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A Study of the Validity of Two Indirect Predictors of Maximal Oxygen Uptake

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A STUDY OF THE VALIDITY OF TWO INDIRECT

PREDICTORS OF MAXIMAL OXYGEN UPTAKE

(TITLE)

BY

ROBERT V. SEDIK

THESIS

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Chapter 1

INTRODUCTION

Physical fitness can be an evasive term that often has as many definitions as it has people defining it. It has been generally agreed among physical educators however that physical fitness has two basic categories: motor fitness and cardiovascular fitness.[1]

The problem that exists for men and women in physical education is not defining fitness but evaluating it. If one was to determine physical fitness then he must either directly measure it through the use of laboratory tests or indirectly predict it through the use of fitness tests. Astrand[2] stated that either of these approaches was acceptable as long as they were based on sound physiological considerations.

When measuring the cardiovascular aspect of physical fitness the typical physical educator must use an indirect approach. He would not have the time, equipment, or finances to perform direct laboratory studies.

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[1]Benjamin Ricci, Physiological Basis of Human Performance (Philadelphia: Lea and Febiger, 1967), p. 233.

[2]Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 345.

NEED FOR THE STUDY

Perhaps the most valid measure of cardiovascular fitness would be maximum oxygen uptake, which measures the maximum amount of oxygen that one can consume per kilogram of body weight. Herbert deVries[3] stated that maximum oxygen uptake probably evaluates, directly or indirectly, the following elements of physical fitness: (1) cardiovascular function, (2) respiratory function, (3) muscular efficiency, (4) strength, (5) muscular endurance, and (6) obesity.

Since maximum oxygen uptake plays such an important role in evaluating physical fitness, it would be important that the physical educator be able to determine this capacity. As mentioned previously one would not always have the ability to directly measure cardiovascular function in a laboratory but would have other usable measures.

Most physical educators must rely on indirect predictors, such as Astrand's bicycle ergometer test and Cooper's twelve-minute run test, when measuring maximum oxygen consumption. Therefore it is very important that the validity of these predictors be proven in various testing situations.

PURPOSE OF THE STUDY

The purpose of the study was to determine the validity of

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[3]Herbert A. deVries, Physiology of Exercise (Dubuque: Wm. C. Brown Company, 1966), p. 205.

two indirect predictors of maximum oxygen uptake at both high and low physical fitness levels.

NULL HYPOTHESIS

There is no statistically significant difference between direct maximum oxygen uptakes taken in a laboratory and the predicted values from Astrand's bicycle ergometer test and Cooper's twelve-minute run test.

LIMITATIONS

The study was limited to sixteen male students at Eastern Illinois University. All subjects were under the age of thirty. Because of time and availability the subjects were tested once in each test.

DEFINITIONS OF TERMS

1. Maximal Oxygen Uptake - Maximal oxygen uptake is the amount of oxygen which a person consumes when oxygen intake per unit of time has attained its maximum and remains constant.

2. Validity - Validity is the extent to which a test measures that which it purports to measure . . . the truthfulness of a test.

3. High Level Fitness Group - Eight trained distance runners from the Eastern Illinois University track team.

4. Low Level Fitness Group - Eight students from Eastern Illinois University who did not regularly participate in strenuous physical activity.

5. Treadmill Test - The treadmill test was a running test that was designed to directly measure maximal oxygen uptake.

6. Bicycle Ergometer Test - The bicycle ergometer test was a submaximal riding test designed by Astrand that attempts to predict maximal oxygen uptake.

7. Twelve-Minute Run Test - The twelve-minute run test was a running test designed by Cooper that attempts to predict maximum oxygen uptake.

CHAPTER II

REVIEW OF RELATED LITERATURE

Although it is agreed among exercise physiologists that maximum oxygen uptake is the single best indicator of physical fitness, there is no single way of determining this capacity. Generally speaking, an individual can either directly measure maximum oxygen uptake or indirectly predict it. For this reason the literature was studied in two parts: (1) direct measures of oxygen uptake; and (2) indirect predictors of oxygen uptake.

DIRECT MEASURES OF MAXIMAL OXYGEN UPTAKE

In laboratory experiments three methods of producing work loads have been used: running on a treadmill, riding on a bicycle ergometer, and performing a step test. The two basic criteria for the work loads are that it should involve large muscle groups and that the measurement for maximal oxygen uptake should be started when the work has lasted a few minutes (the severity of the work load has to be considered when judging the duration of the work period.) Astrand[1] stated:

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[1]P.O. Astrand and K. Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 344.

"The critical question is whether or not the different types of work mentioned above give the same maximal oxygen uptake."

Astrand[2] reported that no statistically significant difference existed in maximal oxygen uptakes between running on a treadmill (inclination 1 =1.75%) and bicycling on an ergometer. Thirty-three female subjects were reported to have a mean value of 2.89 liters per minute on the treadmill as compared to a 2.76 liters per minute on the bicycle ergometer. A mean of 4.04 liters per minute on the treadmill for 34 male subjects was compared to a mean of 4.03 liters per minute on the bicycle ergometer.

Astrand and Saltin[3] compared maximal work of various large muscle group activities. Little difference was found between the maximal oxygen uptake obtained during bicycling with the legs only (mean of 4.23 liters per minute) or with arm and legs simultaneously (mean of 4.24 liters per minute) or when skiing (mean of 4.48). However, when comparing running on a treadmill, inclination of 7.9%, a mean of 4.69 liters per minute was obtained as compared to a mean of 4.47 liters per minute using the legs in a sitting position and a mean of 3.85 liters per minute in a supine position on the bicycle

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[2]Per-Olof Astrand, Experimental Studies of Physical Working Capacity in Relation to Sex and Age (Copenhagen: Munksgard, 1952).

[3]Per-Olof Astrand and Bengt Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity", Journal of Applied Physiology, XVI (November, 1961), pp. 977-981.

ergometer. They concluded that running uphill revealed about five per cent higher maximal oxygen uptake than other types of large muscle exercises (in well-trained subjects).

