The Influence of Physical Training on the Accuracy of Predicting Aerobic Power ($\dot{V}O_2$ max) Using the Åstrand nomogram

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ABSTRACT

The purpose of this study was to determine if the level of physical training influenced the accuracy of predicting aerobic power ($\dot{V}O_2$ max) using the Åstrand nomogram (1960). A total of 48 male subjects (24 trained, 24 untrained) between 19 and 36 years participated. Each subject performed three Åstrand nomogram tests on different days and one $\dot{V}O_2$ max test. The mean predicted $\dot{V}O_2$ max value was compared to the mean actual $\dot{V}O_2$ max value for each group. A two tailed independent t-test was used to determine if significant differences existed between the trained and untrained groups with reference to the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram. The results demonstrated that mean differences betwen actual $\dot{V}O_2$ max and predicted $\dot{V}O_2$ max were significantly different ($t(46)=2.61$, $p<.05$) for the trained and untrained group. Comparison of the predicted $\dot{V}O_2$ max (age corrected) to the actual $\dot{V}O_2$ max produced a correlation of .79 ($p<.05$) for the untrained group and .60 ($p<.05$) for the trained group. The per cent error was 10.5% and 15% for the untrained and trained group, respectively. It was concluded that the level of

physical training did influence the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram. When a correction factor based on actual maximum heart rate was used for the trained subjects, the Åstrand nomogram became a better predictor of $\dot{V}O_2$ max for the trained subjects.

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CHAPTER I

INTRODUCTION

Purpose

The purpose of this study was to determine if the level of physical training influenced the accuracy of predicting aerobic power ($\dot{V}O_2$ max) using the Åstrand nomogram (1960).

Significance of the Study

Aerobic power ($\dot{V}O_2$ max) has been accepted as the best measure of cardiorespiratory fitness (Åstrand, 1954; Hermansen & Oseid, 1971; Metz & Alexander, 1971). In prescribing exercise training, it is essential to have this measure in order to design and assess training programs. There are several disadvantages when one directly measures $\dot{V}O_2$ max. The test requires elaborate equipment, facilities, personnel, considerable motivation on the subject's part and a great deal of time in administering the test. For these reasons, several methods of predicting $\dot{V}O_2$ max from submaximal exercise test data have been developed. Submaximal tests (Physical work capacity, Fox equation, Margaria, Maritz, Harvard step test) have been widely used, as they are easy to administer, inexpensive, consume little time and are safe (Consolazio, Johnson, Phil, & Marek, 1951; Fox, 1973; Margaria, Aghemo &

Rovelli, 1965; Maritz, Morrison, Peter, Strydom & Wyndham, 1961).

One test that has been used quite extensively is the Åstrand nomogram. The Åstrand-Ryhming nomogram was originally constructed from data collected using young (age 18 to 30), healthy, physical education students (Åstrand & Ryhming, 1954) and was later revised to include an age correction factor (Åstrand, 1960).

Quite recently, LaVoie and Jamieson (unpublished data, 1984) have shown that the Åstrand nomogram test underestimated the $\dot{V}O_2$ max of subjects with a high actual aerobic power.

This study attempted to determine if the level of physical training influenced the accuracy of predicting aerobic power ($\dot{V}O_2$ max) using the Åstrand nomogram (1960).

Delimitations

The subjects in the study were 48 males, ranging in age from 19 to 36 years.

The Åstrand nomogram test was used as the predictor of $\dot{V}O_2$ max.

The Cooper point system was used to describe the physical training level of each subject.

<u>Limitations</u>

The subjects were required to accurately describe their regular physical activity level during an interview prior to testing.

The $\dot{V}O_2$ max was predicted using the Åstrand nomogram test based on the following assumptions:

a) As workload increases, heart rate and oxygen consumption increase proportionately (Åstrand & Ryhming, 1954).

b) Heart rate and oxygen consumption reach maximum values at the same time (Åstrand & Ryhming, 1954).

c) Maximum heart rate is age dependent. The original nomogram was based on subjects with a maximum heart rate of 195 beats per minute (Åstrand & Ryhming, 1954).

d) The efficiency for all bicycle riders is 23 per cent (Åstrand, 1960).

e) A heart rate response to a single workload on a bicycle ergometer will place the subject on the proper regression line to estimate $\dot{V}O_2$ max (Åstrand & Ryhming, 1954).

Definitions

Maximal oxygen uptake (aerobic power) ($\dot{V}O_2$ max)

A test of the maximal capacity of the cardiovascular-respiratory system, to take up, transport and give off oxygen to the working tissues and for these tissues to use oxygen (Glassford, Baycroft, Sedgwick, & MacNab, 1965).

Physical Training Level

The level of physical training for each individual was quantified according to the average number of Cooper's aerobic points accumulated per week. Two levels of training were quantified. Trained subjects scored 150 points per week or greater; the untrained subjects scored 30 points per week or less.

Cooper's Aerobic Point

Cooper has scientifically measured the oxygen cost of performing various sports and exercises and has translated the amounts into points. One point is equal to 7 millilitres of oxygen per kilogram of body weight (Cooper, 1977).

