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Prediction of VO2 max from a five-mile bicycle field test and percent body fat

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THE PREDICTION OF $\dot{V}O_2$ MAX FROM A FIVE-MILE BICYCLE FIELD TEST AND PERCENT BODY FAT

By

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The purpose of this study was to determine the validity of the 5-mile bicycle field test, percent body fat, leg strength, weight and height as predictors of $\dot{V}O_2$ max. Forty-five male students attending the University of Montana participated in the study. The 5-mile bicycle field test and percent body fat demonstrated a multiple correlation of R = .81 (R^2 = .65) with $\dot{V}O_2$ max. Leg Strength, weight, and height contributions were almost negligible and not statistically significant.

The results of this study indicate that the 5-mile bicycle field test and percent body fat are strong predictors of $\dot{V}O_2$ max. A chart was developed presenting predicted values of $\dot{V}O_2$ max from the 5-mile bicycle field test and percent body fat. Recommendations were made concerning future investigation of $\dot{V}O_2$ max prediction from a bicycle field test, percent body fat, and other related variables.

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THE PROBLEM

Introduction

Bicycling, along with running, swimming, cross country skiing and jumping rope constitute excellent forms of aerobic exercise. Aerobic fitness is the extent to which an individual is capable of taking in, transporting, and utilizing oxygen (Sharkey, 1979). Many tests have been suggested for assessing aerobic fitness. These tests included treadmill testing, step testing, and stationary bicycle testing. Exercise physiologists have concluded that maximal oxygen consumption during exhaustive work ($\dot{V}O_2$ max) is not only the best indicator of the capacity of an individual for sustaining hard muscular work, but also the most objective method by which one can determine aerobic fitness (Astrand & Rodahl, 1967; Bar-Or, Zwiren & Data, 1978; Boileau, Heyward, Massey, 1977; Cooper, 1968; deVries, 1976; Harrison & Cochrane, 1980; Sharkey, 1979).

$\dot{V}O_2$ max is influenced by age, sex, genetic make-up, body composition and structure and the state of training. Cross sectional studies show that $\dot{V}O_2$ max increases with age up to 20 years. Beyond this point there is a gradual decline, such that a 60 year old attains about 70% of the maximum attained at 25 years of age. Before the age of 12, there is no significant difference between males and females. The average difference in $\dot{V}O_2$ max between males and females amounts to 15% to 30%. From studies of identical and fraternal twins, it was concluded that heredity accounts for up to 93% of the observed differences in $\dot{V}O_2$ max. Body composition and structure, measured in percentage of body fat, has correlated significantly with $\dot{V}O_2$ max. Pollack, Willmore, and Fox (1978) found a correlation of r=.74 between percent body fat and $\dot{V}O_2$ max. Improvements in $\dot{V}O_2$ max with training generally range between 6% to 20%. The state of training has been judged by the performance in a related field test. A correlation of r=.90 was reported between the 12-minute run and $\dot{V}O_2$ max (Astrand & Rodahl, 1967; Cooper, 1968).

The laboratory determination of $\dot{V}O_2$ max (e.g., treadmill testing) is impractical for large groups due to expense, time and personnel requirements, consequently field tests in the form of distance runs have been developed so that mass testing is feasible (Balke, 1963; Cooper, 1968; Krahenbuth, Pongrazi, Peterson, Burket & Schnider, 1978; Sharkey, 1979). The time of the distance run is used to predict $\dot{V}O_2$ max.

The correlations between laboratory $\dot{V}O_2$ max tests on the treadmill, bicycle ergometer and step testing ranged from .40 to .90 (Bar-Or, Zwiren & Data, 1978). The best field test correlations with laboratory $\dot{V}O_2$ max tests, 0.90 and above, have been reported on the running tests (1½-mile and 12-minute run) (Cooper, 1968). The wide range of coefficients can be partly explained by the inconsistencies in testing procedure and control of factors, such as motivation, experience, correct self-pacing, and climatic conditions.

While runners have a field test that grades their fitness level, bicyclists do not have such a test which specifically tests their bicycling fitness level. The popularity of bicycling as a means of transportation and exercise justifies the need for the development of a bicycle field test. Stromme, Ingier and Mean (1977) concluded that the selection of a work situation, for the evaluation of the maximal aerobic fitness level of athletes, should allow the optimal use of the specifically trained muscle fibers. The test should be identical to the athlete's specific activity, assuming a large muscle mass is used during the performance.

A search of cycling physiology literature revealed no information concerning a bicycling field test. Through personal communication with bicycling physiologists (Burke, Note 2; Cavanaugh, Note 3; Faria, Note 4; Hagberg, Note 5) the author determined originality of the study. The information generated by this study will allow bicyclists to predict their $\dot{V}O_2$ max in an easy and convenient manner. By using the testing procedure in a pre- and post-test manner, the bicyclist could judge whether a particular training program was effective. Personal goals relating to bicycling fitness could be judged by one's improvement in the test.

The Statement of the Problem

The purpose of this study was to develop an equation that provides, given the variables below, the most efficient prediction of $\dot{V}O_2$ max. The variables considered were the 5-mile bicycle field test, percent body fat, leg strength, weight, and height. A chart devised ultimately from this equation, would present predicted values of $\dot{V}O_2$ max given known values on the predictors.

Hypothesis

The null hypothesis was as follows:

> There is no relationship between the $\dot{V}O_2$ max test and the time to complete the 5-mile bicycle test, percent body fat, leg strength, weight and height. The level of significance for the correlations between $\dot{V}O_2$ max and the predictor variables was set at the .01 level.

The alternative hypothesis was as follows:

> The relationship between the $\dot{V}O_2$ max test, the time taken to complete the 5-mile bicycle field test, percent body fat, leg strength, weight, and height will correlate in a statistically significant manner at the .01 level.

Assumptions

The following assumptions were accepted in the determination of the testing procedure:

1. Subjects gave a maximal effort during all tests.
2. Through mechanical adjustments, bicycles used for the 5-mile bicycle field test were identical. Each subject was individually fitted to a standardized bicycle.

Delimitations

Generalizations resulting from this study apply to males in the 19-30 age bracket who share characteristics with those tested.

Chapter II

METHODOLOGY

Subject Selection

Sixty males between the ages of 19 and 30 were drawn from students attending the University of Montana. Of the 60 subjects, 45 completed the entire testing procedure. Fifteen subjects subsequently withdrew because of conflicts in test scheduling, illness, and physical injury. All subjects signed a consent form, approved by the University of Montana Institutional Review Board (Appendix A). The physical characteristics of the 45 subjects are presented in Appendix B.

Testing Procedure

Data were gathered on one $\dot{V}O_2$ max test, two 5-mile bicycle field tests, one leg strength test, one percent body fat determination, and weight and height. A data sheet was used to record all test results (Appendix C). All subjects were familiarized with testing procedures prior to the performance of each test (Appendix D).

Instruments and Test Protocol

$\dot{V}O_2$ Max Test

The $\dot{V}O_2$ max was measured directly by a Beckman Metabolic Measurement Cart, using the Faria Graded Exercise Bicycle Test (Appendix C), on a Monarch bicycle ergometer in the University of Montana Human Performance Laboratory. The heart rate of each subject was monitored using an Avionics stress monitor with the maximal heart rate recorded. The respiratory exchange quotient (RQ), the ratio between the carbon dioxide volume produced and the oxygen volume utilized and pulmonary ventilation (VE), the frequency of breathing times the mean expired tidal volume, were also measured by the Beckman.

A bicycle ergometer fitted with a leather saddle, dropped handlebars and toe clips was used (Faria & Cavanaugh, 1978). The subjects wore shorts, shirt, and rubber-soled shoes. After a preliminary warmup period of 1 minute, each subject performed a continuous ride to exhaustion for the determination of $\dot{V}O_2$ max. The duration of the test was between 7 and 10 minutes with a workload increase of 480 $kpm \cdot min^{-1}$ at 2 minute intervals. A trained aide made workload adjustments on the bicycle ergometer at each interval. Verbal encouragement was given to help maintain subject motivation.

All subjects rode at a pedalling rate of 80 rpm, paced by an electric metronome. Progressively increasing the resistance while maintaining a set pedalling rate has been accepted as an effective means of assessing $\dot{V}O_2$ max on a bicycle ergometer (Ovell & Shepard, 1976; Michielli & Stricevic, 1977; Moffatt & Stamford, 1978). To match the metronome, the subject's right foot was at the top of each pedal revolution on each beat.

The saddle and handlebar height on the bicycle ergometer was adjusted to conform to the subject's body size. The most efficient saddle height, 109% of an individual's standing inside leg length, was used (Hamley & Thomas, 1967; Nordeen-Snyder, 1977). When performing the test the subject was instructed to ride in the crouched position, with hands on the drop bar of the handlebar.

The $\dot{V}O_2$ max was achieved and the test was terminated when the measured oxygen consumption reached a value that did not increase despite an increase in workload, or when the pedal cadence fell below 80 rpm (Astrand & Rodahl, 1977; Bar-Or, Zwiren & Data, 1978; Boileau, Borea, Heyward & Massey, 1977; deVries, 1976; Harrison, Brown & Cochran, 1980; Miyamura, Kitamura, Yamada & Matsui, 1978; Moffatt, Stamford, Weltman & Cuddihee, 1977; Sharkey, 1979). Another criterion for the termination of the test included an RQ in excess of 1.05.

If the plateau in $\dot{V}O_2$ max required to ensure a valid assessment of $\dot{V}O_2$ max was not demonstrated, the test was repeated. The plateau was achieved when there was a change of less than 100 $ml \cdot min^{-1}$ with an increased workload.

The efficiency of various pedalling rates had been studied on bicyclists and nonbicyclists on a bicycle ergometer (Faria, Dix & Frazier, 1978; Guell & Sheppard, 1976; Michielli & Stricevic, 1977; Miyamura, Kitamura, Yamada & Matsui, 1978; Moffatt & Stramford, 1978). The findings showed the most efficient range of pedalling was between 50-80 rpm, much lower than the rates used by competitive bicyclists. Moffat and

Stamford (1978) found subjects perceived less exertion associated with higher (80 rpm) than lower (40-60 rpm) pedalling rates at a given workload. The 80 rpm pedalling rate required less frictional resistance to be overcome on each pedal revolution to produce the same energy output.