A study to measure the maximum oxygen intakes of forty active young men during a bicycle ergometer test, an intermittent and a continuous treadmill test, and a step test was reported by Wyndham, et. al.[4] The work position on the bicycle ergometer test was different than normal ergometer cycling. The subject sat in a chair behind the cycle ergometer with his legs almost horizontal. The position is very similiar to cycling in the supine position, which is less efficient for loading the oxygen transport system. A mean oxygen uptake in that position yielded 2.84 liters per minute. In the treadmill test the subject ran until fatigue set in. With the grade of the treadmill at less than one per cent, a mean of the oxygen uptake was found to be 3.08 liters per minute. The results of the study indicate that maximum oxygen uptakes obtained on the treadmill were higher.

Kasch, et. al.,[5] measured the maximum oxygen uptake of

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[4]C.H. Wyndhan, N.B. Strydom, W.P. Leary, and C.G. Williams, "Studies of the Maximum Capacity of Men for Physical Effort", Internationale Zeitschrift Fuer Angewandte Physiologie Einschliesslich Arbeitsphysiologie, XXII (March, 1966) pp. 285-295.

[5]F.W. Kasch, W.H. Phillips, W.D. Ross, J.E.L. Carter, and J.L. Boyer, "A Comparison of Maximal Oxygen Uptake by Treadmill and Step-Test Procedures", Journal of Applied Physiology, XXI (December, 1966), pp. 1387-1391.

twelve male subjects for one minute during a step test and a treadmill test. The step test values ranged from 37.2 to 56.0 ml/kg/min with a mean of 48.0 ml/kg/min and a standard deviation of 5.1 ml/kg/min. Treadmill values ranged from 40.2 to 54.1 ml/kg/min with a mean of 48.3 ml/kg/min and a standard deviation of 4.5 ml/kg/min. The coefficient of correlation between treadmill and step test scores was +.95. From this and a negligible difference of means of 0.24 ml/kg/min the results of the two procedures were practically identical. The investigators recommended that because of its apparent reliability, economy, safety, and versatility in accomodating a wide range of normal and impaired subjects, the step test be used.

Metabolic responses to exercise on the bicycle ergometer, the treadmill, and the step test were investigated by LesPaul.[6] The author used ten college students who were analyzed as two separate groups using an analysis of variance and a factorial design to determine the manner in which the subjects responded to exercise on the different machines. The results showed a significant interaction effect on the treadmill, but a non-significant interaction effect on the bicycle ergometer or the step test.

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[6] Tom LesPaul, "A Comparison of the Energy Cost of Exercises on the Bicycle Ergometer, the Treadmill, and the Stool Step", (unpublished Doctor's Dissertation, Florida State University, Tallahassee, 1965).

Chase, et. al.[7] reported a fifteen per cent higher maximal oxygen uptake during a treadmill exercise than during a bicycle ergometer test. Eighteen young men were used in the experiments. The procedures used in the treadmill exercise were those employed by Taylor, et. al.[8] The mean value for oxygen uptake was found to be 3.86 liters per minute. Maximal oxygen consumption was determined on a bicycle ergometer using a modification of the method of Luft, et. al.[9] The work load on the bicycle ergometer was set at 300 kpm per minute (50-60 rpm) for three minutes warm-up, the load was increased 85 to 100 kpm per minute until the subject could no longer pedal at the required rate. The mean oxygen uptake was 3.28 liters per minute.

Sitting and supine work performed on the bicycle ergometer was studied by Stenberg, et. al.[10] Submaximal and max-

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[7] G.A. Chase, C. Grove, and L.B. Rowell, "Independence of Changes in Functional and Performance Capacities Attending Prolonged Bed Rest", Aerospace Medicine, XXXVII (December, 1966), pp. 1231-1238.

[8] H.L. Taylor, E. Buskirk, and A. Hinschel, "Maximal Oxygen Intake as an Objective Measure of the Cardiorespiratory Performance", Journal of Applied Physiology, VIII (January, 1955), pp. 73-80.

[9] U.C. Luft, D. Cardus, T. Lim, E.C. Anderson, and J.L. Howarth, "Physical Performance in Relation to Body Size and Composition", Annals New York Academy of Sciences, CX (April, 1963), pp. 795-808.

[10] J. Stenberg, P.O. Astrand, B. Ekblom, J. Royce, and B. Saltin, "Hemodynamic Response to Work with Different Muscle Groups, Sitting, and Supine", Journal of Applied Physiology XXII (January, 1967), pp. 61-70.

imal work was performed on the bicycle ergometer with arms, with legs, and with arms and legs, in sitting and supine position, respectively. During maximal exercise with the arms plus legs in the sitting position, the mean oxygen uptake was 3.95 liters per minute. The value exceeds the value found for cycling the ergometer with the legs in the sitting position (mean of 3.87 liters per minute). A relatively low oxygen intake was measured for leg cycling in the supine position (mean of 3.42 liters per minute). At a given sub-maximal oxygen consumption heart rates and pulmonary ventilation were the same in leg exercise as in combined work, but the values were significantly higher during arm work.

Brown[11] reported that higher oxygen uptake values were obtained from treadmill exercise than from bicycle ergometer exercise. He felt that the treadmill provided a superior test of circulorespiratory functions.

Glassford, et. al.[12] gave three direct tests of maximal oxygen uptake and one indirect test to twenty-four male subjects aged 17-33. The results were then correlated. The two

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[11] C.G.Brown, "A Comparison of Circulorespiratory Responses to Weight-Supported and Non Weight-Supported Exercises in Moderately Obese Subjects" (unpublished Masters thesis, Eastern Illinois University, 1971).

[12] R.G. Glassford, G.H.Y. Boycroft, A.W. Sedgwick, and R.B.J. Macnab, "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods", Journal of Applied Physiology, XX (May, 1965), pp. 509-513.

treadmill tests and the indirect test yielded significantly higher mean values (8 per cent) than did the direct bicycle test. However, no other significant differences occurred. The investigators felt that the difference in muscle mass used in the treadmill tests produced the results.

