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CANADIAN THESES ON MICROFICHE / THÈSES CANADIENNES SUR MICROFICHE

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TITLE OF THESIS/*TITRE DE LA THÈSE* PHYSICAL WORK CAPACITY ALONG WITH MUSCULAR STRENGTH AND ENDURANCE LEVELS OF INTERCOLLEGIATE HOCKEY PLAYERS

UNIVERSITY/*UNIVERSITÉ* UNIVERSITY OF ALBERTA

DEGREE FOR WHICH THESIS WAS PRESENTED/*GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* MASTER OF SCIENCE

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1977

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# PHYSICAL WORK CAPACITY ALONG WITH MUSCULAR STRENGTH AND ENDURANCE LEVELS OF INTERCOLLEGIATE HOCKEY PLAYERS

by

Robert McKinley Slipp

A THESES

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

FALL 1977

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PHYSICAL WORK CAPACITY ALONG WITH MUSCULAR STRENGTH AND ENDURANCE LEVELS OF INTERCOLLEGIATE HOCKEY PLAYERS

submitted by Robert McKinley Slipp

in partial fulfilment of the requirements for the degree of Master of Science.

Supervisor

Date 6 Nov 1972

## Abstract

Thirty intercollegiate hockey players at the University of Alberta were tested three times during the 1973 - 1974 ice hockey season to determine changes in fitness during the season. Preseason, midseason and postseason values were determined for physical working capacity, maximal $O_2$ intake and muscular strength and endurance parameters. Sixteen undergraduate students enrolled in service programs of the Department of Physical Education acted as control subjects. Physical working capacity and maximal $O_2$ intake of the hockey players increased significantly between preseason and midseason, and showed no further increase for the remainder of the season. No significant increase was observed in muscular strength and endurance of the hockey players between preseason and midseason testing. An in-season weight training program produced significant increase in the muscular strength and endurance of hockey players. Playing performance of the hockey players correlated significantly with body weight for the varsity players studied. Physical working capacity, maximal $O_2$ intake, arm strength and strength index did not correlate significantly with playing performance. It was concluded that a season of intercollegiate ice hockey increased the physical working capacity and maximal $O_2$ intake but did not significantly improve muscular strength and endurance. An in-season weight training program did increase the strength and endurance levels of ice hockey players.

Dedication

To Cheryl, with love and appreciation for the encouragement, support and loving homelife provided during our two years in Edmonton.

Acknowledgements

I wish to thank my thesis advisor, Dr. Mohan Singh, for his insight and assistance throughout the study, and my committee members, Dr. Larry Wong and Professor Clare Drake for their time, ideas and assistance.

A special note of thanks to the 1973 - 1974 Golden Bears and Bear Cats Hockey Teams, coach Clare Drake and our 16 control subjects for their time, keen interest, curiosity, humor and persistence.

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CHAPTER I

INTRODUCTION

Introduction

A number of studies have been conducted concerning the effects of conditioning programs upon various physiological parameters (Freeman et al, 1936; Brown, 1960; Dirken, 1957; MacKenzie, 1970; Robinson and Harmon, 1941; Astrand et al, 1960). Few studies (Watson, 1965; Zelter, 1964; Chambers, 1967; Green et al, 1970a; Green 1973; Ferguson et al, 1969; and Howell, 1966) have dealt with the training effects of ice hockey programs upon these physiological parameters. At present these studies form the basis of scientific knowledge concerning the physiological response to a competitive season of ice hockey.

Howell(1966) and Ferguson et al (1969) were concerned with the determination of maximal oxygen intake of collegiate hockey players and found values of 57 and 55 ml/kg/min, respectively, for this parameter. Watson (1965) studied maximal oxygen intake as well and found that a season of ice hockey significantly increased the maximal oxygen consumption of ten University of Alberta varsity hockey players from 3.51 to 4.11 l/min or 45.22 to 54.26 ml/kg/min. Green (1972) described a change in maximal oxygen intake from 4.32 to 4.18 l/min or 53.9 to 56.4 ml/kg/min during a season of intercollegiate hockey. These results are consistent with seasonal changes reported by Howell (1966). Green (1973) reported that virtually no seasonal change in maximal oxygen consumption occurred for both university and junior hockey players studied.

For the most part, the studies mentioned above concentrated mainly on maximal oxygen intake as a measure of fitness, although Green et al (1972b) did examine anaerobic capacity as well. The present study was initiated to determine what changes in aerobic capacity, as indicated by $PWC_{170}$ and predicted Max $VO_2$ occurred during a season of intercollegiate ice hockey. Seasonal changes in muscular strength and endurance, and the effectiveness of an in season weight training program were also examined. Since strong emphasis has not been previously placed on the investigation of muscular strength and endurance levels of intercollegiate hockey players, it is hoped that the values measured in the present study are valuable in the establishment of norms for muscular strength and endurance of intercollegiate hockey players. It is also hoped that the assessment of the in season weight training program will establish that such a program is a valuable contribution to the overall fitness of intercollegiate hockey players.

## Statement of the Problem

The main purpose of this study was to determine what changes occurred in the fitness levels of intercollegiate hockey players during a competitive season. The fitness parameters examined were:

1. physical work capacity as measured by the Ástrand $PWC_{170}$ test
2. maximal oxygen intake predicted from the Ástrand - Rhyming nomogram
3. muscular strength and endurance as measured by the Grip Strength, Chin-ups, Shoulder-lifts, Arm Strength Index, Back Strength, Leg Strength, and Strength Index

Two subsidiary problems were also investigated in the study:

1. the effectiveness of an in season weight training program upon muscular strength and endurance levels
2. correlations between the fitness levels of the players and their performance during the season

## Rationale Behind the Study

Scientific investigation of fitness levels and training procedures of Canadian ice hockey players has been limited. Following the first Canada - Russia hockey series in 1972, many hockey and fitness experts advocated the implementation of more scientific training and coaching methods for hockey programs at all age levels.

ways:

types of scientific training stimuli that are necessary during on-ice sessions to develop maximal fitness levels for competitive hockey. The present study examined the training effects of such an on-ice training program, used at the University of Alberta, to see if maximal fitness levels were attained.

Weight training programs have been advocated and used by hockey players for a number of years to supplement on-ice training. Bukac (1968) noted that top level Russian hockey teams started preseason training in July for the coming competitive season. An integral part of this preseason conditioning program was a weight training program to develop a high level of muscular strength and endurance before the competitive season. This high level of strength was maintained during the hockey season by one weight lifting session per week.

In Canada, ~~strict~~ weight training programs are not often performed by hockey players during the off season, but weight training programs have sometimes been conducted during the season. The present study examined the effect of such an in-season weight training program on levels of muscular strength and development.

Limitations and Delimitations of the Study

1. The study was restricted to 30 male intercollegiate hockey players at the University of Alberta, and 18 male university undergraduate students who acted as control subjects.
2. Physical working capacity was determined by the Sjostrand $PWC_{170}$ test.
3. Maximal oxygen intake was predicted using the Astrand - Rhyming Nomogram.
4. Muscular strength and endurance were measured using the Arm Strength and Strength Indices.
5. Subjects were tested three times; October, January and March, corresponding to preseason, midseason, and postseason values.
6. The control subjects were free to exercise at will, individuals who played hockey during the season were not selected as subjects.
7. Temperature, barometric pressure and humidity were not controlled during testing.
8. Subjects were asked not to participate in physical exercise before testing, but no external controls were used to enforce this request.
9. The time of day of testing was not strictly controlled.

Definition of Terms

Maximal oxygen intake (aerobic capacity) is defined in terms of the linear relationship between progressively increasing workloads and $O_2$ consumption; until $VO_2$ per unit time remains constant, falls or slightly increases, even though workload may increase.

Physical Work Capacity$_{170}$ ($PWC_{170}$) is defined as the intensity of work in kilopond meters per minute which the subject could perform at a pulse rate of 170 beats per minute.

Steady state heart rate is the heart rate between two successive readings taken at one minute intervals, which do not differ by more than ±5 beats.

Workload is the calibrated force of a friction belt which must be overcome by a subject while cycling at a prescribed rate. The work done is the product of the cycling rate, the distance cycled as determined by wheel circumference and revolutions, and the belt resistance.

Kilapondmeter (kpm) is the force developed by a kilogram mass under the influence of gravity for one meter.

Arm Strength Index is a muscular endurance index calculated from chin-ups and shoulder-dips, with height and weight factors included.

Strength Index is a fitness inventory obtained by summing values for left and right grip strength, back strength, leg strength, arm strength index and vital capacity.

CHAPTER II

# REVIEW OF LITERATURE

## Aerobic Capacity as a Measure of Fitness

The capacity of an individual to withstand prolonged, heavy work has been reported to be the most important component of fitness (Astrand, 1956; Balke, 1960; Hettinger et al, 1961). Rodahl and Issekutz (1962: 277) state that, "during heavy, prolonged physical work, the individual's performance capacity depends largely on his ability to take up, transport and deliver oxygen to the working muscle." Several other studies consider maximal oxygen intake or aerobic capacity to be the best measure of cardio-respiratory fitness (Astrand, 1956; Hettinger, et al, 1961; Newton, 1963; Rodahl et al, 1961; Taylor et al, 1963).

Astrand and Saltin (1961) suggested that the measurement of maximal oxygen uptake (aerobic capacity) of a subject when performing muscular exercise gives the maximal rate of energy output by combustion within the body. To further illustrate this point, Rodahl et al (1961) stated that

> the reloading of the contractile mechanism demands energy which in turn is liberated either from the restricted stored in the muscles themselves or from food storage from the blood stream. The rate of work that can be maintained over a longer period will, therefore, mainly depend on the transportation capacity of the cardio-respiratory system.

In order to test circulatory and respiratory fitness, work must be chosen that engages large muscle groups at a high intensity for

a duration which is long enough to allow circulatory and respiratory adjustments to the stress of the exercise (Astrand, 1952). Wahlund (1948) stated that tests in which a large number of muscles are required, maximum oxygen consumption should be regarded as a reliable measure of maximum work capacity. He described physical working capacity to be a continuum, from the heart patient to the highly conditioned athlete. The capacity to maintain a high oxygen consumption over a period of time demonstrates a large degree of cardio-vascular and respiratory fitness (Taylor, 1958). Newton (1963) noted that the maximal rate at which oxygen can be consumed is an important measure of the ability of the circulatory and the respiratory systems to withstand the stress imposed by strenuous physical activity. Maximal oxygen intake is not only the best physiological indicator of the capacity of a man for sustaining hard work, it is also the most objective measure which indicated the physical fitness of an individual as reflected by his cardiovascular system (Newton, 1963).

Hettinger et al (1961) agreed that maximal oxygen intake is probably the best measure of a physical fitness, but pointed out a number of problems associated with its direct determination. Elaborate laboratory procedures, time required, the necessity of a maximal workload, and the difficulty of untrained subjects to reach $VO_2$ Max are some of these problems (Hettinger et al, 1961).

