UNIVERSITY OF MANITOBA

THE RELATIONSHIP BETWEEN PREDICTED $\dot{V}O_2$ MAX AND TIME IN THE 1600-METER RUN

by

Marilyn Harris

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Physical Education

Winnipeg, Manitoba 1986

ISBN 0-315-34011-8

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ABSTRACT

The purpose of the present research was to investigate the relationship between $\dot{V}O_2$ max as predicted by the Astrand-Ryhming procedure modified by Mocellin et al. and time in the 1600-meter run. Forty-five 10-year-old girls were tested twice on a bicycle ergometer following the protocol outlined by Astrand and twice in the 1600-meter run. Maximum oxygen uptake values were determined from work load and heart rate.

The mean predicted $\dot{V}O_2$ max value obtained, 36.71 $ml \cdot kg^{-1} \cdot min^{-1}$, was similar to values found by some researchers but lower than those found by many others. The lower value reported in this study might be due to the fact that the subject sample was representative of the population - girls of varying physiques and fitness levels were included in the sample. Many investigators study only athletes and report high $\dot{V}O_2$ max values. The reliability coefficient for the modified Astrand-Ryhming test was low, 0.59. The interpretation of the results of this test should be used with caution.

The mean time in the 1600-meter run was 624 sec. This finding was similar to the results of other researchers. The 1600-meter run was found to be a reliable test. A coefficient of reliability of 0.95 was obtained.

A low correlation was found between predicted $\dot{V}O_2$ max and time in the 1600-meter run (0.44). Multiple linear regression analysis was performed on the data to predict $\dot{V}O_2$ max from height, weight, pretest heart rate and 1600-meter run time. Height, weight and pretest heart rate were not found to have a significant relationship to predicted $\dot{V}O_2$ max. A regression analysis was done to predict maximum oxygen uptake from time as the only independent variable. Because the R^2 value obtained was low (0.19), the use of the regression equation was not advocated.

ACKNOWLEDGEMENTS

This author would like to express appreciation to the members of my committee, Dr. Elizabeth Ready and Dr. Keith Wilson, for their assistance in the preparation of this thesis, to Mr. Jit Tan for his help in the statistical analysis of the data, and to my advisor, Dr. Wendy Dahlgren, for her constant support, encouragement and guidance throughout my graduate program.

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INTRODUCTION

In recent years, a renewed interest in physical fitness has been reflected in the on-going development of physical education programs. Paralleling this interest has been the refinement of measurement techniques evaluating physical fitness status. The most highly regarded and frequently used criterion of physical fitness is maximum oxygen uptake, or $\dot{V}O_2$ max (Astrand, 1952; Balke & Ware, 1960). The measurement of $\dot{V}O_2$ max is normally obtained under laboratory conditions. Laboratory measures of maximum oxygen uptake may be determined through varying methods. Some researchers use the bicycle ergometer (Astrand, 1952; Teraslinna, Ismail & MacLeod, 1966; Mocellin et al., 1971) while others utilize the treadmill (Shephard et al., 1969; Hermansen & Oseid, 1971). The rate of work may be progressive or steady-state (Gadhoke & Jones, 1969; Fernandez, 1974; Thompson, 1977). Differences can also be seen in the duration of work loads (Astrand, 1954; Shephard et al., 1969; Gillam et al., 1969) and rest intervals (Astrand, 1954; Rodahl et al., 1961).

Although test measurements of maximum oxygen uptake are known to be reliable (Rowell, Taylor & Wang, 1964; Saltin & Astrand, 1967), a serious limitation has been the impractical nature of the testing procedures. The estimation of maximal aerobic capacity by the conventional method of measuring oxygen uptake is costly in terms of procedure, time requirements, personnel involved and laboratory equipment. The procedure requires maximal effort and considerable motivation on the part of the subjects. Consequently, it is not commonly used with young individuals. While the direct measurement of maximum oxygen uptake of children can be made, it is infeasible for use for mass testing.

To simplify methods of determining $\dot{V}O_2$ max, several indirect submaximal methods of estimating oxygen consumption have been developed (Astrand, 1952; Maritz et al., 1961; Margaria, Aghemo & Rovelli, 1965). Perhaps the most frequently applied submaximal aerobic capacity test is the Astrand-Ryhming test. In 1954, Astrand and Ryhming presented a nomogram for the prediction of the aerobic capacity of healthy individuals aged 18 to 30 years. The prediction was made using only pulse and workload on a bicycle ergometer. Age and weight factors were introduced later (Astrand, 1960). This test can be easily administered in schools and safely used in the testing of children.

Unfortunately, the individual testing of students is time-consuming. To facilitate the testing of large groups, several authorities have attempted to develop field tests that correlate highly with laboratory determined oxygen consumption values. Balke (1963) was the first to develop a field test based upon a distance run in a given period of time - a 15-minute run-walk test. Cooper

(1968) proposed a modification of this test which employed a 12-minute running period. The Canada Fitness Award program, a series of tests often used in Canadian schools, utilizes timed 800-, 1600- or 2400-meter runs, the distance dependent upon the age of the subject. In recent years, the relationship between timed runs and predicted $\dot{V}O_2$ max has been investigated (Shvartz et al., 1973; Custer & Chaloupka, 1978; Johnson, Oliver & Terry, 1979). Much of this research has been conducted using adults as subjects. The practice of generalizing the findings derived from adult populations to school-aged populations violates the basic principles of reliability and validity. The need exists to investigate valid, easy to administer, submaximal tests of $\dot{V}O_2$ max for school-aged populations.

Statement of the Problem

The primary purpose of this study was to investigate the relationship between $\dot{V}O_2$ max as predicted by the Astrand-Ryhming test modified by Mocellin et al. (1971) and time in the 1600-meter run using 10-year-old girls as subjects. A secondary purpose was to examine the reliability of the Astrand Ryhming test in athletic and non-athletic subjects.

Delimitations

A number of restrictions may have influenced the results of this study:

1. Testing was limited to 10-year-old girls.
2. The sample size was restricted to 45 subjects.
3. The study was concerned with the comparison of 2 indirect tests of aerobic capacity - Astrand-Ryhming test as modified by Mocellin et al. (1971) and the 1600-meter run test.

Definition of Terms

Bicycle Test - as used in this study refers to the Astrand-Ryhming tests as modified by Mocellin et al. (1971).

Cardio-respiratory endurance - the ability of the lungs and heart to take in and transport adequate amounts of oxygen to the working muscles, allowing activities that involve large muscle masses to be performed over long periods of time.

Direct (maximal) tests of aerobic capacity - the direct assessment of oxygen uptake, normally utilizing the Douglas bag method, during maximal work.

Indirect (submaximal) tests of aerobic capacity - the indirect of assessment of oxygen uptake during submaximal work, the prediction based upon the relationship between exercise pulse rate and the corresponding oxygen consumption or equivalent work load.

Kilopond (kp) - one kilopond is the force acting on a mass of 1 kilogram at normal acceleration of gravity.

Maximal Oxygen Uptake, or Maximal Aerobic Power - the highest oxygen uptake that the individual can attain during physical work breathing at sea level (Astrand, 1971).

Nomogram - a graph enabling one to determine by aid of a straight-edge the value of a dependent variable when the values of independent variables are known.

Chapter 2

REVIEW OF RELATED LITERATURE

Considerable significance has been attached to the importance of maximum oxygen uptake as a predictor of physical performance capacity. Over the years, many investigators have endorsed the measurement of maximum oxygen uptake as being superior to any other test evaluating physical fitness (De Vries, 1966; Astrand & Rodahl, 1970). Support for this statement has been given by numerous studies which have investigated the relationship between $\dot{V}O_2$ max and physical performance (Taylor & Brozek, 1944; Astrand, 1952; Balke & Ware, 1960).

Associated with the significance of maximum oxygen uptake as an important predictor of endurance performance capacity have been attempts to determine oxygen uptake ability. One of the most notable and generally accepted tests used to predict $\dot{V}O_2$ max has been the Astrand-Ryhming bicycle test (Astrand & Ryhming, 1954) and the associated nomogram (Astrand, 1969). Although the prediction of $\dot{V}O_2$ max using this procedure has been found to be acceptable (DeVries & Klafs, 1965; Teraslinna et al., 1966; Terry et al., 1977), the underestimation of oxygen uptake by this method has been a source of concern to several investigators (Wyndham et al., 1959; Glassford et al., 1965; Mocellin et al., 1971).

In order to equalize the difference between directly and indirectly determined $\dot{V}O_2$ max, Mocellin et al. (1971) modified the Astrand-Ryhming test. This modification was designed to be used in studies using children as subjects. Mocellin and his colleagues compared the values obtained by the direct measurement of oxygen uptake and the values found by the Astrand-Ryhming test and noted that oxygen uptake was underestimated by 14.5% when the indirect procedures, the Astrand-Ryhming test, was used. By multiplying the indirect values obtained by a factor of 1.17, Mocellin et al. were able to estimate maximum oxygen uptake with nearly equal accuracy to the direct method of determination. The factor 1.17 was obtained using the following equation: 1 - (1 - 0.145) = 1.17. Thus: directly measured $\dot{V}O_2$ max = 1.17 x predicted $\dot{V}O_2$ max.

In order to fully examine the relationship between predicted maximum oxygen uptake and physical performance capacity, the following topics will be discussed:

1. the Astrand-Ryhming test and the prediction of $\dot{V}O_2$ max
    a. adult subjects
    b. school-aged subjects
2. field tests of physical performance and $\dot{V}O_2$ max
    a. adult subjects
    b. school-aged subjects
3. the relationship between predicted $\dot{V}O_2$ max and field tests
    a. adult subjects
    b. school-aged subjects

1. The Astrand-Ryhming Test and the Prediction of $\dot{V}O_2$ Max

A variety of tests have been developed to estimate endurance performance capacity. The most frequently applied submaximal (or indirect) test is the Astrand-Rhyming test. This test predicts maximum oxygen uptake using work load and submaximal heart rate. The test prediction depends essentially upon the fact that the rate of oxygen uptake and the rate of work are linearly related up to a level of work at which a further increase in the rate of work does not produce any rise in the rate of oxygen consumption. The curve is said to "flatten out". Astrand (1952), however, has observed that in a number of his subjects, the anticipated leveling off of the curve did not occur. Hence, the predicted maximum oxygen uptake was underestimated by the procedures. This under prediction has been noted when the Astrand-Ryhming test was used in studies using either adults or children as subjects.

A. Adult Subjects

The Astrand-Ryhming test has been found to be a valid test of oxygen uptake. Astrand and Ryhming (1954) reported a validity coefficient of 0.17 and a 10% standard error. In 1960, an age factor was introduced (Astrand) and a validity coefficient of 0.78 was obtained with a standard error of 15%.

Results of the study by Rowell, Taylor and Wang (1964) are in close agreement with those of Astrand. A validity coefficient of

0.76 was reported. The observed $\dot{V}O_2$ max was underestimated by only 5.6% when this measurement was predicted from the Astrand-Ryhming nomogram. Rowell and his associates concluded that the nomogram provided a reasonably accurate prediction of $\dot{V}O_2$ max. They also found the predicted oxygen uptake values to be more accurate when trained athletes were used as subjects.