A major problem in administering a bicycle ergometer test to semi-fit individuals has been the person's ability to maintain a workload sufficient to produce valid physiological measurements (Jessup, Riggs, Lambert & Miller, 1977). Also, leg fatigue has been a confounding factor in the assessment of $\dot{V}O_2$ max on a bicycle ergometer. With a pedalling rate of 80 rpm the ability to attain valid measurements and reduce leg fatigue was achieved (Guell & Sheppard, 1976; Matsui, Kitamuri & Miyamura, 1978; Moffatt & Stramford, 1977). The 80 rpm pedalling rate used in the Faria Graded Exercise Bicycle Test was an acceptable rate based on the wide range of fitness levels and abilities of the subjects.

Faria, Dix and Frazier (1978) studied the effect of bicycling in two different body positions, crouched and stand-up, on work output parameters. The $\dot{V}O_2$ max and V_E were .24 and .48 $l \cdot min^{-1}$ higher respectively in the crouched position. Faria concluded that the body posture during bicycling is crucial for optimal performance.

5-Mile Bicycle Field Test

The 5-mile bicycle field test required a maximal effort.

The amount of time taken to complete the test was measured in minutes and fraction of minutes. The test took place on a .714-mile oval course east of Missoula, Montana. The course was measured with a Rolatape measuring wheel. Each subject bicycled seven laps around the course to complete the 5 miles. The oval course was selected over a straight or out and back course because of the location, smooth surface, and light automobile traffic.

Each subject performed two 5-mile bicycle field tests in order to assess reliability. Subjects were individually tested with a distance of a ½ lap between the starting times of successive riders. Prior to testing, all subjects were advised to practice bicycling the 5-mile distance with emphasis on pace and the crouched position. The subjects were also informed that drafting behind other subjects was not permissable.

Each subject was told to report to the test wearing gym trunks, shirt, and shoes. The wearing of bicycle racing clothing was not permitted. Whitt (1971) found that mounted bicyclists wearing loose-fitting clothing increased the air resistance surface by 30%. Since most subjects with bicycle racing clothing had an appreciable advantage, and most subjects did not own such clothing, the trunks, shirt and shoes became the required apparel.

Three standardized Raliegh Gran Prix bicycles (21, 23, and 25 inch frame sizes), modified to one speed with a gearing of 75 inches, were used for the test. Bicycle frame size was chosen by straddling the top tube of the bicycle with no more than 1½ inches of clearance. The saddle height was adjusted to 109% of the standing inside leg length. Each subject's bicycle was modified to correct specifications prior to testing.

The wind speed during testing periods was no higher than 10 mph. Wind speed was measured before and after each test with wind anemometer. Wind speed was not measured on two of the five testing dates due to the unavailability of the wind anemometer. The wind on those occasions was subjectively rated below 10 mph. The air temperature, measured by a Fahrenheit thermometer was between 50 and 75 degrees for the comfort of the subjects.

Human factors, such as motivation, willingness to accept and endure the strenuous effort and correct self-pacing were essential for optimum performance (Krahenbuth, Pangrazi, Peterson, Burkett & Schnider, 1978). Verbal encouragement was given by tester and aides at every available moment to assist the subject's motivation. Test aides were located at the starting area of the course in order to inform the subjects of the elapsed time and number of laps remaining, and to provide the helpful verbal encouragement.

The principal components of energy expenditure in bicycling are the internal power loss due to moving muscles, overcoming rolling resistance (Rr) between the bicycle tire and the road, and overcoming air resistance (Ra). In calm conditions Ra equals the bicyclist's speed (Pugh, 1974).

Ra is proportional to the average frontal area exposed when bicycling (Davies, 1980; Faria & Cavanaugh, 1978; Pugh, 1974; Whitt & Wilson, 1980). The crouched riding position, used by the subjects in this test, reduced the frontal area by approximately 30% and thus reduced the Ra by 30%.

Depending on gross weight, road surface and tire characteristics, Rr was constant. The higher the inflation pressure and the thinner the tread of the bicycle tire, the less the Rr (Adams, 1967; Dill, 1954; Faria & Cavanaugh, 1978; Kyle & Edelman, 1974; Whitt, 1971; Wihelm & Wihelm, 1980). Dill (1954) found that a bicyclist expends more energy when the bicycle is equipped with large tires. His study evaluated the energy requirements for bicycling in terms of the cross sectional diameter of the tires. With the recommended inflation pressures, the net oxygen consumption is about 0.19 $l \cdot min^{-1}$ greater on 26 inch x 2-1/8 inch tires than on 26 inch x 1 1/4 inch tires. All bicycles used during the test had the same brand of clincher tire, 75 pounds inflation pressure and 27 inch wheel diameter. These charateristics kept the Rr in the study constant (Adams, 1967; Dill, 1954; Faria & Cavanaugh, 1978; Kyle & Edelman, 1974; Whitt, 1971; Whitt & Wilson, 1980).

The frictional resistance (Rf) in the bicycle bearings was low (Faria & Cavanaugh, 1978; Whitt, 1971; Whitt & Wilson, 1980) and included under Rr. Since the bearings had such small importance in the resistance factors, they were not adjusted. The power lost in the bearings of a bicycle in good maintenance condition is only a few percent of the total energy expenditure of bicycling (Whitt, 1971; Whitt & Silson, 1980).

The bicycles used for the test were modified to one speed, with a gearing of 75 inches. To attain a 75 gearing, a front chainwheel of 50 teeth, a rear cog of 18 teeth and 27 inch wheels were used ($\frac{50 \times 27}{18} = 75$). The single speed eliminated the shifting variable of bicycling. The gearing was the most appropriate gear due to the differences in the subjects' fitness levels. If a higher gear had been used, the untrained subjects may have not been capable of finishing the 5-mile bicycle field test. If a lower gear had been used, the highly trained subjects may have used excess energy to pedal at a higher than normal rate to attain their usual rate of speed. The gear used for the test was low enough to accomodate the untrained subjects pedalling the 5-mile course, but difficult enough that the highly trained subjects could compensate their usual gearing by increasing the pedalling rate to attain their usual rate of speed.

The most efficient saddle height, in accordance with the measurements made by Hamley and Thomas (1967) and Nordeen-Snyder (1977) is 109% of the symphysis pubis height (standing inside leg length). The optimal saddle height put the range of joint angles and various muscles used to pedal at the most efficient range of the force velocity curves. The result of incorrect saddle height is more oxygen consumption, causing an efficiency drop (Faria & Cavanaugh, 1978).

Percent Body Fat

The percent body fat of each subject was determined by skinfold measurements taken with Lange skinfold calipers. Four skinfold sites were used: triceps, biceps, subscapular, and waist (Durin & Womersley, 1974). The calipers were held in the right hand and double skinfold on the subject was lifted with the left hand. The calipers compressed the skinfold about one centimeter from the point where the skinfold was lifted. A table of percent body weight for the sum of the four skinfolds for males of different ages was used to determine an estimate of body fat (Duein & Womersley, 1974).

Leg Strength

Leg strength was determined by one repitition maximum lift (1Rm) on the leg press of a Universal Gym apparatus (Pollack, Wilmore & Fox, 1978). The leg press machine had 30 pound increments between each block of weight. The subject was given a series of trials to determine a maximal which could be lifted only once. If the subject was able to lift a weight more than once an additional block of weight was added until a true one repitition maximum lift was reached.

Weight and Height

Weight in pounds and height in feet and inches were taken using a Continental scale. The weight and height measurements were then converted to kilograms and centimeters.

Chapter III

ANALYSIS AND DISCUSSION

Statistical Analysis

The results of the $\dot{V}O_2$ max test, 5-mile bicycle field test, percent body fat, leg strength, weight, and height are reported in Appendices B, E, F, and G respectively. The means, standard deviations and ranges are reported in Table 1. The intercorrelations among variables are reported in Table 2. Graphical presentations of the relationships between $\dot{V}O_2$ max and the predictors are presented in Appendix H.

TABLE 1

Central Tendency and Variability

Predictor	M	SD	Range
$\dot{V}O_2$ Max	54.50	6.05	42.00 - 65.80
5-Mile Bicycle Field Test	14.01	0.95	11.92 - 15.72
Percent Body Fat	14.81	4.54	6.70 - 25.30
Leg Strength	427.11	82.95	330.00 -660.00
Weight	75.61	9.69	58.50 -105.22
Height	179.41	8.54	162.94 -196.04

Note: N=45

TABLE 2

Intercorrelations

	1	2	3	4	5	6
1. $\dot{V}O_2$ Max		-.69[a]	-.71[a]	.15	-.51[a]	-.14
2. 5-Mile Bicycle Field Test			.51[a]	-.14	.30	.12
3. Percent Body Fat				.02	.68[a]	.03
4. Leg Strength					.06	.20
5. Weight						.50[a]
6. Height						

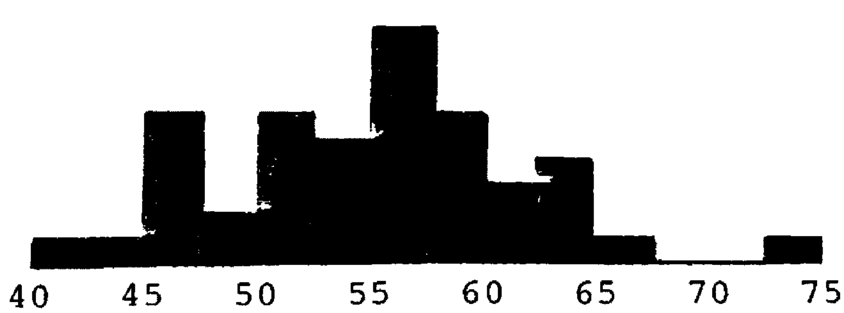
Note: N = 45

[a] $r \geq .37$ significant at $p \leq .01$

One subject was omitted from the analysis due to an extreme $\dot{V}O_2$ max score of 72.9, 1 standard deviation above the highest score. A bar chart of $\dot{V}O_2$ max scores shows the departure of the $\dot{V}O_2$ max score from the remainder of the distribution (Figure 1).