Prediction of Aerobic Capacity

As mentioned above, a number of problems are associated with the direct determination of maximal oxygen intake (Hettinger et al, 1961; Rowell et al, 1964; and Mitchell et al, 1958). Because of these

problems many submaximal tests have emerged which predict aerobic capacity from observations taken during submaximal work (Astrand, 1952; Balke, 1959; Cunningham, 1963; de Vries and Klafs, 1964; Issekutz, 1960; Ljostrand, 1947; Workman et al, 1964; Margaria et al, 1965; Shephard, 1966).

Such submaximal tests can be used to obtain an easy and reasonably accurate estimation of aerobic capacity. Under controlled conditions, the standard error of prediction of submaximal tests is 11 to 15% (Astrand and Rodahl, 1971). Taylor et al (1963) concluded that it is generally agreed that during submaximal work on a bicycle ergometer, $O_2$ consumption can be predicted with a reasonable degree of accuracy if the weight of the subject is known and the rate of work is known and maintained constant.

Astrand - Rhyming Nomogram

In 1954, Astrand and Rhyming introduced a nomogram for the prediction of maximal oxygen intake from a steady state heart rate at a known work load.

The nomogram was based on the heart response of eighty-six physical education students to exercise. Examination of the data showed that the average pulse rate (beats/min) for men and women at an oxygen intake representing 50% of the maximal $O_2$ intake was 128 and 138, respectively. At 70% of maximal $O_2$ intake, average heart rates of 154 (male) and 168 (female) were observed.

Using these results, Astrand and Rhyming constructed the nomogram on the assumption that the heart rate would approximate 128 (male) at 50% maximal $O_2$ intake and a maximal heart rate of 195 beats

per minute. Astrand (1960) outlined the prerequisites for using the nomogram:

1. that the pulse rate increases approximately linearly with the oxygen intake during submaximal exercise.
2. that submaximal pulse rates not lower than 125 beats per minute be used.
3. that the subject can reach a maximal heart rate of 195 (±10) during maximal exercise.

Adjustments have been made to allow the nomogram to be applied to a wider range of people. Astrand (1960) introduced an age factor to deal with the decline in maximal heart rate with age. A further age correction factor was introduced in 1965 for subjects under fifteen years of age (Astrand, 1965).

Validity of the Astrand - Rhyming Nomogram

Astrand and Rhyming (1954) established the validity of their nomogram by comparing the predicted maximal $O_2$ values with the actual values. Analysis of the values revealed a mean difference of 0.023± 0.059 (males) and 0.010± 0.051 (females) litres of $O_2$ per minute between predicted and actual values of maximal $O_2$ intake. Lower standard deviation values were reported for both men and women for a higher range of work: 6.7% (male) and 9.4% (female) at a work load of 1200 and 1800 kpm compared to 10.4% (male) and 14.4% (female) at work loads of 300 and 600 kpm. Astrand and Rhyming (1954) also reported a study using untrained female subjects, 18 - 19 years of age. A mean difference of 0.006± 0.06 l/min was reported between

actual and predicted values.

In 1960, Astrand reported the standard error of the nomogram method for predicting maximal $O_2$ intake to be about 10% for well-trained subjects and about 15% for moderately trained individuals.

Dobeln et al (1967) reported a standard deviation of 17% between predicted and actual maximal $O_2$ values for 84 persons between the ages of 30 and 80. Dobeln found that the nomogram underestimated the maximal $O_2$ intake by 0.15 liter/minute. Rowell et al (1964); Chase et al (1966) and Wyndham et al (1959) reported similar findings. Astrand and Rodahl (1971) stated that untrained persons are often underestimated, while extremely well-trained athletes are often overestimated. However, Glassford et al (1965) reported close agreement between actual and predicted values of maximal $O_2$ intake.

Hettinger et al (1961) reported a significant difference between predicted and actual maximal $O_2$ consumption (2.38 and 2.26 l/min) in 28 policemen 20 to 30 years of age. This difference was significant at the 5 per cent level of confidence. It was suggested that the subjects did not attain true maximal $O_2$ levels due possibly to their lack of training.

In a similar study, Rodahl et al (1961) tested 9 policemen between the ages of 23 and 48 years and found a difference of only 4.8% (2.65 to 2.54 l/min) between predicted and actual values. In another group of untrained men, 23 to 48 years of age, the difference was insignificant; with values of 2.72 and 2.76 l/min for predicted and actual maximal $O_2$ intake (Rodahl et al, 1961).

In 1964, deVries and Klafs used 16 physical education students, 20 to 26 years of age, to determine correlations and

predictive errors in predicting maximal $O_2$ consumption from submaximal tests of work capacity. An $O_2$ consumption value obtained from the Astrand - Rhyming nomogram correlated significantly ( r = 0.736) with a value obtained from a maximal test on the bicycle ergometer.

Wyndham et al (1959) criticized the nomogram because they found that it underestimated the maximal oxygen intake by 0.32±0.14 l/min. They believed that the nomogram did not take into account that the pulse rate - oxygen consumption curve deviates towards $O_2$ consumption at high pulse rates.

Astrand (1960) however, stated that the nomogram was not based on the assumption that heart rate is a linear function of $O_2$ intake throughout the entire range of heart rate values. Astrand pointed out that since the study of Wyndham et al was conducted at an altitude of 5,500 feet, the observed difference between predicted and maximal $O_2$ values might be due to the effects of hypoxia.

Rowell et al (1964) demonstrated the influence of training on prediction with the nomogram. Using subjects 18 to 24 years old, they found the predicted test underestimated the maximal $O_2$ value by 11 ± 7 % after training compared to 27 ± 7 % before training. They also reported an underestimation of 5.6± 4% for a group of 10 highly trained endurance athletes.

Baycroft (1964) compared predicted values using the Astrand-Ryming nomogram with actual valued determined with the Mitchell et al test and the Astrand Bicycle test for 48 physically active males. He reported a significant correlation ( r = .62) with the Astrand Bicycle test values.

Glassford (1964) used 24 physically active males to compare

the Astrand - Rhyming nomogram test with four maximal oxygen tests. Values in liters per minute obtained on the Astrand - Rhyming predicted test correlated well with the Johnson - Brouha - Darling test, ($r = .78$); the Mitchell - Sproule - Chapman test, ($r = .80$); the Taylor - Buskirk - Henschel test, ($r = .72$); and the Astrand test, ($r = .65$). The correlation between the nomogram values and any one set of directly measured values was as good as the correlation between the values of any two direct techniques examined in the study.

Hyde (1965) investigated the validity of the nomogram for secondary school children. He reported predicted values equivalent to those obtained on the Astrand actual test for the 27 females studied. However, the predicted values for the 28 males were underestimated by 9.74%, a significant difference at the 1 per cent level of confidence.

## History of Sjostrand P W C $_{170}$ Test

The first reported use of the Sjostrand test was in 1947, Sjostrand reported findings on the physical work capacity of 20 ore smelting workers. The test utilized workloads of 300, 600, 900, and occasionally 1200 kpm/min for a ten minute interval at each workload, except the last, which was either four or six minutes.

Wahlund (1948) tested 469 adult males on a bicycle ergometer starting at a workload of 300 or 600 kpm/min and increasing the work load every 6½ minutes by 300 kpm/min until the subject was exhausted or work at 1200 kpm was done. Pulse rates were determined at 2 minute intervals throughout the test.

Kjelberg et al (1950) made a further modification of the Sjostrand test by shortening the times of each workload to 6 minutes and extrapolating the pulse curve to 170 beats per minute. Other testing procedures were as outlined by Wahlund.

Bengtsson (1956) refined the Sjostrand test further in 1956. He applied the concept of steady state heart rate to the test. Workloads were adjusted so that heart rates would be approximately 125 - 130, 140 - 150, and about 170 beats per minute for successive workloads.

In 1961 Adams et al used the Sjostrand test to study 243 normal school children in California. They attempted to adjust workloads for each subject so that heart rates of 100 - 120, 120 - 140, and 150 - 170 were attained in successive work periods.

In another study Adams et al.(1961) made a modification to the Sjostrand test by using only 2 successive workloads instead of 3 and trying to obtain heart rates about 140 on the first test and approximately 170 on the second.

Cummings and Cummings (1963) employed the Sjostrand test procedure of Adams (1961b). Cummings and Danzinger (1963) followed the procedure of Adams (1961a) to administer the Sjostrand test.

de Vries and Klafs (1964) also used only two consecutive workloads; however, they used predetermined loads of 450 and 900 kpm/min.

Zahar (1965) used 38 high school students to study the reliability of the test with repeated measures. He used three consecutive six minute work periods, each at a higher work load.

Fedoruk (1969) also studied the reliability and validity of the Sjostrand P W C $_{170}$ test. However, he employed a 12 minute contin-

nous bicycle ride consisting of 3 four minute work periods at successively higher work loads.

## Validity and Reliability of Sjostrand P W C $_{170}$ Test.

Borg and Dahlstrom (1962) reported re-test correlations for the P W C $_{170}$ of r = .76, compared to a value of .71 on the Astrand - Rhyming Nomogram test.

They also reported an intra-test correlation of .97 for the P W C $_{170}$ test. Borg and Dahlstrom checked the validity of the P W C $_{170}$ test as well. Using the results of a ski race as the criterion, they found correlations of r = .46 and r = .54 between the criterion test and the first and second P W C $_{170}$ tests.

Borg and Dahlstrom reported another study done by Linderholm that reported on the reliability of the P W C $_{170}$ test. Linderholm found a test - retest correlation between two tests 4 days apart of .97 for a group of 18 men and women with a P W C $_{170}$ ranging from 625 - 1555 kpm/min.

Fedoruk (1969) reported test - retest correlations of .91 and .75 for males and females when the P W C was expressed in kpm/min. These coefficients reduced to .87 and .70 when expressed in kpm/kg/min. A comparative re-test reliability of .88 (males) and .83 (females) was obtained on the Mitchell - Sproule - Chapman test. Comparison between the correlation coefficients of the mean of two Sjostrand trials with the criterion maximum test and two maximum trials revealed a nonsignificant difference for the male subjects studied. This led Fedoruk to conclude that with the possible exception of the Sjostrand P W C$_{170}$

test, no submaximal test studied was as valid a predictor of physical fitness as was another maximum $O_2$ intake test.

In 1964, de Vries and Klafs conducted a study to investigate the validity of several submaximal work capacity tests by comparing the predicted values with an actual maximal oxygen consumption value determined on a bicycle ergometer. Of the submaximal tests used the Sjostrand P W C $_{170}$ correlated best with the test criterion .877. This correlation was significant at the 5 per cent level of confidence.