CHAPTER 2

LITERATURE REVIEW

Maximum oxygen uptake, the ability of the body to take up, transport and deliver oxygen to active tissues where it is utilized, is accepted as the best measure of cardiorespiratory fitness (Åstrand, 1976; Hettinger, Birkhead, Horvath, Issekutz & Rodahl, 1961; Taylor, Buskirk & Henschel, 1955). However, the direct measurement of $\dot{V}O_2$ max is only feasible in a laboratory setting. Therefore many investigators have attempted to reliably and accurately predict $\dot{V}O_2$ max using submaximal tests that utilize the linear relationship of heart rate and oxygen uptake (Cink & Thomas, 1981; Fox, 1973; Glassford et al, 1965; Jessup, Tolson & Terry, 1974; Kasch, 1984; Hermansen & Oseid, 1971; Metz & Alexander, 1971; Rowell, Taylor & Wang, 1964; Woynarowska, 1980).

A popular and widely used submaximal test was developed by Åstrand and Ryhming (1954). The aerobic power of the individual was predicted from a nomogram using a pulse rate at a submaximal workload. The nomogram was based on the following assumptions:

1. As workload increases, heart rate and oxygen

uptake increase proportionately (Åstrand & Ryhming, 1954).

2. Heart rate and oxygen consumption reach maximum values at the same time (Åstrand & Ryhming, 1954).
3. Maximum heart rate is age dependent. The original nomogram was based on subjects with a maximum heart rate of 195 beats per minute (Åstrand & Ryhming, 1954).
4. The efficiency for all bicycle riders is 23 per cent (Åstrand, 1960).
5. A heart rate response to a single workload on a bicycle ergometer will place the subject on the proper regression line to estimate $\dot{V}O_2$ max (Åstrand & Ryhming, 1954).

However, the accuracy of estimating aerobic power has become a controversial issue (Terry, Tolson, Johnson & Jessup, 1977). The limitation of the Åstrand nomogram seems to be the asymptotic nature of the cardiac frequency/$\dot{V}O_2$ curve. A linear relationship between cardiac frequency and oxygen consumption does exist over most of its working range. However, at near maximal effort the relationship breaks down and the curve becomes asymptotic (Davies, 1968; Maritz et al, 1961; Wyndham, 1967). Heart rate reaches its maximum value at slightly lower work rates than does oxygen uptake. Therefore, the extrapolation of the straight line (by means of a nomogram) to an assumed maximum cardiac frequency will result in a gross underestimation of the individual's $\dot{V}O_2$ max (Davies, 1968; Rowell et al, 1964). On the other hand, Wyndham (1967) has reported that the departure from linearity is small and only introduces a small bias.

Many studies have been undertaken in an attempt to evaluate the validity of the Åstrand nomogram test. Test results have varied due to the utilization of subjects from different training backgrounds and due to different testing techniques (Hyde, 1965).

Several studies have used the Åstrand nomogram test to predict $\dot{V}O_2$ max and have shown a significant underestimation of $\dot{V}O_2$ max (Davies, 1968; Hermansen & Oseid, 1971; Jessup et al, 1974; Jessup, Riggs, Lambert, & Miller, 1977; Kasch, 1984; Oja, Partanen & Teräslinna, 1970; Rowell et al, 1964; Thiart, Blaauw & van Rensburg, 1976; Woynarowska, 1980). The male subjects in these studies ranged in age from 10 to 50 years of age and demonstrated varying fitness levels. The low correlations and high underestimations indicated inaccurate results when predicting $\dot{V}O_2$ max from the Åstrand nomogram.

Other investigations (Cink & Thomas, 1981; Glassford et al, 1965; Greene, 1977; Keren, Magazanik, & Epstein, 1980; Teräslinna, Ismail & MacLeod, 1966), using the Åstrand nomogram test yielded predicted $\dot{V}O_2$ max values which were in close agreement with Åstrand's figures (Åstrand, 1960). Åstrand (1960) found the standard error of the method for the prediction of $\dot{V}O_2$ max from submaximal work to be approximately 10 per cent in relatively well trained individuals of the same age, but up to 15 per cent in moderately trained individuals of the same age, when the age correction factor was applied.

Other reports (Glassford et al, 1965; Hettinger et al, 1961) have shown that the Åstrand nomogram overestimated the prediction of $\dot{V}O_2$ max values. It has been suggested that the overestimation may be partly due to the fact that the nomogram was developed using well trained individuals. Glassford et al (1965) and Hettinger et al (1961) reported that many of the subjects experienced extreme local fatigue, which may have made it impossible for them to fully load their circulation during the actual maximal test, therefore producing lower actual $\dot{V}O_2$ max values than they were capable of. However, more recent work by King, Brodowicz and Ribisi (1982) and LaVoie, Mahoney and Marmelic (1978) demonstrated that actual $\dot{V}O_2$ max values obtained from a cycle ergometer with toe stirrups, were not significantly different from actual $\dot{V}O_2$ max values obtained from the treadmill.

Many researchers have attempted to improve on the submaximal prediction test by developing multiple regression models which include a wide range of respiratory and cardiovascular variables (Hermiston, & Faulkner, 1971; Jessup et al, 1974; Metz and Alexander, 1971; Mastropaolo, 1970; Siconolfi, Cullinane, Carleton & Thompson, 1982; Terry et al, 1977; Von Döbeln, Åstrand & Bergstrom, 1967; Woynarowska, 1980). In many cases there was an improvement in the predictive validity of the simple regression models, and a lowering of the standard error of the estimate (SEE) (Hermiston & Faulkner, 1971; Mastropaolo, 1970; Siconolfi et al, 1982; von Döbeln et al, 1967). However, when laboratory equipment and procedures used to collect the data for prediction, were examined, applicability and practicality were questionable. Some equations involved the use of fatfree weight, blood pressure, respiratory exchange ratio, heart rate range at a specific workload and leg strength. Those equations which did not require complex measurements produced validity coefficients and standard errors of estimates (SEE) similar to simple regression models (Terry et al, 1977). Therefore the majority of the models appeared too difficult and impractical for use by most groups and therefore could only be utilized by well-equipped laboratories.