Figure 1

Distribution of $\dot{V}O_2$ Max with Outlier



In most cases, the correlations among variables decreased slightly with the removal of the outlier. The intercorrelations among the variables with the outlier included are reported in Appendix I.

$\dot{V}O_2$ Max Test

All subjects completed the $\dot{V}O_2$ max test using the Faria Graded Exercise Bicycle protocol without problems of leg fatigue or cramping. The range of the $\dot{V}O_2$ max scores in the study was 42 to 65.8 with a mean of 54.5 ml•kg•min^{-1}. The $\dot{V}O_2$ max for the average male college student is 44 to 48 with active male college students scoring 52 ml•kg•min^{-1} (Sharkey, 1978). The low number of average and below-average $\dot{V}O_2$ max scores was due to an inability to solicit unfit volunteers due to the physical stress encountered in the test.

5-Mile Bicycle Field Test

The 5-mile bicycle field test testing period lasted 3 weeks. Weather problems including rain, high winds and low temperatures, caused numerous test cancellations. Technical limitations regarding the wind anemometer forced estimation of the wind speed in 53 of the 90 trials. This estimation concluded that wind speed was below 10 mph in a westerly direction.

The 10 mph wind speed ceiling was a factor in the time needed to complete the 5-mile bicycle field test (Appendix J).

When wind was present, the subject experienced a headwind on the back stretch of the oval course. Subject 36 experienced no wind on Trial one and a 7 mph headwind on Trial two, with and increase on time of 1.03 minutes. Subject 16 experienced an 8 mph headwind on Trial one and no wind on Trial two, with a decrease of time of .56 minutes. The stronger the wind the slower the completion time of the test. Additional energy was used to pedal into a headwind that, in calm conditions, would have increased speed and decreased completion time.

It is fair to assume that cycling experience (e.g., correct pacing and body position, pedalling efficiency, cornering techniques and relaxation) was a key factor in the amount of time taken to complete the test. Subject 22, an ex-bicycle racer with a 55.6 $\dot{V}O_2$ max, averaged 12.97 minutes, one standard deviation below the mean, while Subject 9, a long-distance runner with a superior $\dot{V}O_2$ max of 60.3 and no bicycling experience, averaged 14.43 minutes, one-half of one standard deviation above the mean.

A test-retest reliability of the 5-mile bicycle field test was $r = .86$, statistically significant at the .01 level. Running field tests have shown reliabilities of $r = .90$ and above (Sharkey, 1979). Under calm wind conditions, the reliability of the 5-mile bicycle field test could be improved.

All subjects completed the two 5-mile bicycle field tests with no complaints of leg fatigue or cramping. The 5-mile distance with a 75 inch gear led to a range of 11.92 to 15.72

minutes. A longer course or alternative gear could possibly increase the range of work intensity, with trained subjects maintaining a higher intensity longer than the untrained subjects. This could improve discrimination between subjects.

Percent Body Fat

The mean percent body fat in this study was 14.8%. The average population value for percent body fat for college males 18-22 years of age is 12.5%. For college males 23-29 years of age it is 14% (Sharkey, 1979). The Equivalent Fat Content table used to determine percent body fat was in error at ±5% of body weight as fat for males (Montoye, 1970). The mean value of percent body fat in this study with a ±5% error closely approximated the average values of college males.

Leg Strength

The weak correlation between leg strength and $\dot{V}O_2$ max could be due in part to limitations in the measurement of leg strength. Leg strength would have been more accurate with smaller weight increments of 5 and 10 pounds. Future testing of leg strength should employ a different apparatus, more accurate than the Universal Gym leg press.

Weight and Height

The strong correlation between weight and $\dot{V}O_2$ max could be explained in part by the fact that $\dot{V}O_2$ max was measured in millileters of oxygen per kilogram of body weight. Height and

$\dot{V}O_2$ max did not produce a statisticaly significant correlation.

Regression Analysis

A stepwise regression analysis was performed using the Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). $\dot{V}O_2$ max was the dependent variable and percent body fat, 5-mile bicycle field test, leg strength, weight, and height were the predictor variables. The order in which the variables were entered was determined by the partial correlations between each predictor and the dependent variable. At each step, an *F*-ratio, and its statistical significance, was determined for the increment in R^2 (ΔR^2) resulting from the entered variable (Kerlinger & Pedhazur, 1973). ΔR^2 represents the contribution of R^2 as the predictor variable entered at a particular step. Summary results are presented in Table 3.

Table 3

Regressing $\dot{V}O_2$ Max on Percent Body Fat, 5-Mile Bicycle Field Test, Leg Strength, Weight, and Height

Predictor	R	R^2	ΔR^2	d.f.	F
Step 1 % of Body Fat	.71	.51	.51	1,43	44.59[a]
Step 2 5-Mile Bicycle	.81	.65	.14	1,42	17.46[a]
Step 3 Leg Strength	.81	.66	.01	1,41	1.11
Step 4 Weight	.82	.67	.01	1,40	1.0
Step 5 Height	.82	.67	.01	1,39	1.0

Note: N = 45
[a] $p<.01$

As can be seen, percent body fat and the 5-mile bicycle field test each contributed significantly to the prediction of $\dot{V}O_2$ max, with $R^2 = .65$ at the second step. Leg strength, weight and height contributions were almost negligible and, at any rate, not statistically significant.

Percent body fat entered before the 5-mile bicycle field test in the regression equation due to a slightly larger partial correlation with $\dot{V}O_2$ max ($\underline{r}$s = -.58 and -.54, respectively). The ΔR^2 associated with the 5-mile bicycle field test was .14. When the 5-mile test is forced before percent body fat, the ΔR^2 associated with percent body fat is .18. One sees, then, ΔR^2 is comparatively low for the variable entered on the second step--whether it is the 5-mile bicycle field test or percent body fat. The relative importance of these two variables in predicting $\dot{V}O_2$ max, therefore, should not be evaluated on the basis of their respective ΔR^2 values. Because these two predictors are correlated ($r = .53$), such an argument is unwarranted; focus, rather, should be on the cummulative R^2 when both variables are in the equation.

The 35% of $\dot{V}O_2$ max not accounted for by the predictors in the present study possibly could be due to the absence of a variable such as anerobic work. Anerobic work is high intensity work for short durations using the body's limited quantities of stored energy. The higher the percentage of $\dot{V}O_2$ max in which the anerobic work occurs, the better the maximal performance (Astrand & Ryming, 1977). This variable, along with others (e.g., speed and power) may prove to correlate significantly with $\dot{V}O_2$ max and increase R^2 when added to the predictors in the present study.

A chart presenting predicted values of $\dot{V}O_2$ max from percent body fat and the 5-mile bicycle field test is presented in Appendix M. Because leg strength, weight, and height contributed so little to the prediction of $\dot{V}O_2$ max, these variables were not included in the chart. An individual's predicted $\dot{V}O_2$ max can be found from his time (to the nearest tenth of a minute) to complete the 5-mile bicycle field test (horizontal axis) and his percent body fat (vertical axis). One should bear in mind that these predicted values are appropriate for individuals similar to the sample from which the values were derived: males between the ages of 19 and 30 years.

Chapter IV

SUMMARY AND RECOMMENDATIONS

The purpose of this study was to determine the validity of the 5-mile bicycle field test, percent body fat, leg strength, weight, and height as predictors of $\dot{V}O_2$ max. The 5-mile bicycle field test and percent body fat demonstrated a multiple correlation of R = .81 (R^2 = .65) with $\dot{V}O_2$ max. Leg strength, weight, and height did little to increase the variance accounted for in $\dot{V}O_2$ max. A chart was developed presenting predicted values of $\dot{V}O_2$ max from the 5-mile bicycle field test and percent body fat.

Due to the small sample size in this study the prediction of $\dot{V}O_2$ max and other results should be used as a foundation for future study. The chart predicting $\dot{V}O_2$ max applies to males in the age bracket who share the characteristics with those tested. Future studies dealing with the replication and improvement of the test procedure should consider the following changes:

1. A larger sample size with a wider range of $\dot{V}O_2$ max scores.
2. The oval course used in this study with no automobile traffic, no stop signals, wide corners, and smooth surface will be difficult to replicate. A straight or out and back course may be more practical.

3. A longer bicycle field test course and different gear ratio may broaden the range of test scores.
4. The bicycle field test location should have a mild climate with calm wind conditions.
5. Although no severe breakdown and maintenance problems occurred in this study, new bicycles should be used in the future.
6. Other variables, such as anerobic work, speed, and power, may contribute significantly to the prediction of $\dot{V}O_2$ max and, consequently, should be considered in subsequent research in this area.

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Appendix A

Consent Form

The purpose of this study is to develop a bicycle field test which will predict an individual's maximal oxygen consumption. I will be requested to perform one laboratory maximal oxygen consumption ($\dot{V}O_2$ max) test and two 5-mile bicycle field tests. The $\dot{V}O_2$ max has been found to be the most objective method by which one can determine aerobic fitness. The $\dot{V}O_2$ max test is a laboratory test of exhaustive work, performed on a Monarch bicycle ergometer. I will pedal the bicycle ergometer at a set frequency, with a progressive increase in workload at two minute intervals. The duration of the test will be between 8 and 12 minutes. Expired air will be collected for analysis during the laboratory test. Heart rate will be monitored using an Avionics stress monitor.

The 5-mile bicycle test is an outdoor bicycle ride which requires a maximal effort. The test is run on a .714 mile oval course. I will pedal seven laps around the course to complete the 5 miles. The only measurement taken is the time needed to complete the course. The time will be used to determine if the $\dot{V}O_2$ max can be predicted.

I will be required to perform the bicycle test on two separate dates east of Missoula on an oval course.

I will gain an understanding of my bicycling fitness level. By using the bicycle test, in a pre- and post-test manner, I can judge whether my training program is sufficient or if aspects of it need to be improved. My personal goals, relating to bicycling fitness, can be judged by my improvement on the test.