Zahar (1965) investigated the reliability of the Sjostrand P W C $_{170}$ test with repeated trials. He reported an initial re-test correlation of .886 with the 38 male high school students studied. The succeeding test - retest reliabilities were: .894, .841, .877, and .947. Zahar concluded that the Sjostrand P W C $_{170}$ test was a highly reliable measure of physical work capacity for the group studied.

Miki (1969) reported that physical working capacity (P W C $_{170}$ kpm/min) was significantly related to oxygen intake in l/min in zero order and first order correlation analysis ($p = .01$). He found that $O_2$ intake in ml/kg/min was the best predictor of P W C $_{170}$ expressed as kpm/kg/min.

Holmgren et al (1967) reported correlation coefficient of .903 between the Sjostrand test and $O_2$ intake values.

## Work Capacity Studies Using the P W C $_{170}$ Test

Adams et al (1961a) used 120 boys and 123 girls between the ages of 6 and 14 years. They found that working capacity increased

with age, height, weight, and body surface area. The best correlations were with the logarithm of the surface area, .81 for males and .80 for females; and with logarithm of the weight, .81 for males and .77 for females.

Adams et al (1964) conducted a study with 196 country and urban school children aged 10 to 17 years. They found that:

1. P W C was significantly greater with increasing degree of training for boys and girls in both city and country environment.
2. P W C was found to increase with age, height, weight, surface area, heart volume and degree of physical fitness.
3. a significant difference in P W C between city and country girls ($p = .02$), but no significant difference between rural and urban boys in P W C.
4. a significant difference ($p = .01$) for Swedish and California girls in P W C.
5. P W C of California boys compared favourably with Swedish boys.

Cummings and Cummings (1963) conducted a work capacity study on 200 Winnipeg school children. They found that:

1. a high correlation existed between P W C of boys and their height, .865, weight, .897 and body surface area, .904.
2. the P W C of 11 and 12 year old Winnipeg boys and girls tended to be smaller than those of similar aged children

in California and Sweden.

Fedoruk (1969) reported a mean P W C $_{170}$ for 24 first year physical education students to be 1345 kpm/min. A CAPHER study reported norms of 873.8 ± 224.5 kpm/min for 17 year old high school males across Canada. Zahar (1965) reported the P W C $_{170}$ of 38 high school males to be 943, 973, 994, 1039, 1018, and 1003 kpm/min on six repeated trials.

Fitness Levels of Intercollegiate Hockey Players

As noted in the introduction, not much research has been carried out into the fitness levels of intercollegiate hockey players. Most of the early studies dealt exclusively in aerobic capacity (Howell et al, (1966); Ferguson et al, (1969); and Watson, (1965).

Watson (1965) studied 10 University of Alberta varsity hockey players to determine the seasonal changes in maximal $O_2$ intake as measured by the modified Mitchell - Sproule - Chapman maximal oxygen consumption test. He found that a season of ice hockey significantly increased the maximal $O_2$ intake of the hockey players over that of a control group when expressed in terms of liters/min. There was no significant difference in maximal $O_2$ intake between the two groups when expressed in ml/kg/min. The hockey players showed a 17.46% increase in $O_2$ intake during the season, going from 3.51 l/min to 4.11 l/min; compared to an 8.65% increase for the control group, who went from 3.38 l/min to 3.67 l/min. The hockey group increased from 45.22 to 54.26 ml/kg/min, when $O_2$ intake was expressed in terms of

body weight.

Howell et al (1966) reported maximal oxygen consumption of intercollegiate hockey players of 57 ml/kg/min. Ferguson et al (1969) observed similar results of 57 ml/kg/min for intercollegiate hockey players.

In recent work at the University of Waterloo, Green and co-workers (1972b) have recognized the need to examine more than just aerobic capacity in assessing the fitness of competitive ice hockey players. Green et al (1972b) have conducted investigations to determine the nature and magnitude of any adaptive changes that occurred in body composition, aerobic capacity, anaerobic capacity, and a number of respiratory functions of ice hockey players during a competitive season. They found increases in aerobic capacity during the season (from 4.02 liters per minute to 4.18 liters per minute; or from 53.9 to 56.4 when expressed in milliliters of $O_2$ per kilogram of body weight per minute) to be nonsignificant. Defencemen underwent the greatest seasonal change, improving from 50.7 to 55.2 ml/kg/min, but nonetheless remained below the post season value of forwards (58.1 ml/kg/min).

In the same study, it was also reported that a 17% increase anaerobic capacity, as measured by peak lactate values and running time on a short exhaustive treadmill run occurred during the season.

Green (1973) reported the aerobic capacity of both junior and intercollegiate hockey players to be approximately 55 ml/kg/min. In discussing seasonal changes, Green observed that virtually no change in aerobic capacity occurred (from 4.30 to 4.43 liters per minute, or 56.4 to 57.1 ml/kg/min). He did, however, find a 15% increase in anaerobic capacity over the course of the season.

A study conducted on a junior hockey team in Canada during the 1973-74 season showed the effects of a supplementary conditioning program (Neilson, 1974). The team participated in a jogging and weight training program to supplement its on-ice practices. Results showed a higher aerobic capacity (62.2 ml/kg/min) than reported elsewhere in the literature for hockey teams.

Also investigated in the above study were muscular strength measures. Grip strength values tended to remain constant, with post-season values reported of 124 pounds for left grip strength and 137 pounds for the right grip strength. Definite improvements during the season in back and leg strength were noted, however. Post season values of 426 pounds (back strength) and 1018 pounds (leg strength) were reported.

# CHAPTER III

## METHODS AND PROCEDURE

Thirty intercollegiate hockey players and sixteen male undergraduate students at the University of Alberta during the 1973-74 year were used in the study. The sixteen control subjects were students enrolled in physical activity service courses offered by the Department of Physical Education.

All subjects were tested three times during the course of the hockey season: the preseason test was done during training camp before the season began. Midseason testing was conducted in January, and the postseason testing was carried out in March, at the completion of the season.

During each testing session, the subjects' height and weight were recorded. The subject was then tested on the following test items: vital capacity, right and left grip strength, back strength, leg strength, shoulder dips, chin-ups, and $PWC_{170}$. Arm strength and strength index were calculated from the raw data. The $PWC_{170}$ values were calculated with an Olivetti program. Maximal $O_2$ intake values were predicted using the Astrand - Rhyming Nomogram.

All hockey players were given the opportunity to participate in the in-season weight training program. The program was based on the 10 RM principle with players performing two sets of ten repetitions two days a week. The program was maintained for seven weeks during the second half of the season, between the second and third test trials. Some players could not participate in the program due to academic or

extracurricular commitments. Fifteen players participated in the weight training program, while the other fifteen did not.

The subjects were divided into three groups for the purpose of data analysis. The sixteen non-hockey players from the activity classes acted as control subjects. The fifteen hockey players who did not weight train were classified as the first treatment group, while the fifteen hockey players who did weight train comprised a second treatment group.

Changes in aerobic capacity and physical working capacity were anticipated for the two hockey groups. The effect of the in-season weight training program on the muscular strength and endurance of the hockey players was examined. The activity levels of the control subjects were not limited, therefore small changes in some parameters studied may have occurred due to the physical activity that they pursued.

## Muscular Strength and Endurance

Testing procedures for grip strength, back strength, leg strength, shoulder-dips, chin-ups, vital capacity, arm strength index and strength index were conducted as described by Clarke (1967).

## Modified Sjostrand P W C $_{170}$ Test

The Sjostrand P W C $_{170}$ test is based on the principle of a linear relationship that exists between steady state pulse frequencies and the work load producing these pulse frequencies (Astrand, 1965).

The value of the P W C $_{170}$ is usually found by extrapolation after plotting the work load and heart rates obtained during the test. In this study this extrapolation was done by an Olivetti 101 program.

The subjects were required to complete a twelve minute continuous exercise bout consisting of three four minute work periods at successively higher workloads. The cycle rate of 60 rpm was used.

Subjects started at work loads ranging from 360 - 720 kpm. The second and third work loads were adjusted according to the steady state heart rate during the third and seventh minutes of cycling. Adjustment of the workload was aimed at attaining three steady state heart rates within the ranges of 110 - 125, 135 - 145, 155 - 165 bpm at the fourth, eighth, and twelth minutes of cycling.

Pedal revolutions were counted and recorded at the end of each four minute period to enable accurate determination of work performed in each period.

The heart rates were plotted against workloads and the workload necessary to produce a heart rate of 170 bpm was determined to be the P W C $_{170}$. The subject's score was the work in kilapond meters that would produce a steady heart rate of 170 beats per minute.

## Prediction of Maximal $O_2$ Intake

Maximum $O_2$ intake was predicted using the Astrand - Rhyming nomogram (Astrand and Rhyming, 1954). The nomogram like the Sjostrand test is based on linear relationships existing among heart rate, oxygen consumption, and workload throughout the range of heart rate values to

approximately 195 ± 10 bpm.

## Statistical Analysis

The data was analyzed using a two factor ANOVA with repeated measures on one factor (Winer, 1972). The Newman - Keuls Test was used to examine the difference between mean scores (Kirk, 1969). Differences at the .05 level of confidence were considered to be significant. Data analysis was conducted on the University of Alberta 3600 computer system.

## Fitness and Performance

A paired preference test was given to the hockey players to determine which players were the best performers during the season. The test asked the question, "for each of the pairs listed below choose the player you felt made a more valuable contribution to the performance of the team during the season."

Scores obtained from the test were correlated with the post season values for P W C $_{170}$, maximum $O_2$ intake, arm strength index, strength index and body weight to illustrate any relationship that may have existed between fitness levels and performance.

The hockey players were split into two groups, juniors and seniors for the purpose of making the fitness-performance comparison.

# CHAPTER IV

# RESULTS

## Within Subject Differences (Time Effect)

The analysis of variance* revealed significant differences in P W C $_{170}$, $MVO_2$ (liters/min), $MVO_2$ (ml/kg/min), arm strength, strength index, back strength, right grip strength, chin-ups, shoulder-dips and vital capacity (Tables 6, 7, 8, 9, 10, 11, 14, 15, 16, 17) within subjects over the three trials at the .01 level of significance. Leg strength and left grip strength (Table 12 and 13) also changed significantly ($p = .05$).

P W C $_{170}$, $MVO_2$ (liters/min) and $MVO_2$ (ml/kg/min) varied similarily over the three trials. The Newman - Keuls** test of significance showed a significant change ($p = .01$) between trials 1 and 2 and trials 1 and 3, but no significant difference between trials 2 and 3 (Tables 18 to 20).

Arm strength and back strength were the only parameters studied that increased significantly between trials 2 and 3 ($p = .05$) and between trials 1 and 3 ($p = .01$), while shoulder dips (Table 28) increased significantly between trials 1 and 2 ($p = .05$) and between trials 1 and 3 ($p = .01$).

Strength indes (Table 22) showed a significant change between trials 1 and 3 only ($p = .05$).