INDIRECT PREDICTORS OF MAXIMAL OXYGEN UPTAKE

In a study by Astrand and Rhyming[13] a nomogram was developed that would allow maximal oxygen consumption to be predicted from a submaximal test. The nomogram was based on the results obtained from testing eighty-six male physical education majors. The test consists of a six minute ride on a bicycle ergometer. The subject rides at a set load (300-2400 kilopond metres/min) and a set pedal rate (50 rpm). The mean heart rate value is determined for the fifth and sixth minute and then applied to the nomogram. The submaximal pulse rates must be within a range of 120-170 beats per minute for the nomogram to be valid. An error in prediction of 6.7 per cent was reported.

In a later study by I. Astrand[14] it was reported that persons over twenty-five years of age consistently had their maximal oxygen uptakes overestimated. Through the results of the study

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[13] P.O. Astrand and I. Ryhming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate during Submaximal Work", Journal of Applied Physiology, XII (February, 1954) p. 218.

[14] I. Astrand, "Aerobic Work Capacity in Men and Women with Special Reference to Age", Acta Physiologica Scandinavica, XLVII (October, 1960), Supplement 169.

the original nomogram was subsequently modified to include an age correction factor.

The work of von Dobeln, et. al.[15] concluded that the nomogram underestimated the maximal oxygen uptake by 0.15 liter/min. The standard deviation was 17 per cent. Utilizing electronic data-handling techniques they observed that the introduction of a new correction factor for age eliminated the difference obtained between measured and predicted maximal oxygen uptake. The best prediction was obtained if submaximal heart rate, maximal heart rate, and age were used (SD=8.4 per cent). The precision was only slightly reduced if maximal heart rate was omitted. It was also found that the age factor could not be substituted by maximal heart rate without the loss of accuracy of prediction.

Teraslinna and others[16] attempted to determine the validity coefficient for the nomogram developed by Astrand and Ryhming[17] at an older age level. The data was collected on 31 members of faculty at Purdue University. The expired air was analyzed to determine the actual maximal oxygen uptake. The heart rates were also recorded and then used to predict the maximal oxygen uptake. The values were corrected for age. The validity coeffecient obtained was .92. The authors concluded that the nomogram was a satisfactory predictor.

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[15]W. von Dobeln, I. Astrand, and A Bergstrom, "An Analysis of Age and Other Factors Related to Maximal Oxygen Uptake", Journal of Applied Physiology, XXII (June, 1967) p. 934.

[16]P. Teraslinna, A.H. Ismail, and D.F. MacLeod, "The Nomogram by Astrand and Ryhming as a Predictor of Maximum Oxygen Uptake", Journal of Applied Physiology, XXI (May, 1966) pp. 513-515.

[17]Astrand and Ryhming, loc cit.

Klufs and deVries[18] calculated a validity coefficient of .736 for the Astrand nomogram. The study was based on the results obtained from sixteen male physical education majors with the mean age of 22.4 years.

Wyndhan, et. al[19] criticized the nomogram because it was based on a rectilinear relationship between heart rates and oxygen consumption. The authors demonstrated that the relationship between the variables concerned was asymptotic and that the curve of oxygen intake/work rate approached its asymptote more slowly than the curve of heart rate/oxygen intake. Therefore, it was felt reasonable to assume that there was a tendency to underestimate the maximum value of oxygen uptake if the asymptote of the heart rate is considered as the criterion of maximal effort.

The predictability of maximal oxygen uptake was studied by Rowell, et. al.[20] in four groups of normal men, 18-24 years of age. It was shown that the predicted method (Astrand-Rhyming nomogram) significantly underestimated the actual method in a sedentary group, before and after two and one half to three

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[18]C.E. Klufs and H.A. deVries, "Prediction of Maximal Oxygen Intake from Submaximal Tests", Journal of Sports Medicine and Physical Fitness, Iv (April, 1965) p. 207.

[19]C.H. Wyndhan, C.B. Strydom, J.S. Maritz, J.F. Morrison, J. Peter, and Z.U. Potgieter, "Maximum Oxygen Intake and Maximum Heart Rate During Strenuous Work", Journal of Applied Physiology, XIV (June, 1959) pp. 927-936.

[20]L.B. Rowell, H.L. Taylor, and Y. Wang, "Limitations to Prediction of Maximal Oxygen Uptake", Journal of Applied Physiology, XVIII (June, 1964) p. 919.

months of physical training. There was a marked trend toward improved accuracy of prediction with increased degree of physical training.

Three indirect predictors of maximal oxygen uptake were compared to an actual measure of maximal oxygen uptake by Oja, et. al.[21] The study attempted to determine the validity coefficient of the indirect predictors. The authors stated that the validity of the Astrand[22] method, the von Dobeln[23] method, and a serum lactate method did not appear very good. It was stated that the results might have been due to an unsatisfactory direct measurement of the maximum oxygen uptake.

Margaria and others[24] developed a nomogram for obtaining the value of maximum oxygen consumption per kilogram of body weight from the heart rate values observed at two submaximal work loads. The exercise consisted of stepping up and down on a 30 to 40 cm bench at a frequency of 15 to 25 times per minute. The procedure could be applied to all classes of subjects. The variability of the data obtained was within seven per cent of the scores obtained by a direct measure.

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[21] P. Oja, T. Partanen, and P. Teraslinna, "The Validity of Three Indirect Methods of Measuring Oxygen Uptake and Physical Fitness", Journal of Sports Medicine and Physical Fitness, X (January, 1970) pp. 67-71.

[22] Astrand and Rhyming, loc. cit.

[23] von Dobeln, Astrand, and Bergstrom, loc. cit.

[24] R. Margaria, P. Aghemo, and E. Rowell, "Indirect Determination of Maximal Oxygen Consumption in Man", Journal of Applied Physiology, XX (July, 1965) p. 1070.

