 on the bicycle ergometer. Astrand and Rhyming assume a resting heart rate value of 60 bts/min for calculation purposes (Astrand & Rhyming, 1954). This assumed value is the first point on a line which is drawn through the individual's S. This line is then extrapolated to a predicted max VO2 value (deVries, 1980). As the nomogram is presently set up, S is used as an indicator of an individual's physiological response to a workload. For every increase in S an increase in response to work is shown (above the assumed R). However, the use of an assumed resting HR will cause S to become a false indicator of physiological response to a workload. Buy not taking into consideration the subject's R an increase in HR above R (D) is no longer represented by S.

The procedure used when developing the Astrand-Rhyming nomogram eliminated the consideration of any possible influence of the resting heart rate on the steady-state heart rate. The purpose of this study is to determine if resting heart rate does actually influence the steady-state heart rate.

SUMMARY

In summary, it has been explained how max VO2 can be used as a means of establishing cardiovascular performance. The efficiency of the oxygen transport system can be measured by determining the amount of oxygen used at different levels of activity.

The exact methods for measuring this cardiovascular efficiency are maximal tests of work. These tests are best because they allow for exact measurements of VO2 and can directly compare that to a precise point of maximal effort. Maximal testing may not always be appropriate or possible. It has been found that a linear relationship between VO2 and HR exists. The submaximal tests which are used to predict max VO2 are based on this linear relationship. By means of previously established methods (Astrand & Rhyming, 1954) the slope of the HR increase will predict the efficiency of the cardiovascular system.

Astrand and Rhyming's bicycle ergometer test is a prime example of a submaximal test. Although this test is widely used, certain premises of the test may be in question. In particular, the premise that people have similar resting heart rates. The purpose of this study is to determine if other factors should be taken into consideration when predicting max VO2 and if resting heart rate has an influence on steady-state heart rate.

Chapter 3

PROCEDURES

This chapter describes the methods and procedures used in this study. Methods described include: selection of subjects, equipment, bicycle ergometer procedures, determination of resting heart rate, determination of steady-state heart rate and statistical treatment.

SUBJECTS

Young men and women from 18 to 28 years of age were accepted on a volunteer basis for this study. For the most part, the group consisted of college students enrolled in a required physical education course at Kansas State University. Prior to testing, all subjects involved in the study signed an informed consent document (Appendix A) which briefly outlined the purpose, procedures and risks involved.

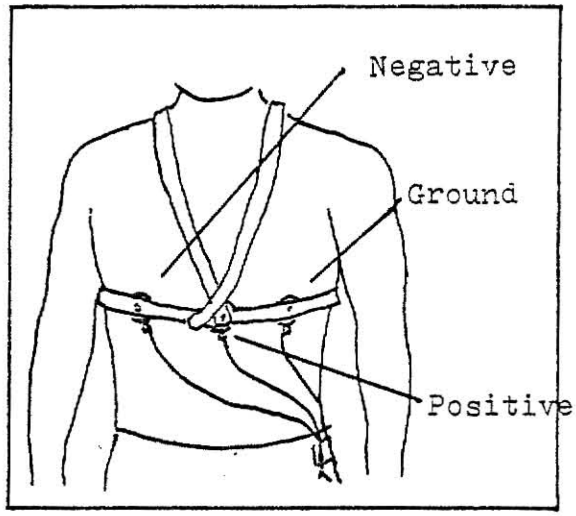
EQUIPMENT

The equipment used in this study include: 1) a Monark-Crescent AB model bicycle ergometer, 2) a metronome, 3) a clock with a second-hand sweep and 4) a Quinton model 650 electronic heart rate monitor.

PROCEDURES

Subjects met on two separate occassions for thirty minutes each session. The first session was used for familiarization with the equipment and signing the informed consent document. Subjects had been instructed not to eat or exercise for at least 60 minutes prior to testing. During the remainder of the first session the procedures were as follows: 1) The subjects were fitted with an elastic harness which held 3 electrodes against the chest (see figure 1). These electrodes pick up the electrical signals generated by a heart beat. The heart rate meter counted heart rate over a 10 second interval and displayed the heart rate count during the subsequent 10 seconds; 2) The subjects reclined on a padded table for fifteen minutes. The heart rate at the end of the 15 minutes was used as the resting heart rate; 3) A steady-state heart rate was determined after 5-6 minutes on the bicycle ergometer at a workload of 750 kpm for males and 450 kpm for females.

Figure 1



The exercise task was as follows: The metronome was set at one-hundred bts/min and the subjects were instructed to maintain a pedalling rate of 50 revolutions/min on the bicycle. After the pedalling rate was established at zero resistance, the workload was increased to 750 kpm for the males and 450 kpm for the females. The HR was monitored during the last 20 seconds of every minute until a steady-state was reached, which took 5-6 minutes. The HR was accepted as S when the HR for two succeeding minutes did not differ by more than 5 beats.

The resting and working HR procedures were repeated on a second day, at least 24 hours later. Subjects were tested at as close to the same time of day as possible for both sessions to control for diurnal variation.

STATISTICAL TREATMENT

A test-retest reliability study was done to determine the consistancy of the variables (resting HR, steady-state HR and delta HR) from trial 1 to trial 2. Two methods were used to determine how the variables correlated to each other. The two methods used were the Pearson Product Moment Correlation and the Spearman Rank Order Correlation. The mean, standard deviation and range were computed for each variable. These correlations were used to show the influence of one variable on another. Further correlations were done using the Pearson Product Moment Correlation method to determine relationships between variables S and D within separate categories of S (below 130 bts/min, between 130 and 150 bts/min and above 150 bts/min).

A t-test was done to test for differences between R for the males and the females.

Chapter 4

RESULTS AND DISCUSSION

This chapter presents the data and contains descriptive statistics, an interpretation of the results and a discussion of the results of this study.

DESCRIPTIVE DATA

Subjects used in this study consisted of volunteers enrolled in courses offered by the Health, Physical Education and Recreation Department at Kansas State University in the spring semester of 1982. A total of 82 volunteers, 46 male and 36 female, completed two separate days of testing. The mean ages (approximately 21 years) and age ranges (approximately 18-28 years) of the subjects were similar for both the males and the females. These figures along with the means and ranges for weight of the subjects are presented in Table 1.

RELIABILITY TESTING

Three variables were considered in a test-retest reliability study: 1) resting heart rates (R), 2) steady-state heart rates (S) and 3) the difference in heart rates (D) from R to S (S - R = D). The results of the reliability testing are presented in Table 2.

Table 1

Subject Data

	Male	Female
$\bar{X}$ Age	21.0 yrs	21.3 yrs
Standard Deviation	2.2	2.8
Age Range	18-27 yrs	18-28 yrs
$\bar{X}$ Weight	77.26 kg	58.99 kg
Standard Deviation	12.5	6.4
Weight Range	59.55-133.64 kg	47.73-84.09 kg

Table 2

Reliability Statistics

Variables		Standard Deviation	Correlation
	R	5.91	.81
Male	S	6.35	.89
	D	5.28	.92
	R	8.05	.65
Female	S	7.68	.87
	D	5.90	.87

The males show a high correlation from trial 1 (T1) to trial 2 (T2) in all three variables. The highest correlation was found in D, with that correlation being .92 . Of the two trials for the females, the correlation for D was also high, at .87 . Overall the correlation results indicate that the variables measured in this study were acceptably reliable.