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* ANOVA tables are found in Appendix A

** Newman - Keuls tests of significance are found in Appendix B

Leg strength, left and right grip strength and vital capacity (Tables 24, 25, 26, 29) revealed no significant difference between trials.

Between Subjects Differences (Group Effect)

The analysis of variance (Tables 6 to 8) indicated a significant difference existed among the three treatment grou the .01 level of significance for $PWC_{170}$, $MVO_2$ (liters/min), a (ml/kg/min). However, examination of mean differences failed to reveal any differences except between the control and hockey groups in $MVO_2$ when expressed in ml/kg/min ($p = .05$) (Tables 30 to 32).

No significant differences were found between groups for any of the other variables studied (arm strength, strength index, back strength, leg strength, grip strength, chin-ups, shoulder-dips, or vital capacity) (Tables 33 to 41).

Group Times Time Differences (Interaction Effect)

Data analysis disclosed that significant interaction effect (group . time) existed at the .01 level of confidence for arm strength, strength index, chin-ups, and shoulder dips (Tables 9, 10, 15, 16). $PWC_{170}$, $MVO_2$ (liters/min), $MVO_2$ (ml/kg/min), and leg strength showed an interaction effect at the .05 level of confidence (Tables 42, 43, 44 and 48).

The remaining variables studied (back strength, grip strength and vital capacity) did not undergo an interaction effect.

FIGURE I

PHYSICAL WORKING CAPACITY

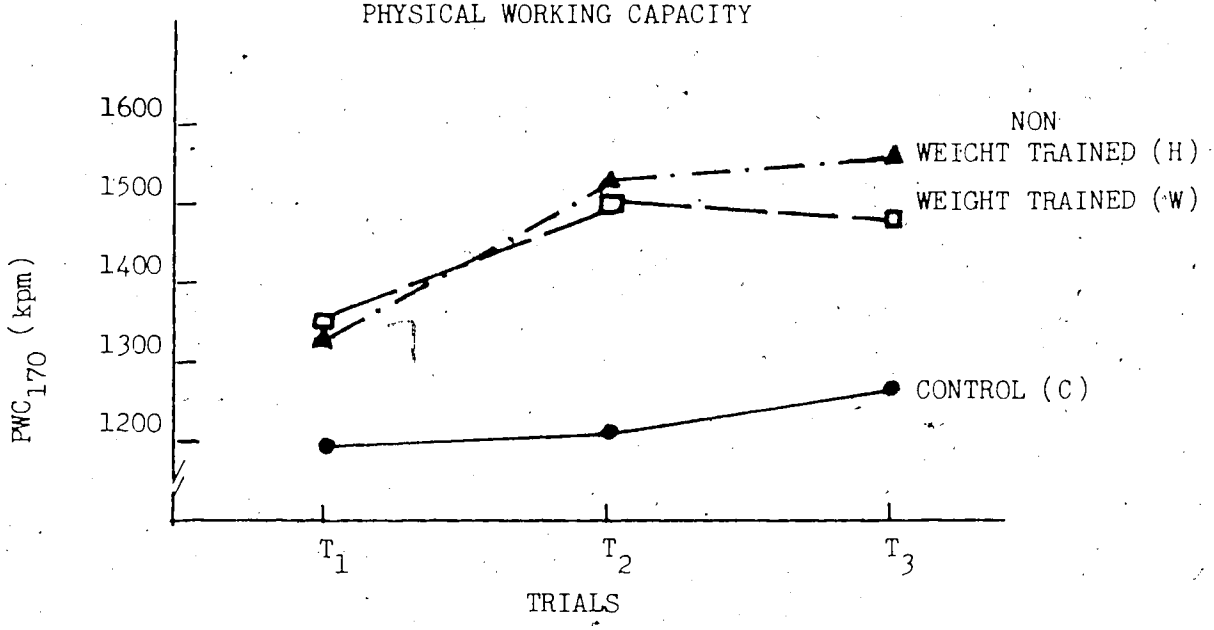



FIGURE 2

MAXIMAL $O_2$ INTAKE (lit/min)

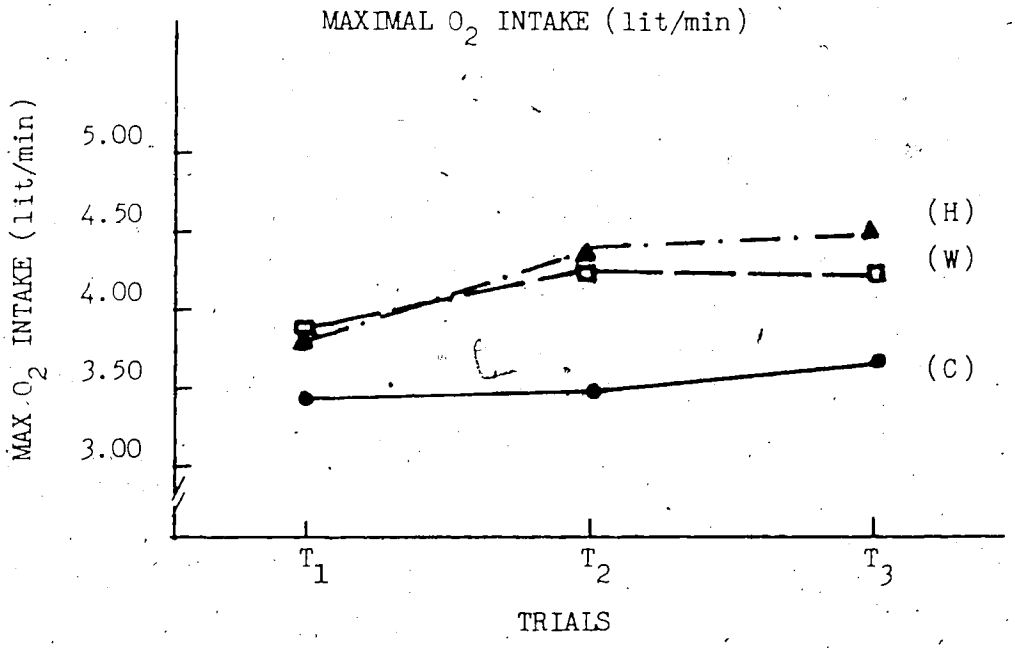


FIGURE 3

MAXIMAL $O_2$ INTAKE (ml/kg/min)