Glassford et al. (1965) compared the Astrand-Ryhming test with 4 directly determined maximum oxygen uptake tests. Correlation coefficients between oxygen uptake values in these 4 tests and the value obtained by the Astrand-Ryhming test ranged between 0.65 and 0.78 and were found to be significant. Maximum oxygen uptake was underestimated by approximately 8% by the Astrand-Ryhming test. Glassford and his associates attributed this to local muscular fatigue. The total muscle mass used in the bicycle test is, in all likelihood, not equivalent to that used in treadmill running. They concluded, however, that the Astrand-Ryhming nomogram produces a good estimation of $\dot{V}O_2$ max.

The purpose of the study by Teraslinna et al. (1966) was to obtain a validity coefficient for the Astrand-Ryhming nomogram. They found an uncorrected correlation coefficient of 0.69 which agreed with that of Astrand (1954). When corrected for age, the value of the coefficient rose to 0.92. The researchers concluded that the nomogram by Astrand and Ryhming is a satisfactory predictor of maximum oxygen uptake.

DeVries and Klafs (1965) evaluated 6 commonly used tests, including the Astrand-Ryhming nomogram, against directly measured

$\dot{V}O_2$ max. The nomogram showed a correlation of 0.74 with measured maximum oxygen uptake. The investigators concluded that $\dot{V}O_2$ max could be estimated with reasonable error of prediction from submaximal tests. The analysis of the data demonstrated that tests in which heart rate is measured during work load, such as the Astrand-Ryhming test, appear to have a greater predictive ability than those using recovery heart rate. The closest predictive values to directly measured oxygen uptake were obtained from the Astrand-Ryhming test.

The results of the study by Terry et al. (1977) are in agreement with the findings of Astrand and Ryhming (1954). A validity coefficient of 0.65 was obtained. This validity coefficient was slightly lower than is usually reported. The researchers felt that this may have been due to the relatively homogeneous nature of the volunteer sample. Terry and his associates concluded that the prediction of maximum oxygen uptake using the Astrand-Ryhming test is clinically acceptable.

The underprediction of $\dot{V}O_2$ max has been a source of concern to several researchers. Wyndham et al. (1959) criticized the Astrand-Ryhming nomogram because it is based on a rectilinear relationship between heart rate and oxygen consumption. It appears that after maximum heart rate is reached, the oxygen uptake continues to rise. This would account for the tendency of the nomogram to underestimate the maximum value of oxygen uptake. Wyndham noted an intra-individual variation in heart rate of 10% at low intensities. This large variability may have an important effect on the accuracy of predicted values. The error of the nomogram decreased when heart rates near 160/beats min were obtained.

The findings of the studies involving adults as subjects indicate that the Astrand Ryhming test is a good estimator of maximum oxygen uptake. The validity coefficients for this test have been reported as ranging between 0.63 and 0.92 (Glassford et al., 1965; Teraslinna et al., 1966; Terry et al., 1977). A summary of the validity coefficients obtained in studies with adults as subjects is given in Table 1.

B. School-aged Subjects

Hermansen and Oseid (1971) studied the accuracy of the Astrand-Ryhming method in school-aged children. The predicted values for $\dot{V}O_2$ max were found to be 15% lower than observed direct values. When the values were corrected for differences in maximal heart rate, the difference was reduced to 11%. Hermansen and Oseid noted that although there was a fairly good agreement between average values obtained for the whole group by direct and indirect methods of determination, the intra-individual differences were considerable.

The Astrand-Ryhming test was modified by Mocellin et al. (1971) in order to correct for the tendency of the nomogram to underpredict $\dot{V}O_2$ max. The predicted results from the modified procedure were compared to those directly obtained by treadmill

Table 1. Validity coefficients (v) of the Astrand - Ryhming test with adults as subjects

Author	V
Astrand & Ryhming (1954)	
(uncorrected)	0.71
(corrected for age)	0.78
Rowell et al. (1964)	0.76
Glassford et al. (1964)	0.78
DeVries & Klafs (1965)	0.69
Teraslinna et al. (1966)	
(uncorrected)	0.69
(corrected for age)	0.92
Terry et al. (1977)	0.65

exercise. The coefficient of reliability for the indirect method, 0.91 proved to be better than that found for the direct method, 0.87. The validity coefficient for the modified procedure was 0.78 which was similar to indices obtained by Astrand (1960) at 0.78, Rowell et al. (1964) at 0.76, Glassford et al. (1965) at 0.78, and Davies (1968) at 0.80. Mocellin and his colleagues concluded that $\dot{V}O_2$ max could be estimated by the modified Astrand-Ryhming procedures with nearly equal accuracy to direct methods of determination.

Gutin, Keith & Stewart (1976) studied 20, 10- to 12-year-old children and compared the $\dot{V}O_2$ max obtained by treadmill exercise and by the Astrand Ryhming test as modified by Mocellin et al. (1971). The predicted value, 52.2 $ml \cdot kg^{-1} \cdot min^{-1}$, overestimated the directly measured maximum oxygen uptake value of 47.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Predicted $\dot{V}O_2$ max was not closely related to directly measured $\dot{V}O_2$ max, a correlation of only 0.50 being found between the two measures. Gutin et al. concluded that predicted $\dot{V}O_2$ max provided little information regarding aerobic power.

As stated above, the studies involving adults as subjects showed that oxygen uptake is underestimated by the Astrand-Ryhming test. Research on children demonstrated a similar trend. Mocellin et al. (1971) modified the Astrand-Ryhming procedure and found that the modification allowed for a nearly equal indirect measurement of $\dot{V}O_2$ max as compared to directly measured values. Gutin and his colleagues (1976) investigated the modification of the

Astrand-Ryhming test and did not concur with the findings of Mocellin et al. The validity and reliability coefficients obtained in these studies are presented in Table 2.

2. Field Tests of Physical Performance and $\dot{V}O_2$ Max

A variety of distance run tests have been used to evaluate physical fitness. The distance run varies from 600 yards to 5 miles in length. Studies have demonstrated that distance run tests are reliable and provide stable, measurable construct (Falls, Ismail & MacLeod, 1966; Katch et al., 1973; Disch, Frankiewicz & Jackson, 1975). Research indicates that the relationship between performance in timed runs and maximal oxygen uptake improves as the distance is increased. For distances of 400 yards or less, the correlation coefficient is not significantly different from zero. The magnitude of the correlation between $\dot{V}O_2$ max and runs of a mile or longer, or the 12-minute run, has varied considerably but is significantly different from zero. Conflicting results have been reported for distances between 400 yards and 1 mile.

A. Adult Subjects

Many researchers have investigated running tests of endurance performance using adults as subjects. Ribisl and Kachadorian (1969) evaluated college males in a variety of timed runs between

Table 2. The validity coefficients (v) and reliability coefficient (r) obtained for the modified Astrand-Ryhming test with children as subjects.

Author	V	R
Mocellin et al. (1971)	0.78*	0.91*
Gutin et al. (1976)	0.50*	–

* Significant beyond the 0.05 level of confidence.

60 yards and 2 miles. They found that times in the mile and 2-mile runs were significantly related to directly measured maximum oxygen uptake. Correlations of -0.79 and -0.85 were reported.

This is consistent with the findings of Shaver (1975) who timed 18- and 26-year-old males in runs ranging from 100 yards to 3 miles. He concluded that the 2-mile and 3-mile runs were good predictors of maximum oxygen uptake, r=-0.76 and r=-0.82, but that the 880-yard and mile runs should be used with caution.

Timed shorter distances were investigated by Falls and his associates (1966) and by Shvartz et al.(1973). Falls et al. tested 87 males aged 23 to 58 years in the 600-yard run-walk and reported a correlation of -0.64 with directly measured $\dot{V}O_2$ max. Shvartz et al. examined the relationship between a timed kilometer run and predicted maximum oxygen uptake using 17- to 19-year-old males as subjects. The correlation coefficient found was -0.34. These correlations are lower than those obtained in the longer distances.

In a study of college males, Katch and Henry (1972) found a correlation of -0.55 when comparing 2-mile run times with directly measured $\dot{V}O_2$ max. Wiley and Shaver (1972) also studied the 2-mile, as well as the 3-mile run, and reported values of -0.43 and -0.47 respectively between directly determined maximum oxygen uptake and the run times of college men. The correlation coefficients obtained were lower than those found by Ribisl and Kadchadorian (1969) and Shaver (1975).

Costill (1967) found a direct relationship between maximum oxygen uptake and performance in a 4.7-mile run. College male cross-country runners were tested and a correlation coefficient of -0.83 was found between the 2 measures. The results of the study by Costill (as well as those by the previous investigators) indicate that the correlation coefficient between $\dot{V}O_2$ max and running performance generally increases with increasing distances.

Kearney and Byrnes (1974) tested male physical education majors in the 1/2-mile, mile, and 12-minute runs. The correlations found between performance time in these runs and predicted $\dot{V}O_2$ max (r=-0.30, r=-0.59, and r=0.64) improved as the length of the run increased.

The relationship between predicted maximal oxygen consumption and running performance in the 12-minute run was examined by Custer and Chaloupka (1978) in their study of college females. The magnitude of the difference between the correlations of the 6-minute run, 0.45, and the 12-minute run, 0.49, was not significant. They concluded that the 6-minute run could be used instead of the 12-minute run as a measure of cardio-respiratory endurance.

Cooper (1968) tested adult males aged 17 to 52 years in the 12-minute run. He reported a correlation of 0.90 between performance in the 12-minute run and maximal oxygen consumption. Cooper advocated the use of the 12-minute run as a predictor of $\dot{V}O_2$ max.

Katch (1970), however, found a correlation of only 0.54 between 12-minute run performance and $\dot{V}O_2$ max in his study of college males. Gregory (1970) also used college males as subjects when he compared the 12-minute run to maximal oxygen consumption. He found a correlation of r=0.66 between the two measures of performance. The correlation coefficients reported by Katch and Gregory are considerably lower than the 0.90 value found by Cooper.

The results of the study by Johnson, Oliver and Rerry (1979) give support to Cooper's investigation. Eighteen- to 29-year-old male and female subjects were tested in Cooper's 12-minute run test by Johnson et al. Correlations between time in the run and predicted $\dot{V}O_2$ max were 0.90 for males and 0.91 for females.

A summary of this research can be found in Table 3. While the results of these tests are sometimes conflicting, the findings generally indicate that the relationship between performance in timed runs and maximum oxygen uptake improves as the distance is increased and that running performance in distances longer than a mile is a good predictor of maximum oxygen uptake.

B. <u>School-aged Subjects</u>

The relationship between performance in timed runs and $\dot{V}O_2$ max has been investigated in school-aged populations. As can be seen in the studies using adult subjects, results indicate that the correlation between $\dot{V}O_2$ max and running performance improves with increasing distance.