CORRELATION DATA

The complete data for all subjects, including gender, age weight, R (T1 & T2), S (T1 & T2) and D (T1 & T2) can be found in Appendix B. Table 3 presents means, standard deviations, and ranges of the variables resting heart rate, steady-state heart rate and delta heart rate (R, S and D respectively).

A slight lowering from T1 to T2, which was not statistically significant, was found for the three variables in Table 3. The ranges of the variables were hihger in T2 when compared to T1. The means for the females are found to be similar in pattern to the males. A t-test was done comparing the resting heart rates of the males to those of the females in T1 and T2. The results of these tests showed the resting heart rates to be significantly different for T1 ($t = 2.11$, $p < .05$), but not so for T2 ($t = 1.21$, $p > .20$). Anxiety in the females may be the reason for the R to be significantly different in T1.

The means for D1 and D2 of both males and females were extremely similar from T1 to T2. This may be explained by the fact that D is a function of S and R, which would have the effect of lessening differences between trials, since R and S both changed in the same direction from T1 to T2.

Table 3

Means of Resting, 'Steady-State', and Delta Heart Rates During Both Trials for the Males and Females

	Males			Females		
Variables	Mean	SD	Range	Mean	SD	Range
R1	63.86	9.6	45.8- 89.3	68.72	11.23	36.0- 92.2
S1	137.1	13.47	113.5-166.5	135.72	16.99	94.0-171.5
D1	73.24	12.9	50.5- 97.2	67.0	11.93	40.5- 93.0
R2	62.1	11.07	44.7- 93.8	65.04	10.84	36.0- 92.0
S2	135.12	14.49	103.5-173.0	131.54	15.19	92.5-162.0
D2	73.02	14.21	45.0-104.8	66.51	12.52	47.5-103.0

VARIABLE CORRELATION METHODS

Pearson Product Moment Correlation

Two methods were used in establishing correlations between the three variables (R, S & D) and between trials 1 & 2. One method used was the Pearson Product Moment Correlation (PPMC). The PPMC tests the linear relationship between the variables. These correlations are presented in Tables 4 & 5. For both the males and the females, there was a good correlation between S and D. Delta heart rate, which is the change in the heart rate from resting to working, would be an indicator of a subject's physiological response to the workload. A highly significant correlation between S and D (.70-.74 for the males and .71-.75 for the females) indicates that as an individual's physiological response increases so does that individual's S. Those who had the higher S generally were the ones with the higher increase in heart rate above R. In most cases, the R for the male group was not found in high correlation with either of the other two variables. The most significant relationship that involved R was when it was correlated with the S of the same trial, though it is a low correlation (.41, for T1 and T2). The correlations between R and S for the females were higher than those for the males (.71 & .58 for T1 and T2 respectively). This shows a tendency for those with a lower R to have a lower S. In the instance of T1 for the females the correlation between R and S is almost as high as the correlation between S and D. But in both cases, male and female, the influence of resting heart rate on test results is statistically significant.

A statistically significant inverse relationship was also found between R and D for the males (-.30 to -.36). This means that a subject with a low resting HR tends to have a larger difference in HR above resting, or a person with a high resting HR would tend to have a low difference in HR above resting. This runs counter to the expectation that a lower R would have the lower D, if lower R is due to cardiovascular fitness. With the females, there was no correlation between R and D.

The Astrand-Rhyming predictions for max VO2 are based on the steady-state heart rate. For this reason it would be expected that a high correlation be present between T1 and T2 for S. It is of interest to examine the correlations from T1 to T2 for each individual variable. The relationship of R1 to

Table 4

Pearson Product Moment Correlations, for Males

Males					
Variables	S1	D1	R2	S2	D2
R1	.414	-.311	.69	.234	-.299
p	.004	.04	.0001	.12	.04
S1		.736	.278	.802	.60
p		.0001	.06	.0001	.0001
D1			-.222	.663	.849
p			.14	.0001	.0001
R2				.407	-.364
p				.005	.01
S2					.702
p					.0001

(Note: Whenever P-values are presented p = P-value for testing the hypothesis Ho: $\rho = 0$.)

R2 was higher in the case of the males than for the females. The lower correlation with the females may be a result of anxiety during the first trial, due to placement of the electrodes. In both cases however, the correlation was the lowest of the three variables. A high correlation was found in both the males and the females between S1 and S2 which showed testing consistency. The data for the males showed that the comparison between D1 and D2 produced the highest correlation of the three variables. The females tested also showed a high correlation between D1 and D2 though it was not quite as high as

Table 5

Pearson Product Moment Correlations, for Females

Females Variables	S1	D1	R2	S2	D2
R1	.714	.076	.51	.465	.123
p	.0001	.66	.002	.004	.5
S1		.752	.418	.806	.616
p		.0001	.01	.0001	.0001
D1			.116	.711	.763
p			.5	.0001	.0001
R2				.582	-.159
p				.0002	.4
S2					.71
p					.0001

S1 to S2. The high correlation between D1 and D2 in both males and females indicates a consistency of physiological response from T1 to T2. This physiological response in the case of the males is even more consistent than either S or R by themselves. Looking back to Table 3, the means of D1 and D2 are the most consistent of all the variables. This seems to indicate that although R and S may show day to day variation, D was quite consistent and thus may be a better variable to measure.

Spearman Rank Order Correlation

The other method used to establish correlations was the Spearman Rank Order Correlation (SROC) method. This method

Table 6

Spearman Rank Order Correlation Coefficients, for Males

Males

Variables	S1	D1	R2	S2	D2
R1	.405	-.281	.763	.251	-.29
p	.005	.06	.0001	.09	.051
S1		.73	.279	.747	.592
p		.0001	.06	.0001	.0001
D1			-.242	.608	.842
p			.11	.0001	.0001
R2				.361	-.362
p				.01	.01
S2					.667
p					.0001

involves making rank order comparisons between variables without regard to the spacing between consecutive values. These correlations are presented in Tables 6 & 7.

The SROC for the males were similar to those results found by the PPMC method, in that correlations were found between S and D (.67-.73). The SROC coefficients for the females also showed the highest correlations to be between S and D (.70-.75), indicating that there was a good correspondence between the ordering of individuals based on change in HR and on steady-state HR. No relationship was found between R1 and D1. The only significant relationship found between R and D was in the

Table 7

Spearman Rank Order Correlation Coefficients, for Females

Females

Variables	S1	D1	R2	S2	D2
R1	.603	-.002	.396	.367	-.003
p	.0001	.99	.02	.03	.99
S1		.75	.28	.737	.538
p		.0001	.1	.0001	.0007
D1			.015	.667	.751
p			.9	.0001	.0001
R2				.434	-.22
p				.008	.2
S2					.704
p					.0001

case of the males for R2 and D2. The relationship was an inverse one, which would indicate that a low R would be related to a high D, or a high R would be associated with a low D. As with the results of the PPMC method, the SROC method produced some interesting results in comparing T1 to T2 for each variable. The relationship of R1 to R2 for the males showed a high correlation (.76). This however, was not the case for the females. The R1 to R2 comparison for the females was low (.40) but statistically significant. The relation between S1 and S2 for both the males and the females were high (.75 & .74 respectively). It is important to note that in each testing group, male and female, the highest correlations were found for D1 to D2.