The effects of physical conditioning on the prediction of $\dot{V}O_2$ max from submaximal values has received little attention. Studies illustrating the effects have reported conflicting results. Rowell et al (1964) found that values obtained for predicted $\dot{V}O_2$ max collected before and after a physical training program differed significantly. The magnitude of underestimation decreased from 27 per cent to 14 per cent as a result of training. In addition, endurance athletes participating in the study produced an underestimation of only 5.6 per cent. It was concluded that there was a trend toward an improved accuracy of the prediction with an increase in physical conditioning (Davies, 1968; Rowell et al, 1964).

Conversely, it has been reported that $\dot{V}O_2$ max estimated from the Åstrand nomogram overestimated the directly measured $\dot{V}O_2$ max values for well-trained athletes who had a high $\dot{V}O_2$ max (Åstrand & Rodahl, 1986). Further, Thiart's et al (1976) investigation of highly trained subjects showed that the nomogram consistently recorded an overestimation of true maximum values. This was especially noticeable in conditioned long distance athletes, with individual overestimations greater than 25 per cent.

Quite recently, LaVoie and Jamieson (1984) revealed different results. They found the Åstrand nomogram test underestimated the $\dot{V}O_2$ max of subjects with a high actual aerobic power.

Evidently there is a discrepancy associated with the accuracy of the predicted $\dot{V}O_2$ max values from the Åstrand nomogram.

The original Åstrand nomogram was computed from data for 58 subjects who performed submaximal tests on the cycle ergometer and maximal tests on the cycle ergometer or the treadmill (Åstrand & Ryhming, 1954). However, 144 subjects tested for the modification of the nomogram, used only the cycle ergometer for the submaximal and maximal tests. The data from both sets of subjects were combined to form the modified nomogram (Åstrand, 1960). Therefore it would appear that the most appropriate method of evaluating the validity of the nomogram would be to duplicate the testing mode used for its computation (Cink & Thomas, 1981, p.182-185).

Reliability figures for $\dot{V}O_2$ max predicted by the nomogram are scarce. Williams (1975) examined schedules of days, trials, and days by trial interaction to derive desired levels of reliability. It was found that the reliability increased with the number of times the test was administered. A schedule of one trial a day for three days was necessary for a reliability greater than .80. A schedule of multiple test days should be used rather than multiple trials within a day, as there was a significant trial effect which may have been due to fatigue (Williams, 1975).

To reduce the discrepancy associated with the accuracy of the Åstrand nomogram, the following procedures should be considered.

Studies have shown that subjects reveal a procedural adaptation to the Åstrand nomogram test (Davies, Tuxworth & Young, 1970; Day, 1967; Rowell et al, 1964). Initially, pulse rates were elevated but once the individual had become accustomed to the lab equipment and personnel, the pulse rates lowered (Day, 1967; Rowell et al, 1964). Anxiety levels on the part of the subjects were affected by a lack of orientation to the facilities and also because of the doubts and fears associated with the testing session (Day, 1967). Pulse rates can further be influenced by the following conditions; day to day variations, emotional state, elapsed time after previous meal, temperature changes, and dehydration (Davies, 1968; Rowell, 1974; Rowell et al, 1964; Taylor, Wang, Rowell, & Blomquist, 1963). Therefore, to ensure a valid test, it would be appropriate to try to control all of these factors and to administer the submaximal test on more than one occasion in a quiet, relaxed atmosphere.

There is a general consensus that a relatively high workload intensity is necessary for the Åstrand nomogram to yield its best estimate of aerobic power (Davies, 1968; deVries & Klafs, 1965; Glassford et al, 1965; Terry et al, 1977; Wyndham, 1967). This is based on the fact that the coefficient of variation of the cardiac frequency around the oxygen uptake is not constant. At lower intensities, the intra-individual variation was 3 to 8 per cent, but as exercise increased in intensity, the variability of cardiac frequency diminished (Davies, 1968; Wyndham, 1967). This variability plays an important role in the accuracy of the submaximal tests.

According to the literature, adherence to the aforementioned procedures will help to establish an optimal prediction of $\dot{V}O_2$ max from the Åstrand nomogram.

Physical Activity

Fitness can be reliably measured using maximal oxygen uptake tests ($\dot{V}O_2$ max). However, physical activity is much more difficult to quantify. The existence of so many methods for measuring activity levels attests to the lack of consensus about an optimal method of measurement (Edelman & Smits, 1984).

When quantifying physical activities that are intense such as those aimed at cardiorespiratory fitness, the survey method appears to be most appropriate (LaPorte, Black-Sandler, Cauley, Link, Bayles & Marks, 1983).

The Cooper point system is a means of measuring the training level of an individual. Many exercises have been scientifically measured to determine the amount of oxygen consumed by the body during a particular activity. The exercises were measured by oxygen uptake tests performed on the treadmill or during the actual field event. For those exercises which were impossible to measure by these means, charts were devised to estimate the oxygen uptake and the energy requirements. Periodic tests were performed to revalidate the data. Each exercise was assigned a certain number of points based on the amount of oxygen required to perform it. One Cooper point is equal to 7 millilitres of oxygen per kilogram of body weight. An example will clarify the system further. If a person runs a mile under eight minutes, it demands an expenditure of 35 millilitres of oxygen per Kg body weight to produce the required energy. Therefore a mile run under eight minutes equals 5 points. The concept of points was based on the intensity and duration of physical activity. Running longer distances or exercising for greater periods results in extra points (endurance points) because of a greater aerobic benefit. Cooper has accumulated extensive data on various sports and exercises that can be used to quantify training levels (Cooper, 1968, 1970, 1977).