If I experience problems, leg cramps, dizziness, or severe difficulties in breathing during the bicycle field test I may terminate riding. If I experience any difficulties, such as leg cramps, dizziness, or severe difficulties in breathing, during the $\dot{V}O_2$ max test, resistance and speed will be lowered. If my EKG is or becomes abnormal the test will be immediately terminated and I will be referred to medical care.

My participation is voluntary and I am free to withdraw at any time of my choosing. If I have any questions concerning the tests they will be promptly answered by the tester. Confidentiality will be maintained in any published materials by references to me by numbers only.

"In the event physical injury results from biomedical or behavior research the human subject should individually seek appropriate medical treatment and shall be entitled to reimbursement or compensations consistent with the self insurance program for Comprehensive General Liability established by the Department of Administration under authority of MCA Title 2, Chapter 9, MCA, Sec. 2-90 315. In the event of a claim for such physical injury further information may be obtained from the University Legal Counsel."

I have read and understand the above statement and wish to participate in the study.

Name____________________

Investigator____________________

Date____________________

Before participating in this study, please answer the following questions:

Yes	No	
		Your doctor said you have heart trouble, a heart murmer, or you have had a heart attack.
___	___	You frequently have pains or pressure--in the left or midchest area, left neck, shoulder, or arm--during or right after you exercise.
___	___	You often feel faint or have spells of severe dizziness.
___	___	You experience extreme breathlessness after mild exertion.
___	___	Your doctor said your blood pressure was too high and is not under control. Or you don't know whether or not your blood pressure is normal.
___	___	Your doctor said you have bone or joint problems such as arthritis.
___	___	You have a family history of premature coronary artery disease.
___	___	You have a medical condition not mentioned here which might need special attention in an an exercise program.

If you answered NO to all questions you have reasonable assurance of your suitability for this study.

This form has been adapted from the questionnaire contained in Exercise and your Heart published by the U.S. Department of Health and Human Services, NIH Publication #81-1677, May, 1981.

Appendix B

Physical Characteristics

Subject	Age	Weight (kg)	Height (cm)
1	21	77.10	188.43
2	24	64.85	170.58
3	23	68.48	168.04
4	23	62.58	168.04
5	23	68.48	168.04
6	28	70.75	185.86
7	23	74.38	183.31
8	25	67.57	175.67
9	23	68.93	180.77
10	22	64.85	180.77
11	21	76.19	183.31
12	23	74.83	183.31
13	29	73.92	183.31
14	24	74.83	175.67
15	19	67.57	165.49
16	27	82.54	183.31
17	26	73.02	185.86
18	21	78.00	178.22
19	20	61.68	170.58
20	23	78.00	180.77
21	26	78.46	188.40
22	21	75.28	193.50
23	24	78.00	190.95
24	30	77.55	168.04
25	23	79.39	180.77
26	18	73.02	168.00
27	22	78.46	190.95
28	23	80.73	185.86
29	22	70.29	185.86
30	22	66.21	183.31
31	21	78.46	185.86
32	22	82.99	185.86
33	23	66.21	168.00
34	22	82.09	162.94
35	23	70.75	170.58
36	23	83.90	185.86
37	22	88.89	185.86
38	21	62.58	173.13
39	22	94.33	170.58
40	23	69.84	170.58
41	23	86.17	185.86
42	20	88.18	175.64
43	22	58.50	173.13
44	22	105.22	188.40
45	23	98.41	196.04
Mean	22.3	75.61	179.44

Appendix C

Sample Data Sheet

Faria Bicycle Test

Subject____

Test Administrator(s)____________________________

____

Graded Exercise Test

age: weight: height:

Stage	Duration (min)	Time (min)	Speed (rpm)	Workload (kpm/min)	kp
1	2	1-2	80	480	1.0
2	2	3-4	80	960	2.0
3	2	5-6	80	1440	3.0
4	2	7-8	80	1920	4.0
5	2	9-10	80	2400	5.0

Skinfold Caliper Results:

Percent Body Fat:

Strength Test:

Max Heart Rate:

RQ:

Five-Mile Test Times (1):

(2):

$\dot{V}O_2$ Max:

Appendix D

Instructions to the Subjects

$\dot{V}O_2$ Max Test

During the testing session your aerobic fitness level, your ability to take in, transport, and utilize oxygen during work will be determined. You will ride this bicycle ergometer during the test. The test requires a maximal effort.

Before you begin the test, electrodes need to be attached to your chest in order to monitor your heart rate during the test. The saddle of the bicycle ergometer will be adjusted, to your body size, by taking a measurement of your standing inside leg length. Now that the saddle is adjusted, sit down on the bicycle ergometer and practice pedalling. A better test score will be achieved if you place your hands in the drops of the handlebars (demonstrate).

Begin pedalling action. A pace of 80 rpm will be your pedalling speed. You will achieve this pace by matching the beat of this metronome. To match the metronome your right foot should be at the top of each pedal revolution on each beat. The toe clips will help you keep your feet on the pedals.

Every 2 minutes the workload will be increased by adjusting the resistance on the bicycle ergometer. Test aides will provide encouragement during the test and inform you as to the length of time remaining in your present workload. At the final workloads, you will be asked if you have 30 seconds remaining in your effort. Signal your response by shaking your head "yes" or "no." If you need to terminate the test at any time merely stop pedalling.

To collect your expired gas for measurement by the Beckman a mouthpiece will be inserted in your mouth. It goes behind the lips and in front of the teeth (demonstrate). A nose clip will be attached in order to insure all expired gas leaves through your mouth. Once the mouthpiece and nose clip are adjusted you are ready to start. Do you have any questions? (questions answered.)

5-Mile Bicycle Test

During this testing session the time it takes you to complete the 5-mile ride will be the only measurement taken. You will ride the bicycle 7 laps around an oval course. The test requires a maximal effort.

The bicycle you will ride will be modified to the correct specification of your size prior to each ride. The bicycle has been modified to a one speed, so no gear shifting is required. The toe clips will help your feet stay on the pedal.

During the test it is desired that you ride in a crouched position, with your hands on the drops of the handlebars (demonstrate). Remember to ride as fast as you possible but pacing is also important. We will provide encouragement during the test and inform you as to the distance you have remaining to ride at mile and a quarter intervals. If you need to terminate the test at any time merely stop pedalling and pull off the road.

Percent Body Fat

During the testing session your percent body fat will be determined. Four skinfold sites; triceps, biceps, subscapular, and waist will be measured using skinfold calipers. A table of equivalent fat content will be used to estimate your percent body fat.

Leg Strength Test

During the testing session your leg strength will be determined by a one repetition maximum lift on the leg press of a Universal Gym apparatus. If you are able to lift a weight more than once more weight will be added until a true one repetition is reached.

Weight and Height

During the testing session your weight and height will be determined using a Continental scale.

Do you have any questions? (questions answered.)

When you are ready, we can begin the test.

Appendix E

$\dot{V}O_2$ MAX TEST

Subject	$\dot{V}O_2$ Max (ml• kg• min -1)	Max HR	RQ
01	65.8	193	1.06
02	65.0	187	1.01
03	64.6	195	1.03
04	64.3	200	1.11
05	63.9	195	1.05
06	61.8	190	1.00
07	60.9	195	1.18
08	60.3	185	1.06
09	59.6	195	1.09
10	59.1	200	1.12
11	58.7	185	1.03
12	58.3	185	1.20
13	58.1	190	1.21
14	57.6	190	1.01
15	57.3	195	1.04
16	57.1	185	1.08
17	56.6	190	1.15
18	56.6	190	1.07
19	56.3	180	1.02
20	56.0	195	1.12
21	55.6	190	1.00
22	55.6	188	1.11
23	55.2	200	1.02
24	54.5	185	1.02
25	54.4	190	1.14
26	53.8	190	1.04
27	53.0	280	1.08
28	52.8	109	1.06
29	52.7	180	1.08
30	52.0	187	1.08
31	51.5	190	1.05
32	51.5	145	1.04
33	50.5	280	1.00
34	50.4	190	1.04
35	50.1	200	1.07
36	49.1	185	1.14
37	48.0	190	1.09
38	47.4	195	1.18
39	47.2	195	1.03
40	46.8	190	1.07
41	45.7	184	1.03
42	45.4	200	1.12
43	45.4	180	1.17
44	44.1	188	1.08
45	42.0	190	1.10
Mean	54.5	191	1.07

Appendix F

5-Mile Bicycle Field Test

Subject	Trial 1	Trial 2	Trial Average
01	11.93	12.03	11.98
02	13.13	13.50	13.32
03	13.50	13.70	13.60
04	12.05	11.78	11.92
05	12.02	12.23	12.13
06	13.35	13.23	13.29
07	12.67	12.43	12.55
08	14.63	14.22	14.43
09	14.03	13.80	13.92
10	12.87	12.82	12.85
11	12.87	12.97	12.92
12	14.45	14.58	14.51
13	14.03	13.80	13.92
14	12.77	12.67	12.72
15	14.73	14.17	14.45
16	14.00	13.43	13.71
17	15.35	15.53	15.44
18	14.67	13.93	14.30
19	13.48	14.37	13.93
20	15.02	15.33	15.18
21	12.70	13.23	12.96
22	14.92	14.42	14.67
23	13.97	13.75	13.80
24	13.37	14.32	13.85
25	13.93	13.50	13.71
26	13.67	13.50	13.59
27	14.17	13.93	14.05
28	13.50	14.07	13.79
29	14.15	13.75	13.95
30	13.50	13.72	13.61
31	14.00	14.25	14.13
32	14.53	16.02	15.28
33	14.48	14.10	14.29
34	13.22	14.17	13.70
35	14.90	14.50	14.70
36	15.73	14.82	15.28
37	14.17	13.70	13.94
38	15.02	14.42	14.72
39	15.98	15.20	15.59
40	15.33	14.37	14.85
41	15.10	14.78	14.94
42	14.18	13.70	13.94
43	15.97	15.47	15.72
44	15.41	14.63	15.02
45	14.97	15.33	15.15
Mean	14.07	13.97	14.00