This would indicate a greater amount of consistency between trials, again showing that D is a good variable to test. It would be expected that S would be most consistent seeing as how this is the criterion for judgement used by the Astrand-Rhyming test. As in the Pearson correlations, it has been shown that D is a variable with as good or greater consistency than S.

Data Plots

The variables of primary interest were S and D. Figures 2 and 3 present the plots of S2 vs D2 for the males and the females, respectively. These plots demonstrate the strong linear relationship between these two variables.

Instructions by Astrand for administering the submaximal bicycle test, as found in early literature on the subject, require that only working heart rate values within the range of 125-170 bts/min be used (Astrand & Rhyming, 1954). More recently, for best interpretation of the results, Astrand has recommended that the working heart rate of the subject be between 130 and 150 bts/min (Astrand, 1965). Accordingly, the group data was divided into three categories: 1) working heart rate below 130 bts/min, 2) working heart rate from 130-150 bts/min and 3) working heart rate above 150 bts/min. Based upon S alone, this grouping would generally differentiate the high, medium and low fitness groups, respectively, with the middle group representing those individuals for whom the workload was most appropriate in conducting the test, since HR fell between 130 and 150 bts/min. Figures 4 and 5 present the data from 2 and 3, respectively, with the boundaries of the three groups drawn in. Within each group, the previously found linear relationship

Figure 2

Plotting of S2 vs D2

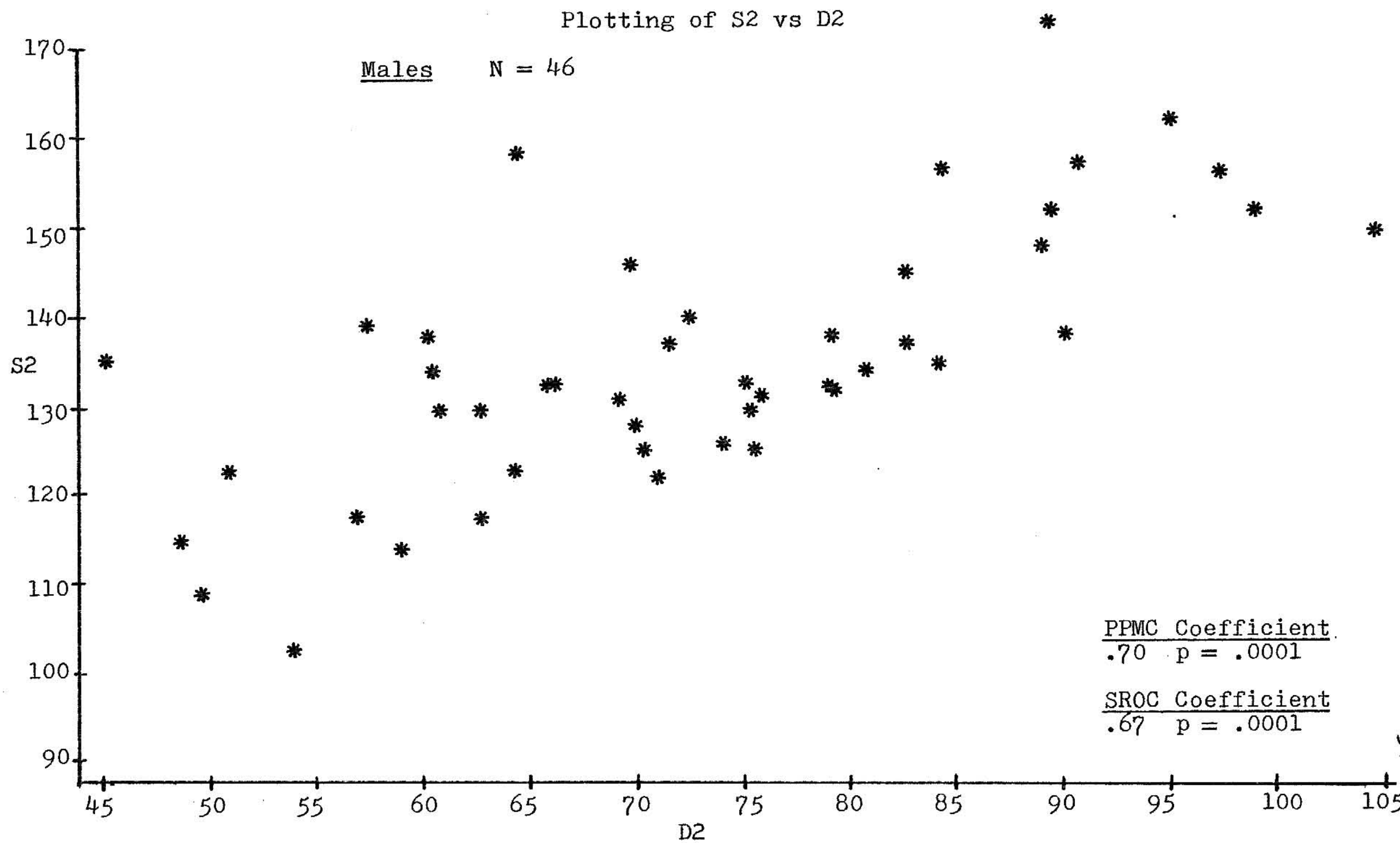
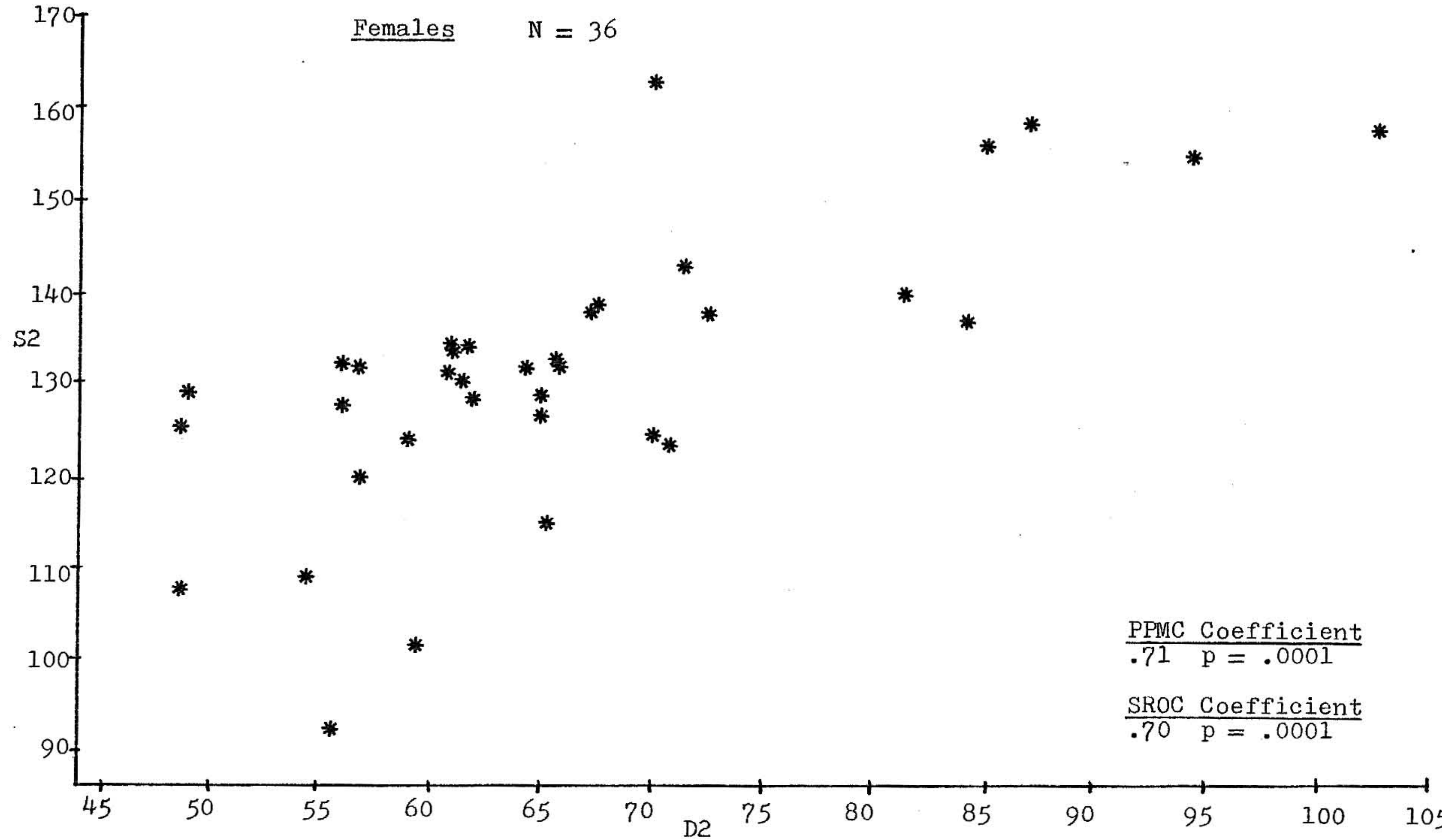