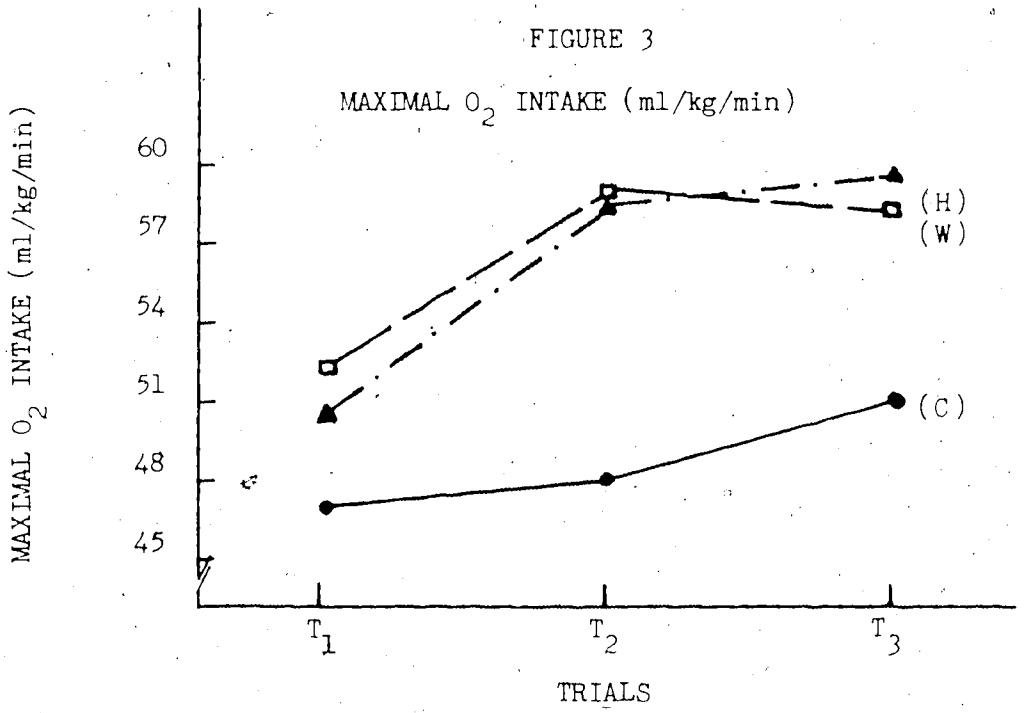



FIGURE 4

ARM STRENGTH INDEX

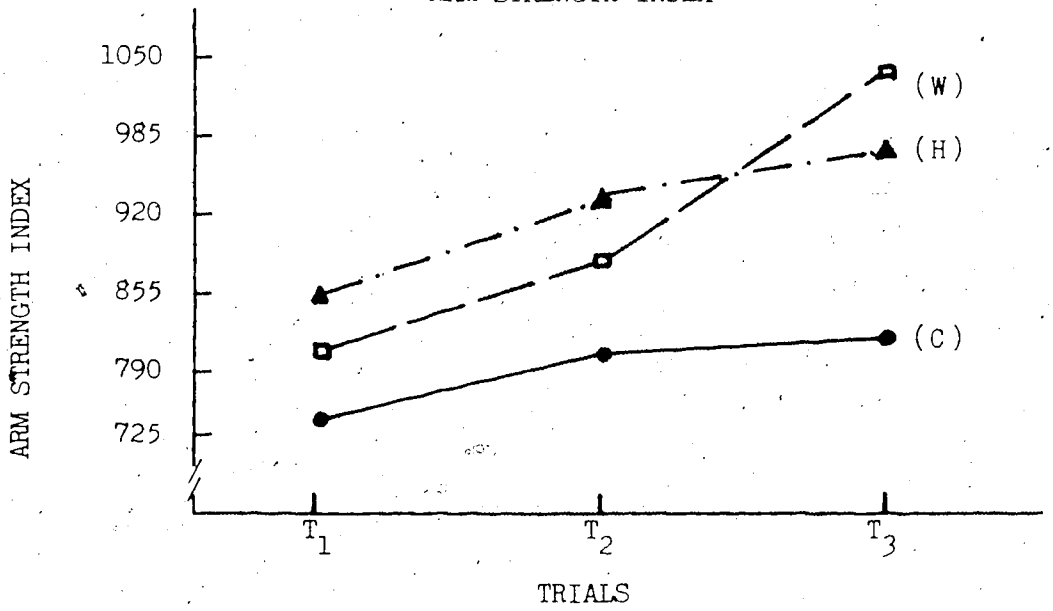


FIGURE 5

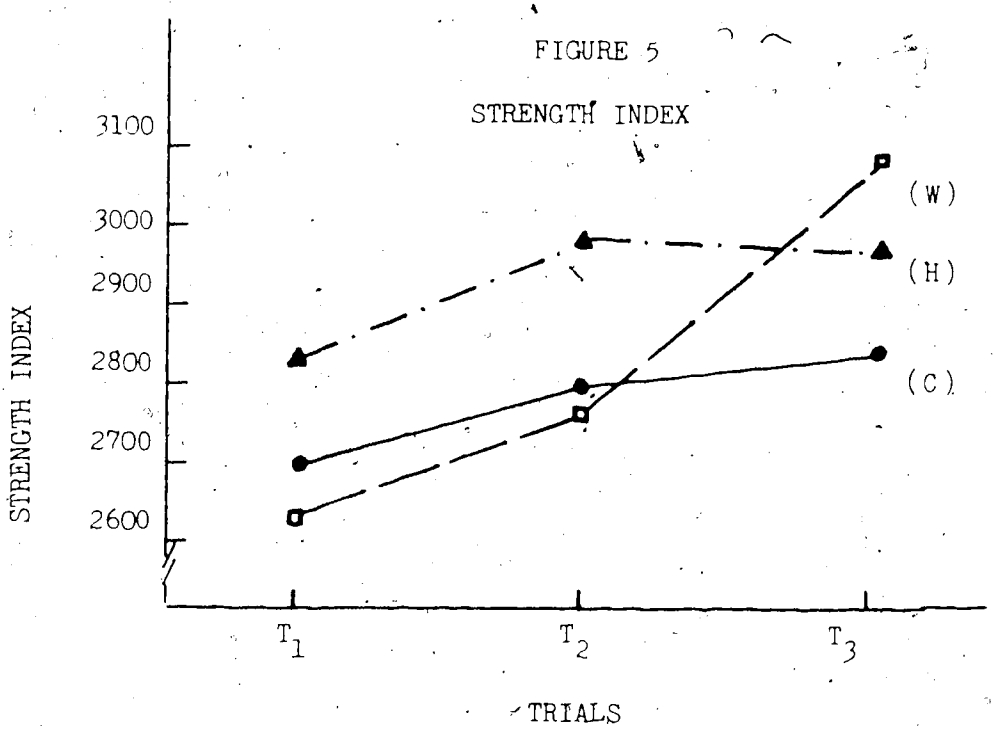
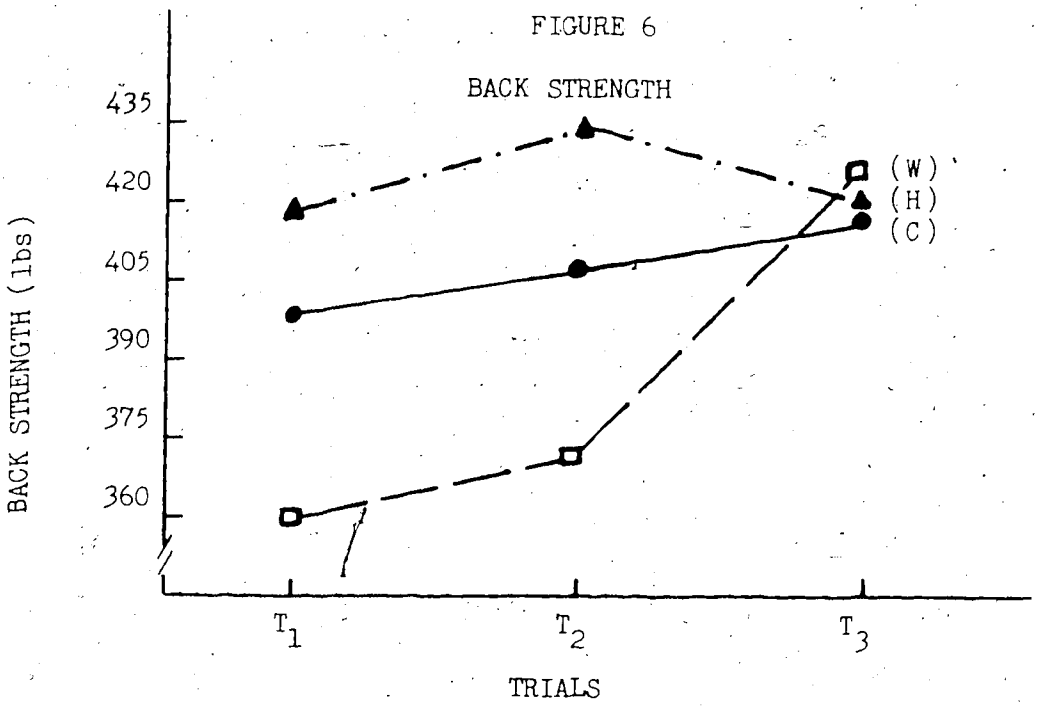



FIGURE 6



Control Group

The control group underwent no changes in any of the variables studied, with the exception of an increase in vital capacity between trials one and two (Figures 1 to 12).

The control group differed from the two hockey groups in $PWC_{170}$ $MVO_2$ (liters/min), and $MVO_2$ (ml/kg/min) on all three trials (Tables 42 to 44). There were no differences between the control group and the hockey group on back strength or leg strength throughout the season.

Hockey Group

The non-weight training hockey group increased in $PWC_{170}$, $MVO_2$ (liters/min) and $MVO_2$ (ml/kg/min) from trial one to trial two, (Figures 1 to 3), but remained at that level for the remainder of the season (Tables 42 to 44). Arm strength increased significantly from trial one to trial three; however, no differences were observed between pre- and mid-season values or mid- and post-season values (Table 45).

The chin-ups of the non-weight trained hockey players changed from trial two to trial three (Table 51).

A significant decrease in right grip strength was noted between trials one and two (Table 50).

The back strength, leg strength, strength index, shoulder-dips, left grip strength, and vital capacity of this group remained the same during the season.