CHAPTER 3

METHODOLOGY

The purpose of this study was to determine if the level of physical training influenced the accuracy of predicting aerobic power ($\dot{V}O_2$ max) using the Åstrand nomogram (1960).

Research Design

The Cooper point system was used to place subjects into two groups: trained and untrained. Trained subjects scored 150 points per week or greater. The untrained subjects scored 30 points per week or less. All subjects from both groups performed three Åstrand submaximal tests on three different days, at about the same time. After the third Åstrand test, each subject then performed a $\dot{V}O_2$ max test on the cycle ergometer. The actual $\dot{V}O_2$ max value and the Åstrand predicted $\dot{V}O_2$ max value for the trained and untrained groups were examined to see if the accuracy of predicting $\dot{V}O_2$ max differed between the trained and untrained groups.

Subjects

The subjects were 48 males between the ages of 19 and 36 years. They volunteered to participate because of an advertisement in the newspaper, general meeting held at the university, or through an affiliation with a sports club. All participants were either attending Lakehead University or living in the Thunder Bay area.

Pilot Study

A pilot study was undertaken to develop the experimentor's skills, decide on an appropriate strategy and to determine the optimal number of times the Åstrand nomogram test was to be administered (Day, 1967; LaVoie & Evans, 1978; Williams, 1975).

Åstrand Nomogram Test

All subjects were tested individually by this experimentor to ensure that all participants were treated the same. Each subject was informed not to eat a large meal or engage in exercise prior to coming to the laboratory. All subjects performed three submaximal tests, on three different days, at the same time each day to control for daily individual variations in physical responsiveness.

Upon arrival at the Human Performance Laboratory, all testing procedures were explained to each subject and the following standardized testing protocol was given to each subject. "The subject will pedal at 50 revolutions per minute (rpm) at a specified workload for 6 minutes. After the initial 6 minutes, the workload will be increased and the subject will continue to pedal at 50 rpm for 6 additional minutes. Each workload is designed to elicit heart rates between 125 and 170 beats per minute (bpm). Heart rates will be taken at the fifth and sixth minutes of each workload. The heart rates and workloads will be used to predict $\dot{V}O_2$ max."

The tests were performed on a Monark Cycle ergometer with the seat height adjusted to ensure that the subject's knee was slightly flexed when the leg was extended.

Calibration procedures were employed prior to each testing session.

<u>Aerobic Power Test ($\dot{V}O_2$ max)</u>

After completing the third Åstrand nomogram test (which also served as a warmup), each subject performed a continuous progressive $\dot{V}O_2$ max test. Each subject pedalled at 60 rpm with the workload increasing by .5 kilopond (kp) every 2 minutes. The expired air was expelled into a Beckman Metabolic Cart, Horizons System II. Heart rate was continuously monitored via a three lead (Cambridge VS4 model) electrocardiograph. The test continued until the subject satisfied one or more of the following criteria:

1. A levelling off or a decrease in $\dot{V}O_2$ despite an increasing workload (MacDougall, Wenger, Green, 1982).
2. A heart rate in excess of the age predicted maximum heart rate (MacDougall et al, 1982).
3. A respiratory exchange ratio greater than 1.0 (MacDougall et al, 1982).
4. Two successive $\dot{V}O_2$ measurements which do not exceed each other by more than 2 ml/kg/min or 100 ml/min. (MacDougall et al, 1982).

Verbal encouragement was given throughout the test.

Cooper Point System

Each subject appeared individually for consultation with the experimentor and described as accurately as possible his habitual physical activity pattern for the last month. Activities were charted and points were assigned and totalled according to the Cooper system in order to determine the approximate training level of each subject prior to the actual testing.

Data Analysis

The Åstrand predicted $\dot{V}O_2$ max values were calculated using the age correction factor and using the correction factor based on actual maximum heart rate.

Pearson product moment correlations were used to compare submaximal and maximal $\dot{V}O_2$ max values between trained and untrained groups.

The two tailed independent t-test was used to determine if significant differences existed between the trained and untrained groups with reference to the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram.

The alpha level of significance was set at .05.

CHAPTER 4

RESULTS

The means and standard deviations for age, body weight, maximum heart rate, and Cooper's aerobic points per week for trained and untrained subjects are presented in Table 1.

The pilot study demonstrated that the Åstrand nomogram test should be administered at least three times. Pearson product-moment correlations were used to obtain reliability coefficients. It was found that one trial a day for three days was necessary to achieve a correlation of .94 ($p<.05$) (see Table 2).

However, in the actual study it was found that high reliability coefficients existed (.96 $p<.05$, untrained), (.88 $p<.05$, trained) for the first trials of the Åstrand nomogram test (see Table 3).