Figure 3

Plotting of S2 vs D2



between S and D was not as prevelant. These Pearson correlations are presented in Tables 8 & 9. The combination of the three groups together produced a high correlation, but this masked a much weaker relationship within each of the three groups.

In the majority of the categories, no relationship was found between S and D. There were only three instances where significant correlations were present. A high correlation was found in T2 in category 1 of the males (.71). A significant correlation was also found in category 2 of the males for T2, although it was not a very high correlation (.41). The only significant correlation in the data from the females was in category 2 for T2. This correlation is relatively high (.69). The strong linear relationship between S and D, reported in Tables 4 & 5, does not appear to the same extent when data is broken into categories. In category 2 for the males and the females there is a significant correlation between S and D only for T2. The second category represents the area of reliable response as suggested by Astrand (1965). However, as Tables 8 & 9 show, there is an inconsistency between T1 and T2. With D representing the physiological response of the HR to work and S doing the same (as a function of D), a high correlation would be expected in this second category between S and D.

DISCUSSION

As expected, the S correlations from T1 to T2 were high (Table 1). This is somewhat supportive of the Astrand-Rhyming test; however, the correlations were not entirely consistent.

Figure 4

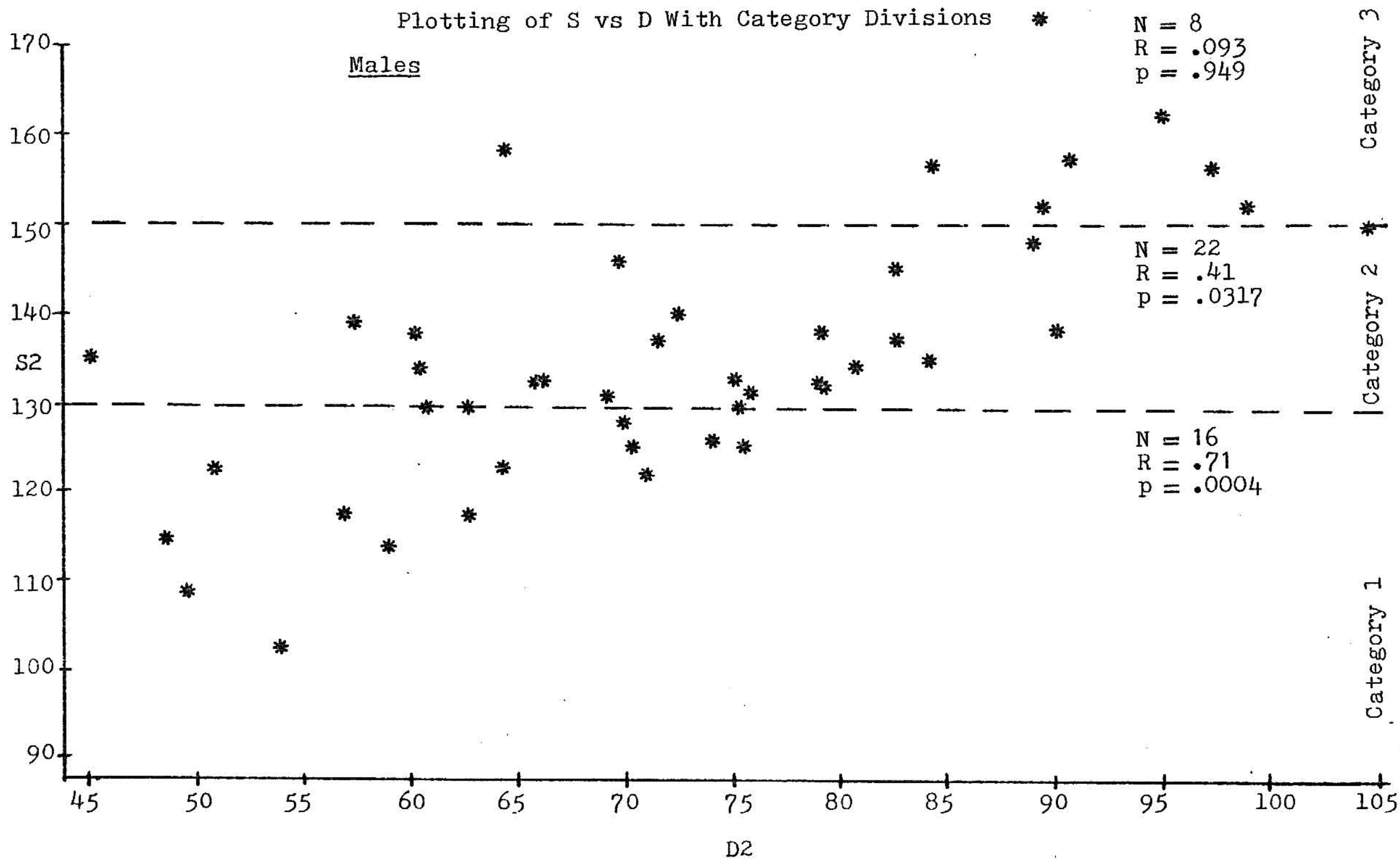

Plotting of S vs D With Category Divisions
Males
N = 8
R = .093
p = .949
N = 22
R = .41
p = .0317
N = 16
R = .71
p = .0004
Category 3
Category 2
Category 1
S2
D2
170
160
150
140
130
120
110
100
90
45
50
55
60
65
70
75
80
85
90
95
100
105