FIGURE 7

LEG STRENGTH

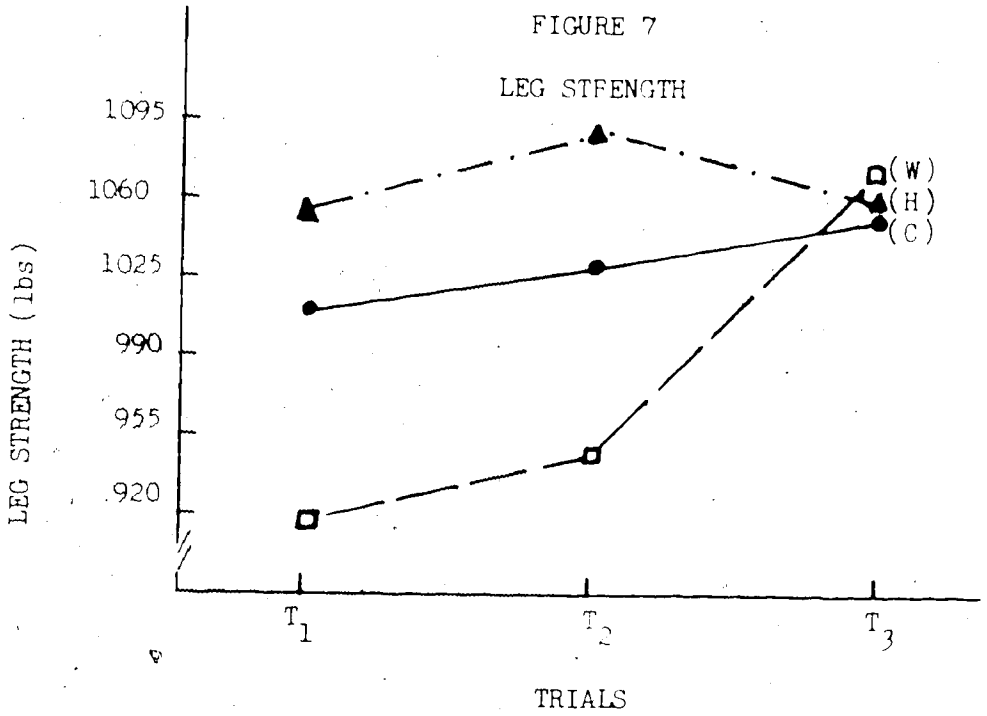



FIGURE 8

LEFT GRIP STRENGTH

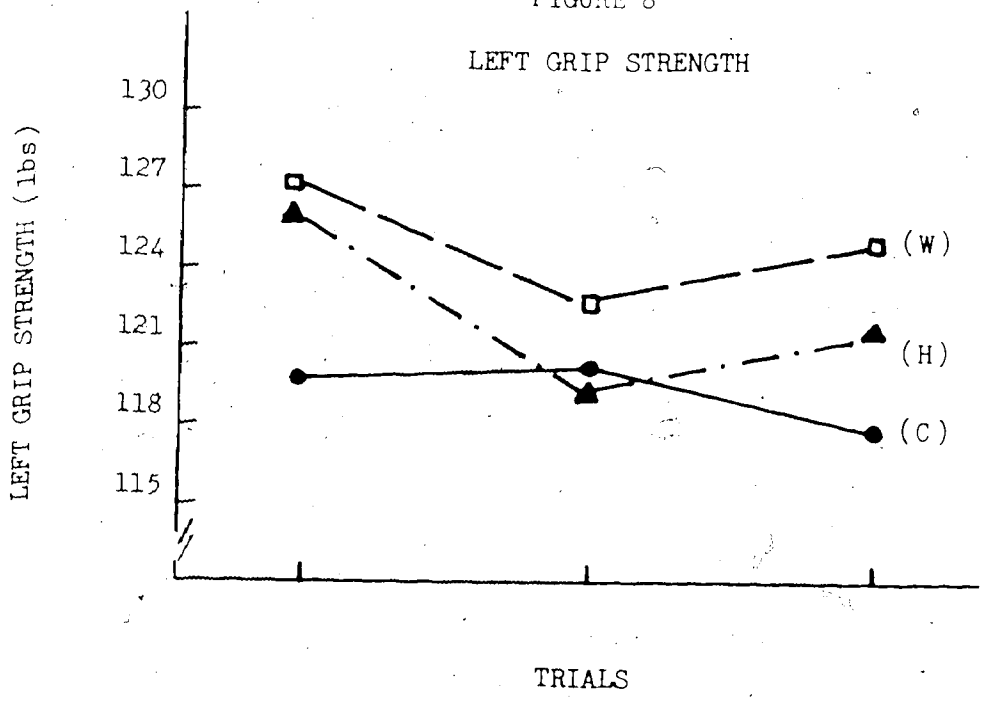


FIGURE 9

RIGHT GRIP STRENGTH

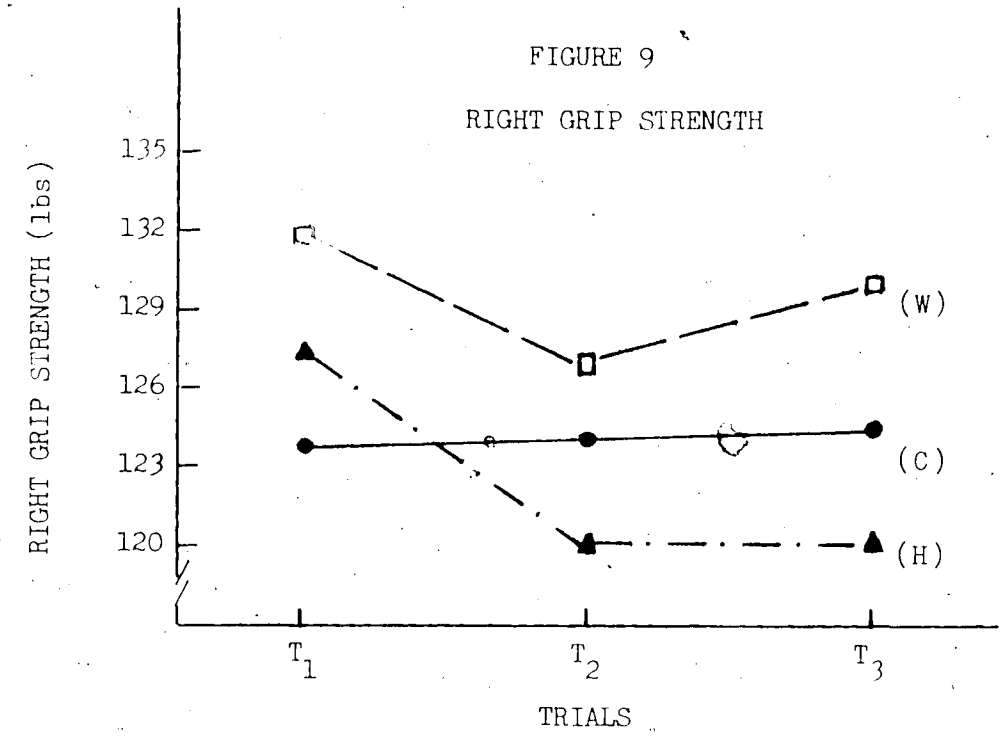



FIGURE 10

CHIN-UPS

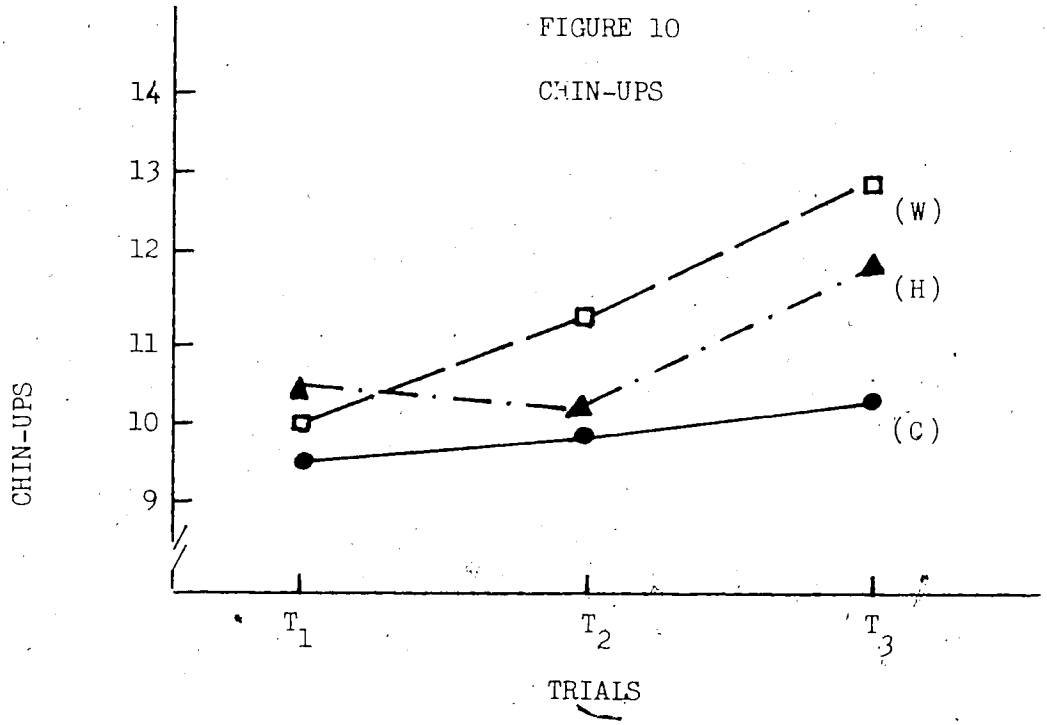


FIGURE 11

SHOULDER DIPS

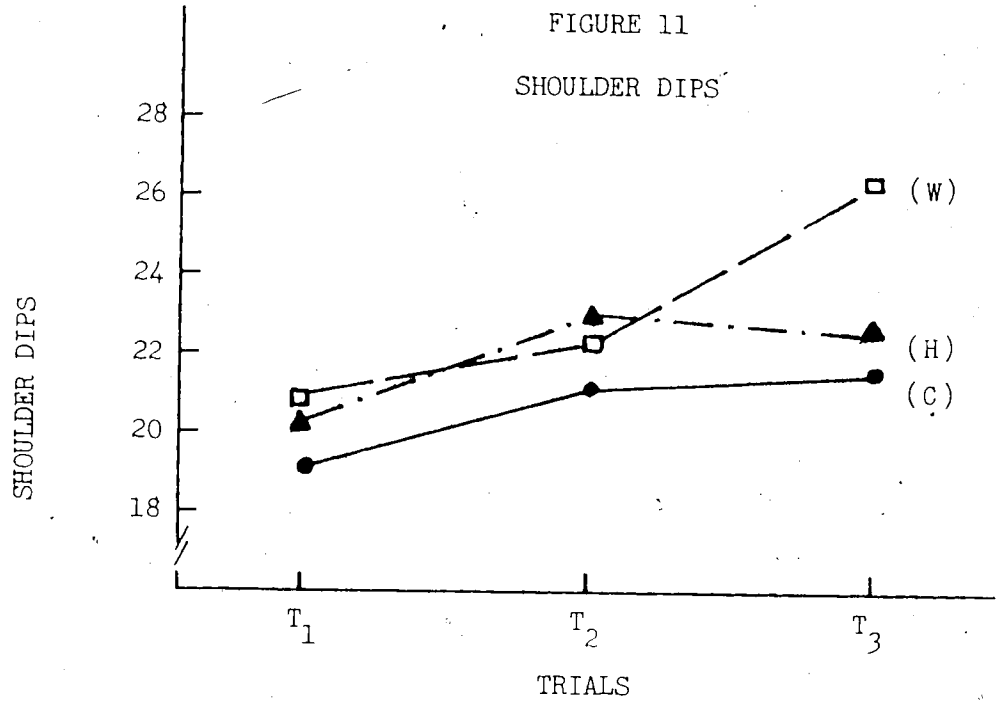
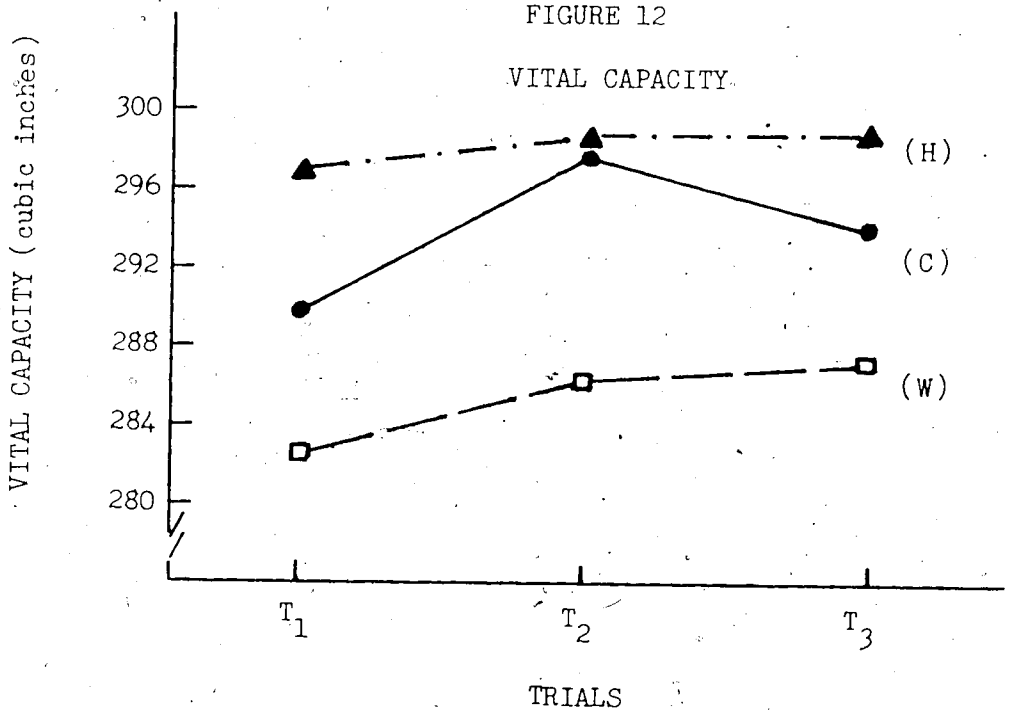



FIGURE 12

VITAL CAPACITY



Weight Trained Group

The hockey players that weight-trained showed an identical pattern with the non-weight-trained group in $PWC_{170}$ and $MVO_2$ during the season (Figures 1 to 3)

The weight-trained group remained at the same level in back strength, leg strength, strength index, arm strength, chin-ups and shoulder dips from trial one to trial two. However, a significant change was observed for all these parameters between trial two and trial three. (Tables 45, 46, 47, 48, 51 & 52).

No changes occurred in grip strength or vital capacity during the season.

Fitness-Performance Correlations:

The performance rating from the preference test correlated ($r = .552$) significantly with body weight only for the senior team ($p = .05$) (Table 67). No significant correlations were observed between the performance rating and fitness parameters of the junior players (Table 66).

Body weight of the junior players correlated significantly with $PWC_{170}$ ($r = .666$) and maximum $O_2$ intake when expressed in liters per minute ($r = .683$); while that of the senior players correlated significantly only with maximum $O_2$ intake ($r = .574$).

Significant correlations of $r = .806$ and $r = .998$ were observed between the $PWC_{170}$ and Max $VO_2$ (liters/min) for the senior and junior values. The $PWC_{170}$ values of both groups also correlated

significantly with Max $VO_2$ expressed in ml/kg/min.

The strength index of the junior hockey players correlated ($p = .05$) with $PWC_{170}$ ($r = .562$), Max $VO_2$ (liters/min) ($r = .575$), and arm strength index ($r = .727$), but no relationship between these measurements were observed in the senior hockey players.