Pearson product-moment correlation coefficients betweeen the three Åstrand nomogram tests are presented in Table 3. Trial 1 and Trial 2 for the untrained group demonstrated the highest correlation. Therefore they were used to calculate the mean predicted $\dot{V}O_2$ max value. Trial 2 and Trial 3 demonstrated the highest

TABLE 1

Means and Standard Deviations for Age, Body Weight, Maximum Heart Rate and Cooper's Aerobic Points

	Age (Years)	Body Weight (Kg)	Maximum Heart Rate (bpm)	Aerobic Points (per week)
Untrained n = 24	23.30 (4.74)	77.17 (7.41)	187.60 (7.59)	18.10 (7.20)
Trained n = 24	25.29 (5.30)	73.85 (10.29)	184.00 (7.40)	213.60 (78.60)

$p < .05$

TABLE 2

Pilot Study: Correlation Coefficients Between 3 Åstrand Nomogram Tests (n = 10)

		TESTS	
	1 X 2	1 X 3	2 X 3
Correlation Coefficient (r)	.59	.68	.94

$p < .05$

correlation coefficient for the trained group and were used to determine mean values for predicted $\dot{V}O_2$ max.

Correlation coefficients between mean maximal aerobic power and mean predicted aerobic power are shown in Table 4. Maximal aerobic power correlated significantly ($p<.05$) with predicted $\dot{V}O_2$ max in both the trained and untrained groups. However, higher correlations were demonstrated for the untrained group.

The means and standard deviations for the predicted $\dot{V}O_2$ max, actual $\dot{V}O_2$ max and percentage error of the estimate are presented in Table 5. The trained group produced a mean actual $\dot{V}O_2$ max value of 51.30 ± 5.96 ml/kg/min. as compared to the untrained group's mean actual $\dot{V}O_2$ max of 40 ± 6.82 ml/kg/min.

Comparison of the actual $\dot{V}O_2$ max to the predicted $\dot{V}O_2$ max for the untrained group demonstrated a percentage error of (10.5 ± 8.3) using the age correction factor and (11.70 ± 7.6) using the correction factor based on actual maximum heart rate.

The trained group revealed a lower percentage error (8.3 ± 5.7) when the Åstrand nomogram value was corrected for differences in maximum heart rate as compared to values corrected for age (15.0 ± 5.96).

TABLE 3

Correlation Coefficients Between Values Obtained From 3 Åstrand Submaximal Tests

	TESTS		
	1 X 2	1 X 3	2 X 3
Untrained Group	r = .96	r = .91	r = .90
Trained Group	r = .88	r = .86	r = .92

$p<.05$

TABLE 4

Correlation Coefficients Between Maximal Aerobic Power ($\dot{V}O_2$ max) Values and Predicted $\dot{V}O_2$ max Values

	Actual $\dot{V}O_2$ max x Predicted $\dot{V}O_2$ max (Corrected for age)	Actual $\dot{V}O_2$ max x Predicted $\dot{V}O_2$ max (Corrected for maximal heart rate)
Untrained Group	r = .79	r = .78
Trained Group	r = .60	r = .65

$p<.05$

TABLE 5

Means and Standard Deviations for Predicted $\dot{V}O_2$ max (ml/kg/min), Actual $\dot{V}O_2$ max (ml/kg/min), and Per Cent Error

	Predicted $\dot{V}O_2$ max		Actual $\dot{V}O_2$ max	% Error[a]	
	Corrected for Age	Corrected for Maximal Heart Rate		Corrected for Age	Corrected for Maximal Heart Rate
Untrained Group	41.30 (8.82)	38.10 (8.71)	40.0 (6.82)	10.5 (8.30)	11.7 (7.6)
Trained Group	57.40 (8.72)	52.10 (6.48)	51.30 (5.96)	15.0 (5.96)	8.30 (5.70)

a % Error = $\frac{\text{Actual } \dot{V}O_2 \text{ max} - \text{Predicted } \dot{V}O_2 \text{ max}}{\text{Actual } \dot{V}O_2 \text{ max}} \times 100$

The accuracy of the Åstrand nomogram test was significantly different for the trained and untrained groups. The mean difference between the actual $\dot{V}O_2$ max value and the Åstrand predicted $\dot{V}O_2$ max value (corrected for age) for the trained group (7.60 ml/kg/min ± 5.29) and the untrained group (4.20 ml/kg/min ± 3.53) was significantly different (Table 6). However, when the $\dot{V}O_2$ max predicted using the Åstrand nomogram was corrected using the correction factor based on actual maximum heart rate, the mean difference between the actual and predicted $\dot{V}O_2$ max values for the trained (4.30 ml/kg/min ± 2.99) and the untrained (4.66 ml/kg/min ± 3.38) was no longer significant. Actual-predicted $\dot{V}O_2$ max values (Table 6) were calculated by taking <u>each</u> subject's actual-predicted $\dot{V}O_2$ max value, determining the mean actual-predicted $\dot{V}O_2$ max value, then subtracting this figure from the mean actual $\dot{V}O_2$ max value.

TABLE 6

Statistical Summary Table - Independent t-test: Means and Standard Deviations for Trained and Untrained Groups

	n	df	Actual - Predicted $\dot{V}O_2$ max (ml/kg/min) Untrained	Trained	Reported T	Criterion T
a	48	46	4.20 (3.53)	7.60 (5.29)	2.61	2.02 $p<.05$
b	48	46	4.66 (3.38)	4.30 (2.99)	.39	2.02 $p<.05$

a Åstrand Predicted $\dot{V}O_2$ max Values Corrected Using the Age Correction Factor.

b Åstrand Predicted $\dot{V}O_2$ max Values Corrected Using the Correction Factor Based on Actual Maximum Heart Rate.

CHAPTER 5

DISCUSSION

The results of the study reveal that the level of physical training does influence the accuracy of predicting aerobic power using the Åstrand nomogram.