Figure 5

Plotting of S vs D With Category Divisions

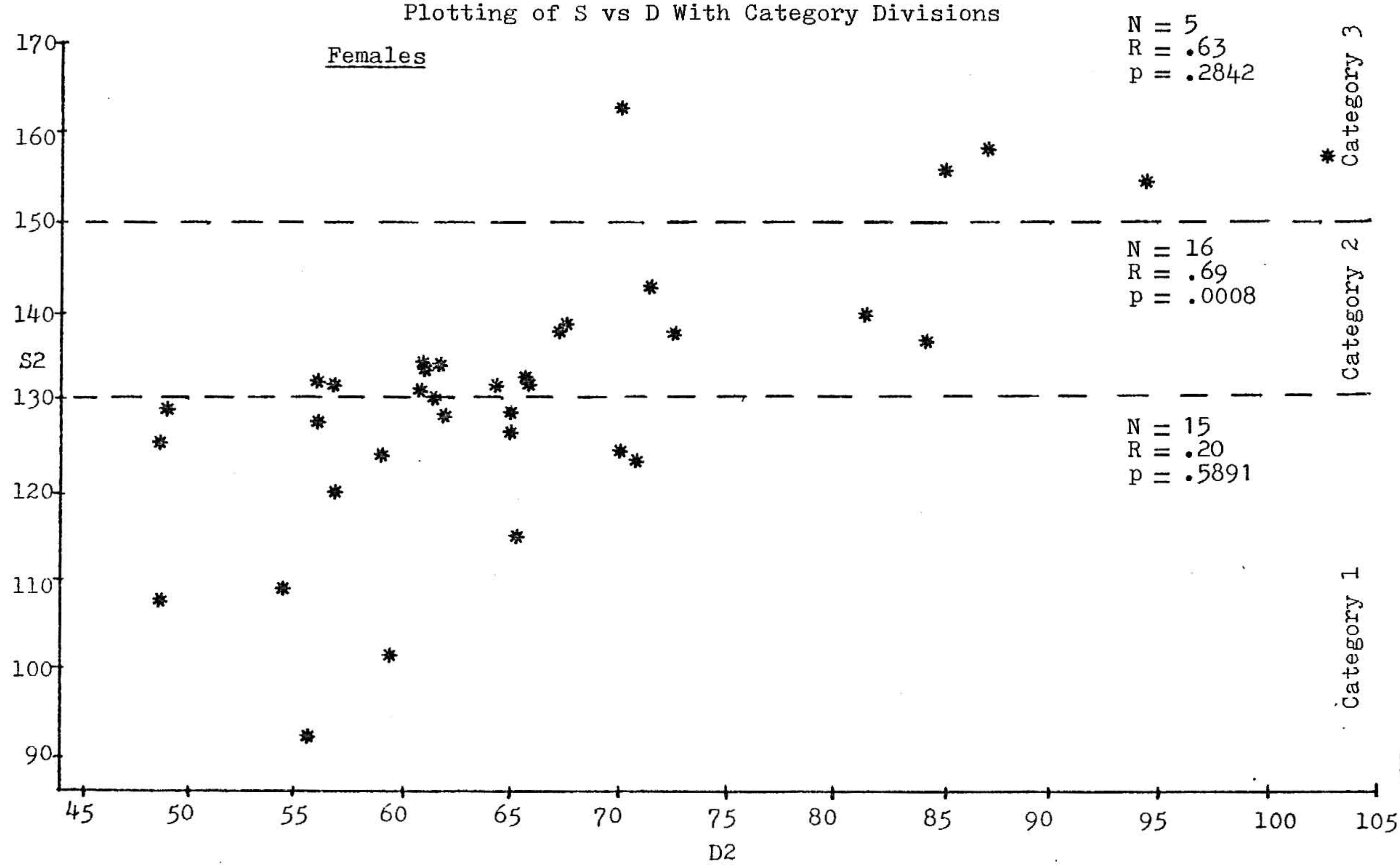


Table 8

Pearson Correlations Between S and D,
Within Categories, for Males

Males Variables	(N)	Correlation	P-value
		Category 1	
T1	12	.035	.988
T2	16	.711	.0004
		Category 2	
T1	27	.299	.1066
T2	22	.413	.0317
		Category 3	
T1	7	.504	.2728
T2	8	.093	.949

The correlations between D1 and D2 from T1 to T2 were also found to be high. This may be partially explained by the fact that S is a function of the physiological response of the HR to work (D). But the results of SROC cannot be ignored. In those results (Tables 5 & 6) D was found to be more consistent from trial to trial than any of the other variables compared. This would seem to indicate that a subject's HR response to a work-load is more consistent than the S. It may also indicate, due to D being established by subtracting R from S, that taking

Table 9

Pearson Correlations Between S and D, Within Categories, for Females

Females Variables	(N)	Correlations	P-value
		Category 1	
T1	13	.365	.2289
T2	15	.202	.5891
		Category 2	
T1	15	.234	.4909
T2	16	.685	.0008
		Category 3	
T1	8	.048	.9861
T2	5	.6296	.2842