All other correlations examined were insignificant (Appendix C).

# CHAPTER V

# DISCUSSION

## Physical Working Capacity

Both groups of hockey players underwent significant changes in physical working capacity during the season while the control group remained relatively the same. The non-weight-trained hockey players increased 16% in $PWC_{170}$ from a preseason value of 1339 kpm to a mid-season value of 1552 kpm ($p = .01$); then increased a further 2% to a postseason value of 1585 kpm.

The weight-trained hockey group experienced a 13% increase, from 1354 kpm to 1526 kpm, followed by a 1% decrease in the latter part of the season.

The $PWC_{170}$ of the control group increased nonsignificantly from 1200 kpm to 1314 kpm, and finished at 1278 kpm during the season.

The $PWC_{170}$ scores obtained in several other studies are presented in Table one. Tornvall (1963) and Hellstrom (1961) investigated the physical working capacity of military conscripts and reported mean $PWC_{170}$ values of 1064 kpm and 929 kpm. Wendelin et al (1965) reported a mean $PWC_{170}$ value of 1107 kpm for 153 medical students. This value is quite similar to the 1143 kpm value obtained by Miki (1969) for 54 Physical Education students. De Vries and Klafs (1965), Fedoruk (1969), and Holmgren et al (1967) also studied the physical working capacity of Physical Education majors and cited means of 1266 kpm, 1345 kpm, and 1400 kpm.

TABLE 1

A COMPARISON OF PHYSICAL WORKING CAPACITY STUDIES*

| INVESTIGATOR | SUBJECTS | N | AGE | WEIGHT | $PWC_{170}$ (kpm/min) |
|---|---|---|---|---|---|
| Miki (1969) | P. E. majors | 54 | 22.4 ± 1.35 | 75.96 ± 10.71 | 1143 ± 186.8 |
| deVries & Klafs (1965) | P. E. majors | 16 | 22.4 | 78.5 | 1266 ± 276 |
| Fedoruk | P. E. majors | 24 | 19.97 | 76.1 | 1345 |
| Holmgren et al (1967) | P. E. majors (Swedish) | 10 | | 71.6 ± 9.0 | 1400 ± 237.7 |
| Wendelin et al (1965) | Medical Students | 153 | 21.5 | 69.5 | 1107 ± 301 |
| Tronvall (1963) | Military Conscripts | 89 | 19.5 | 68.3 | 1064 ± 218 |
| Tornvall (1963) | Middle Distance Runners | 23 | 22.5 ± 3.3 | 69.3 | 1551 ± 151 |
| Hellstrom (1961) | Middle Distance Runners | 48 | | 66.3 ± 4.5 | 1607 ± 174 |

* Adapted from Miki (1969) p. 94

The difference in the $PWC_{170}$ scores listed above may be due to sample variation in regards to:

1. lean body weight
2. superior cardiorespiratory fitness and/or,
3. mechanical efficiency (Miki, 1969).

The difference between the $PWC_{170}$ of the military conscripts and the Physical Education majors may be attributed to heavier body mass of the students and higher cardio-vascular efficiency. Miki (1969) reasoned that the higher physical working capacity (1400 kpm) of the Swedish Physical Education majors was due to a higher level of fitness and an advantage in pedalling efficiency compared to the North American students examined in other studies (deVries and Klafs, 1965; Miki, 1969; Fedoruk, 1969).

The physical working capacity of highly-trained middle distance runners (1551 kpm ± 151 kpm and 1607 kpm ± 174 kpm) have been reported by Tornvall (1963) and Hellstrom (1961). The thirty hockey players studied in the present study improved from an initial mean $PWC_{170}$ score of 1346 kpm to a midseason value of 1539 kpm, and a postseason value of 1545 kpm. This initial value of 1346 kpm is similar to the 1345 kpm reported by Fedoruk (1969) for twenty-four first year Physical Education students. The midseason and postseason values for the hockey players in the present study were comparable with the 1551 kpm value of the middle distance runners studied by Tornvall (1963), but below the value of 1607 kpm obtained for another group of distance runners (Hellstrom, 1961). The weight of the hockey players was greater than that of the middle distance runners, therefore, the runners exhibited superior cardiorespiratory fitness. This greater efficiency is evident when the physi-

cal working capacity is adjusted for body weight. The postseason $PWC_{170}$ of the hockey players (20.4 kpm/Kg.) is below that reported for the middle distance runners (22.4 kpm/Kg. and 24.3 kpm/Kg).

Hellstrom (1961) reported an 18 percent improvement in $PWC_{170}$ for 88 young military conscripts following a three month training period (1273 kpm to 1502 kpm). The hockey players in the present study showed a 15 percent improvement in physical working capacity during the season.

Maximal Oxygen Intake

Maximal $O_2$ intake values of the two hockey groups improved significantly ($p = .01$) from preseason to midseason, then remained unchanged for the rest of the season. Table two presents a summary of the changes in maximal $O_2$ intake during the season. The control subjects showed a tendency to improve during the season, but no significant change was observed. The thirty hockey players demonstrated mean $O_2$ intake values of 3.84 liters/min., 4.38 liters/min., and 4.40 liters/min. at the three testing sessions during the season.

Figures 2 and 3 show that both hockey groups levelled off in maximal $O_2$ intake during the second half of the season. The hockey group that weight-trained dropped slightly from 4.34 to 4.28 liters/min. between trial two and three, while the other hockey group increased slightly from 4.4 to 4.51 liters/min.

TABLE 2

CHANGES IN MAXIMAL $O_2$ INTAKE DURING A SEASON OF ICE HOCKEY

| Group | N | Maximal $O_2$ Intake Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|---|
| Control | 16 | 3.43[+]<br>46.19[++] | 3.48<br>47.43 | 3.69<br>50.12 |
| Hockey (non weight training | 15 | 3.82<br>49.67 | 4.41**<br>58.12** | 4.51<br>59.32 |
| Hockey (weight training) | 15 | 3.85<br>51.53 | 4.34**<br>58.39** | 4.28<br>57.37 |
| Hockey (total) | 30 | 3.84<br>50.60 | 4.38*<br>58.25* | 4.40<br>58.34 |

* p = .05

** p = .01

[+] liters/minute

[++] ml/kg/min

Table three presents a summary of studies reporting the maximal $O_2$ intake of other ice hockey players. The postseason value of 4.40 liter/min., or 58.34 ml/Kg/min. observed for the 30 hockey players in the present study agrees closely with the values presented in Table three. Only the value of 62.2 ml/Kg/min., reported by Nellson for 18 O.H.A. junior A hockey players, is higher than the peak value obtained in the present study. Results of the present study showed an improvement in the aerobic capacity of hockey players at the University of Alberta compared with the 1965 seasonal values presented by Watson (1965) of 4.11 liters/min. or 54.26 ml/Kg/min.

Green (1973) observed that only minimal seasonal changes (3%) occurred in aerobic capacity with the 18 players studied. Another study by Green et al (1972b) reported a similar change of 4% during the season. The findings of the present study in regards to aerobic capacity (15% seasonal increase) concurs with those of Watson (1965) who reported a 17.46% improvement during the year. This would indicate that University of Alberta ice hockey players received a more adequate training stimulus during the season than the players studied by Green et al (1972b) and Green (1973).

Green concluded that intercollegiate hockey players measured well below endurance athletes in aerobic capacity. A value of 65.8 ml/Kg/min. (Buskirk et al, 1957) was reported for five cross country runners about twenty years of age. One of the highest aerobic capacities ever recorded was 85 ml/Kg/min. for a Swedish cross country skier (Saltin and Astrand, 1967). The aerobic capacity of most ice hockey teams studied has ranged between 53 - 58 ml/Kg/min. This would tend to support Green's

conclusion. The highest aerobic capacity reported for an ice hockey team has been the 62.2 ml/Kg/min. (Nielson, 1974). This particular team participated in a supplementary jogging program along with the on-ice conditioning sessions during the ice hockey season. The high degree of aerobic capacity attained by this group can be attributed to a great extent to the jogging program emphasizing again the need for better training of ice hockey players, in terms of maximal $O_2$ intake.

TABLE 3
MAXIMAL $O_2$ INTAKE OF ICE HOCKEY PLAYERS

| Investigator | Subjects | N | Maximal $O_2$ Uptake liters/min | ml/kg/min |
|---|---|---|---|---|
| Watson (1965) | Intercollegiate | 10 | 4.11 | 54.26 |
| Howell (1966) | Intercollegiate | - | - | 57.0 |
| Ferguson et al (1969) | Intercollegiate | - | - | 55.0 |
| Green et al (1972b) | Intercollegiate | 20 | 4.18 | 56.4 |
| Green et al (1972c) | Intercollegiate | 8 | 4.04 | 53.4 |
| Neilson (1974) | Junior A | 14 | - | 62.2 |
| Green (1973) | Junior A | 18 | 4.43 | 57.1 |
| Present Study | Intercollegiate | 30 | 4.40 | 58.34 |

Muscular Strength and Endurance

As mentioned previously, the control group did not change significantly on arm strength, strength index, back strength, leg strength, chin-ups of shoulder-dips during the hockey season. Both hockey groups demonstrated no significant change in arm strength, strength index, back strength, leg strength, chin-ups and shoulder dips from preseason to midseason values. The right and left grip strength of the weight-trained group remained the same throughout the study, as did the left grip strength of the non-weight-trained group. The right grip of the non-weight-trained group decreased significantly ($p = .01$) between trial one and two, then remained relatively the same.

The in-season weight-training program was conducted during the second half of the season. The effectiveness of this program to develop and maintain muscular strength and endurance was assessed by a comparison of the means for the two hockey groups between trial two and three. The non-weight-trained group failed to make any significant improvement in arm strength, strength index, back strength, leg strength, left and right grip strength, and shoulder-dips. An increase in chin-ups from 10.57 to 12.40 was the only significant change measured in strength or endurance for the non-weight-trained group between trial two and three ($p = .01$). An overall increase in arm strength index was noted preseason and postseason values ($p = .01$).