The trained group reported a greater mean difference between the actual and the Åstrand predicted $\dot{V}O_2$ max values. The correlation coefficients were lower and the percent error of the predictions were higher, indicating a less accurate prediction of $\dot{V}O_2$ max for the trained group.

Results from several investigations involving males between 17 and 70 years of age, who performed submaximal and maximal tests on the cycle ergometer are shown in Table 7. The mean values (40 ± 6.82 ml/kg/min/51.30 ± 5.96 ml/kg/min) for the actual $\dot{V}O_2$ max for untrained and trained subjects respectively compare favourably with values reported by many investigators.

Correlation coefficients and per cent error reported for the untrained group were in close agreement with Åstrand's (1954, 1960) figures. The trained group reported slightly lower correlations

TABLE 7

Comparison of Åstrand Nomogram Predicted $\dot{V}O_2$ max Values with Actual $\dot{V}O_2$ max Values by Different Investigators

Investigators	N	Åstrand Predicted $\dot{V}O_2$ max ± S.D. (ml/kg/min)		Actual $\dot{V}O_2$ max ± S.D. (ml/kg/min)	r		% Error ± S.D.
Present Study Untrained	48	41.3 (8.82)	38.1[a] (8.71)	40.0 (6.82)	.79	.78[a]	10.5 (8.3)
Trained		57.4 (8.72)	52.1[a] (6.48)	51.30 (5.96)	.60	.65[a]	15.0 (8.3)
Astrand and Ryhming (1954)	42	57.8		58.6	.71		10.4
Cink (1981)	40	52.9 (13.5)		54.6 (10.21)	.83		-
Glassford (1965)	24	49.3 (5.7)		46.3	.63		-
Jessup[b] (1974)	40	42.3 (5.7)		48.6 (4.86)	.64		-
Kasch (1984)	83	32.1 (5.2)	34.3[a] (5.1)	38.8 (5.40)	.58	.63[a]	-
Keren (1980)	15	59.9 (1.4)		60.2 (1.45)	.85		-

a Predicted $\dot{V}O_2$ max Values Corrected for Differences in Maximal Heart Rate.

b Bike and Treadmill Used.

(r=.60, r=.65 corrected for differences in maximal heart rate, $p<.05$) and a higher percent error (15 ± 5.96) than Åstrand's figures. However, the data from the trained group was comparable to many other investigations (Table 7).

A t-test revealed that the accuracy of the Åstrand nomogram test was significantly different for the trained and untrained group. However, the significant difference disappeared after using the correction factor based on actual maximum heart rate. Such findings were not reported in the reviewed literature.

Åstrand (1960) found that there was a tendency for the $\dot{V}O_2$ max to be underestimated for untrained subjects and overestimated for trained subjects. This study found the Åstrand nomogram to be a good predictor of $\dot{V}O_2$ max for the untrained subjects. However, the predicted aerobic power values were 12 per cent higher than actual values for trained subjects. Åstrand (1960) and Thiart et al (1976) produced similar findings.

This study found that when the predicted $\dot{V}O_2$ max was corrected for differences in maximal heart rate, the overestimation was reduced from 12 per cent to 1.5 per cent for the trained group. The per cent error was also reduced and the correlation coefficient between actual and predicted $\dot{V}O_2$ max values became stronger. This has been confirmed in other investigations (Hermansen & Oseid, 1971; Kasch, 1984).

This may be explained by the fact that the Åstrand nomogram is a predictor of $\dot{V}O_2$ max from measurements of heart rates during submaximal workloads, with an extrapolation to a maximum heart rate of 195 beats per minute. Åstrand corrects for this using an age correction factor which alters the maximal heart rate depending on the age of the subject.

Consequently, for subjects with a maximum heart rate below 195 beats per minute and using the age correction factor, predicted values for $\dot{V}O_2$ max would be overestimated. In the present study, the mean maximum heart rate for the trained group was slightly lower than the untrained group's mean maximum heart rate (Table 1). The variation in maximum heart rate may partially explain differences existing between trained and untrained subjects with reference to the accuracy of the Åstrand nomogram.

Further, it has been reported that physical training changes the individual slopes of the curves for heart rate and oxygen uptake (Åstrand, 1960). The lack of linearity in the heart rate/oxygen uptake relationship for many trained subjects could account for differences in the accuracy of the Åstrand predicted $\dot{V}O_2$ max value.

The pilot study and reviewed literature (Day, 1967; Williams, 1975) have confirmed that administering more than one Åstrand nomogram test would result in a more reliable predicted $\dot{V}O_2$ max value. However, this study demonstrated high correlation coefficients for initial trials of the Åstrand nomogram test. This may be due to the fact that subjects participating in this study were familiar with the experimentor and the procedures prior to reporting to the laboratory.

The results of the present study suggest that the level of physical training influenced the accuracy of predicting aerobic power using the Åstrand nomogram.

This study confirms that a properly performed Åstrand nomogram predicted procedure can be a reliable measure of $\dot{V}O_2$ max for untrained men between the ages of 19 and 36 years.

For highly trained subjects, the Åstrand nomogram was not as accurate a predictor of $\dot{V}O_2$ max as compared to the untrained subjects. However, the Åstrand nomogram became a more accurate predictor when the athlete's actual maximum heart rate was known. Therefore, knowledge of the athlete's maximum heart rate would improve upon the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram. Maximum heart rate would also be a useful tool for prescribing and monitoring exercise programs.