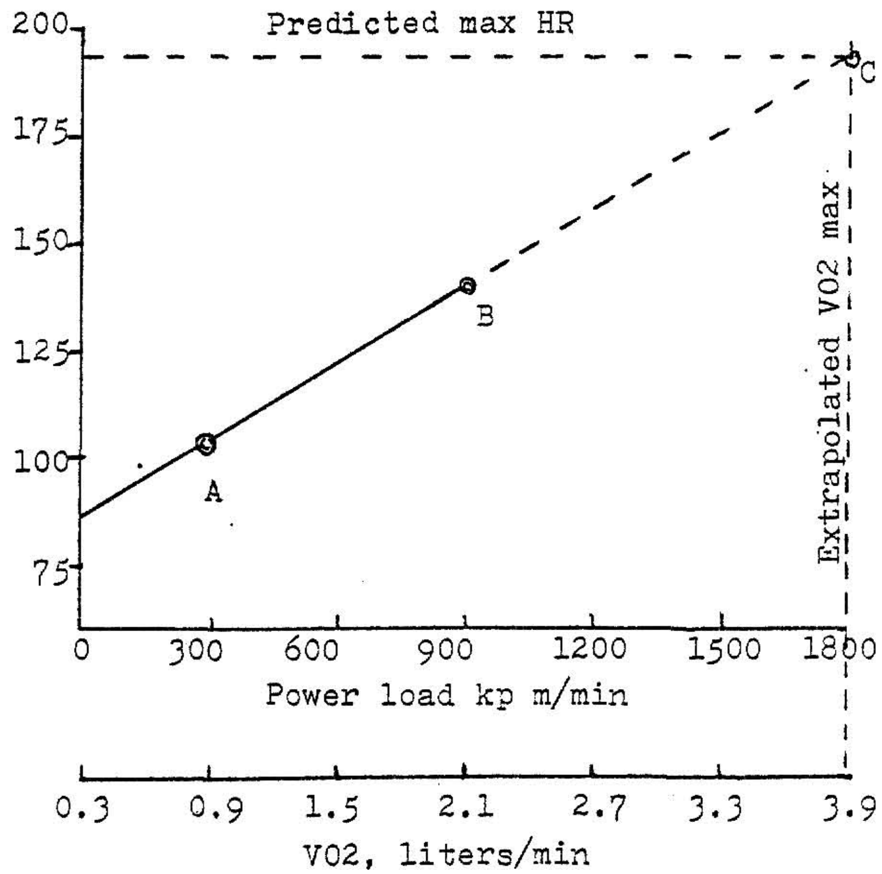
these two variables into consideration together may be more consistent than either one on its own. The Astrand-Rhyming test, as it is set up, does not insure that the S represents the true physiological response to a workload. The assumption of a universal R of 60 bts/min eliminates the individuality of each subject's physiological response by not observing the actual increase in HR above resting.

In the development of the nomogram for predicting maximal oxygen uptake by submaximal testing, Astrand used an average resting heart rate of 60 bts/min as a starting point. The next point used is the steady-state heart rate value. Through these two points a line is drawn and extrapolated to a predicted maximal heart rate value. This procedure is represented in Figure 6. The mean resting heart rate values for the males in both T1 and T2 were higher than the 60 bts/min value used by Astrand by 2-3 bts/min. The mean resting HR values for the females were even higher (5-8 bts/min). These higher mean R values alone would show need for adjustment of the nomogram to the population being tested. But taking the point even further one should consider the wide range of resting heart rates. Assuming the value of 60 bts/min for two subjects who each achieved a working heart rate value of 135 bts/min a similar predicted maximal VO2 would be given to each. They would have had the same physiological response to the workload, according to Astrand's method. In reality however, this may not be the case. If these two subjects started with different resting heart rates of 55 and 65 the mean R would be 60 bts/min. But this mean would not show the individual physiological responses to the workload. One subject's D would be 80 and the other subject would have a D of 70, showing that different responses have been made but over-looked by the nomogram method. One can plainly see the improvement in accuracy by adjusting the nomogram to the individual. The assumed value of 60 bts/min for R may be higher or lower than the actual R of the individual being tested. Such differences would alter the predicted values given by the Astrand-Rhyming test.

Correlations between variables were of great interest to the hypotheses of this study. In particular, the correlation

Figure 6

Extrapolation of Submaximal V02 Data to Estimate Maximal V02



Extrapolation of submaximal V02 data to estimate V02 max. Linear extrapolation of the two measured V02-HR points (A and B) to point C, the intersection with the estimated maximum heart rate line, provides an estimate of V02 max = 3.9 liters/min. (deVries, 1980)

between S and D. Tables 3 & 4 present the correlations as found by the Pearson Product Moment Correlation method. In every instance, male and female, the R was significantly correlated to the S of the same trial. Similarly, the Spearman correlation coefficients (Tables 5 & 6) revealed a significant correlation between R and S of the same trials. This was the case for both the males and the females. In many of the comparisons, the correlations between R and S were not found to be high. The correlations are, never the less, statistically significant and indicate that resting heart rate does to some extent influence the steady-state heart rate of that trial.

Astrand's suggested S for administering the submaximal bicycle test was stated as being between 130 and 150 bts/min (Astrand, 1965). Each group of data was divided into three categories: 1) working heart rate below 130 bts/min, 2) working heart rate between 130 and 150 bts/min and 3) working heart rate above 150 bts/min. The S range of 130 to 150 bts/min encompasses a wide range of predicted maximal VO2 values. For the males, at a workload of 750 kpm the S range of 130-150 bts/min would cover a range in predicted max VO2 of 3.55-2.75 l/min (Astrand, 1965). This would result in an aerobic working capacity rating which spans three groups: 1) low, 2) fair and 3) average (I. Astrand, 1960). At a workload of 450 kpm for the females, the S range of 130-150 bts/min would cover a predicted max VO2 range of from 2.7-2.0 l/min (Astrand, 1965). This would result in an aerobic working capacity rating which spans two groups: 1) average and 2) good (I. Astrand, 1960). Complete table values (Astrand, 1965; and I. Astrand, 1960) expressed in this text can be found in Appendix C.

It is interesting to note that in the plottings of S related to D, the group plottings give the appearance of a linear relationship between S and D. However, when viewing the plottings broken down into categories the linear relationship is not as evident (Tables 7 & 8). One of the strongest criticisms of Astrand's nomogram method for maximal oxygen uptake prediction was made extremely visible by the plottings of S and D. It can be noted that there is a wide range of D within each single category. D represents the physiological response of a subject's HR to a workload. The ranges in D for categories 1 and 3 do not overlap into each other. However, category 2 has individuals that cover nearly the entire range of D (56.17-97.17 bts/min for males and 52.5-80.17 bts/min for females), overlapping both categories 1 (50.5-70.5 bts/min for males and 40.5-68.83 bts/min for females) and 3 (77.5-94.83 bts/min for males and 74.5-93.0 bts/min for females). The wide range of D in category 2 shows a wide range of physiological responses to the workload. This great difference between individuals within category 2 suggests a strong need for consideration of other factors, in addition to S, for the prediction of maximal oxygen uptake. The R, for example, was shown to influence the S in the Pearson and Spearman correlations. R could be used to determine a D for the individual, showing the individual's HR response. The Astrand-Rhyming test does not consider the R of the individual. Instead, an assumed R of 60 bts/min is used for all subjects. Using the assumed value instead of a true R, endangers the ability of S to truly represent the subject's physiological response to the workload. The SROC showed the D to be more consistent from day to day than merely the point at which that individual's HR levels off during submaximal work. In any event it is clear that additional data can improve the accuracy of the Astrand and Rhyming nomogram method.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter contains a summary of the study and results found within this study. Also included are the conclusions drawn from this work as well as the recommendations for further study.

SUMMARY

The purpose of the study was to determine if resting heart rate levels are important in the interpretation of working heart rate. In doing so a major premise of the Astrand-Rhyming nomogram method for prediction of VO2 max was challenged. That premise was the assumed average resting heart rate of 60 bts/min by the nomogram.

Forty-six male and thirty-six female students, 18 to 28 years of age, at Kansas State University in the Spring of 1982 volunteered as subjects for this investigation. These subjects met on two separate occasions. On each meeting the subject's resting heart rate was determined after lying supine for 15 minutes. Then the subject was tested on the bicycle ergometer to determine a steady-state heart rate at a set workload (750 kpm for males and 450 kpm for females). From this testing three variables were established: 1) resting heart rate (R), 2) 'steady-state' heart rate (S) and 3) delta heart rate (D)(the increase in heart rate above resting).