Table 3. Correlations between running tests and maximum oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) in studies using adults as subjects

Researcher	Number in sample	Composition of sample	Distance run	Correlation
Katch & Henry (1972)	35	College males	100 yd	-0.10
Ribisl & Katchadorian (1969)	11	College males	100 yd	-0.23
Wiley & Shaver, (1972)	35	College males	440 yd	-0.22
Ribisl & Katchadorian (1979)	11	College males	440 yd	-0.31
Falls et al. (1966)	87	Males 23-58	600 yd	-0.64
Ribisl & Katchadorian (1969)	11	College males	880 yd	-0.67
Kearney & Byrnes (1974)	10	Physed majors	880 yd	-0.30
Shaver (1975)	30	Males 18-26	880 yd	-0.35
Shvartz et al. (1973)	44	Males 17-19	1 km	-0.34
Shaver (1975)	30	Males 18-26	1 mi	-0.43
Wiley & Shaver (1972)	35	College males	1 mi	-0.29
Kearney & Byrnes (1974)	10	Physed majors	1 mi	-0.59
Ribisl & Katchadorian (1969)	11	College males	1 mi	-0.79
Katch & Henry (1972)	35	College males	2 mi	-0.55
Ribisl & Katchadorian (1969)	11	College males	2 mi	-0.85
Ribisl & Katchadorian (1969)	24	Adult males	2 mi	-0.86
Wiley & Shaver (1972)	35	College males	2 mi	-0.47
Shaver (1975)	30	Males 18-26	2 mi	-0.76
Shaver (1975)	30	Males 18-26	3 mi	-0.82
Wiley & Shaver (1972)	35	College males	3 mi	-0.43
Costil (1967)	17	College males	4.7 mi	-0.83
Kearney & Byrnes (1974)	17	Runners	5 mi	-0.38
Custer & Chaloupka (1978)	40	College women	6 min	0.45
Custer & Chaloupka (1978)	40	College women	12 min	0.49
Burris (1970)	30	College women	12 min	0.74
Gregory (1974)	-	College males	12 min	0.66
Cooper (1968)	115	Males 17-52	12 min	0.90
Jessup et al. (1975)	40	College males	12 min	0.34
Katch (1970)	50	College males	12 min	0.54
Katch et al. (1973)	36	College women	12 min	0.67
Kearney & Byrnes (1974)	34	College women	12 min	0.63
Johnson et al. (1979)	100	Males	12 min	0.90
Johnson et al. (1979)	50	Females	12 min	0.91

Krahenbuhl et al. (1977) investigated the relationship between timed 600-yard, 3/4-mile and mile runs and directly determined $\dot{V}O_2$ max in grade 3 children. They found the mile run to be the best predictor of $\dot{V}O_2$ max among those studied, r=-0.62.

In a subsequent study, Krahenbuhl and his colleagues (1978) found the 1600-meter run to be a useful test in evaluating the cardiovascular fitness of primary school children. They examined the 800-, 1200- and 1600-meter runs and found only the correlations of -0.60 for boys and -0.75 for girls between performance time in the 1600-meter run and directly measured $\dot{V}O_2$ max to be acceptable.

Low correlations for shorter distances have been reported by Metz and Alexander (1970) in their investigation of the relationship between maximal aerobic work capacity and physical fitness in 12- to 15-year-old boys. Correlations between directly determined maximum oxygen uptake and time in the 600-yard run-walk were -0.66 for the 12- to 13-year-old group and -0.27 for the 14- to 15-year-old group. Neither correlation was significant. The difference in the correlations between the 2 groups was attributed to the lower motivation of some of the older subjects and to the onset of puberty. Metz and Alexander suggested that a modification of the test was necessary in order to better assess the aerobic capacity of adolescents of that age.

A study by Orlee (1955) assessing the validity of the 600-yard run-walk test also showed low values. A validity coefficient of

-0.53 was found between performance time and directly measured $\dot{V}O_2$ max for the boys tested, 16 to 17 years of age.

Vodak and Wilmore (1975) examined the validity of both the 6-minute job-walk and the 600-yard run-walk in estimating endurance capacity in boys 9 to 12 years of age. Directly measured $\dot{V}O_2$ max correlated 0.50 with the 6-minute job-walk and -0.50 with the 600-yard run-walk. These tests were considered to be poor predictors of $\dot{V}O_2$ max with that age group.

The 9-minute run was found to be a suitable test for predicting maximum oxygen uptake in the study by Jackson and Coleman (1976). A maximum uptake test and the 9- and 12-minute runs were administered to 22 boys and 25 girls at the grades 4, 5, and 6 levels. The distance run tests were significantly correlated with maximum oxygen uptake. Identical correlation coefficients were found between these variables in both the 9- and 12-minute runs. Correlations of 0.82 for boys and 0.71 for girls were reported. The investigators supported the use of the 9-minute run since the additional 3 minutes of the 12-minute run did not improve the validity over the 9-minute test.

Doolittle and Bigbee (1968) studied 153 ninth grade boys in the 12-minute run and the 600-yard run-walk and found the 12-minute run to be a highly reliable and valid measure of directly determined maximum oxygen uptake. Reliability and validity coefficients of 0.94 and 0.90 were reported. A lower validity coefficient of 0.62 was found for the 600-yard run-walk.

A variety of field tests including the 12-minute, 600-yard, 1200-yard and 1800-yard runs were compared to $\dot{V}O_2$ max by Gutin et al. (1976). Correlations of 0.75, -0.71, -0.81 and -0.76 were found between directly measured maximum oxygen uptake and run performance. Gutin and his associates concluded that a run of about 1200 yards is an adequate measure of aerobic capacity.

Martens (1978) compared 4 cardiovascular fitness tests including the 9-minute and the mile run. The tests were administered to 33 grades 4, 5 and 6 boys and girls. Correlations between the 9-minute run and the mile run were found to be significant. Martens concluded that both tests were good measures of aerobic capacity for that age group.

The findings of Martens were not supported by Maksud and Coutts (1971) or Goode et al. (1976). Maksud and Coutts studied the 12-minute run-walk test with 80 boys, 11 through 14 years of age. The correlation coefficient of 0.65 between run time and directly measured $\dot{V}O_2$ max was statistically significant, but not high enough for predictive purposes. Goode et al. examined the effects of physical activity in adolescent boys and girls. Low correlations were reported between maximum oxygen uptake and both the 600-yard run-walk and the 12-minute run.

In his investigation of the determinants of distance running performance in children 7 to 12 years of age, Cureton (1977) found correlations of -0.62 and -0.66 between the 600-yard run-walk and the mile run and directly determined maximum oxygen uptake. Individual differences in distance run performance were attributed to variations in body size, body composition and running speed as well as to cardiovascular-respiratory capacity. $\dot{V}O_2$ max was not found to be the dominant factor in distance run performance.

Massicotte, Markon and Gautier (1985) studied the validity of the 800-, 1600- and 2400-meter endurance runs as measures of aerobic capacity using 573 Quebec children as subjects. For boys and girls 6 to 9 years of age, correlations of -0.69 and -0.75 between time in the 800-meter run and directly measured $\dot{V}O_2$ max were reported. Correlations of -.065 and -0.67 were found for the 10 to 12 age group and -0.71 and -0.76 for the 13 to 17 age group between $\dot{V}O_2$ max and the 1600- and 2400-meter runs respectively. The analysis of their data indicated that these endurance runs provide an adequate measure of $\dot{V}O_2$ max.

A summary of this research can be found in Table 4. As was seen in the research using adults as subjects, studies demonstrate that the relationship between running performance and maximum oxygen uptake improves as the distance run is increased. Performance in runs of a mile or longer, or in the 12-minute run, is generally found to be significantly related to $\dot{V}O_2$ max.

3. The Relationship Between Predicted $\dot{V}O_2$ Max and Field Tests

Distance running has been reported as being a good predictor of directly determined uptake. A number of researchers have also investigated the relationship between running performance and

Table 4. Correlations between running tests and maximum oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) in studies using children as subjects

Researcher	Number in sample	Composition of sample	Distance run	Correlation
Doolittle & Bigbee (1968)	153	Boys, gr 9	600 yd	-0.62
Metz & Alexander (1970)	30	Boys, 12-13	600 yd	-0.66
Metz & Alexander (1970)	30	Boys, 14-15	600 yd	-0.27
Gutin et al. (1976)	20	Children,10-12	600 yd	-0.71
Cureton et al. (1977)	196	Children, 7-12	600 yd	-0.62
Vodak & Wilmore (1975)	69	Boys, 9-12	600 yd	-0.50
Krahenbuhl et al. (1977)	44	Children, gr 3	600 yd	-0.42
Krahenbuhl et al. (1978)	49	Boys, gr. 1-3	800 m	-0.22
Krahenbuhl et al. (1978)	34	Birls, gr 1-3	800 m	-0.50
Massicotte et al. (1985)	130	Boys, 6-9	800 m	-0.70
Massicotte et al. (1985)	122	Girls, 6-9	800 m	-0.76
Krahenbuhl et al. (1977)	44	Children, gr 3	3/4 mi	-0.56
Gutin et al. (1976)	20	Children,10-12	1200 m	-0.81
Krahenbuhl et al. (1978)	49	Boys, gr 1-3	1200 m	-0.47
Krahenbuhl et al. (1978)	34	Girls, gr 1-3	1200 m	-0.44
Massicotte et al. (1985)	63	Boys, 10-12	1600 m	-0.68
Massicotte et al. (1985)	63	Girls, 10-12	1600 m	-0.68
Massicotte et al. (1985)	21	Girls, 10	1600 m	-0.69
Krahenbuhl et al. (1978)	49	Boys, gr 1-3	1600 m	-0.60
Krahenbuhl et al. (1978)	34	Birls, gr 1-3	1600 m	-0.75
Gutin et al. (1976)	20	Children,10-12	1800 m	-0.76
Cureton et al. (1977)	196	Children, 7-12	1 mi	-0.66
Krahenbuhl et al. (1977)	44	Children, gr 3	1 mi	-0.62
Massicotte et al. (1985)	96	Boys, 13-17	2400 m	-0.72
Massicotte et al. (1985)	99	Girls, 13-17	2400 m	-0.77
Vodak & Wilmore (1975)	69	Boys, 9-12	6 min	0.50
Jackson & Coleman (1976)	22	Boys, gr 4-6	9 min	0.82
Jackson & Coleman (1976)	25	Girls gr 4-6	9 min	0.71
Doolittle & Bigbee (1968)	153	Boys, gr 9	12 min	0.90
Jackson & Coleman (1976)	22	Boys, gr 4-6	12 min	0.82
Jackson & Coleman (1976)	25	Girls, gr 4-6	12 min	0.71
Maksud & Coutts (1971)	80	Boys, 11-14	12 min	0.65
Gutin et al. (1976)	20	Children 10-12	12 min	0.75

predicted maximal oxygen consumption as estimated by the Astrand-Ryhming test.

A. Adult Subjects

Wiley and Shaver (1972) compared $\dot{V}O_2$ max as estimated by the Astrand-Ryhming test to 1/4-, 1-, 2- and 3-mile runs. Only 2 significant correlations between maximum oxygen uptake and performance time were found: -0.47 for the 2-mile run and -0.43 for the 3-mile run. The trend observed was that correlations increased as the distance run increased: 1/4-mile, -0.22; 1-mile -0.29; 2-miles; -0.47; and 3-miles, -0.43. Wiley and Shaver advised that running performance and the Astrand Ryhming test be used with caution for the prediction of maximum oxygen uptake.

The relationship between $\dot{V}O_2$ max, as predicted by the Astrand-Ryhming test, and a selection of timed runs, the 880-yard, mile, 5-mile and 12-minute runs, has been studied by Kearney and Byrnes (1974). The subject population of college students was divided into 3 sub-groups according to athletic ability: non-athletic students, physical education majors and varsity cross-country runners. Among these sub-groups, the correlation coefficients decreased as a function of increasing performance capabilities. Kearney and Byrnes suggested that, as the skill level increases, motivation and pain tolerance may become more critical determinants of performance than $\dot{V}O_2$ max. In the 12-minute run, correlations between performance time and predicted $\dot{V}O_2$ max were reported as 0.80, 0.64 and 0.28 for non-athletes, physical education majors and cross-country runners, respectively. The same relationship also increased as a function of distance. Correlations between the two variables were cited as -0.30, -0.59 and 0.64 for the 1/2-mile, mile and 12-minute runs.