CHAPTER 6

CONCLUSIONS, SUMMARY AND RECOMMENDATIONS

Conclusions

Within the limits of this study, the following conclusions have been made:

1. A significant difference existed between the trained and the untrained groups when comparing the accuracy of predicting aerobic power using the Åstrand nomogram.
2. The untrained group yielded a more accurate prediction of $\dot{V}O_2$ max when corrected for age than did the trained group.
3. A properly performed Åstrand nomogram procedure can be a reliable measure of $\dot{V}O_2$ max for untrained men between 19 and 36 years.
4. Differences in maximum heart rates between trained and untrained groups may have accounted for part of the difference in predictability of $\dot{V}O_2$ max.
5. For trained subjects, the use of the correction factor based on maximum heart rate will improve upon the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram.

Summary

The purpose of the study was to determine if the level of physical training influenced the accuracy of predicting aerobic power ($\dot{V}O_2$ max) using the Åstrand nomogram (1960).

A total of 48 male subjects between 19 and 36 years participated. The trained group consisted of 24 males each accumulating 150 or more Cooper aerobic points per week. The untrained group was comprised of 24 males, accumulating 30 or fewer Cooper aerobic points per week.

Each subject performed three Åstrand nomogram tests on different days and one $\dot{V}O_2$ max test. The mean predicted $\dot{V}O_2$ max value was compared to the mean actual $\dot{V}O_2$ max value for each group.

The results demonstrated that mean differences between actual $\dot{V}O_2$ max and predicted $\dot{V}O_2$ max using the age correction factor were significantly different ($t(46)=2.61, p<.05$) for the trained and untrained group. Comparison of the predicted $\dot{V}O_2$ max value (age corrected) to the actual $\dot{V}O_2$ max value produced a correlation of .79 ($p<.05$) for the untrained group and

.60 ($p<.05$) for the trained group. The per cent error was 10.5 per cent and 15 per cent for the untrained and trained group, respectively.

When the Åstrand predicted $\dot{V}O_2$ max values were corrected for actual maximum heart rates, there was an improvement in the per cent error (to 8.3 per cent) and the correlation coefficient ($r=.65$, $p<.05$) for the trained group.

It was concluded that the level of physical training did influence the accuracy of predicting $\dot{V}O_2$ max using the Åstrand nomogram. When a correction factor based on actual maximum heart rate was used, the Åstrand nomogram became a better predictor of $\dot{V}O_2$ max for the trained subjects.

Recommendation

1. Further research is necessary to examine the relative contribution physical training has on the prediction of $\dot{V}O_2$ max using the Åstrand nomogram.

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APPENDIX A

Habitual Activity Form and Consent Form

ACTIVITY SCHEDULE

Subject: ______________________

FREQUENCY PER WEEK

WALKING

Activity	Distance / Time	1	2	3	4	5	6	7
WALKING	1 to 2 miles							
	2 miles or more							

JOGGING

Distance		Time	1	2	3	4	5	6	7
1 mile		over 8 mins.							
		under 8 mins.							
		under 6 mins.							
1 to 2 miles		under 12 mins.							
		under 16 mins.							
3 to 5 miles		8 mins. or more/mile							
		7 mins./mile							
		6 mins./mile							
		less than 6min/mile							
6 to 10 miles		9 mins or more/mile							
		8 mins/mile							
		7 mins/mile							
		less than 6min/mile							
___ miles or more									

Activity	Distance	1	2	3	4	5	6	7
CYCLING	1 to 5 miles							
	5 to 10 miles							
	10 miles or more							
SWIMMING	200 to 500 yards							
	500 to 1000 yards							
	1000 yards or more							

Activity	Time	1	2	3	4	5	6	7
HANDBALL/SQUASH BASKETBALL/BASEBALL	Less than 30 mins.							
	30 to 50 mins.							
(continuous activity time excluding breaks)	50 to 70 mins.							
	70 to 90 mins.							
	90 mins. or more							

football

GOLF	- 9 holes							
	- 18 holes							
Rowing	(20 strokes) 6 mins.							
	18 mins.							
	36 mins.							
TENNIS	1 set							
	2 set							
	3 set							
WRESTLING	5 min.							
	10 min.							
	15 min.							

OTHER (Specify)							

CONSENT FORM

I, ____________________, have been informed that the research in which I am about to participate will place me in some demanding situations. I understand that the demands may be both physical and mental in nature but that the experience will not be dangerous for a normal healthy person. I also realize that if at any time I wish to discontinue an experimental session, I may indicate this to the experimenter and I will be free to leave. I have been told by the experimenter that the research techniques are standard procedures that have been well thought out and tested. With this understanding, I have consented to be a participant.