In a study by Issekutz, et. al.[25] work respiratory quotients (RQ) increased logarithmically with the work load and that maximal oxygen uptake was reached at an increase in RQ value of 0.40. For each work RQ between 0.95 and 1.15 a factor was presented together with the aid of a simple equation which gave a good approximation (generally within ten per cent) of the actual maximum oxygen uptake.

Another study was made by Falls and others[26] to investigate the validity of estimating maximal oxygen uptake from the AAHPER Youth Fitness Test. The results indicated that over a wide age range the optimally-weighted motor fitness items possessed about as high a predictive value as other tests.

The work of Cooper[27] concluded that a validity coefficient of 0.897 existed between the twelve-minute run test and a direct measure of maximum oxygen consumption. The author felt that the significance of the study made it possible to estimate with considerable accuracy the maximal oxygen consumption from only the results of the twelve-minute run test.

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[25]B. Issekutz, N.C. Birkhead, and K. Rodahl, "Use of Respiratory Quotients in Assessment of Aerobic Work Capacity", Journal of Applied Physiology, XVII (January, 1962) pp. 47-50.

[26]H.B. Falls, A.H. Ismail, and D.F. MacLoed, "Estimation of Maximum Oxygen Uptake in Adults from AAHPER Youth Fitness Test Items", Research Quarterly, XXXVIII (March, 1966) p. 192.

[27]K.Cooper, "Correlation Between Field and Treadmill Testing as a Means of Assessing Maximal Oxygen Intake", Journal of American Medical Association, CCIII (February, 1968) pp. 201-203.

Ribisl and Kachadorian[28] attempted to relate the maximal oxygen intake capacity to performance times for various running events. It was concluded that distances beyond a half-mile were significantly related to maximal oxygen intake while distances less than a half-mile were not significantly related. The two mile run showed the highest relationship of all running events.

It was the problem of the investigation by Doolittle and Bigbee[29] to evaluate the distance covered in twelve minutes as an indicator of cardiorespiratory fitness, and to compare it with the 600 yard run in that regard. It was shown that the distance covered during the twelve-minute run was a highly reliable and valid (r=.90) indicator of cardiorespiratory fitness and that it was to be preferred to the 600 yard run as a predictor of maximum oxygen uptake.

Wiley and Shaver[30] studied the prediction of maximum oxygen uptakes from the running performances of untrained young men. The investigators concluded that the correlations between running times and maximum oxygen uptake increased as the running distances increased. However the correlations were significantly lower than others had reported.

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[28]P.M. Ribisl and W. Kachadorian, "Maximal Oxygen Intake Prediction in Young and Middle-Aged Males", Journal of Sports Medicine and Physical Fitness, IX (January, 1969) pp. 17-22.

[29]T.L. Doolittle and R. Bigbee, "The Twelve-Minute Run-Walk: A Test of Cardiorespiratory Fitness of Adolescent Boys", Research Quarterly, XXXIX (August, 1968) pp. 491-495.

[30]J.F. Wiley and L.G. Shaver, "Prediction of Maximum Oxygen Intake from Running Performances of Untrained Young Men", Research Quarterly, XLIII (February, 1972) pp. 89-93.

In an unpublished doctoral dissertation, Wanamaker[31] studied the validity and reliability of the twelve-minute run test. It was concluded that the twelve-minute run was not an effective predictor of maximum oxygen uptake. It was however considered a reliable measure.

A validity correlation of .65 for the twelve-minute run test was reported by Maksud and Coutts.[32] Seventeen 11-14 year old male children were tested under laboratory conditions in the study. The authors felt the low correlation may have been due to the relatively small and homogenous subsample.

SUMMARY

Maximum Oxygen consumption seems to be the best single indicator of physical fitness. There are two basic methods of determining this capacity: direct measurement or indirect prediction. The critical question when dealing with either of these methods is whether or not they will yield the same maximal oxygen uptake.

During direct measurement of maximal oxygen uptake three methods of producing workloads have been used: Running on a treadmill, riding on a bicycle ergometer, and performing a step

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[31]G.S. Wanamaker, "A Study of the Validity and Reliability of the Twelve-Minute Run Under Selected Motivational Conditions" (unpublished Doctoral dissertation, Texas A&M University, College Station, 1971).

[32]M.G. Maksud and K.D. Coutts, "Application of the Cooper Twelve-Minute Run-Walk Test to Young Males", Research Quarterly, XLII (January, 1971) pp. 54-59.

test. Although the results of various studies were often contradictory it was generally indicated that tests on the treadmill produced significantly higher maximal oxygen uptakes. That was felt to be true because the treadmill tests involved a greater muscle mass than the other two workloads.

Though numerous indirect predictors have been developed Astrand's bicycle ergometer test and Cooper's twelve-minute run test were most widely used. The research available on these predictors was contradictory.

CHAPTER III

METHODOLOGY

In order to provide an accurate account of the methodology used in the collection of data, the description of the subjects, the design of the study, and the test procedures employed have been presented in this chapter.

SUBJECTS

High Level Fitness (HLF)

The eight volunteer subjects in the HLF group were distance runners from the Eastern Illinois University varsity track team. The top four distance runners from the varsity squad were not included in the study. The subjects had an age range from eighteen to twenty-one with a mean of nineteen years. The body weight ranged from 47.72 Kg to 71.82 Kg with a mean of 62.49 Kg.

Low Level Fitness (LLF)

The eight volunteer subjects in the LLF group were students at Eastern Illinois University who did not participate in regular physical exercise. The subjects had an age range from nineteen to twenty-seven with a mean age of twenty-two years. The body weight ranged from 67.05 Kg to 81.14 Kg with a mean of 71.82 Kg.

DESIGN OF STUDY

Each subject was administered the three different tests within a fifteen day period. The subjects were never tested two days in a row, and no more than five days were allowed to pass between tests. It was felt that the testing should be at least two days apart to assure that the physical effort of one test would not be a factor in the next test. At the same time however, it was believed that too much time elapsed between tests might influence the results.