Custer and Chaloupka (1978) investigated the relationship between the predicted maximal oxygen consumption and running performance of college females. A significant relationship was found between $\dot{V}O_2$ max and the 6-minute run (r=0.45) and the 12-minute run (r=0.49). Custer and Chaloupka suggested that since the magnitude of the difference between the correlations was not significant, the 6-minute run could be used in place of the 12-minute run as a measure of aerobic capacity. The findings and conclusions of Custer and Chaloupka were consistent with those of Kearney and Byrnes (1974). Johnson et al. (1979) similarly examined the relationship between maximum oxygen uptake and the 12-minute run. Correlations for males were 0.90, for females, 0.91, and for the total group, 0.90. Johnson and his associates also established regression equations, for both males and females, for predicting performance in the 12-minute run based on $\dot{V}O_2$ max values as predicted by the Astrand-Ryhming test.

In summary, the relationship between predicted maximum oxygen uptake and running performance in distances of a mile or longer is significant. Two trends have been noted. The relationship between the two improves as the distance run is increased. There also appears to be some evidence that the correlation decreases as a function of increasing performance abilities.

B. School-aged Subjects

The relationship between running performance and oxygen uptake as predicted by the Astrand-Ryhming test as modified by Mocellin et al. has only been investigated by Gutin et al. (1976). $\dot{V}O_2$ max was compared to running performance in the 12-minute, 600-, 1200- and 1800-yard runs. Predicted $\dot{V}O_2$ max was not found to be closely related to distance running ability. A significant relationship, r=-0.58, was obtained between $\dot{V}O_2$ max and time in the 1200-yard run. Gutin et al. did not advocate the use of the modified Astrand-Ryhming test to evaluate aerobic capacity.

A very limited amount of research has been done comparing maximum oxygen uptake as predicted by the Astrand-Ryhming test to running performance using children as subjects. The need exists to investigate valid, easy to administer, submaximal tests of $\dot{V}O_2$ max for school-aged subjects.

Chapter 3

METHODS AND PROCEDURES

Subjects

Forty-five 10-year-old girls from 2 Winnipeg public schools served as subjects. All children were fully informed and consent was obtained in writing from parents before the children were allowed to participate in the study. Students given permission to participated were included in the sample. Information regarding past health and activity was obtained using a questionnaire. None had had any recent serious illness and all participated in normal school sporting activities. The letter of permission and a sample of the questionnaire may be found in Appendix A.

All subjects had previously run the 1600-meter run as a part of the Canada Fitness Award program. The children were familiar with bicycle exercise, but none had prior experience with bicycle exercise tests.

The subjects were randomly divided into 2 groups. Half of the participants were tested in the Astrand-Ryhming test several days prior to the 1600-meter run; the others were tested afterwards. All of the students at each school were tested in the 1600-meter run together in one large group.

Experimental Design

In order to standardize test procedures, 7, 9- and 11-year-old girls were tested on these protocols one week prior to testing. No problems in procedure were apparent.

The participants were scheduled for testing according to the groups to which they had been randomly assigned. The test-retests for both the 1600-meter run and the Astrand-Ryhming test were scheduled within 5 days of each other. Each subject completed the 4 tests within a 2-week time span.

Subjects were asked to maintain normal physical activity throughout the 2-week period of testing, but to refrain from strenuous muscular activity during the 48 hours prior to testing. The participants were also asked not to eat after 1 p.m. and to report for testing in gym apparel.

Data Collection

Subjects reported for testing in the post-absorptive state and were tested between 4 p.m. and 5:30 p.m. The children had not engaged in heavy muscular activity during the last 48 hours. Information concerning eating habits of the day, physical activity and physical well-being was obtained through a questionnaire before each test.

The testing protocol for each test consisted of a 10-minute warmup, a 5-minute rest period (during which the test procedures were explained) followed by the exercise test.

Flexibility and light aerobic exercises were utilized as warmup activities for the endurance tests. The standardized warmup which was used is found in Appendix B.

The bicycle ergometer test was administered according to the protocol outlined by Astrand (1978) given in Appendix C. Two calibrated Monarch bicycles were used for testing. Heart rate was continuously monitored throughout the test by using Extrasensory heart monitors. The pedalling frequency was set by a metronome at 100 rpm. An Accu-split stop-watch was used for timing. It was not possible to exercise rigid controls upon room temperature, however, the temperature was within a range of 18^{o} to 20^{o} centigrade.

After the subject completed the warmup, the height of the saddle on the bicycle ergometer was adjusted to the individual to insure a slight bending of the knee (approximately 15^{o}) when the anterior part of the foot was placed on the pedal in its lowest position. Differences in mechanical advantage were thus kept at a minimum (Klimt & Voigt, 1971). With the subject seated on the bicycle ergometer, but not touching the pedals, the mark on the pendulum weight was set at 0 kp. The heart rate monitor was placed on the subject. The exercise procedure was explained. A pretest heart rate was taken and recorded.

The subject was asked to remain in an upright, sitting position during the test and to begin cycling in time with the metronome. Subjects were encouraged to maintain a constant pedalling speed. The resistance was set at 1 kp for an initial work load of 300 kpm/min. Timing was then begun. At the end of each minute, the heart rate was recorded and the work load checked. The resistance was increased by 1 kp every 6 minutes until a steady state heart rate of at least 150 beats/min was attained. A steady state was deemed to be present when the difference between the readings after 5 and 6 minutes did not exceed 5 beats/min. If the difference was more than 5 beats/min, the working time was prolonged one or more minutes until a constant level was reached. Upon termination of the test, the heart rate monitor was removed and a cool down of slow stretching activities was performed.

Test procedures for the retest were the same as used in the first test. Subjects were retested on the same bicycle that they used initially.

The 1600-meter run was performed on a 400-meter grass circuit. An Accu-split stop-watch was used to monitor the time to the nearest second. Subjects were told that the 1600-meter run was 4 laps in total. They were instructed to maintain a constant, steady pace, to complete the run as quickly as possible and to walk if they were unable to continue running. It was also suggested that the participants increase their pace during the last lap, if able, and that they put forth their best effort in the test. On the signal "Ready, go", the girls began running, Following the completion of the run, they were asked to walk once around the circuit and to slowly stretch their muscles as cool down activities. After the cool down, the run times were recorded. The 1600-meter run test protocol can be found in Appendix D. The same procedure was used in the retest as was used in the initial test. Climatic conditions were similar on the test-retest days.

Data Analysis

The Astrand-Ryhming test data were tabulated and the means, standard deviations and ranges were calculated. Correlations between height, weight, pretest heart rate, predicted $\dot{V}O_2$ max and time in the 1600-meter run were calculated.

Predicted $\dot{V}O_2$ max ($l \cdot min^{-1}$) was found using the equation presented by Mocellin et al. (1971) for the modified Astrand-Ryhming test. Maximum oxygen uptake was then divided by body weight (kg) and expressed in $ml \cdot kg^{-1} \cdot min^{-1}$.

The test-retest reliabilities of pretest heart rate, predicted $\dot{V}O_2$ max ($l \cdot min^{-1}$) and 1600-meter run time were determined using the Pearson product-moment method. The subject sample was then subdivided into 2 groups, athletic and non-athletic, to further examine the reliability of the Astrand-Ryhming test.

Multiple linear regression analysis was performed on the data to predict $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) from height, weight, pretest heart rate and 1600-meter run time. Further, a regression analysis was done to predict maximum oxygen uptake from run time as the only independent variable.

Chapter 4

RESULTS AND DISCUSSION

Introduction

In recent years, the relationship between timed runs and predicted $\dot{V}O_2$ max has been investigated (Shvartz et al., 1973; Custer & Chaloupka, 1978; Johnson, Oliver & Terry, 1979). Much of this research has been conducted using adults as subjects. The need exists to investigate valid, easy to administer tests of $\dot{V}O_2$ max for school-aged populations. The purpose of this study was to investigate the relationship between $\dot{V}O_2$ max as predicted by the Astrand-Ryhming test modified by Mocellin et al. (1971) and time in the 1600-meter run using 10-year-old girls as subjects. Forty-five girls from 2 Winnipeg schools served as subjects. The participants were scheduled for testing according to the groups to which they had been randomly assigned. Subjects were tested twice on a bicycle ergometer following the protocol outlined by Astrand (1978). Maximum oxygen uptake values were predicted from work load and heart rate. Subjects were also tested twice in the 1600-meter run. Test procedures for the retests were the same as those used in the initial test.

The descriptive data for the subjects are presented in Appendix E. The anthropometric data, bicycle performance scores, predicted maximum uptake, and 1600-meter run times for the subjects are given. In this chapter, the results of the statistical analysis will be presented as well as relevant tables and graphs. A discussion of the findings will follow the presentation of the statistical analysis.

A. Anthropometric Data

Body height and weight were measured by the usual methods. The mean height was 142.8 +/- 6.9 cm and the mean weight 36.9 +/- 6.4 kg. A comparison of the anthropometric data with mean values for girls of the same age in other studies revealed that the body heights and weights were similar to those previously found by Canadian researchers. Body heights and weights were within 3 cm and 2.5 kg of the Manitoba norm determined by the Manitoba Schools Physical Fitness Survey (1976-77) and the Canadian norms presented in the Canada Fitness Award program (Gautier et al., 1980). Mean values for the variables in these studies are shown in Table 5.

B. Reliability Coefficients

The means, standard deviation, and minimum and maximum values for the variables are given in Table 6.

Predicted maximum oxygen uptake ($l \cdot min^{-1}$) was determined from measurements of heart rate and work load using the Astrand Ryhming

Table 5. Mean heights and weights of girls age 10

Study	Height* (cm)	Weight* (kg)
Manitoba Schools Physical Fitness Survey (1976-77)	140.6 +/- 8.1	34.5 +/- 7.2
CAHPER Fitness Performance Test (1980)	139.9 +/- 7.5	34.8 +/- 6.9
Present Investigation (1986)	142.8 +/- 6.9	36.9 +/- 6.4

*Mean height and weight +/- S.D.

Table 6. Means, standard deviations, and minimum and maximum values for the variables

Variable	Mean	S.D.	Minimum Value	Maximum Value
Pretest Heart Rate 1 (beats/min)	101	13	72	132
Pretest Heart Rate 2 (beats/min)	101	12	72	132
Mean Pretest Heart Rate (beats/min)	101	9	81	119
$\dot{V}O_2$ Max ($l \cdot min^{-1}$) Test 1	1.27	0.41	0.81	2.12
$\dot{V}O_2$ Max ($l \cdot min^{-1}$) Test 2	1.42	0.51	0.81	2.68
Mean $\dot{V}O_2$ Max ($l \cdot min^{-1}$)	1.35	0.41	0.84	2.30
Mean $\dot{V}O_2$ Max ($ml \cdot kg^{-1} \cdot min^{-1}$)	36.71	9.84	20.95	63.54
Run Time 1 (sec)	619	125	418	935
Run Time 2 (sec)	628	119	454	985
Mean Run Time (sec)	624	120	441	830

procedure as modified by Mocellin et al. (1971). The following equation was applied:

$$\dot{V}O_2 \max (l \cdot min^{-1}) = \frac{195 - 69}{HF - 69} \times (F \times W \div BMR) \times 0.001 \times 1.17$$

195 represents the mean maximal heart rate (beats/min) for children of this age. HF is the mean heart rate based upon the mean corresponding work load W (kpm). F is the factor for conversion of work load to oxygen consumption, which has a value for 2 at stepwise increasing loads. BMR is the basal metabolic rate, determined for this age level to be 37 calories per kilogram of body weight per day (Davis & Dobbing, 1981) and taken as a constant value.