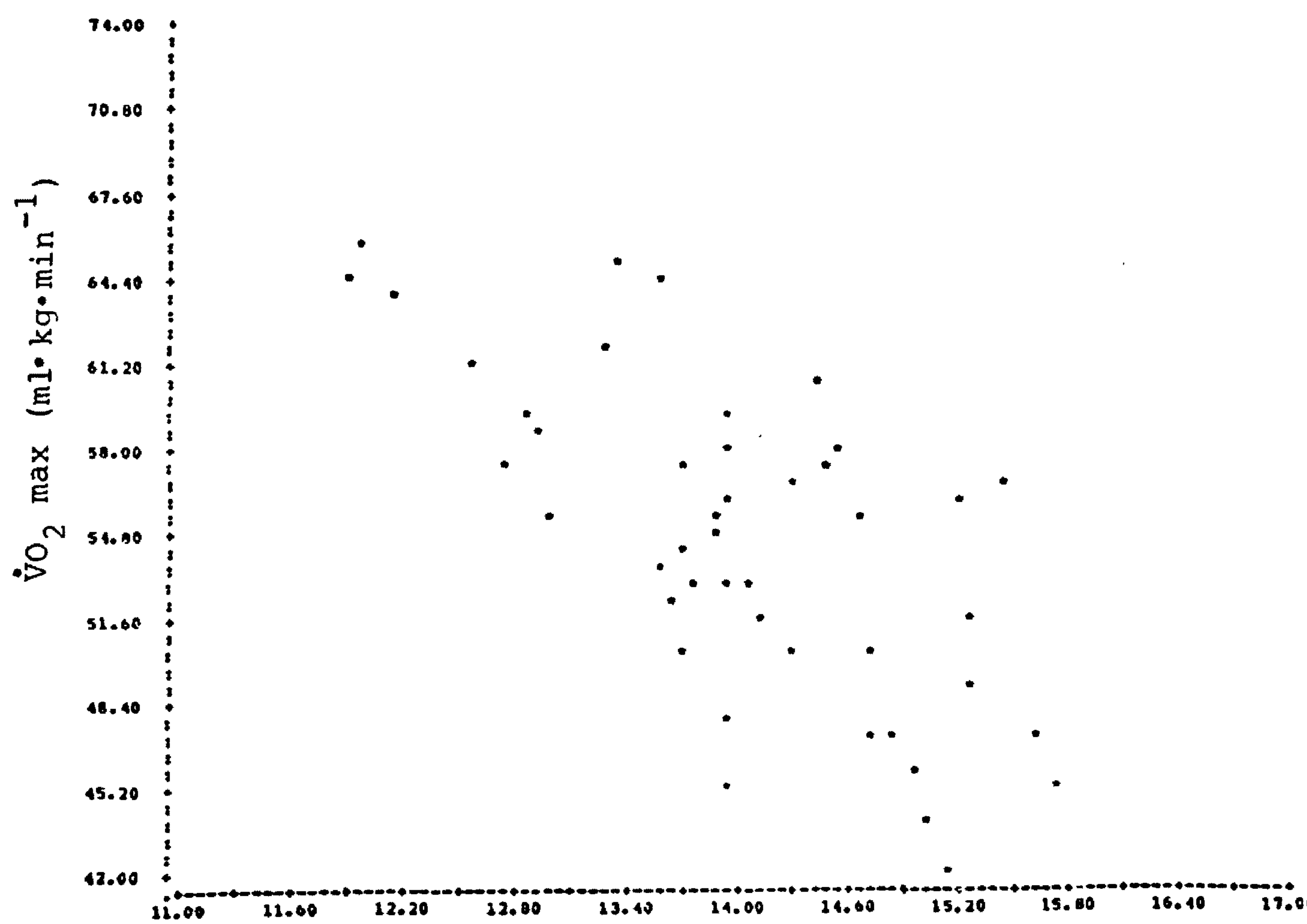
Appendix G

Percent Body Fat and Leg Strength

Subject	Percent Body Fat	Leg Strength (lbs.)
01	12.0	450
02	8.7	480
03	11.0	580
04	6.7	660
05	11.0	580
06	10.5	420
07	9.8	360
08	14.4	360
09	9.7	360
10	10.5	330
11	13.0	540
12	9.5	450
13	11.5	390
14	17.3	450
15	15.5	330
16	16.0	420
17	11.0	390
18	16.7	570
19	16.0	420
20	16.9	420
21	12.6	360
22	12.6	450
23	14.9	330
24	13.0	390
25	11.0	360
26	14.8	390
27	18.0	360
28	14.5	390
29	10.4	330
30	14.0	390
31	10.0	330
32	18.5	450
33	14.5	420
34	22.5	420
35	21.5	360
36	19.0	390
37	20.1	510
38	10.0	390
39	25.3	480
40	17.0	600
41	20.8	360
42	22.7	330
43	14.5	420
44	21.7	510
45	23.8	540
Mean	14.8	427

Appendix H

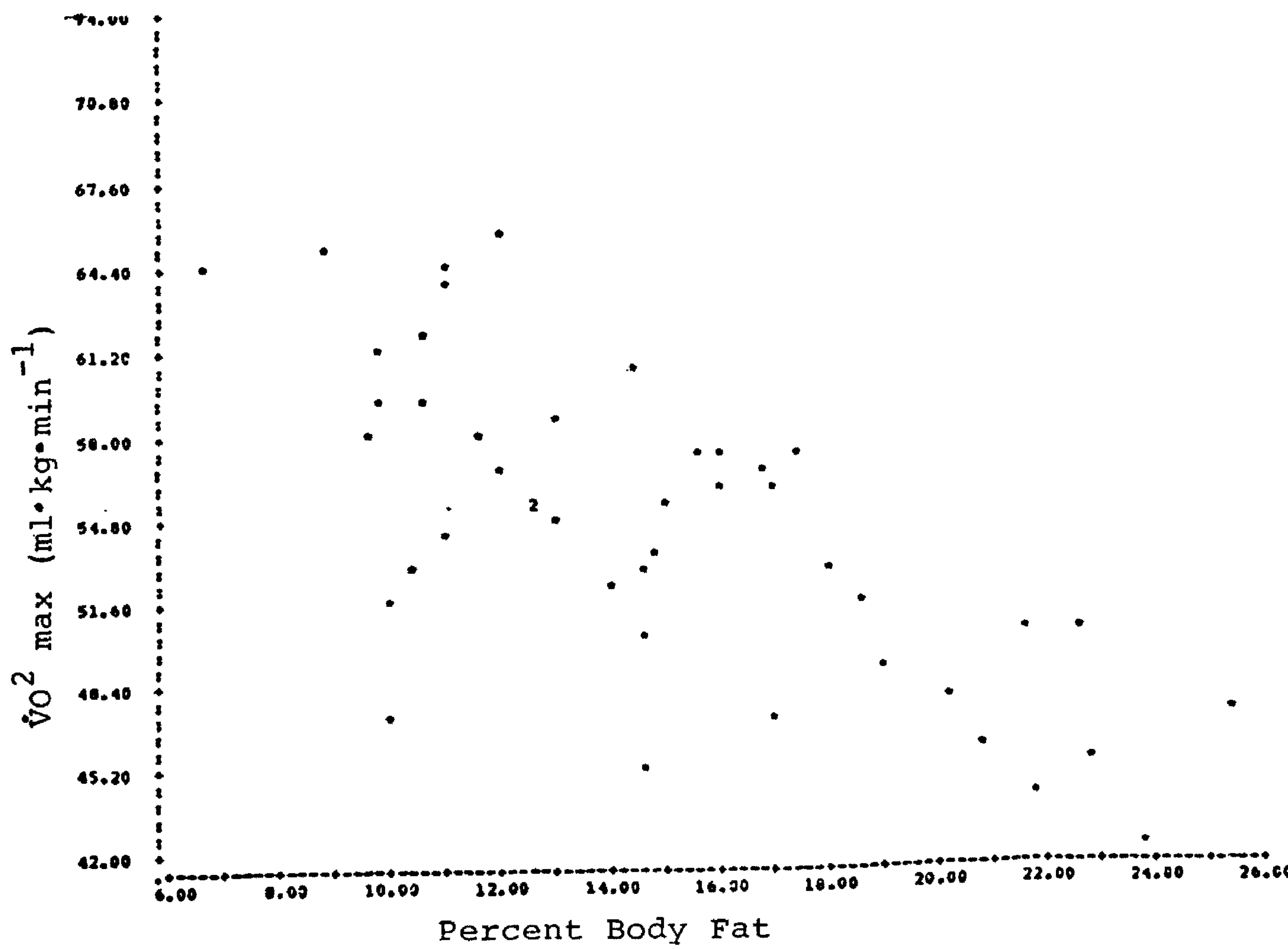
$\dot{V}O_2$ Max With 5-Mile Bicycle Field Test