The order in which the tests were given was intentionally varied between the subjects. Four separate testing schedules were developed and then followed by four different subjects thus randomizing any training effect that might occur.

TABLE I

BASIC TESTING SCHEDULES

Group	N	Order
LLF	4	Bicycle Ergometer - Twelve-Minute Run - Treadmill
LLF	4	Twelve-Minute Run - Treadmill - Bicycle Ergometer
HLF	4	Treadmill - Twelve-Minute Run - Bicycle Ergometer
HLF	4	Twelve-Minute Run - Bicycle Ergometer - Treadmill

Each subject was instructed not to eat or smoke within two hours of the tests. Subjects were also asked not to participate in any strenuous physical activity within three to four hours of the tests. The subjects were told in advance what each test entailed and every effort was made to reduce any anxiety-causing factors related to the testing.

Both the treadmill test and the bicycle ergometer test were given in the Physical Education Research Laboratory at Eastern Illinois University. These tests were given on an individual basis. The tests were scheduled at various times of the day (between 8 a.m. and 8 p.m.) depending upon the availability of the subject. The twelve-minute run test was administered on a group basis at the outdoor varsity track at Eastern Illinois University. Three separate groups took the test within a four-hour period on the same afternoon. The first group consisted of seven subjects, the second group had five subjects, and the third group had four subjects. This was done so that all subjects would run under similar weather conditions. It was also hoped that by running in groups the subjects would have a higher motivational state.

TESTING PROCEDURES

Although the tests were different in nature, the procedures involved in administering the tests consisted of three similar phases. The general phases were an orientation phase, a warm-up phase, and the actual testing phase. This general procedure was applied to each test.

Preliminaries

When the subject entered the research laboratory for the first time he was weighed in his t-shirt, running shorts, supporter, and socks on a calibrated Healthometer Scale. His weight was read to the nearest half pound and converted into kilograms by dividing by 2.2. His age, the date, the time of day, and pre-test activities were also noted. This information was recorded on a data sheet designed by Johnson.[1]

Treadmill Test

Phase I. The orientation began with an explanation of the purpose of the treadmill test and what demands the test would make upon the subject.

The subject was then asked to stand on the treadmill, holding on to the safety bar with both hands. Once the subject was in that position the treadmill was started. It had been preset at three miles per hour, zero per cent grade. A small window fan suspended in front of the subject had also been turned on to simulate air flow. When the subject was walking comfortably, he was instructed to release his grip on the bar with one hand and then the other, letting the arms swing naturally at his sides.

The grade was then raised to the 8.6 per cent level with the speed remaining the same. It was explained that this was the

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[1]Robert E. Johnson, Francis Robbins, and others, "A Versatile System for Measuring Oxygen Consumption in Man", Journal of Applied Physiology, XXII (February, 1967), pp. 377-379.

grade at which the subject would be running. The rubber mouthpiece, connected to the suspended Collins Triple "J" valve, was then adjusted to the height of the subject. Procedures for inserting the mouthpiece were then reviewed. Holding on to the safety bar with one hand, the subject inserted the mouthpiece. He then released the bar and continued to walk naturally. The subject was allowed to practice this until he could do it easily.

The subject was then told to place both hands on the safety bar as the speed was gradually increased to seven miles per hour. He was also instructed to begin jogging whenever he felt it was necessary to keep pace with the treadmill. When the subject felt comfortable he released the bar and ran naturally. He then practiced inserting the mouthpiece on the run, using the same procedure as before. This was practiced until he could do it easily.

Phase II. A combination of techniques was employed by the subjects for warm-up purposes. The different methods used included calisthentics, walking on the treadmill, running on the treadmill, and running on the indoor track. All the subjects used two or more of these methods as a warm-up. It was felt that the method of warm-up was not a crucial factor so long as some minimal controls were exerted. For this purpose no warm-up was allowed to last more than seven minutes and all subjects were asked to use some type of warm-up.

Phase III. The treadmill test was given on an A.R. Young Treadmill. The workload was established by review of previous work. This workload varied between and within the two groups. The HLF group was asked to run at nine miles per hour on an 8.6 per cent grade for six minutes. Three subjects ran at an eight mile per hour pace and one subject ran at a 7.5 mile per hour pace. The LLF group was asked to run at a seven mile per hour pace at the same grade and for the same length of time. All subjects except one performed at that workload. That subject ran at six miles per hour at a six per cent grade and lasted only three minutes. It was felt that so long as the treadmill run provided a physically stressful situation for the runner an accurate measure of maximum oxygen consumption could be determined. The experimenter's estimation of the actual test provided the final criterion of the stressfulness of the run.

Before the test started the experimenter placed the sponge noseclips on the subject. It was explained that if they should fall off during the test, he should hold his nose with his fingers whenever the mouthpiece was inserted, and that if he felt he had to stop for any reason, he should say so and the test would be terminated immediately.

During the course of the test two, 30 second samples of the subject's expired air were taken. The first sample was taken at approximately the middle of the run. This was from 3:00 to 3:30 for most subjects. The second sample was taken as close to the end of the run as possible. Some subjects could not last the full six minutes while a few others needed to run an extra minute or two.

Ten seconds prior to taking the air sample the subject was told to put the mouthpiece in place. That was ample time to both secure the mouthpiece and flush out the sampling chamber.

By synchronizing their actions with the Gra Lab Universal Timer, the experimenters were able to open the Parkinson-Cowan CD4 gas meter and to turn the vacuum pump on at the start of the thirty second period. The CD_4 meter measured the inspired volumes of air. The air volumes were later corrected to Standard Temperature and Pressure Dry (STPD). The vacuum pump sucked a sample of the subject's expired air out of a plexiglass sampling chamber which was connected to the suspended Triple "J" Valve. The air was collected in a vacuumized bag designed by Johnson.[2]

The temperature of the expired air was measured in degrees Centigrade by an atmospheric probe in the mixing chamber. The probe was plugged into a calibrated YSI Tele-Thermometer.