The mean predicted $\dot{V}O_2$ max obtained was 1.35 +/- 0.41 $l \cdot min^{-1}$. The influence of weight upon the scores was removed by dividing the predicted value of each subject by body weight and expressing maximum oxygen uptake in $ml \cdot kg^{-1} \cdot min^{-1}$. The mean value calculated was 36.71 +/- 9.84 $ml \cdot kg^{-1} \cdot min^{-1}$.

The reliability coefficient for the Astrand-Ryhming test was determined by finding the Pearson product-moment correlation between test and retest performances. A reliability coefficient of 0.59 was found, which is significant beyond the 0.01 level of confidence.

Although no significant difference was found between values of mean $\dot{V}O_2$ max in the first and second tests, the results obtained in the second test, 1.42 $l \cdot min^{-1}$, were better than those in the first test, 1.27 $l \cdot min^{-1}$. The range of the predicted $\dot{V}O_2$ max scores also increased in the second test. The lower value obtained remained the same, 0.81 $l \cdot min^{-1}$, but the upper value increased from 2.12 $l \cdot min^{-1}$ in the first test to 2.68 $l \cdot min^{-1}$ in the second. The difference in performance between the two tests is probably due to the apprehension that the subjects felt about taking the test. None of the subjects had ever been tested on the bicycle ergometer, nor had they had their heart rate monitored. The fear and apprehension were less apparent during the second test which may account for the improved performance. The mean $\dot{V}O_2$ max value obtained in the 2 tests was divided by body weight to determine maximal oxygen uptake per kilogram body weight. Had the better of the 2 scores been selected to determine $\dot{V}O_2$ max, the predicted value would have been higher.

Mocellin et al. (1971) reported their modification of the Astrand-Ryhming test to be reliable, citing a coefficient of reliability of 0.91. The lower coefficient obtained in the current study, 0.59, was not attributed to the administration of the test. The test procedures as outlined by Astrand (1978) were strictly followed. Subjects were tested at the same time of day, on the same bicycle, and in the same room as used in the initial test. The temperature of the room was kept relatively constant. Subjects did not overexert themselves physically in the 48 hours prior to testing. The factor which may have caused the variability in the scores between tests was the anxiety level of the subjects. Performance on the second test notably improved, the predicted $\dot{V}O_2$

max increasing from 1.27 $l \cdot min^{-1}$ to 1.42 $l \cdot min^{-1}$. In order to decrease the effect of anxiety on testing, it is suggested that the subjects be familiarized with test procedures a few days prior to testing.

The subject sample was subdivided into 2 groups to further examine the reliability of the Astrand-Ryhming test. Subjects who participated in extra-curricular sports at least 3 times/week were placed in Group 1 (N=20) and those who were less involved in athletics were placed in Group 2 (N=25). The Astrand-Ryhming test was found to be more reliable for the athletic subsample, r=0.44, than for the non-athletic group, r=0.26. However, no significant difference was found between the 2 correlations. The Astrand-Ryhming test may have been more reliable for the athletic group than for the non-athletic group because athletes normally adapt more quickly to new physical activities than do non-athletes. This adaptation may have reduced the anxiety caused by a new testing experience and enable them to perform more consistently than the non-athletes.

The mean 1600-meter run time of the subjects in the present study was 624 +/- 120 seconds. The mean and standard deviation were similar to those found for this age group by Massicotte et al. (1985) and Gautier et al. (1980). The reliability of the test was determined by finding the Pearson product-moment correlation between test and retest performance. The reliability coefficient of 0.95 was found, which is significant beyond the 0.01 confidence level. Test-retest reliabilities for the variables can be found in Table 7.

The 1600-meter run test was found to be a reliable measure of running performance. The reliability coefficients determined by other researchers for distance run tests using children as subjects are reported in Table 8. Distance run tests appear to be very reliable for young, motivated subjects. Askew (1966), however, noted that stress and a lack of motivation appeared to be limiting factors at the senior high level. Eighty-five percent of the subjects in Askew's study of senior high school children had been previously tested in the 600-yard run-walk at the junior high school level. The reliability of this test dropped significantly at the senior high level. For the girls, the reliability of the test lowered from 0.92 to 0.65 and for the boys, from 0.92 to 0.76. Askew concluded that senior high school students need more teacher motivation than do younger subjects. The 10-year-old subjects involved in the present study were highly motivated, which is typical of children at this age level. The subjects tried their best to attain the best possible performance in the 1600-meter run test. The girls were encouraged by the testing team throughout the run. Although the influence of motivation cannot be directly measured, the importance of student motivation and teacher encouragement in distance running tests at any age level must be stressed.

Table 7. Reliability coefficients of test - retest variables in the current investigation

Variable	R
Pretest heart rate (beats/min)	-0.06
$\dot{V}O_2$ Max (l/min)	0.59*
1600 meter run time (sec)	0.95*

*Significant beyond the 0.01 level of confidence

Table 8. Reliabilities of running tests using children as subjects

Researcher	Subjects	No. in Sample	Distance	R
Askew (1966)	Grade 11 girls	46	600 yd	0.65
Askew (1966)	Grade 11 boys	71	600 yd	0.76
Doolittle & Bigbee (1968)	Jr. high boys	149	600 yd	0.98
Maksud & Coutts (1971)	Boys 11-14 yrs	80	12 min	0.92
Vodak & Wilmore (1975)	Boys 9-12 yrs	69	6 min	0.89
Vodak & Wilmore (1975)	Boys 9-12 yrs	69	600 yd	0.88
Krahenbuhl et al. (1978)	Gr. 1-3 children	120	1600 m	0.82
Present study (1986)	Girls 10 yrs	45	1600 m	0.95

C. Predicted $\dot{V}O_2$ Max

The mean maximum oxygen uptake value for the subjects in the present study was 36.71 +/- 9.84 $ml \cdot kg^{-1} \cdot min^{-1}$. Normal standards of reported oxygen uptake in children have been found to vary. A summary of the research involving girls from 6 to 16 years of age is presented in Table 9. The $\dot{V}O_2$ max value obtained in this study is similar to those found by Knuttgen (1967), 33.6 $ml \cdot kg^{-1} \cdot min^{-1}$, Shephard et al. (1969), 36.8 $ml \cdot kg^{-1} \cdot min^{-1}$, Seliger (1971), 37.5 $ml \cdot kg^{-1} \cdot min^{-1}$, and Gutin et al. (1978), 37.0 $ml \cdot kg^{-1} \cdot min^{-1}$. A considerably lower value was reported by Rodahl (1959), 29.0 $ml \cdot kg^{-1} \cdot min^{-1}$. Higher values ranging from 40.6 to 51.5 $ml \cdot kg^{-1} \cdot min^{-1}$ have been found by other researchers (Astrand, 1952; Wilmore & Sigerseth, 1967; Massicotte et al. 1985).

In order to explain the variability of reported oxygen uptake values, the influence of the following factors on $\dot{V}O_2$ max has been investigated.

1. Testing Procedures

A number of different testing procedures are generally used by researchers. In laboratory experiments, 3 methods of testing with standardized work loads are utilized: treadmill running, bicycle ergometer and stepping tests. These different types of tests do not give the same maximum oxygen values. Table 10 summarizes the mean values from several different studies. It appears that

Table 9. Normal standards of oxygen uptake in girls aged 6 to 16

Author	Nation	Age (yrs)	VO_2 Max ($ml \cdot kg^{-1} \cdot min^{-1}$)
Astrand (1952)	Sweden	6-8	51.5
Cumming (1967)	Canada	6-8	50.5
Krahenbuhl et al. (1978)	U.S.A.	6-8	41.2
Massicotte et al. (1985)	Canada	6	45.2
		7	46.3
		8	47.3
		9	45.9
		10	46.7
Krahenbuhl et al. (1977)	U.S.A.	8-9	42.9
Cureton (1977)	U.S.A.	7-12	45.4
Wilmore et al. (1967)	U.S.A.	7-13	51.0
Ceretelli et al. (1963)	Italy	8-16	45.0
Shephard et al. (1969)	Canada	9-10	36.8
		9-13	36.9
		10-12	38.7
		11	35.9
		12-13	38.3
Jackson & Coleman (1976)	U.S.A.	10-12	40.6
Astrand (1952)	Sweden	10-16	48.8
Rodahl et al. (1959)	U.S.A.	10-16	29.0
Andersen (1964)	Norway	10-16	45.4
Cumming (1967)	Canada	10-16	40.6
Gutin et al. (1978)	U.S.A.	11-12	37.0
Seliger (1971)	Czech	12	37.5
Eisenman & Golding (1975)	U.S.A.	12-13	49.6
Knuttgen (1967)	U.S.A.	15-18	33.6
Present investigation (1986)	Canada	10	36.7

Table 10. Comparison of mean oxygen uptake values attained in various types of exercise

Type of Exercise	$\dot{V}O_2$ max in %	References
Running, uphill (>3 incline)	100	Astrand & Saltin (1961) Hermansen & Saltin (1969) Hermansen et al. (1970)
Running, horizontal	95-100	Hermansen & Saltin (1969)
Bicycling, upright	92-96	Astrand & Saltin (1969) Glassford et al. (1965) Hermansen & Saltin (1969) Hermansen et al. (1970)
Step Test	97	Shephard et al. (1968)

* The $\dot{V}O_2$ max obtained during uphill running is termed as 100%

running uphill on the treadmill, with an inclination of 3^{o} or more, may bring oxygen uptake to a maximum. Running horizontally or at a lesser inclination results in a lower $\dot{V}O_2$ max. Bicycling, on the average, produces a 5 - 8% lower oxygen uptake than running uphill on a treadmill. The step test has been found to give oxygen uptake values of about 3% less than uphill treadmill running, but this test is seldom used since it is poorly standardized and the ability of the researcher to vary the workload is limited.

It is difficult at present to explain the difference in results from these procedures. The activation of a larger muscle mass during uphill running compared with work on a bicycle ergometer is likely not the reason, since simultaneous work with both the arms and legs does not produce a higher $\dot{V}O_2$ max than work with the legs only (Astrand & Saltin, 1961). The higher work tempo during running may enhance venous return, but this does not explain the difference in oxygen uptake between uphill and horizontal running. The discomfort of local muscular fatigue, however, may cause subjects in bicycling testing to terminate activity before maximum oxygen uptake is obtained. The motivation of the subjects during cycling may also cause them to work at a reduced speed, thus lowering oxygen uptake. This is impossible on the treadmill since the subject must follow the speed of the ergometer or jump off.

Work load on the treadmill or bicycle ergometer is normally increased in several ways: 1.) the load may be immediately increased to the level at which previous experiments found to predict the work load of the subject; 2.) the load may be increased stepwise, with each load lasting 5 to 6 minutes, with or without rest periods between loads; or 3.) the load may be increased stepwise every 1 to 2 minutes until exhaustion. While the first and third methods may obtain quicker results, the second method has been preferred by investigators in that steady state conditions are obtained when measuring oxygen uptake. It is important to note, however, that the $\dot{V}O_2$ max measured by the steady state and progressive methods has not been determined to be the same for identical work loads. This may account for some of the variance in reported values of maximum oxygen uptake.