5-Mile Bicycle Field Test

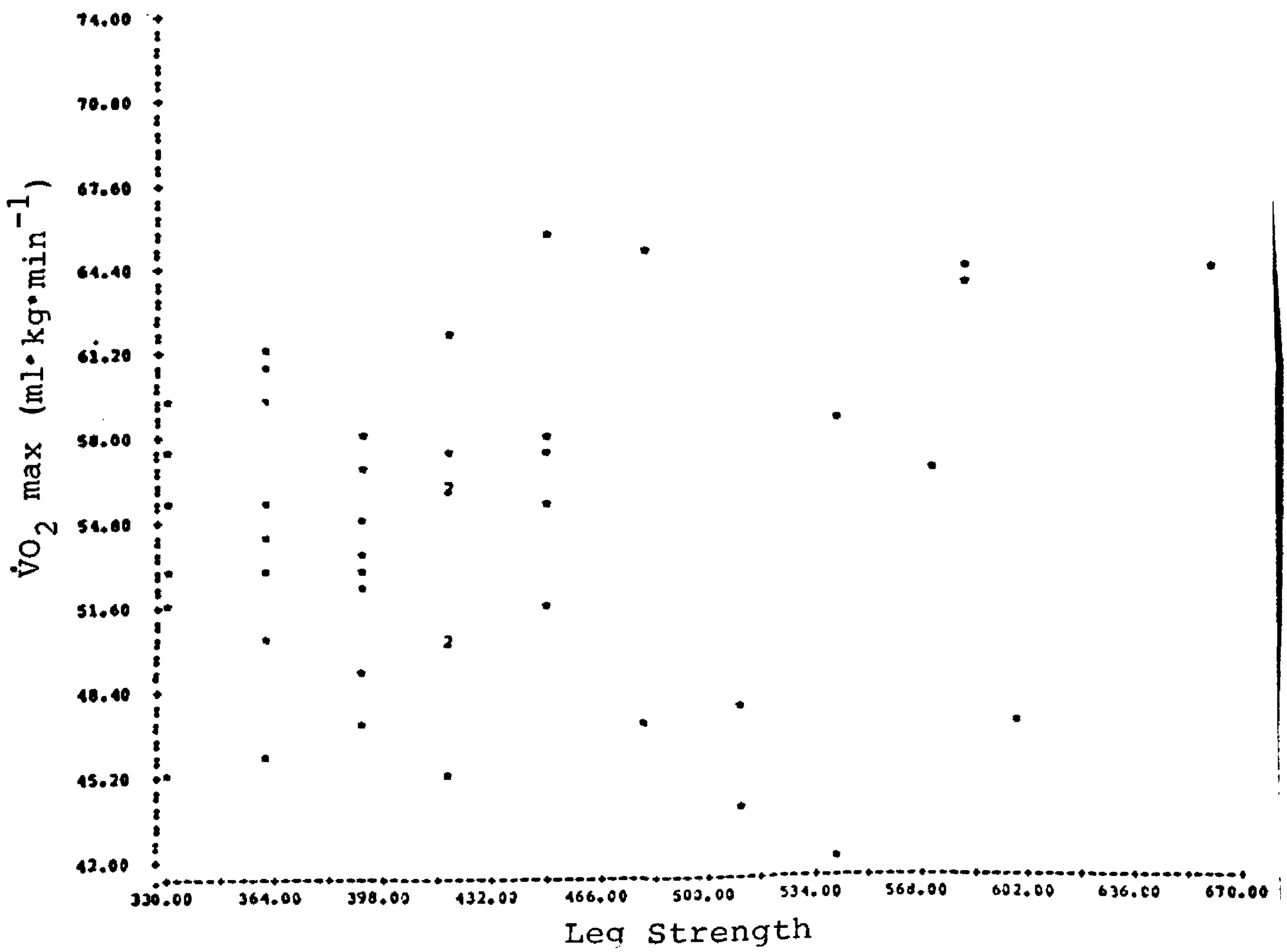
(minutes)