The expired air samples were analyzed by a Beckman Model E_2 Oxygen Analyzer and a Beckman LB-1 Medical Gas Analyzer to determine oxygen and carbon dioxide content.

<u>Bicycle Ergometer Test</u>

<u>Phase I</u>. The subject was originally oriented to Astrand's bicycle ergometer test by an explanation of the test.

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[2]Johnson, ibid.

The height of the bicycle seat was then adjusted to each individual so that there was a slight bending of the knee (approximately 170° angle behind knee joint) when the foot was placed on the pedal in its lowest position.

The subject was then allowed to coordinate his pedalling frequency with the beat of a metronome. The metronome was set at fifty beats per minute. Each subject was asked to make one complete revolution with the pedals each time the metronome ticked.

Phase II. The bicycle ergometer ride was a submaximal test so consequently little warm-up was needed. The time the subject spent orienting himself to the bike served as a sufficient warm-up.

Phase III. To insure that an accurate heart rate was taken a Sanborn Model 500 Viso Cardiette was used. This machine provided a graphic record of the QRS complex which when measured by a calibrated ruler enabled one to determine heart rates in beats per minute (bpm).

In order to use the electrocardiagraph machine the subject had to be specially prepared. When he first entered the research laboratory he was asked to assume a supine position with his t-shirt removed. The body hair was then shaved at the V_2 and V_5 chest electrodes positions. A small amount of electrode jelly was rubbed vigorously on these areas to remove dead skin and provide an area of irritation for electrode attachment and contact. Excess jelly was removed with a towel. Two electrodes were then attached at the V_2 and V_5 positions with a pea-sized drop of jelly being placed inside the electrode ring to help provide better contact with the skin. The electrodes were then directly connected to the electrocardiograph machine via a Becton-Dickinson patient cable. A resting heart rate was then taken to determine if the system was functioning properly.

The subject rode a Monark bicycle ergometer for six minutes with heart rates taken within the last ten seconds of each minute. If the difference between the fifth minute and sixth minute heart rates exceeded five beats per minute the riding time was extended. The test then continued until a difference of five beats or less occurred. No test lasted longer than eight minutes.

The workload recommended by Astrand[3] for male subjects was 900 kilopond metres per minute (kpm/min). The workload was not constant for all subjects however. Some of the subjects rode at a load of 1050 or 1200 kpm/min while others rode at 600 or 750 kpm/min. Heart rate was the factor used to determine the workload for each subject. Astrand required that the mean value of the final two heart rates be within a range of 130 to 160 bpm. The workloads were adjusted accordingly. The highly trained subjects usually rode at a higher load while the less fit subjects rode at a lesser workload.

The workload was adjusted on the bike with the aid of the handwheel. When turned clockwise the handwheel would stretch the friction belt, causing an increased resistance to the pedaling and thereby creating a greater workload. The ride was started at

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[3]Per-Olof Astrand, Work Tests with the Bicycle Ergometer (Varberg, Sweden: Monark), p. 16.

zero kpm/min and then increased to 900 kpm/min after the pedaling had begun. It was important to check the load at least once each minute.

It was also important that the subject kept pace with the metronome, thus insuring that the total distance each subject rode was controlled. The subject made approximately fifty complete revolutions each minute.

A Gra Lab Universal Timer electric clock was used to time the ride. The clock was placed in a position which made it visible to both the subject and the investigator.

When the ride was completed the electrodes were removed and the subject was allowed to leave the laboratory.

Twelve-Minute Run Test

Phase I. The orientation phase for the Cooper twelve-minute run test was brief. All that was involved was an explanation of the purpose of the test and what it entailed. It was important to emphasize to the subjects that they remember how many laps they ran. This provided a double check with the investigator's count of the total number of laps run.

Phase II. All subjects were allowed a five minute warm-up period. During that time they were told to stretch out and run as much as they felt was necessary. As might be expected, the HLF group ran more during the warm-up period than did the LLF group.

Phase III. Before the test started each subject was given a numbered tongue depressor. A record of each subject's number was kept by the investigator. The subjects were instructed to keep the stick in their possession during the run, either by holding it in one hand or by placing it under the elastic band of their running shorts. They were also told to drop the stick to the track when the twelve minute whistle was blown.

The subjects were then gathered behind a single starting line and were asked to run within the first two inside lanes of the track. At the sound of a whistle the subjects ran and at that same time a stop watch was also started.

The test lasted for twelve minutes. The subjects tried to cover as much distance as they could during that time either by walking or running. Only three subjects walked at some time during the twelve minutes. Each time the subject completed a lap the time that had elapsed was read aloud to him.

When the twelve minute period was over, a whistle was blown signalling the end of the test. At that time the subjects dropped the numbered tongue depressors, marking the spot where they finished.

The experimenter then took a measuring wheel and marked off the number of feet each subject ran during his last partial lap. This number was recorded along with the total number of full laps each subject had run.

CHAPTER IV

ANALYSIS OF DATA

Sixteen male students at Eastern Illinois University were studied in order to determine the validity of two indirect predictors of maximum oxygen uptake. The subjects were placed into either a high fitness group or a low fitness group as defined earlier. Each subject was given a treadmill test, a bicycle ergometer test, and a twelve-minute run test. The results of the bicycle ergometer test and the twelve-minute run test were compared to the treadmill test to determine their validity. All raw data is presented in Appendices A and B.

DATA CONVERSION

In order to analyze the data, in some instances, raw scores were converted into more meaningful units.

The body weight scores were converted to kilograms by weighing each subject to the nearest half pound and then dividing by 2.2.