Although laboratory determined measures of oxygen uptake have been obtained with a reasonable degree of accuracy, the expense, personnel, time and equipment requirements have lead investigators to utilize submaximal tests to predict $\dot{V}O_2$ max. The standard error of the prediction of oxygen uptake has been found to be about 10% in well-trained subjects, but up to 15% in moderately trained or unfit individuals (Astrand, 1960). Unfit subjects are normally underestimated, while trained individuals are overestimated. There are several sources of error that cause the variance between predicted and measured values of $\dot{V}O_2$ max. Predictive tests, such as the Åstrand-Rhyming test, are based on the feature that oxygen uptake increases linearly with heart rate. In some individuals, oxygen uptake increases relatively more than heart rate (Astrand, 1960). As a consequence, $\dot{V}O_2$ max will be underestimated from the prediction from submaximal heart rate. Another source of error is that since maximal heart rate declines with age, the $\dot{V}O_2$ max of older subjects may be overestimated while that of younger subjects will be underestimated. In 1960, Astrand introduced an age factor which allowed for a correction to be made. However, the standard deviation for each age group is about +/- 10 beats/min, which means that 50% of the subjects will still be overestimated and the rest underestimated. A final factor to be considered is that when oxygen uptake is predicted from work load on a bicycle, the mechanical efficiency may vary by +/- 6%. The $\dot{V}O_2$ max of subjects with a low mechanical efficiency will be underpredicted and those with a higher one will be overpredicted. All of the above factors exert a decisive influence over the accuracy of the estimation of maximum oxygen uptake.

Maximum oxygen uptake is thus dependent on the type of test utilized: maximal vs. submaximal, bicycle vs. treadmill, and stepwise vs. progressive. The oxygen uptake values determined are influenced by the apparatus and procedure selected. The modification by Mocellin applied to the Astrand-Rhyming test was aimed at reducing the effects of the underprediction of $\dot{V}O_2$ max. The value obtained in this investigation, 36.71 $ml \cdot kg^{-1} \cdot min^{-1}$, was similar to values obtained by some researchers (Shephard et al., 1969; Seliger, 1971; Gutin, 1978), but it was also considerably lower than those found by others (Astrand, 1960; Massicotte et al., 1985).

2. Sample Composition

The composition of the sample studied also affects the reported $\dot{V}O_2$ max values. Astrand (1952) tested the most physically fit students of school classes and reported a maximum oxygen uptake value of 51.5 $ml \cdot kg^{-1} \cdot min^{-1}$. His sample was biased in favor of highly fit subjects. Rodahl et al. (1959), on the other hand, studied very unfit individuals and reported $\dot{V}O_2$ max scores of only 29.0 $ml \cdot kg^{-1} \cdot min^{-1}$. Some of these subjects may not have even attained their maximum oxygen uptake. In the present investigation, the sample was definitely representative of the school population. Obese, thin, fit, average, and unfit subjects all participated. As would be expected, the value for maximum oxygen uptake found in this study was higher than that obtained by Rodahl and his colleagues, but lower than that found by Astrand. It should be mentioned that the larger the sample size, the more likely it is that the sample is representative of the population.

The sample was divided into 2 subgroups for further analysis. The subjects in Group 1 (N=20) participated in extra-curricular sporting activities at least 3 times per week. Group 2 subjects (N=25) were less physically active. A mean oxygen uptake value of 43.60 $ml \cdot kg^{-1} \cdot min^{-1}$ was obtained by Group 1. This value compares favorably with $\dot{V}O_2$ max values found by other researchers (Cureton, 1977; Massicotte et al., 1985). A much lower oxygen uptake value was found for the less active group - 32.11 $ml \cdot kg^{-1} \cdot min^{-1}$.

The $\dot{V}O_2$ max reported in this investigation was specific to the 10-year-old female age group. The results of many of the studies to which this maximum oxygen uptake value is being compared involve girls in broader age groups, including younger and older girls than those observed here. It is generally agreed that the aerobic power in younger girls per unit of body mass is larger in younger girls than in older girls (Shephard, 1971). This finding must be taken into account when comparing the value obtained in this study with those reported in other investigations. However, many of the values for both younger and older subjects in other studies are superior to those obtained in this study (Astrand, 1952; Cumming, 1967; Wilmore et al., 1967).

3. <u>Sociological Factors</u>

The sociological factors influencing the subjects of the different studies have also been considered. In Canada, the aerobic power of 14- to 18 - year-old females living in rural areas was found to be 5.9% larger than those living in urban settings (Howell et al, 1965; in Shephard, 1971). A similar trend was noted in Sweden (Adams et al., 1961). The higher maximum oxygen uptake values were attributed to the greater level of habitual activity of rural subjects. While the sociological effects of $\dot{V}O_2$ max are difficult to determine, their influence cannot be negated when comparing varying values of oxygen uptake.

4. Time of Year

No general agreement has been obtained on changes in aerobic capacity during the course of the school year. In Canada, the climatic conditions vary so much from one region to another that it would be highly unlikely that any generalizations could be made. Cumming (1971) found no significant seasonal effects in the maximum oxygen uptake of Canadian school children. The effect of seasonal factors on $\dot{V}O_2$ max, if any, is small.

5. Height and Weight

The effect of body heights and weights on the predicted $\dot{V}O_2$ max in this study was not found to be significant. The correlations found between height and weight and $\dot{V}O_2$ max were 0.24 and -0.10, respectively. The weight/height ratio, 0.258 kg/cm, found for the subjects was similar to those reported by other researchers. A summary of body weight/height ratios given in other studies can be found in Table 11. It is difficult to attribute low aerobic fitness levels to high weight/height ratios, since the ratio found by Rodahl et al. (1961) for unfit subjects was similar to those calculated by other researchers, and the ratio reported by Wilmore et al. (1967) for subjects with a good aerobic capacity was noticeably higher.

6. Pretest Heart Rate

Pretest heart rate was measured before the first and second Astrand-Ryhming tests. A very low reliability coefficient of -0.06

Table 11. Body weight/height ratios of school girls (kg/cm)

Author	Nation	Age	Wt/Ht Ratio
Cumming et al. (1963)	Canada	11-12	0.272
Shephard et al. (1969)	Canada	10	0.240
Manitoba Schools Physical Fitness Survey (1976-77)	Canada	10	0.245
CAHPER (1979)	Canada	10	0.249
Massicotte et al. (1986)	Canada	10	0.233
Stuart et al. (1946)	U.S.A.	11	0.247
Rodahl et al. (1959)	U.S.A.	10	0.252
Adams et al. (1961)	U.S.A.	11	0.297
Wilmore et al. (1967)	U.S.A.	10-11	0.259
Holt (1948)	U.K.	10	0.231
Provis & Davis (1955)	U.K.	11.5	0.239
Adams et al. (1961)	Sweden		
	(urban)	11	0.247
	(rural)	11	0.278
Astrand (1952)	Sweden	11	0.241
Rutenfranz (1967)	Germany	11	0.266
Hollman et al. (1967)	Germany	11	0.246
Present investigation (1986)	Canada	10	0.258

was obtained between the 2 measures. Pretest heart rate was not found to be significantly correlated with predicted maximum oxygen uptake r = 0.15. This finding is in agreement with previous research (Shephard, 1971) which indicates that no measurements taken at rest will reveal the capacity for maximal aerobic power.

The variability in reported $\dot{V}O_2$ max is thus mainly attributed to the different types of tests utilized, the fitness level of the subjects, the composition of the sample and the sociological factors influencing the subjects. The maximum oxygen uptake value reported in this study has been shown to be similar to those found by other researchers, but it is also lower than those reported by many other investigators.

D. Performance in the 1600-Meter Run

The mean 1600-meter run time of the subjects in the present investigation was 624 +/- 120 seconds. The mean and standard deviation were similar to those found for this age group by Massicotte et al. (1985) and Gautier et al. (1980). Massicotte and his colleagues reported a time of 601 +/- 74 seconds in their study of 20, 10-year-old Quebec girls. Gautier et al. made a comprehensive study of Canadian school children to determine norms for the Canada Fitness Award program and found a mean of 664 +/- 112 seconds for the 1600-meter run. These performance times are noticeably slower than the mean time found in an earlier investigation, the Manitoba Schools Physical Fitness Survey

(1976-77). The mean reported was 534 +/- 34 seconds. The sample size, height, weight, and run times of the subjects in these studies are shown in Table 12.

The variation in performance times between the studies may be explained by several factors. First of all, the composition and size of the subject samples varied considerably. Massicotte and his colleagues tested a sample of 20 Quebec school girls in the 1600-meter run and a $\dot{V}O_2$ max test. No report was given concerning the number of subjects who refused to participate or who dropped out of the study. Athletes are likely more inclined to participate in physical fitness tests than average or unfit children. In the 1980 CAHPER investigation by Gautier et al., 386 girls were included in the original sample but only 352 participated in the 1600-meter run. Nine percent of the girls who completed the majority of the battery of tests of the Canada Fitness Award program did not run the endurance run. It is very likely that the majority of these girls were poorly motivated and unfit. In the Manitoba Schools Physical Fitness Survey, 15% of the 447 subjects did not run the 1600-meter run. The mean time reported for this group was 534 seconds which is 67 seconds faster than the Massicotte mean, 134 seconds faster than that found by Gautier, and 90 seconds faster than the mean found in the present study. The faster mean time may be attributed to the fact that the less motivated and fit subjects were not included in this test, thus improving the performance mean.

Table 12. Sample sizes and run times of selected studies

Study	No. in original sample	No. in 1600 m run	Run time (sec)
Manitoba Schools Physical Fitness Survey (1976-77)	447	380	534 +/- 84
Canada Fitness Test (1980)	386	352	664 +/- 112
Massicotte et al. (1986)	Not reported	21	601 +/- 74
Present investigation (1986)	45	45	624 +/- 120

The motivation to perform well in running tests is often influenced by the encouragement given by the testing team. In the procedure of the 1600-meter run of Massicotte et al., a maximum of 4 children were directly supervised and constantly encouraged by a member of the evaluating team. This may account for the superior mean run time of the subjects in this study as compared to the mean times found in the Gaùtier et al. study and in the present investigation.

The differences in performance time between groups could also be attributed to the superior aerobic capacity of the subjects of the different studies. The $\dot{V}O_2$ max value reported by Massicotte and his colleagues, 47.6 $ml \cdot kg^{-1} \cdot min^{-1}$, was superior to those reported in two other Canadian studies by Cumming (1969) and Shephard et al. (1969). Cumming studied 10- to 16-year-old girls and found a maximum oxygen uptake of 40.6 $ml \cdot kg^{-1} \cdot min^{-1}$. Shephard et al. reported a $\dot{V}O_2$ max of 36.8 $ml \cdot kg^{-1} \cdot min^{-1}$, which is similar to the value found in the present investigation, 36.7 $ml \cdot kg^{-1} \cdot min^{-1}$. It must be noted that the sample size in the Massicotte study was small: only 20, 10-year-old girls were tested, and this group may have had an above average aerobic fitness level. An increased sample size would decrease the likelihood of a select group of subjects being chosen.