Two correlation methods, the Pearson Product Moment Correlation (PPMC) and the Spearman Rank Order Correlation (SROC), showed a significant correlation between resting heart rate and steady-state heart rate for the same trial. By the same correlation methods, it was also found that there was a statistically significant relationship between S and D, indicating a trend to associate a high D with a high S. This would mean a smaller D would relate to a higher fitness rating by the Astrand & Rhyming method. Correlations between variables also indicated that D was the most consistent from trial to trial of all three variables, indicating that it may be a good variable to consider for testing and predicting purposes.

CONCLUSION

Within the limits of the study, the hypothesis that a discrepency will exist when measuring physiological response to a workload by the steady-state HR as opposed to the increase in HR. And in the cases where the discrepency is evident, results in the Astrand-Rhyming test, based upon S, will be biased to favor those with a lower resting HR was supported.

RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that further research be conducted in this area with certain adaptations. Some factors which might be considered in future investigations are as follows:

1. Repeated study with the inclusion of a maximal VO2 test. This would offer a basis for actual comparison of S and

D to maximal VO_2 values.

2. It may be fruitful to reconstruct the nomogram using slopes of heart rate increase as a guide to fitness ratings rather than S.

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APPENDIX A

INFORMED CONSENT

Investigator: Timothy C. Field
Department of HPER, Phone- 532-6240
Advisor: Dr. Wilcox

Title of Investigation: The influence of resting heart rate on the working heart rate as determined by the Astrand-Rhyming bicycle test in college age males.

This is to certify that I ____________________ volunteer to participate in a research investigation at Kansas State University under the supervision of the department of HPER.

The procedures involved in this study and their risks are: 1) upon consent of participation in the study a working heart rate will be established through use of bicycle. 2) selection of a convenient time for testing. 3) at time of testing heart rate will be monitored. 4) procedures for working heart rate testing will be explained. 5) resting heart rate will be established. 6) findings will be made available at the end of the investigation.

Risks and discomforts may include: 1) physical discomfort while being tested on the bicycle. 2) slight discomfort in the wearing of heart rate monitoring equipment.

I understand all the results will be kept confidential with data processed using coded numbers. If the results of the study are prepared for publication, no participants will be identified by name.

I understand that in the event of physical injury resulting from the research procedure involved in the experiment, no financial compensation will be available since the regulations of the state prohibit Kansas State University from carrying insurance as such.

I understand that questions I might have will be answered immediately on completion of the study and that results will be made available to me and that I can withdraw my consent at any time. I have the right to withdraw from participation in this project at any time.

I understand the procedures, potential risks, and agree to voluntarily take part in this study.

____________________	____________________
Date	Signature
____________________	____________________
Date	Witness

APPENDIX B

Raw Data

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
01	M	21	86.36	59.0	130.5	71.5	60.0	138.5	78.5
02	M	23	75.0	65.5	118.5	53.0	61.0	118.0	57.0
03	M	18	73.64	68.17	163.0	94.83	84.0	173.0	89.0
04	M	21	65.45	54.0	137.5	83.5	54.0	132.5	78.5
05	M	23	87.27	67.17	130.5	63.33	67.5	140.0	72.5
06	M	25	86.36	78.0	128.5	50.5	90.0	135.0	45.0
07	M	23	83.64	55.67	117.0	61.33	49.83	103.5	53.67
08	M	19	78.64	68.67	155.5	86.83	66.0	161.0	95.0
09	M	19	60.0	78.0	155.5	77.5	62.33	145.0	82.67
10	M	18	76.82	59.33	142.0	82.67	57.0	132.0	75.0
11	M	22	75.91	49.33	146.5	97.17	48.0	138.0	90.0
12	M	18	70.45	48.0	138.5	90.5	44.67	149.5	104.83
13	M	22	80.0	54.0	136.5	82.5	51.33	122.5	71.17

Raw Data (continued)

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
14	M	21	65.45	67.5	156.0	88.5	67.0	157.5	90.5
15	M	21	92.73	68.83	150.0	81.17	63.67	136.0	72.33
16	M	23	79.55	62.0	132.5	70.5	58.0	122.0	64.0
17	M	23	68.18	54.0	135.5	81.5	54.0	151.5	97.5
18	M	20	82.73	58.0	128.5	52.17	52.17	126.5	74.33
19	M	19	74.09	68.17	137.0	68.83	66.0	129.5	63.5
20	M	22	89.55	75.33	138.5	63.17	66.0	132.0	66.0
21	M	24	88.18	71.83	126.5	54.67	54.67	118.0	63.33
22	M	22	77.73	60.0	113.5	53.5	54.67	113.5	58.83
23	M	20	95.45	75.0	139.5	64.5	62.0	130.5	68.5
24	M	26	93.64	66.67	121.0	54.33	70.83	123.0	52.17
25	M	18	65.0	56.0	141.0	85.0	54.0	137.5	83.50
26	M	20	67.27	68.83	131.0	62.17	78.0	138.5	60.5
27	M	21	66.36	54.0	132.0	78.0	53.5	134.5	81.0
28	M	21	85.45	76.0	143.0	67.0	66.0	132.5	66.5

Raw Data (continued)

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
29	M	24	72.27	45.83	134.5	88.67	54.17	125.0	70.83
30	M	23	73.64	75.0	157.0	82.0	72.0	156.5	84.5
31	M	21	61.36	54.0	115.0	61.0	54.0	129.5	75.5
32	M	21	59.55	67.67	138.5	70.83	77.0	146.0	69.0
33	M	19	71.36	67.0	139.5	72.5	67.67	129.5	61.83
34	M	20	74.09	54.5	120.5	66.0	58.17	128.0	69.83
35	M	19	65.0	78.67	166.5	87.83	60.0	148.5	88.5
36	M	22	73.64	60.33	148.5	88.17	61.33	151.0	89.67
37	M	21	78.18	71.0	150.0	79.0	93.83	158.0	64.17
38	M	19	77.27	48.67	117.5	68.83	49.0	125.0	76.0
39	M	18	89.55	70.0	126.5	56.5	64.17	113.0	48.83
40	M	22	71.82	59.83	114.0	54.17	60.0	109.5	49.5
41	M	18	66.36	51.33	132.0	80.67	49.67	134.0	84.33
42	M	21	79.55	61.5	130.5	69.0	72.83	133.0	60.17
43	M	21	72.27	68.0	148.0	80.0	54.5	130.5	76.0

Raw Data (continued)