The maximum oxygen uptake scores were obtained through separate techniques. In the treadmill test, the maximum oxygen uptake scores were obtained directly through the method developed by

Johnson.[1] The scores were converted to Standard Temperature and Pressure Dry (S.T.P.D.) and expressed in liters per minute (L/min) and/or milliliters per kilogram of body weight per minute (ml/kg/min). The heart rates obtained in the bicycle ergometer test were transformed into predicted maximum oxygen uptake scores (ml/kg/min) via the tables established by Astrand.[2] In the twelve-minute run test, oxygen uptake values were obtained by converting the total distance run into ml/kg/min through the use of the mathematical formula ($V_{O_2} = \frac{\text{Distance run} - 0.3138}{0.0278}$) established by Cooper.[3]

STATISTICAL TREATMENT

Two types of statistical treatments were applied to the data collected in the study. The *t* test for small samples was applied to determine any statistically significant differences between means. The Pearson Product Moment method of correlation was utilized to ascertain what relationships, if any, existed between the variables. The computations were made on the IBM 360 Model H Computer. The .05 level of confidence was selected to denote statistical significance.

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[1]Robert E. Johnson, Francis Robbin, and others, "A Versatile System for Measuring Oxygen Consumption in Man", *Journal of Applied Physiology*, XXII (February, 1967), pp. 377-379.

[2]P.O. Astrand and I. Rhyming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate during Submaximal Work", *Journal of Applied Physiology*, XII (February, 1954), p. 218.

[3]K. Cooper, "Correlations Between Field and Treadmill Testing as a Means of Assessing Maximal Oxygen Intake", *Journal of American Medical Association*, CCIII (February, 1968), pp. 201-203.

FINDINGS

A complete summary of the findings was listed in Tables II and III. Table II shows the results of the t tests and Table III presents the results of the correlations.

t Tests

HLF Group. The mean scores from the bicycle ergometer test, the twelve-minute run test, and the treadmill test were compared. There was no statistically significant differences between the means.

LLF Group. The means of the bicycle ergometer test and the twelve-minute run test were compared to each other and to the mean of the treadmill test. There were no statistically significant differences between the means of the bicycle ergometer test and the twelve-minute run test or the twelve-minute run test and the treadmill test. However there was a significant difference of 3.643 between a mean of 48.38 from the treadmill test and a mean of 43.00 from the bicycle ergometer test.

All Subjects. The raw data for all subjects was combined. The means of the bicycle ergometer test, the twelve-minute run test, and the treadmill test were compared. There were no statistically significant differences between the means.

Correlations

HLF Group. The results of the bicycle ergometer test, the twelve-minute run test, and the treadmill test were correlated.

TABLE II

THE t TEST RESULTS INVOLVING THE TREADMILL TEST, THE BICYCLE ERGOMETER TEST, AND THE TWELVE-MINUTE RUN TEST

Group	T. M. Mean	T. M. S.D.	B. E. Mean	B. E. S.D.	12-Min. Mean	12-Min. S.D.	t Test
High Fitness	63.82	2.72	66.44	5.99	--	--	1.066
High Fitness	63.82	2.72	--	--	66.13	4.25	1.545
High Fitness	--	--	66.44	5.99	66.13	4.25	0.142
Low Fitness	48.38	7.85	43.00	5.01	--	--	3.643*
Low Fitness	48.38	7.85	--	--	47.51	9.83	0.380
Low Fitness	--	--	43.00	5.01	47.51	9.83	1.492
All Subjects	56.10	9.79	54.72	13.23	--	--	0.802
All Subjects	56.10	9.79	--	--	56.82	12.08	0.517
All Subjects	--	--	54.72	13.23	56.82	12.08	1.109

* Denotes significance at .01 and .05 levels of confidence

TABLE III

A SUMMARY OF THE CORRELATIONS BETWEEN THE TREADMILL TEST, THE BICYCLE ERGOMETER TEST, AND THE TWELVE-MINUTE RUN TEST

Group	Variables	Correlations
High Fitness	T. M. vs B. E.	-0.146
High Fitness	T. M. vs 12-Min.	0.330
High Fitness	B. E. vs 12-Min.	0.338
Low Fitness	T. M. vs B. E.	0.880*
Low Fitness	T. M. vs 12-Min.	0.752*
Low Fitness	B. E. vs 12-Min.	0.495
All Subjects	T. M. vs B. E.	0.862*
All Subjects	T. M. vs 12-Min.	0.892*
All Subjects	T. M. vs 12-Min.	0.824*

* Denotes significance at .01 and .05 levels of confidence

In all instances, the correlations were not statistically significant.

LLF Group. The treadmill test had statistically significant correlations of 0.880 with the bicycle ergometer test and 0.752 with the twelve-minute run test. The correlation between the bicycle ergometer test and the twelve-minute run test was not statistically significant.

All Subjects. The raw data for all subjects was combined. The significant correlations were 0.862 between the treadmill test and the bicycle ergometer test, 0.892 between the treadmill test and the twelve-minute run test, and 0.824 between the bicycle ergometer test and the twelve-minute run test.

DISCUSSION

It was the purpose of the study to determine the validity of two indirect predictors of maximum oxygen uptake. That was accomplished by establishing a high fitness group and a low fitness group and administering a treadmill test, a bicycle ergometer test, and a twelve-minute run test to each subject.

The study made no attempt to establish cause and effect. However, when discussing the findings, a few statements arrived at through observation during the investigation appear warranted.

Each of the *t* tests indicated that there was no statistically significant difference between means except in one case. That *t* test was between the means of the treadmill test and the bicycle test of the low fitness group. The fact that this occurred only in the low fitness group indicates a possible reason for its occurrence. Previous studies indicate that non-weight supported exercise makes greater demands on the body than does weight supported exercise, especially in subjects who are in poorer physical condition. This would seem to be the case in this instance. The non-weight supported exercise (treadmill test) seemed to make greater demands on the body than did the weight supported exercise (bicycle ergometer test) and thereby creating a significant difference between the means of the two tests.

The correlations obtained for both the high fitness group and the low fitness group should not be relied upon to a great extent. The size of the groups are so small that it would seem careless to make generalized statements from the limited data. The fact that the scores were clustered also prevents one from getting a clear picture of the situation. It is very easy for correlations to become distorted when working with clustered data. By combining the groups however, these problems are overcome to some extent. The correlations obtained when the groups were combined were statistically significant.