The mean heights and weights of the subjects were similar to those reported in the previously mentioned studies. The correlations between 1600-meter run performance and height and weight were $r=-0.11$ and $r=0.26$, respectively. Neither of these variables was found to be significantly correlated with run time. The influence of these variables on performance was not significant.

E. The Relationship between Predicted $\dot{V}O_2$ Max and Time in the 1600-Meter Run

The correlations between height, weight, pretest heart rate, run time, and $\dot{V}O_2$ max are presented in Tables 13 and 14. Linear regression analysis was performed on the data to predict $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) from mean run time. The linear regression equation was calculated to be:

$$\text{Predicted } \dot{V}O_2 \text{ Max} = 59.02 - 0.04 \times \text{Mean Run Time}$$

The correlation coefficient for this data was -0.44, which is significant beyond the 0.01 level of confidence. The R^2 value obtained, 0.19, indicates that 19% of the variability in predicted $\dot{V}O_2$ max can be explained by time in the 1600-meter run. The R and R^2 values found for this equation were unacceptably low. Figure 1 shows the relationship between the observed and the predicted scores when plotted about the least squares regression line. The confidence limits are indicated by the dotted lines and represent one standard error of estimate. Information regarding height, weight and pretest heart rate failed to improve the regression variance for maximum oxygen uptake and 1600-meter run time. Since

Table 13. Correlation coefficients between selected variables

Variable	1	2	3	4	5	6
1. Height (cm)						
2. Weight (kg)	0.70 **					
3. Mean Pretest Heart Rate (beats/min)	0.10	-0.01				
4. Mean VO_2 max ($l \cdot min^{-1}$)	0.62**	0.43**	-0.13			
5. Mean VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.24	-0.10	0.15	0.83**		
6. Mean Run	-0.11	0.26	0.04	-0.31*	-0.44**	

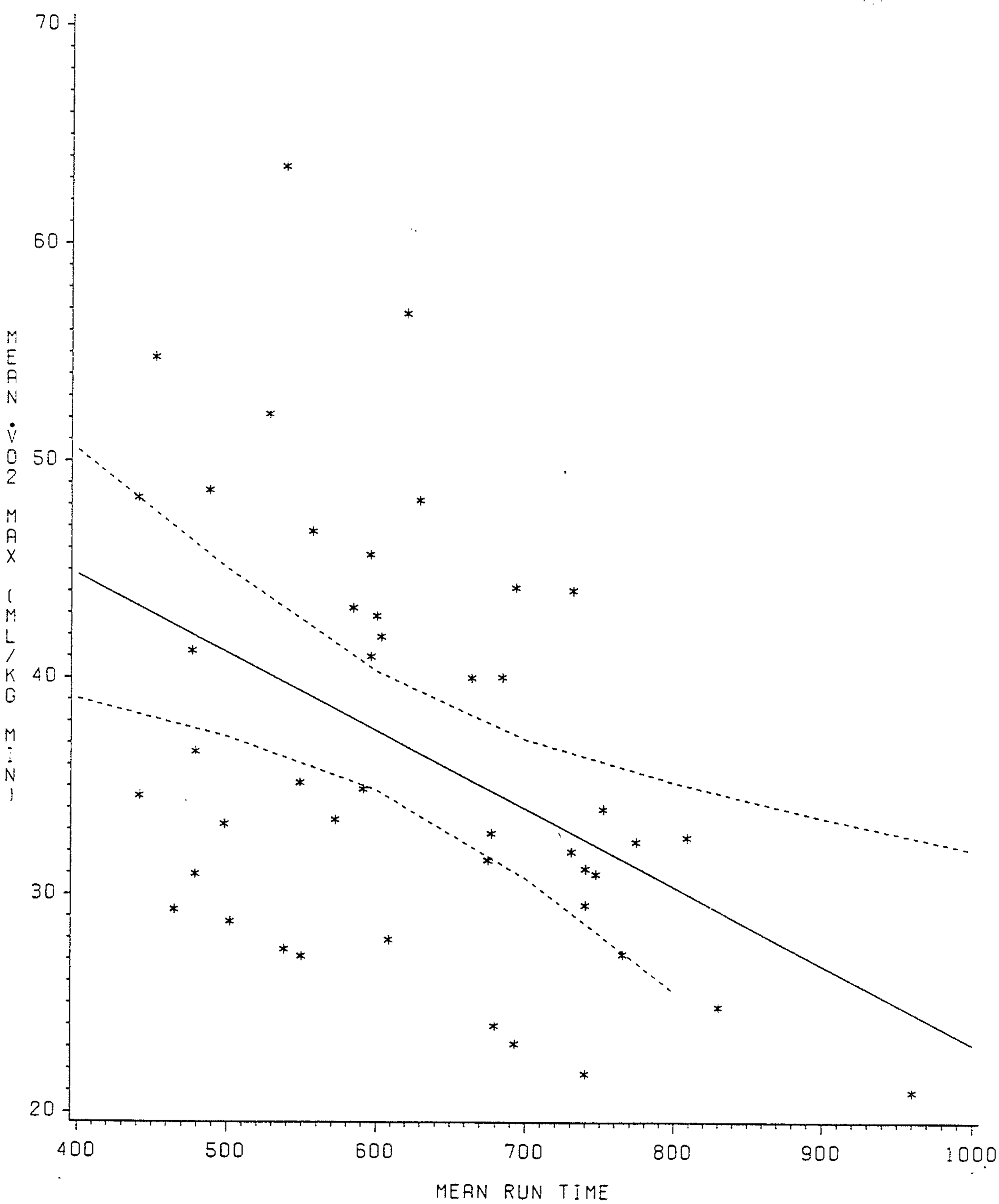
* Significant beyond the 0.05 level of confidence
** Significant beyond the 0.01 level of confidence

Table 14. Correlations between selected variables and $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$)

Variable	R	R^2	Mean	S.D.
Height (cm)	0.24	0.06	142.8	6.9
Weight (kg)	0.10	0.01	36.9	6.4
Mean Pretest Heart Rate (beats/min)	0.15	0.03	101	9
Mean Run Time (sec)	0.44*	0.19	624	120

* Significant beyond the 0.01 level of confidence

SIMPLE LINEAR REGRESSION



PLOT OF REGRESSION EQUATION AND 95% CONFIDENCE LIMITS
R = -0.44

height is significantly correlated to weight, r=0.70, and $\dot{V}O_2$ max was expressed per unit body weight, it is not surprising that these two variables did not improve the regression variance. Because a low correlation was found between predicted $\dot{V}O_2$ max and pretest heart rate, the effect of pretest heart rate on the variance was also minimal.

Cureton et al. (1977) observed that the determinants of individual differences in distance run performance was complex and must be interpreted with caution. $\dot{V}O_2$ max was not found to be the predominant determinant of time in the 600-yard or the mile run. Percent fat and running speed explained more of the variance in endurance performance than did oxygen uptake capacity. The influence of percent fat was also noted to be significant by Krahenbuhl et al. (1977) who found that the knowledge of skinfold measurements improved the regression variance between distance run times and $\dot{V}O_2$ max. Gutin et al. (1978) obtained a correlation of 0.92 between time in the 1120-yard run and a sum of 5 skinfolds in primary school children. Gutin and his colleagues supported the conclusion of Cureton et al. that for children of around 7 to 12 years of age, endurance performance is more a function of body composition and anaerobic power than of oxygen uptake capacity. Percent fat and running speed were not determined for the subjects in the current study. It would appear that a fairly accurate regression equation could be obtained if $\dot{V}O_2$ max was predicted from percent fat, running speed and distance performance. The regression equation, as presented in this study does not incorporate the effects of these variables and therefore cannot be used with any degree of accuracy to predict $\dot{V}O_2$ max.

The results of the present investigation indicate that the modified Astrand-Ryhming test may not be a reliable test for girls of this age with no previous bicycle testing experience. The 1600-meter run was found to be a reliable test. Predictd $\dot{V}O_2$ max and time in the 1600-meter run were not highly correlated. It is recommended that other factors such as percentage body fat and running speed be used in addition to time in the 1600-meter run to predict the endurance capacity of girls of this age.

Chapter 5

SUMMARY AND CONCLUSIONS

The majority of the research investigating the relationship between timed runs and predicted $\dot{V}O_2$ max has been conducted using adults as subjects. The need exists to investigate valid, easy to administer tests of $\dot{V}O_2$ max for school-aged populations. The purpose of this study was to investigate the relationship between $\dot{V}O_2$ max as predicted by the Astrand-Ryhming bicycle test modified by Mocellin et al. (1971) and time in the 1600-meter run. Forty-five 10-year-old girls from 2 Winnipeg schools served as subjects. Participants were scheduled for testing according to the groups to which they had been randomly assigned. Subjects were examined twice in each of the tests. Maximum oxygen uptake was predicted from work load and heart rate according to the procedure outlined by Mocellin et al. (1971).

The calculated mean value for predicted $\dot{V}O_2$ max ($36.71\ ml \cdot kg^{-1} \cdot min^{-1}$) was similar to values cited by some researchers but notably lower than the values found by many others. The reliability coefficient found in the present study for the Astrand-Ryhming test (0.59) was lower than is usually reported. It is suggested that the low reliability coefficient might be due to the anxiety level of the subjects during the first session of testing. The subject sample was subdivided into 2 groups, athletic and non-athletic, to further examine the reliability of the Astrand-Ryhming test. The test was found to be more reliable for the athletic subsample, r=-0.44, than for the non-athletic group, r=-0.26. No significant difference was found between the 2 correlations.

The mean performance time of the subjects in the 1600-meter run (624 sec) was similar to that reported for girls of the same age group. The test was found to be highly reliable (r=0.95).

Height, weight and pretest heart rate were not found to have a significant effect on distance run performance nor on predicted $\dot{V}O_2$ max. Sixteen hundred-meter run time and maximum oxygen uptake were significantly correlated, but the correlation between the 2 variables was low (-0.44). A regression equation was presented to predict $\dot{V}O_2$ max from 1600-meter run time.

The following conclusions appear to be justified:

1. The modified Astrand-Ryhming test is not a reliable test for girls of this age with no prior bicycle testing experience.

2. The 1600-meter run test is a reliable test. This test would appear to give a good indication of the distance running ability of the subjects.

Based on the results of this study, the following recommendations can be made:

1. Young subjects who are to be tested on the bicycle for the first time should be familiarized with test procedures a few days

prior to testing in order to reduce anxiety levels and to improve the reliability of the test.

2. The poor relationship found between predicted $\dot{V}O_2$ max and time in the 1600-meter run may have been a result of the low reliability coefficient found for the Astrand-Ryhming test. It is suggested that the reliability of the Astrand-Ryhming test be further investigated for subjects of this age. If a high reliability coefficient can be obtained, the 2 tests should be again compared.

3. It is recommended that other factors such as percentage body fat and anaerobic power be used in addition to time in the 1600-meter run to predict the endurance capacity of girls of this age.

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APPENDICES

APPENDIX A

THE LETTER OF PERMISSION AND THE INDIVIDUAL BIKE TEST PERFORMANCE RECORD AND QUESTIONNAIRE

Dear Parents:

Each year, the fitness levels of Manitoban students are evaluated by means of the Canada Fitness Award program or the Manitoba Schools Physical Fitness Survey. The endurance capacity of the students is evaluated using timed distance runs, the distance dependant upon the age of the subject.