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
44	M	18	133.64	89.33	145.5	56.17	81.67	139.5	57.83
45	M	27	77.73	62.5	137.5	75.0	51.67	131.0	79.33
46	M	20	65.91	65.17	159.5	94.33	58.67	156.5	97.83
47	F	26	51.36	69.5	162.5	93.0	71.67	159.5	87.83
48	F	28	65.45	72.83	138.0	65.17	67.0	131.5	64.5
49	F	21	62.73	68.0	116.0	48.0	80.33	129.0	48.67
50	F	19	55.45	72.0	144.5	72.5	71.33	139.0	67.67
51	F	19	64.55	59.17	128.0	68.83	54.5	124.5	70.0
52	F	20	53.64	56.83	134.5	77.67	65.33	131.5	66.17
53	F	26	56.36	90.0	164.5	74.5	71.0	156.0	85.0
54	F	19	47.73	59.0	127.5	68.5	53.0	137.0	84.0
55	F	20	84.09	77.5	118.0	40.5	60.0	108.5	48.5
56	F	20	59.09	62.83	133.5	70.67	51.17	123.0	71.83
57	F	21	57.27	77.83	153.0	75.17	71.0	.38.0	67.0
58	F	20	53.18	46.5	102.0	55.5	42.17	101.5	59.33

Raw Data (continued)

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
59	F	21	64.55	85.5	138.0	52.5	54.5	109.0	54.5
60	F	23	55.0	66.67	130.0	63.33	63.0	120.0	57.0
61	F	24	59.55	63.83	131.5	67.67	71.5	133.0	61.5
62	F	22	58.18	67.83	129.5	61.67	74.0	131.5	57.5
63	F	19	61.82	74.33	159.5	85.17	65.0	138.5	73.5
64	F	19	59.55	60.0	136.0	76.0	66.0	128.0	62.0
65	F	20	59.09	73.67	139.0	65.33	72.0	133.5	61.5
66	F	24	61.36	73.5	124.0	50.5	78.0	125.5	47.5
67	F	19	56.82	78.0	138.0	60.0	70.0	131.5	61.5
68	F	21	54.55	58.0	126.5	68.5	64.0	129.5	65.5
69	F	19	55.0	68.0	126.5	58.5	62.5	127.5	65.0
70	F	26	67.73	69.17	119.5	50.33	50.0	115.5	65.5
71	F	18	58.64	77.17	134.0	56.83	72.17	128.5	56.33
72	F	25	58.18	81.0	158.5	77.5	92.0	162.0	70.0
73	F	20	61.82	36.0	94.0	58.0	36.0	92.5	56.5

Raw Data (continued)

Subject	Gendre	Age (yrs.)	Weight (kg)	R1	S1	D1	R2	S2	D2
74	F	22	59.09	92.17	171.5	79.33	58.0	140.0	82.0
75	F	26	60.0	72.83	136.0	63.17	72.33	134.5	62.17
76	F	20	50.91	76.0	143.0	67.0	75.83	132.5	56.67
77	F	19	57.27	71.5	132.5	61.0	71.0	143.5	72.5
78	F	19	70.0	63.5	129.5	66.0	66.0	124.5	58.5
79	F	21	53.64	54.0	114.5	60.5	65.83	132.5	66.67
80	F	25	60.91	61.33	141.5	80.17	67.83	130.0	62.17
81	F	19	53.64	65.0	150.5	85.5	55.0	158.0	103.0
82	F	18	55.45	73.0	160.5	87.5	60.33	155.0	94.67

APPENDIX C

Table a

Prediction of Maximal Oxygen Uptake from Heart Rate and Workload on a Bicycle Ergometer (From a Nomogram by P. Astrand)

Heart Rate	Maximal Oxygen Uptake liters/min.		Heart Rate	Maxiaml Oxygen Uptake liters/min.	
	Females 450 kpm/min	Males 750 kpm/min		Females 450 kpm/min	Males 750 kpm/min
120	3.4	4.15	148	2.1	2.8
121	3.3	4.05	149	2.1	2.75
122	3.2	4.0	150	2.0	2.75
123	3.1	4.0	151	2.0	2.7
124	3.1	3.9	152	2.0	2.7
125	3.0	3.8	153	2.0	2.6
126	3.0	3.8	154	2.0	2.6
127	2.9	3.7	155	1.9	2.6
128	2.8	3.65	156	1.9	2.55
129	2.8	3.6	157	1.9	2.5
130	2.7	3.55	158	1.8	2.5
131	2.7	3.45	159	1.8	2.45
132	2.7	3.45	160	1.8	2.45
133	2.6	3.35	161	1.8	2.4
134	2.6	3.35	162	1.8	2.4
135	2.6	3.3	163	1.7	2.4
136	2.5	3.25	164	1.7	2.35
137	2.5	3.2	165	1.7	2.35
138	2.4	3.2	166	1.7	2.3
139	2.4	3.1	167	1.6	2.25
140	2.4	3.1	168	1.6	2.25
141	2.3	3.05	169	1.6	2.25
142	2.3	3.0	170	1.6	2.2
143	2.2	2.95			
144	2.2	2.95			
145	2.2	2.9			
146	2.2	2.85			
147	2.1	2.85			

Table b

Norms for Maximal Oxygen Consumption

(From I. Astrand)

Females

Low	Fair	Average	Good	High
1.69 28	1.70-1.99 29-34	2.00-2.49 35-43	2.50-2.49 44-48	2.80- 49-

Males

Low	Fair	Average	Good	High
2.79 38	2.80-3.09 39-43	3.10-3.69 44-51	3.70-3.99 52-56	4.00- 57-

Lower figure = milliliters of oxygen per kilgram body weight

Only values meaningful to the appropriate age group (18-28 years) are shown in this table.

Table a is from a nomogram by P. Astrand. Acta Physiologica Scandinavica 49 (suppl. 169), 1960.

Table b is from I. Astrand, Acta Physiologica Scandinavica 49 (suppl. 169), 1960.

Upper figure = liters of oxygen consumption per minute

THE RELATIONSHIP BETWEEN RESTING HEART RATE AND WORKING HEART RATE DURING THE ASTRAND-RHYMING SUBMAXIMAL BICYCLE TEST

by

TIMOTHY C. FIELD

B. S., Lock Haven State College, 1980

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Health, Physical Education and Recreation

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

The purpose of the study was to determine if resting heart rate levels are important in the interpretation of working heart rate. This was attempted by correlating resting heart rate (R) and the increase in heart rate above resting in response to a workload (D) to steady-state heart rate (S).

Eighty-two students (46 male and 36 female) at Kansas State University, between the ages of 18 and 28 years, volunteered to participate in this investigation. Resting heart rates of the subjects, as well as steady-state heart rates, were recorded on two separate occasions. S values were established on the bicycle ergometer at 750 kpm for males and 450 kpm for females. From this information D values were determined ($S - R = D$). Correlation studies showed that R influenced S in every trial for both males and females (r's were between .36-.41 for males and .43-.71 for females). These same correlational studies showed a high relationship between S and D (r's were between .67-.74 for males and .70-.75 for females). However, when data was broken into categories by heart rate (below 130 bts/min, between 130 and 150 bts/min, and above 150 bts/min) intra-category correlations between S and D were not as predominant. In addition, test-retest data showed D (.92 for males and .87 for females) to be the most consistent of the three variables measured (R, S and D). The study showed that S is influenced by R, suggesting that R is important in the interpretation of S. It was also determined that D was a more consistent variable from trial to trial than S, indicating that the single variable S is not as consistent as R and S being considered together.