In summary, the data obtained from the sixteen male subjects indicates that the bicycle ergometer test and the twelve-minute run test were valid predictors of maximum oxygen uptake in the high fitness group and that the twelve-minute run test was also a valid predictor of maximum oxygen uptake in the low fitness group.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The study was conducted at Eastern Illinois University in Charleston, Illinois. It was undertaken during the spring quarter of the 1972-1973 academic year. The purpose of the study was to determine the validity of two indirect predictors of maximum oxygen uptake at both high and low physical fitness levels. Astrand's bicycle ergometer test and Cooper's twelve-minute run test were the two indirect predictors considered. In order to determine validity, the results of the indirect predictors were compared to a direct measurement of maximum oxygen uptake which was obtained by administering a treadmill test to each subject.

Sixteen male students from Eastern Illinois University took part in the investigation. The subjects were placed into either a high level fitness group or a low level fitness group. The eight subjects in the high level fitness group were all long distance runners from the varsity track team. The subjects had a mean age of nineteen years and a mean body weight of 62.49 kilograms. The eight subjects in the low level fitness group were students who did not regularly participate in strenuous activity. The subjects had a mean age of twenty-two years and a mean body weight of 71.82 kilograms.

The three different tests were administered to each subject within a fifteen day period. The subjects were never tested on ccessive days, and no more than five days elapsed between tests. The order in which the tests were given was intentionally varied between the subjects. This procedure was employed to eliminate any training or learning effect.

Although the tests were different in nature, the procedures involved in administering the tests consisted of three similar phases. The general phases were an orientation phase, a warm-up phase, and the actual testing phase. This general procedure was applied to each test.

The treadmill test was given on an A.R. Young Treadmill. The workload varied between and within the two groups. The HLF group was asked to run at nine miles per hour on a 8.6 per cent grade for six minutes while the LLF group was asked to run at a seven mile per hour pace at the same grade and for the same length of time. During the course of the test, two thirty second samples of the subject's expired air were taken. The expired air samples were then analyzed by a Beckman Model E_2 Oxygen Analyzer and a Beckman LB-1 Medical Gas Analyzer to determine oxygen and carbon dioxide content.

The bicycle ergometer test was given on a Monark bicycle ergometer. The test lasted for six minutes with heart rates taken within the last ten seconds of each minute. If the difference between the fifth and sixth minute heart rates exceeded five beats per minute the riding time was extended. The workload was originally set at 900 kilopond meteres per minute. This load was either raised or lowered if the subject's heart rate did not fall within a range of 130 to 160 beats per minute. Each subject rode the bike at a pace of approximately fifty complete revolutions per minute.

The twelve-minute run test was given on the outdoor track at Eastern Illinois University. The subjects were told to cover as much distance as they possibly could during the twelve-minute period. The total distance each subject ran was recorded by the investigator.

A student t test was used to describe statistically significant differences between means on the various tests. The Pearson Product Moment method of correlation was also used to investigate what relationships, if any, existed between the variables. The .05 level of confidence was selected to denote statistical significance.

CONCLUSIONS

Based on the findings of the investigation the following conclusions appear to be warranted:

1. The Cooper twelve-minute run test is a valid indirect predictor of maximum oxygen uptake at both high and low physical fitness levels.

2. The Astrand bicycle ergometer test is a valid indirect predictor of maximum oxygen uptake at a high physical fitness level.

3. The Astrand bicycle ergometer test is not a valid indirect predictor of maximum oxygen uptake at a low physical fitness level.

RECOMMENDATIONS

The following recommendations are presented as a result of the study:

1. Another study of this nature could be conducted using subjects of an older age range.

2. Further studies should be undertaken to test the validity of other measures of cardiovascular fitness such as the step-test or the 600 yard run.

3. A more extensive study of this nature should be conducted using women as the subjects.

4. Another study of this nature should be conducted with more subjects and with a broader spectrum of fitness levels.

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APPENDIXES

APPENDIX A

MAXIMUM OXYGEN UPTAKE SCORES FROM THE LOW FITNESS GROUP

SUBJECT	TREADMILL (ml/kg/min)	BICYCLE ERGOMETER (ml/kg/min)	12-MIN. RUN (ml/kg/min)
1	49.68	40.00	50.14
2	43.85	37.00	50.28
3	49.79	46.00	52.38
4	47.57	44.00	44.54
5	53.26	45.00	60.68
6	32.90	36.00	26.17
7	60.29	51.00	48.54
8	49.74	45.00	47.36

APPENDIX B

MAXIMUM OXYGEN UPTAKE SCORES FROM THE HIGH FITNESS GROUP

SUBJECT	TREADMILL (ml/kg/min)	BICYCLE ERGOMETER (ml/kg/min)	12-MIN. RUN (ml/kg/min)
1	64.99	67.00	69.65
2	64.24	70.00	69.65
3	60.18	68.00	63.68
4	65.58	74.00	70.37
5	62.17	61.00	69.53
6	64.14	72.25	63.71
7	60.77	63.00	58.75
8	68.51	56.25	63.71

VITA

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The writer was born in Hammond, Indiana on January 25, 1949. His family moved to Highland Park, Illinois in 1956. He attended Highland Park High School and participated in football and baseball four years. He was selected as a member of the National Honor Society his senior year. He was also awarded all conference honors his junior and senior years in baseball and was named to an all-state team in football his senior year.

He accepted a four year baseball scholarship to Southern Illinois University in Carbondale. He received a Bachelor of Science degree from there with a major in physical education. In his senior year he was named to the NCAA University Division third all-american team. In June, 1971 he signed as a free agent with the Kansas City Royals baseball organization. He played one season with their Kingsport, Tennessee franchise.

In February, 1972 he married the former Laura Katherine Winston. In May of that same year he accepted a graduate assistantship in physical education at Eastern Illinois University. He expects to complete requirements for a Master of Science degree in August, 1973.

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