Appendix H
$\dot{V}O_2$ Max With Percent Body Fat



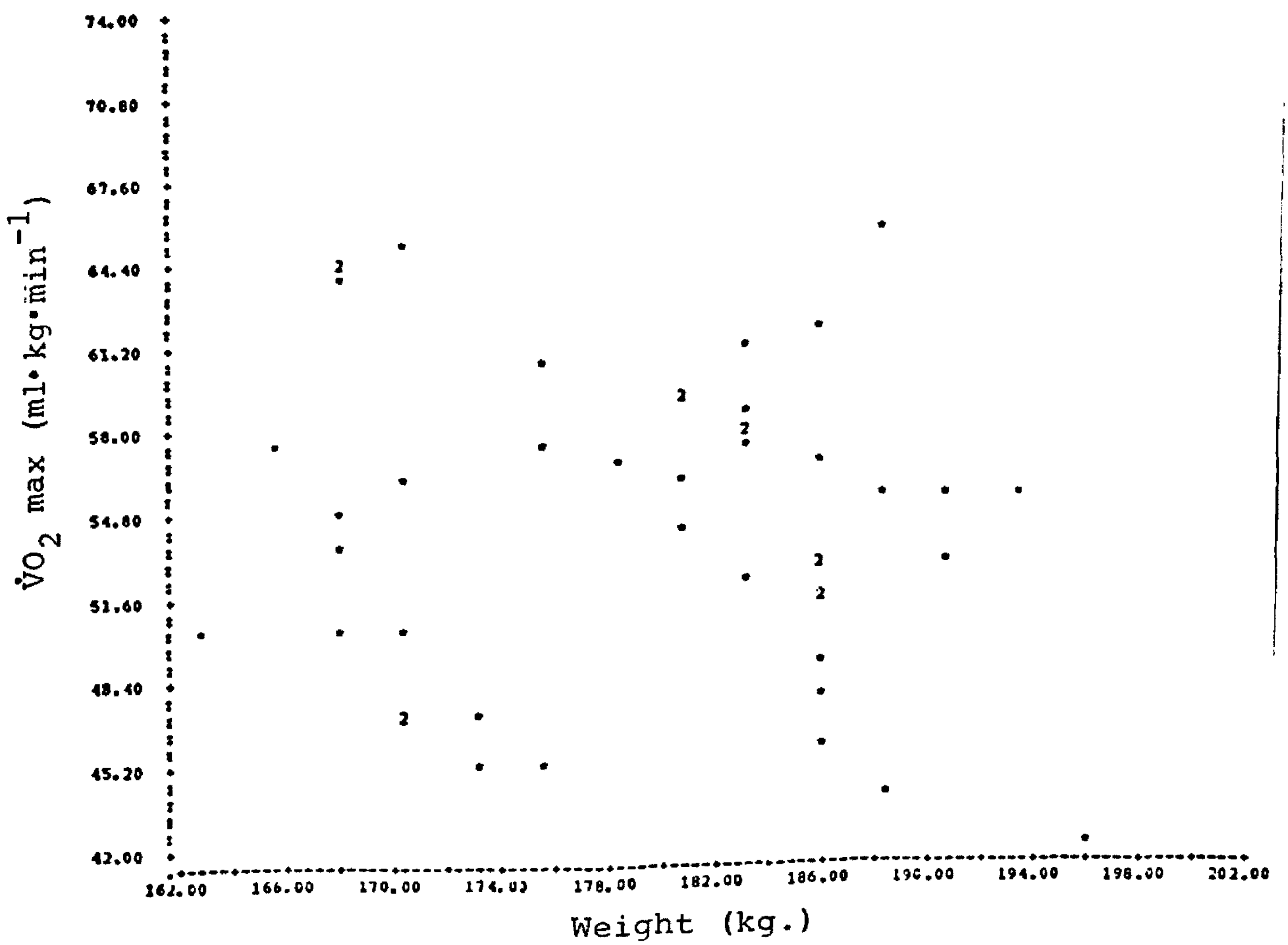
Appendix H

$\dot{V}O_2$ Max With Leg Strength



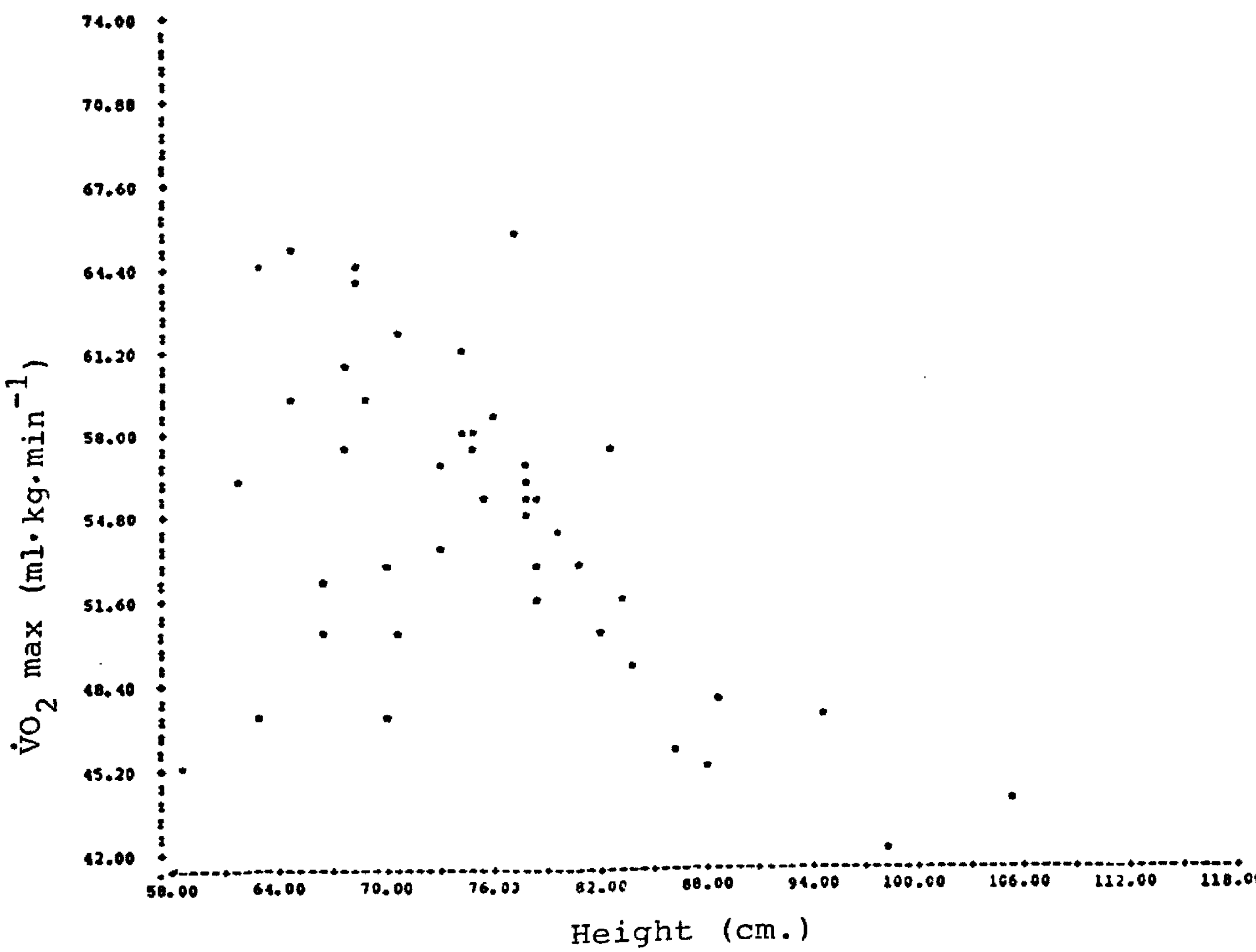
Appendix H

$\dot{V}O_2$ Max With Weight



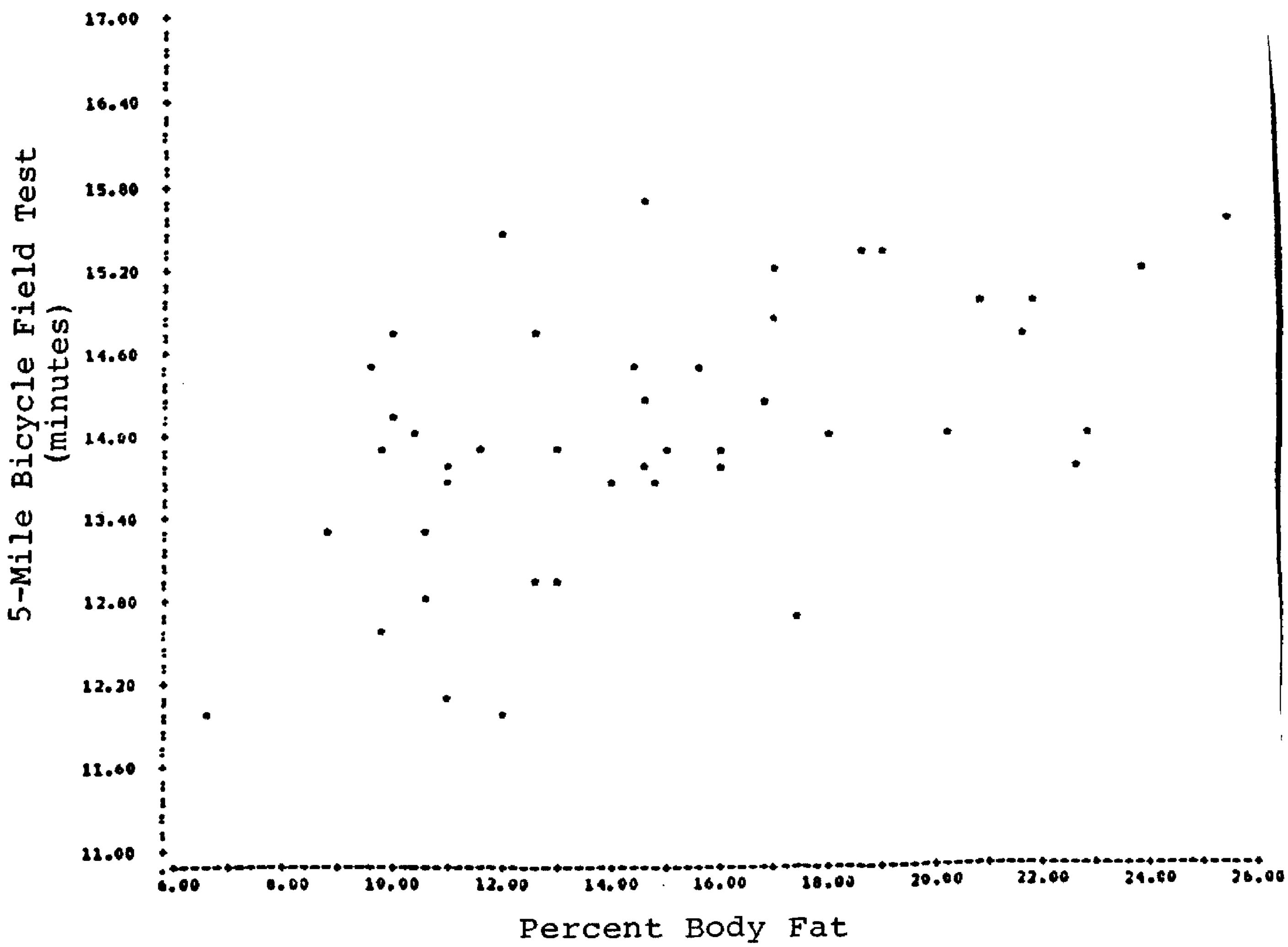
Appendix H

$\dot{V}O_2$ Max With Height



Appendix H

5-Mile Bicycle Field Test
With Percent Body Fat



Appendix I

Intercorrelations with Outlier

	1	2	3	4	5	6
1. $\dot{V}O_2$ Max		-.72[a]	-.71[a]	.24	-.54[a]	-.24
2. 5-Mile Bicycle			.53[a]	-.21	.34	.19
3. Percent Body Fat				-.02	.69[a]	.07
4. Leg Strength					.01	-.26
5. Weight						.49[a]
6. Height						

Note: N=46

[a] $r \geq .372$ significant at $p \leq .01$

Appendix J

5-Mile Bicycle Field Test Wind Speed and Temperature

Subject	Time	Wind (mph)	Temperature (Fahr.)	Time	Wind (mph)	Temperature (Fahr.)
1	11.93	*	60	12.03	*	58
2	13.13	*	62	13.50	*	62
3	13.50	*	70	13.70	*	70
4	12.05	2	65	11.78	*	70
5	12.02	*	64	12.23	*	70
6	13.35	2	65	13.23	*	71
7	12.67	5	65	12.43	*	63
8	14.63	*	71	14.22	*	64
9	14.03	8	63	13.80	*	65
10	12.87	*	59	12.82	*	63
11	12.87	*	55	12.07	5	58
12	14.45	*	60	14.58	*	55
13	14.03	*	64	13.80	*	60
14	12.77	*	62	12.67	*	65
15	14.73	5	65	14.17	*	70
16	14.00	6	65	13.43	0	60
17	15.35	1	65	15.53	6	63
18	14.67	6	65	13.93	*	70
19	13.48	*	65	13.37	*	71
20	15.02	2	64	15.33	8	65
21	12.70	7	60	13.23	*	62
22	14.92	1	65	14.42	8	65
23	13.97	7	60	13.75	I	63
24	13.37	2	52	14.32	7	65
25	13.93	*	60	13.50	*	65
26	13.67	3	64	13.50	*	60
27	14.17	*	70	13.93	*	70
28	13.50	*	65	14.07	*	65
29	14.15	*	60	13.75	*	70
30	13.50	0	68	13.72	5	65
31	14.00	2	68	14.25	6	65
32	14.53	1	57	16.02	5	62
33	14.48	*	58	14.10	*	68
34	13.22	*	60	14.17	*	70
35	14.90	1	70	14.50	5	65
36	15.73	0	69	14.82	7	63
37	14.17	*	71	13.70	*	62
38	15.02	5	63	14.42	5	65
39	15.98	*	63	15.20	*	62
40	15.33	5	70	14.37	*	65

Appendix J (Cont'd.)

Subject	Time	Wind (mph)	Temperature (Fahr.)	Time	Wind (mph)	Temperature (Fahr.)
41	15.10	5	70	14.78	*	70
42	14.18	2	70	13.70	*	64
43	15.97	4	68	15.47	*	65
44	15.41	8	70	14.63	0	70
45	14.97	*	65	15.33	0	70

*Wind speed estimated below 10 mph.

Appendix K

The Prediction of $\dot{V}O_2$ Max From the 5-Mile Bicycle Field Test and Percent Body Fat

To find the predicted $\dot{V}O_2$ max:*

1. Locate 5-mile bicycle field test time to the nearest tenth of a minute on the horizontal axis.
2. Locate the percent of body fat on the vertical axis.
3. Predicted $\dot{V}O_2$ max is at the intercept of the two axes.

*Standard error of estimate for $\dot{V}O_2$ max is $\pm$ 3.64 $ml \cdot kg \cdot min^{-1}$.

Accuracy of the predicted $\dot{V}O_2$ max will be effected by variations in windspeed during the 5-mile bicycle field test.

Appendix K (Cont'd.)

The Prediction of $\dot{V}O_2$ Max From the 5-Mile Bicycle Field Test and Percent Body Fat

Percent Body Fat	5-Mile Bicycle Field Test (Minutes)					
	11.9	12.0	12.1	12.2	12.3	12.4
6.7	65.7	65.4	65.2	64.9	64.6	64.3
7.0	65.5	65.2	65.0	64.7	64.4	64.1
7.5	65.2	64.9	64.6	64.4	64.1	63.8
8.0	64.9	64.6	64.3	64.0	63.7	63.5
8.5	64.6	64.3	64.0	63.7	63.4	63.1
9.0	64.2	63.9	63.7	63.4	63.1	62.8
9.5	63.9	63.6	63.3	63.1	62.8	62.5
10.0	63.6	63.3	63.0	62.7	62.4	62.2
10.5	63.3	63.0	62.7	62.4	62.1	61.8
11.0	62.9	62.6	62.4	62.1	61.8	61.5
11.5	62.6	62.3	62.0	61.8	61.5	61.2
12.0	62.3	62.0	61.7	61.4	61.2	60.9
12.5	62.0	61.7	61.4	61.1	60.8	60.5
13.0	61.6	61.4	61.1	60.8	60.5	60.2
13.5	61.3	61.0	60.7	60.5	60.2	59.9
14.0	60.7	60.7	60.4	60.1	59.9	59.6
14.5	60.7	60.4	60.1	59.8	59.5	59.2
15.0	60.3	60.1	59.8	59.5	59.2	58.9
15.5	60.0	59.7	59.5	59.2	58.9	58.6
16.0	59.7	59.4	59.1	58.8	58.6	58.3
16.5	59.4	59.1	58.8	58.5	58.2	58.0
17.0	59.0	58.8	58.5	58.2	57.9	57.6
17.5	58.7	58.4	58.2	57.9	57.6	57.3
18.0	58.4	58.1	57.8	57.5	57.3	57.0
18.5	58.1	57.8	57.5	57.2	56.9	56.7
19.0	57.7	57.5	57.2	56.9	56.6	56.3
19.5	57.4	57.1	56.9	56.6	56.3	56.0
20.0	57.1	56.8	56.5	56.3	56.0	55.7
20.5	56.8	56.5	56.2	55.9	55.6	55.4
21.0	56.5	56.2	55.9	55.6	55.3	55.0
21.5	56.1	55.8	55.6	55.3	55.0	54.7
22.0	55.8	55.5	55.2	55.0	54.7	54.4
22.5	55.5	55.2	54.9	54.6	54.3	54.1
23.0	55.2	54.9	54.6	54.3	54.0	53.7
23.5	54.8	54.5	54.3	54.0	53.7	53.4

Appendix K (Cont'd.)