Signed ______________________

Date ________________________

APPENDIX B

Raw Data

RAW DATA - TRAINED SUBJECTS

Subject	Age (Yrs)	Weight (Kg)	Predicted $\dot{V}O_2$ max (age) ml/kg/min #1	#2	#3	Mean Predicted $\dot{V}O_2$ max (age)	Predicted $\dot{V}O_2$ max (max HR) ml/kg/min #1	#2	#3	Mean Predicted $\dot{V}O_2$ max (max HR)	Average Coopers Aerobic Points (per wk)
1	26	76.3	59	67.5	70	68.8	51	58.5	61	59.8	190
2	22	65.5	51.5	55	59	57	49.5	52	56	54	200
3	26	83.2	60	68.5	63	65.8	56	63.5	58.5	61	175
4	21	71.5	66	62	64	63	51.5	48.5	50.5	49.5	161
5	21	69.7	65.5	70	65	67.5	50.5	54.5	50	52.3	164
6	22	71.5	56	59	60	59.5	44	46	47	46.5	400
7	21	66.2	55.5	60.5	64.5	62.5	51	56	58.5	57.3	206
8	21	57.1	61	57.5	57	57.3	58.5	55.5	54.5	55	155
9	19	63.5	56.5	57.5	55.5	56.5	51.5	52.5	51	51.8	400
10	22	65	63.5	65	68.5	66.8	54	55.5	58.5	57	200
11	21	71.9	74	77	78	77.5	63.5	66	67	66.5	300
12	20	72.5	41	43.5	44	43.8	40	41.8	42.5	42.2	155
13	26	76	51.5	53.5	49	51.3	45	46.5	43	44.8	170
14	21	73.2	71	64	65	64.5	65	58.5	60.5	59.5	360
15	34	76.3	45	43	43	43	47.5	45.5	45.5	45.5	155
16	25	72	55.5	53.5	54	53.8	45.5	44.5	45	44.8	155
17	27	80.5	49	50	51.5	50.8	49	49.8	51	50.4	152
18	21	82.5	55	59.5	51.5	55.5	52	55	49	52	170
19	28	74.2	51.5	50	51.5	50.8	51	50	51	50.5	152
20	35	72.6	54	62.5	60	61.3	51	59	57.5	58.3	300
21	36	95.2	39	48	49.5	48.8	40.5	50.5	51.5	51	151
22	30	105	43.8	47.6	38.5	43.1	41	44.8	36.5	40.7	170
23	27	68.2	52	56.5	54	55.3	51.5	55	52.5	53.8	210
24	35	62.8	54.5	53	55.5	54.3	45.5	44.5	47.5	46	275

RAW DATA - TRAINED SUBJECTS (Continued)

Subject	Actual $\dot{V}O_2$ max ml/kg/min	L/min	$\dot{V}E$ BTPS	RER	Maximum Heart Rate
1	53.4	4.08	136.5	1.27	181
2	63.8	4.13	161.8	1.14	191
3	56.5	4.71	146.4	1.15	187
4	52.7	4.3	110.6	1.15	173
5	49.0	3.42	121.9	1.24	172
6	57.3	3.9	139.9	1.19	173
7	58	3.85	141.6	1.20	188
8	51.8	2.96	72.4	1.22	194
9	53	3.37	118.4	1.32	190
10	51.1	3.33	96.8	1.21	181
11	57.7	4.16	151.7	1.22	182
12	49	3.6	132.1	1.28	194
13	40.2	3.1	85.8	1.14	181
14	58.7	4.3	132.6	1.22	188
15	47.9	3.6	106	1.28	191
16	44.3	3.2	87.4	1.30	178
17	42.3	3.4	93.3	1.38	184
18	49.2	4.1	120.7	1.19	191
19	48.5	3.6	122.7	1.16	186
20	55.6	4.1	124.5	1.28	180
21	43.9	4.2	165.3	1.22	187
22	43.6	4.6	194.5	1.25	185
23	55.7	3.8	140.3	1.18	191
24	48.7	3.07	94.8	1.21	167

RAW DATA - UNTRAINED SUBJECTS

Subject	Age (Yrs)	Weight (Kg)	Predicted $\dot{V}O_2$ max (age) ml/kg/min #1	#2	#3	Mean Predicted $\dot{V}O_2$ max (age)	Predicted $\dot{V}O_2$ max (max HR) ml/kg/min #1	#2	#3	Mean Predicted $\dot{V}O_2$ max (max HR)	Average Coopers Aerobic Points (per wk)
1	22	70.3	48	51	52	49.5	42	44.5	45.5	42.3	20
2	20	88.9	32.5	35	32	33.7	29	31.5	28.5	30.3	10
3	28	89	26.5	29	30	27.8	24	26	27	25	8
4	21	62	67.5	66	56	66.7	65	63.5	54	64.3	30
5	19	82.6	37	37	36.5	37	30	30	30	30	10
6	22	75.7	39	44	36	41.5	33.5	38	31	35.7	25
7	19	80	33.5	35.5	37.5	34.5	29	30.5	32	29.7	16
8	20	70.5	41	41.5	41	41.3	35.5	36	35.5	35.8	21
9	19	74.4	35	40	44	37.5	33	38	41.5	35.5	20
10	19	70.8	41	43	43	42	39	41	41	40	20
11	22	79.5	27	25.5	27	26.3	28.5	27	28.5	27.8	10
12	31	67.3	43	42.5	39	42.8	42.5	41.5	38.5	42	19
13	19	65.5	42	49	40.5	45.5	40.5	46.5	39	43.5	28
14	32	79.7	30.5	33.5	32	32	27	29.5	28.5	28.3	10
15	26	80.8	45	49.5	45.5	47.3	34	37.5	34.5	35.8	12
16	26	81.2	53.5	53.5	47.5	53.5	51.5	51.5	45.5	51.5	20
17	24	90.1	39.5	36.5	41	38	36	33.5	37.5	34.8	15
18	24	82.9	51	48	47	49.5	51.5	49	47.5	50.3	20
19	23	77	43.8	43	43	43.4	42.5	42	42	42.3	29
20	21	79.6	41.8	43	43	42.4	38.5	39.5	39.5	39	24
21	23	82.5	47.5	47.5	41.5	47.5	40	40	35	40	18
22	21	78.7	43	42.5	43.5	42.7	39	38.8	39.5	38.9	28
23	26	72	29	33	31	31	30	34	32	32	5
24	33	71	36	40	35.5	38	36.5	40.5	36	38.5	15