I am a physical education teacher at Golden Gate School. I am presently investigating the relationship between two tests of endurance for my Master of Physical Education thesis. For my research, I am using 10-year-old girls as subjects. Testing includes two 1600-meter run tests and two bicycle ergometer tests. I would appreciate the assistance of your daughter as a test subject.

If you have any questions, please contact me at Golden Gate School, 837-5808. Thank you for your support.

Sincerely yours,

Marilyn Harris

. . . .

I give my permission for my daughter ______________________________
to participate in the above mentioned fitness tests.

____

Signature of Parent/Guardian

Individual Bike Test Performance Record and Questionnaire

Date
Test number
Name of subject
Date of birth
Height
Weight

Work Load (kpm/min)	Heart Rate (beats/min)						Mean Heart Rate (beats/min)
Minute	1	2	3	4	5	6	

Have you been ill at any time during the last 3 weeks?

How many hours of sleep did you have last night?

When did you eat last?

Do you do any form of exercise each week? What type of activity?

APPENDIX B

THE STANDARDIZED WARMUP USED BEFORE TESTING

The Standardized Warmup Used Before Testing

The warmup is to be done slowly. The emphasis is to be placed on the slow stretching of the muscles.

10 half neck rools in each direction

15 arm circles in each direction

4 sets of 4 side stretches on each side

10 trunk turns in each direction

8, 10-second quadraceps stretches, alternating legs

15 prolonged toe touches with head to knees

15 rises to toes while standing

30 jumping jacks

2 minute slow jogging on the spot

APPENDIX C

THE ASTRAND-RYHMING TEST PROTOCOL

The Astrand-Ryhming Test Protocol

Astrand (1980) outlined the protocol for the Astrand-Ryhming bicycle test as follows:

Setting the Load. The bicycle ergometer should stand on a level, firm foundation. With the subject mounted, but not touching the pedals, adjust the "0" mark on the scale with the screw so that it coincides with the pendulum weight. This setting must be made accurately if the load is to be precisely set.

Work is started with a slack brake belt. Thereafter the belt should be stretched with the aid of the handwheel until the required work load is obtained. Start the "work time" clock. As the belt and wheel get warmed up the friction will change, necessitating readjustment, especially if the apparatus has been unused for any length of time. Check the load at least once a minute.

Procedure of the Work Test. Adjust the saddle and handle-bar to suit the subject. The most comfortable position, and in the case of very heavy work the most effective one, is the saddle height that, when the subject has the front part of his foot on the pedal, gives a slight bend of the knee-joint in the lower position (i.e. with the front part of the knee straight above the tip of the foot).

Provided that the work is not too heavy, respiration and circulation increase during the first few minutes and then attain a steady state. The increase in heart rate can be established by counting the heart rate once every minute. After 4-5 minutes the heart has generally reached the steady state. (In order to work the muscles need oxygen and nutritive substances, carbon dioxide and waste products have to be removed. This transport exerts a load on respiration and circulation.) As a rule, about 6 minutes is thus sufficient to adapt the heart rate to the task being performed. The heart rate should be counted or recorded every minute, the mean value of the heart rate at the 5th and 6th minutes being designated the working pulse for the load in question. If the difference between these two heart rates exceeds 5 beats per minute, the working time should be prolonged one or more minutes until a constant level is reached.

Choice of Load. For trained, active sportsmen, the risk of strain in connection with a work-test is very slight. For female subjects a suitable load is 600 kpm/min, for male subjects, 900 kpm/min. If the heart rate exceeds about 130 beats per minute the load can be considered adequate and the test can be discontinued after 6 minutes. If the heart rate is slower than about 130 beats per minute, the load should be increased after 6 minutes by 300 kpm/min. If time permits testing at several loads, increase by 300 kpm/min in 6 minute periods for as long as the heart rate remains below about 150 beats per minute. The next working period may be continued for 6 minutes, even if the heart rate then exceeds 150 beats per minute. For persons expected to have a lower physical work capacity, smaller loads should be chosen, and an initial intensity of 300 kpm/min will be suitable.

APPENDIX D

THE 1600-METER RUN TEST PROTOCOL

The 1600-Meter Run Test Protocol

Equipment.	A 400-meter square with markers placed at each of the corners and a stopwatch are required.
Start.	Begin in a standing position.
Performance.	The subject is informed that 4 laps must be completed.
Scoring.	The elapsed time from the starting signal to the passage of the subject across the finish line is recorded to the nearest second.

Subjects should be encouraged to complete the distance in as short a time as possible. If necessary, they may walk or rest but they should try to begin running again as soon as possible.

APPENDIX E

THE ANTHROPOMETRIC DATA, PRETEST HEART RATES, TEST HEART RATES, PREDICTED $\dot{V}O_2$ MAX VALUES AND 1600-METER RUN TIMES FOR THE SUBJECTS

Table 15. Anthropometric data for the subjects.

Subject	Height (cm)	Weight (kg)
1	140	47.5
2	150	45.5
3	140	32.0
4	146	34.0
5	143	35.5
6	150	46.0
7	139	31.0
8	151	47.0
9	152	42.0
10	144	38.5
11	145	34.0
12	141	35.0
13	134	30.0
14	134	26.0
15	152	37.5
16	139	34.0
17	140	38.0
18	152	39.0
19	135	30.0
20	140	38.0
21	142	31.0
22	151	43.5
23	136	34.0
24	157	46.5
25	148	37.0
26	128	28.0
27	139	33.5
28	131	25.0
29	144	55.0
30	150	36.0
31	151	42.0
32	146	38.0
33	150	50.0
34	145	39.0
35	148	38.0
36	146	38.0
37	127	32.0
38	135	30.0
39	137	33.5
40	143	38.0
41	145	33.5
42	137	32.5
43	136	32.5
44	142	36.5
45	143	37.5

Table 16. Pretest heart rate 1, pretest heart rate 2, and mean pretest heart rate

Subject	Rate 1 (beats/min)	Rate 2 (beats/min)	Mean Rate (beats/min)
1	78	90	84
2	90	112	101
3	108	102	105
4	103	86	95
5	120	114	117
6	90	91	91
7	100	120	110
8	108	100	104
9	108	114	111
10	132	91	112
11	113	108	111
12	86	126	106
13	100	114	107
14	78	114	96
15	106	132	119
16	109	93	101
17	96	120	108
18	96	108	102
19	124	93	109
20	72	90	81
21	89	89	89
22	125	97	111
23	127	99	113
24	96	95	96
25	87	114	101
26	102	90	96
27	108	84	96
28	122	94	108
29	119	102	111
30	96	99	98
31	94	97	96
32	102	97	100
33	105	100	103
34	109	89	99
35	100	108	104
36	99	102	101
37	102	100	101
38	84	102	93
39	104	96	100
40	89	72	81
41	98	98	98
42	98	97	98
43	88	97	93
44	103	100	102
45	102	103	103

Table 17. Astrand-Ryhming test heart rate 1, heart rate 2, work load 1, and work load 2.

Subject	Rate 1 (beats/min)	Rate 2 (beats/min)	Mean Rate (beats/min)	WL 1 (kpm)	WL 2 (kpm)	Mean WL (kpm)
1	152	151	152	300	300	300
2	160	150	155	600	600	600
3	160	168	164	300	300	300
4	176	168	172	600	600	600
5	169	159	164	300	300	300
6	192	152	172	600	600	600
7	166	157	162	300	300	300
8	156	152	154	600	600	600
9	162	164	163	300	600	450
10	162	154	158	300	600	450
11	154	163	159	300	300	300
12	180	150	165	600	300	450
13	158	158	158	300	300	300
14	176	183	180	600	600	600
15	169	170	170	300	600	450
16	159	170	165	300	600	450
17	172	150	161	300	300	300
18	181	170	176	600	600	600
19	179	155	167	300	300	300
20	185	168	177	300	300	300
21	166	172	169	300	600	450
22	167	169	168	300	600	450
23	177	165	171	300	300	300
24	155	165	160	600	600	600
25	163	186	175	300	600	450
26	172	164	168	300	300	300
27	169	173	171	300	300	300
28	184	180	182	300	300	300
29	150	151	151	300	300	300
30	169	151	160	600	300	450
31	164	170	167	600	900	750
32	177	161	169	600	600	600
33	151	160	156	300	300	300
34	163	169	166	300	300	300
35	186	171	179	600	300	450
36	174	162	168	600	600	600
37	156	185	171	300	300	300
38	172	180	176	300	300	300
39	165	168	167	300	300	300
40	182	180	181	600	600	600
41	153	163	158	300	300	300
42	156	168	162	300	300	300
43	159	152	156	300	300	300
44	156	158	157	600	600	600
45	173	167	170	600	600	600

Table 18. Predicted $\dot{V}O_2$ max 1 ($l \cdot min^{-1}$), $\dot{V}O_2$ max ($l \cdot min^{-1}$), mean $\dot{V}O_2$ max ($l \cdot min^{-1}$), and mean $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$).

Subject	$\dot{V}O_2$ Max 1 ($l \cdot min^{-1}$)	$\dot{V}O_2$ Max 2 ($l \cdot min^{-1}$)	Mean $\dot{V}O_2$ Max ($l \cdot min^{-1}$)	Mean $\dot{V}O_2$ Max ($ml \cdot kg^{-1} \cdot min^{-1}$)
1	1.13	1.15	1.14	23.97
* 2	2.00	2.25	2.13	46.76
3	1.03	0.95	0.99	30.95
* 4	1.70	1.84	1.77	52.16
5	0.94	1.04	0.99	27.92
* 6	1.48	2.20	1.84	40.00
7	0.97	1.07	1.02	32.83
8	2.10	2.20	2.15	45.68
9	1.01	1.92	1.47	34.87
* 10	1.01	2.15	1.58	40.98
* 11	1.11	1.00	1.06	30.94
12	1.64	1.16	1.40	40.03
13	1.06	1.06	1.06	35.17
* 14	1.70	1.60	1.65	63.54
* 15	0.94	1.81	1.38	36.60
* 16	1.04	1.81	1.43	41.90
17	0.91	1.16	1.04	27.25
* 18	1.63	1.81	1.72	44.03
19	0.85	1.09	0.97	32.43
20	0.81	0.95	0.88	23.13
21	0.97	1.77	1.37	44.17
22	0.96	1.82	1.39	31.98
* 23	0.87	0.98	0.93	27.17
* 24	2.12	1.90	2.01	43.23
* 25	1.00	1.56	1.28	34.56
26	0.91	0.99	0.95	33.93
27	0.94	0.90	0.92	27.49
28	0.82	0.85	0.84	33.25
29	1.16	1.15	1.16	20.95
* 30	1.82	1.15	1.49	41.24
* 31	1.92	2.68	2.30	54.77
* 32	1.69	1.98	1.84	48.30
33	1.15	1.03	1.09	21.77
34	1.00	0.94	0.97	24.85
35	1.56	0.92	1.24	32.63
* 36	1.74	1.96	1.85	48.65
37	1.08	0.81	0.95	29.52
* 38	0.91	0.85	0.88	29.30
39	0.98	0.95	0.97	28.76
* 40	1.61	1.64	1.63	42.85
41	1.12	1.00	1.06	31.60
42	1.08	0.95	1.02	31.20
43	1.04	1.13	1.09	33.46
* 44	2.10	2.05	2.08	56.79
* 45	1.75	1.86	1.81	48.19

* Subjects who exercised 3 or more times per week.