Percent Body Fat	5-Mile Bicycle Field Test (Minutes)					
	11.9	12.0	12.1	12.2	12.3	12.4
24.0	54.5	54.2	53.9	53.7	53.4	53.1
24.5	54.2	53.9	53.6	53.3	53.1	52.8
25.0	53.9	53.6	53.3	53.0	52.7	52.4
25.3	53.7	53.4		52.8		52.2
	12.6	12.8	13.0	13.2	13.4	
6.7	63.7	63.2	62.6	62.0	61.5	
7.0	63.5	63.0	62.4	61.8	61.3	
7.5	63.2	62.7	62.1	61.5	61.0	
8.0	62.9	62.3	61.8	61.2	60.6	
8.5	62.6	62.0	61.4	60.9	60.3	
9.0	62.2	61.7	61.1	60.6	60.0	
9.5	61.9	61.4	60.8	60.2	59.7	
10.0	61.6	61.0	60.5	59.9	59.3	
10.5	61.3	60.7	60.1	59.6	59.0	
11.0	61.0	60.4	59.8	59.3	58.7	
11.5	60.6	60.1	59.5	58.9	58.4	
12.0	60.3	59.7	59.2	58.6	58.0	
12.5	60.0	59.4	58.8	58.3	57.7	
13.0	59.7	59.1	58.5	58.0	57.4	
13.5	59.3	58.8	58.2	57.6	57.1	
14.0	59.0	58.4	57.9	57.3	56.7	
14.5	58.7	57.6	57.6	57.0	56.4	
15.0	58.4	57.2	57.2	56.7	56.1	
15.5	58.0	56.9	56.9	56.3	55.8	
16.0	57.7	56.6	56.6	56.0	55.4	
16.5	57.4	56.3	56.3	55.7	55.1	
17.0	57.1	56.5	55.9	55.4	54.8	
17.5	56.7	56.2	55.6	55.0	54.5	
18.0	56.4	55.8	55.3	54.7	54.2	
18.5	56.1	55.5	55.0	54.4	53.8	
19.0	55.8	55.2	54.6	54.1	53.5	
19.5	55.4	54.9	54.3	53.7	53.2	
20.0	55.1	54.6	54.0	53.4	52.9	
20.5	54.8	54.2	53.7	53.1	52.5	
21.0	54.5	53.9	53.3	52.8	52.2	
21.5	54.1	53.6	53.0	52.4	51.9	

Appendix K (Cont'd.)

Percent Body Fat	5-Mile Bicycle Field Test (Minutes)				
	12.6	12.8	13.0	13.2	13.4
22.0	53.8	53.3	52.7	52.1	51.6
22.5	53.5	52.9	52.4	51.8	51.2
23.0	53.2	52.6	52.0	51.5	50.9
23.5	52.9	52.3	51.7	51.2	50.6
24.0	52.5	52.0	51.4	50.8	50.3
24.5	52.2	51.6	51.1	50.5	49.9
25.0	51.9	51.3	50.7	50.2	49.6
25.3	51.7	51.1	50.6	50.0	49.4
	13.6	13.8	14.0	14.2	14.4
6.7	60.9	60.3	59.8	59.2	58.6
7.0	60.7	60.2	59.6	59.0	58.5
7.5	60.4	59.8	59.3	58.7	58.1
8.0	60.1	59.5	58.9	58.4	57.8
8.5	59.7	59.2	58.6	58.0	57.5
9.0	59.4	58.9	58.3	57.7	57.2
9.5	59.1	58.5	58.0	57.4	56.8
10.0	58.8	58.2	57.6	57.1	56.5
10.5	58.4	57.9	57.3	56.8	56.2
11.0	58.1	57.6	57.0	56.4	55.9
11.5	57.8	57.2	56.7	56.1	55.5
12.0	57.8	56.9	56.3	55.8	55.2
12.5	57.2	56.6	56.0	55.5	54.9
13.0	56.8	56.3	55.7	55.1	54.6
13.5	56.5	55.9	55.4	54.8	54.2
14.0	56.2	55.6	55.0	54.5	53.9
14.5	55.9	55.3	54.7	54.2	53.6
15.0	55.5	55.0	54.4	53.8	53.3
15.5	55.2	54.6	54.1	53.5	52.9
16.0	54.9	54.3	53.8	53.2	52.6
16.5	54.6	54.0	53.4	52.9	52.3
17.0	54.2	53.7	53.1	52.5	52.0
17.5	53.9	53.3	52.8	52.2	51.6
18.0	53.6	53.0	52.5	51.9	51.3
18.5	53.3	52.7	52.1	51.6	51.0
19.0	52.9	52.4	51.8	51.2	50.7

Appendix K (Cont'd.)

Percent Body Fat	5-Mile Bicycle Field Test (Minutes)				
	13.6	13.8	14.0	14.2	14.4
19.5	52.7	52.1	51.5	51.0	50.4
20.0	52.3	51.7	51.2	50.6	50.0
20.5	52.0	51.4	50.8	50.3	49.7
21.0	51.6	51.1	50.5	49.9	49.4
21.5	51.3	50.8	50.2	49.6	49.1
22.0	51.0	50.4	49.9	49.3	48.7
22.5	50.7	50.1	49.5	49.0	48.4
23.0	50.3	49.8	49.2	48.6	48.1
23.5	50.0	49.5	48.9	48.3	47.8
24.0	49.7	49.1	48.6	48.0	47.4
24.5	49.4	48.8	48.2	47.7	47.1
25.0	49.0	48.5	47.9	47.4	46.8
25.3	48.9	48.3	47.7	47.2	46.6
	14.6	14.8	15.0	15.2	15.4
7.0	57.9	57.3	56.8	56.2	55.6
7.5	57.6	57.0	56.4	55.9	55.3
8.0	57.2	56.7	56.1	55.5	55.0
8.5	56.9	56.3	55.8	55.2	54.7
9.0	56.6	56.0	55.5	54.9	54.3
9.5	56.3	55.7	55.1	54.6	54.0
10.0	55.9	55.4	54.8	54.2	53.7
10.5	55.6	55.1	54.5	53.9	53.4
11.0	55.3	54.7	54.2	53.6	53.0
11.5	55.0	54.4	53.8	53.3	52.7
12.0	54.6	54.1	53.5	52.9	52.4
12.5	54.3	53.8	53.2	52.6	52.1
13.0	54.0	53.4	52.9	52.3	51.7
13.5	53.7	53.1	52.5	52.0	51.4
14.0	53.4	52.8	52.2	51.7	51.1
14.5	53.0	52.5	51.9	51.3	50.8
15.0	52.7	52.1	51.6	51.0	50.4
15.5	52.4	51.8	51.2	50.7	50.1
16.0	52.1	51.5	50.9	50.4	49.8
16.5	51.7	51.2	50.6	50.0	49.5

Appendix K (Cont'd.)

Percent Body Fat	5-Mile Bicycle Field Test (Minutes)				
	14.6	14.8	15.0	15.2	15.4
17.0	51.4	50.8	50.3	49.7	49.1
17.5	51.1	50.5	50.0	49.4	48.8
18.0	50.8	50.2	49.6	49.1	48.5
18.5	50.4	49.9	49.3	48.7	48.2
19.0	50.1	49.5	49.0	48.4	47.8
19.5	49.8	49.2	48.7	48.1	47.5
20.0	49.5	48.9	48.3	47.8	47.2
20.5	49.1	48.6	48.0	47.4	46.9
21.0	48.8	48.2	47.7	47.1	46.6
21.5	48.5	47.9	47.4	46.8	46.2
22.0	48.2	47.6	47.0	46.5	45.9
22.5	47.8	47.3	46.7	46.1	45.6
23.0	47.5	47.0	46.4	45.8	45.3
23.5	47.2	46.6	46.1	45.5	44.9
24.0	46.9	46.3	45.7	45.2	44.6
24.5	46.5	46.0	45.4	44.8	44.3
25.0	46.2	45.7	45.1	44.5	44.0
25.3	46.0	45.5	44.9	44.3	43.8

Percent Body Fat	15.6	15.7
7.0	55.1	54.8
7.5	54.7	54.5
8.0	54.4	54.1
8.5	54.1	53.8
9.0	53.8	53,5
9.5	53.4	53.2
10.0	53.1	52.8
10.5	52.8	52.5
11.0	52.5	52.2
11.5	52.1	51.9
12.0	51.8	51.5
12.5	51.5	51.2
13.0	51.2	50.9
13.5	50.8	50.6
14.0	50.5	50.2

Percent Body Fat	5-Mile Bicycle Field Test (Minutes	
	15.6	15.7
14.5	50.2	49.9
15.0	49.9	49.6
15.5	49.5	49.3
16.0	49.2	48.9
16.5	48.9	48.6
17.0	48.6	48.3
17.5	48.3	48.0
18.0	47.9	47.6
18.5	47.6	47.3
19.0	47.3	47.0
19.5	47.0	46.7
20.0	46.6	46.3
20.5	46.3	46.0
21.0	46.0	45.7
21.5	45.7	45.4
22.0	45.3	45.1
22.5	45.0	44.7
23.0	44.7	44.4
23.5	44.4	44.1
24.0	44.0	43.8
24.5	43.7	43.4
25.0	43.4	43.1
25.3	43.2	42.9

Note: Complete chart is available at the Department of Health and Physical Education, University of Montana, by request.