Significant increases were observed for the weight-trained group in arm strength index, strength index, leg strength, chin-ups and shoulder-dips ($p = .05$). Back strength increased from 397 pounds

TABLE 4

MUSCULAR STRENGTH AND ENDURANCE CHANGES BETWEEN TRIAL TWO AND TRIAL THREE

| Group | Arm Strength Index | | | Strength Index | | | Back Strength | | | Leg Strength | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_2$ | $T_3$ | D | $T_2$ | $T_3$ | D | $T_2$ | $T_3$ | D | $T_2$ | $T_3$ | D |
| Control | 795.8 | 819.1 | 23.3 | 2797 | 2838 | 41 | 412.8 | 422.8 | 10 | 1038 | 1060 | 22 |
| Hockey (non weight trained) | 933.3 | 970.3 | 37.0 | 2992 | 2974 | 18 | 414.3 | 395 | 19.3 | 1104 | 1066 | 38 |
| Hockey (weight trained) | 993.3 | 1046 | 162.7** | 2758 | 8095 | 337** | 397 | 421.3 | 24.3 | 952 | 1087 | 135* |

TABLE 4 (cont.)

| Group | Chin-ups | | | Shoulder Dips | | |
|---|---|---|---|---|---|---|
| | $T_2$ | $T_3$ | D | $T_2$ | $T_3$ | D |
| Control | 10.09 | 10.59 | 0.5 | 21.37 | 21.81 | 0.44 |
| Hockey (non weight trained) | 10.57 | 12.40 | 1.83** | 23.63 | 23.10 | 0.53 |
| Hockey (weight trained) | 11.67 | 13.53 | 1.86** | 22.40 | 26.90 | 4.50** |

* $p = .05$
** $p = .01$

at $T_2$ to 421.3 pounds, but this was not a significant change. A seasonal increase in back strength was noted, however, between trial one and trial three.

Table four summarized the changes which occurred in muscular strength and endurance during the second half of the season. Chin-ups and shoulder-dips increased 15.9% and 20.0% respectively for the weight-trained group. The arm strength index, which is a measure of dynamic endurance, increased 18.4% from 883.3 to 1046. These increases in chin-ups, shoulder-dips and arm strength index are highly significant ($p = .01$), however, they were well below the improvements reported by Dennision et an (1961) for a similar weight-training program.

Dennison et al had an experimental group of ten University of British Columbia undergraduates employ a weight-training program twice a week for eight weeks. They reported a 66% increase in shoulder-dips (6.2 to 10.3), a 64% increase in chin-ups (5.3 to 8.7) and a 71% increase in arm strength index (321 to 550.1), which were significant at the .02, .01 and .01 level of confidence, respectively. The greater increases reported by Dennison et al can be attributed to the low initial values, longer program and stricter control over the weight-training sessions. The university undergraduates probably had not had as much weight-training experience as the hockey players of the present study; therefore, the students started at a lower percentage of their maximum strength and endurance capacities. Not all of the hockey players in the weight-trained group were able to complete the fourteen training sessions, due to on-ice practice sessions and academic commitments. This would have detracted from the upper body endurance gains measured by the chin-ups,

shoulder-dips and arm strength index.

Cureton (1943) found a 28% increase in chin-ups and a 49.3% increase in shoulder-dips following a one-hour physical conditioning class carried out twice-weekly over a period of 12 weeks. Kistler (1944) conducted a conditioning program one half hour, three times a week, for eight weeks. He found a 8% increase in chinning and a 17.6% increase in shoulder-dips.

Capen (1950) reported increases of 27.9% in chinning and 16.4% in dipping after a weight-training program. Scott (1964) reported an insignificant increase of 5.5% in chin-ups and a significant increase of 22.6% in shoulder dips following a twice-weekly conditioning program that lasted for eight weeks. Scott also reported a significant ($p = .05$) increase in left grip strength from 107.4 pounds to 117.67 pounds, and a significant increase in leg strength from 469.9 to 520.1 pounds. Back strength increased from 341 pounds to 349 pounds, a 2.4% difference.

Back strength and leg strength of the weight-trained group in the present study increased from 397 to 421.3 pounds, and 952 pounds to 1087 pounds, between trials two and three. This was a nonsignificant 6.1% rise in back strength and a significant 14.2% increase in leg strength ($p = .01$). These results concur closely with those of Tuttle et al (1955) and Miki (1969). Tuttle et al found a back strength of 368 ± 73 pounds and a leg strength of 1107 ± 381 pounds for a group of three subjects aged 24 to 46 years of age. Miki reported a mean back strength of 527.4 ± 77 pounds and a mean leg strength of 1140 ± 189 pounds for fifty four undergraduate Physical Education majors at the University of British Columbia.

TABLE 5

COMPARISON OF STRENGTH AND ENDURANCE LEVELS OF THE TWO HOCKEY GROUPS

| Parameter | Trial 1 | | | Trial 2 | | | Trial 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight | Hockey | Diff. | Weight | Hockey | Diff. | Weight | Hockey | Diff. |
| Arm Strength Index | 794.5 | 851.7 | 57.2 | 883.3 | 933.3 | 50 | 1046 | 970 | 75.5* |
| Strength Index | 2622 | 2833 | 211* | 2758 | 2992 | 234* | 3095 | 2974 | 121 |
| Back Strength | 365.3 | 390 | 24.7 | 397 | 414.3 | 17.3 | 421.3 | 395 | 26.3 |
| Leg Strength | 921.7 | 1065 | 143.3* | 952 | 1104 | 152* | 1087 | 1.66 | 21 |
| Chin-ups | 10.23 | 10.67 | 0.44 | 11.67 | 10.57 | 1.10 | 13.53 | 12.40 | 1.13* |
| Shoulder Dips | 20.93 | 20.77 | 0.16 | 22.40 | 23.63 | 1.23 | 26.90 | 23.10 | 3.80* |
| Right Grip Strength | 132.5 | 128 | 4.5 | 127.3 | 120.3 | 7.0* | 130.4 | 120.3 | 10.1** |
| Left Grip Strength | 128 | 126.6 | 1.4 | 123.1 | 120.1 | 3.0 | 125.3 | 122.1 | 3.2 |

* p = .05
** p = .01

Further evaluation of the weight-training program employed in the present study is possible by comparing the means of the weight-trained and non-weight-trained hockey groups. No significant difference between the two groups existed at trial one or two for the following muscular strength and endurance measures: shoulder-dips, chin-ups, and arm strength index. However, following the weight-training program, the postseason values of the weight-trained group were significantly ($p = .01$) greater than those of the group that did not weight-train for these three parameters.

The means of the two groups for leg strength and strength index were significantly different at trial one and trial three, with the non-weight-trained group having the larger mean. Postseason differences for leg strength and strength index were not significant, indicating that the weight-training program was effective in reducing the difference between the two hockey groups. Table five gives the comparison of means for the two experimental hockey groups.

Muscular strength and endurance levels observed in the present study concur closely with those reported by Neilson (1974) for Peterborough Petes Junior hockey players. Neilson found a mean post-season back strength value of 426 pounds compared to 421 (weight-trained) and 395 (non-weight-trained) observed in the present study. The leg strength of the weight-trained group (1087 lbs.) was higher than the 1066 of the non-weight-trained group and the 1018 reported by Neilson. The right and left grip strengths (130 pounds and 125 pounds) of the weight-trained group in the present study concurred with the O.H.A. junior team (137 pounds and 124 pounds). The other hockey group studied in the present study demonstrated somewhat lower (120 pounds and 122 pounds) values for right and left grip strength.

Fitness-Performance Relationships

As mentioned in Chapter IV, the correlation between the performance scores of the senior hockey players with their body weight was the only significant relationship found. Correlations comparing the performance score with the fitness measures: $PWC_{170}$, Maximum $O_2$ intake, arm strength index and strength index were not significant for either group. The results of the present study indicated that body weight was closely associated with performance, at least in the senior team, while the fitness measures studied were not related to performance as measured by the paired-performance test.

# CHAPTER VI

# SUMMARY AND CONCLUSIONS

## Seasonal Fitness Changes

Fitness appraisal was conducted three times during the 1973-4 season on thirty intercollegiate hockey players at the University of Alberta to observe inseason fitness changes. Physical working capacity, maximal $O_2$ intake, grip strength, back strength, leg strength, arm strength index, strength index, chin-ups, shoulder dips, and vital capacity were the fitness measures examined. Subjects were tested in October (preseason), January (midseason), and March (postseason). Sixteen moderately-active undergraduates from the university acted as control subjects for the experiment.

This study revealed that the hockey players examined increased significantly in physical working capacity and maximal $O_2$ intake between pre and midseason testing, then remained at that same level for the rest of the season. The control group increased slightly on mid and post season measures of $PWC_{170}$ and Max $VO_2$, but not significantly.

Muscular strength and endurance were evaluated by the grip strength, back strength, leg strength, arm strength index, chin-ups, shoulder dips and strength index. The hockey players did not show any improvement in arm strength index, strength index, back strength, leg strength, chin-ups or shoulder dips between pre and midseason testing.

## Weight Training

The hockey players were split into two groups to evaluate the effectiveness of an in-season weight training program conducted during the second half of the season. The non-weight-trained hockey group demonstrated no change in arm strength index, back strength, leg strength, grip strength or shoulder dips between mid and postseason testing. An increase in chin-ups was measured between trial two and trial three.

The hockey group that did participate in the weight training program improved significantly in arm strength index, strength index, leg strength, chin-ups and shoulder dips during the second half of the season. Back strength increased nonsignificantly between trials two and three, resulting in a significant improvement between trials one and three.

The control group remained unchanged on all strength and endurance measures over the three testing sessions.

Fitness and Performance

An attempt was made to relate playing performance of the hockey players to the various fitness measures taken. Scores obtained from a paired preference test completed by the hockey groups were correlated with postseason values of $PWC_{170}$, Max $VO_2$, arm strength index, strength index and body weight.

It was found that body weight correlated significantly with the performance score ($r = .552$), whereas $PWC_{170}$, Maximal $O_2$ intake, arm strength, and strength index did not.

## Conclusions

Within the limitations of the present study, the following conclusions can be drawn:

1. a season of intercollegiate ice hockey significantly improved the physical working capacity and oxygen intake of the players studied.

2. improvement in physical working capacity and maximal $O_2$ intake was confined to the first half of the season.

3. back strength, leg strength, strength index, shoulder dips and grip strength are not changed by a season of intercollegiate hockey; arm strength index and chin-ups may be improved by this type of hockey program.

4. an inseason weight-training program can make a significant contribution to the muscular strength and endurance of intercollegiate ice hockey players.

5. the hockey players in the present study compare favourably in Maximum $O_2$ intake and strength and endurance measures to players previously studied.

6. the players in this study were lower in Maximum $O_2$ intake than endurance athletes previously studied.

7. playing performance as measured by a paired-preference test was not closely related to physical working capacity, maximum $O_2$ intake, arm strength index or strength index.

8. playing performance at the intercollegiate level was associated with body weight for the senior players studied.

Recommendations

1. Further study be done to determine if the peak values for physical working capacity and maximal $O_2$ intake obtained in this study at midseason are representative of the training pattern for intercollegiate hockey teams.

2. Improved aerobic training methods be utilized in training intercollegiate hockey players to increase aerobic capacity, especially during the second half of the season.

3. The effectiveness of inseason weight-training programs should be compared to that of preseason programs for increasing strength and endurance.

4. Further investigation should be undertaken to relate playing performance to fitness parameters, game skills and motivational factors.

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# APPENDIX A

## ANALYSIS OF VARIANCE TABLES

TABLE 6

ANALYSIS OF VARIANCE

FOR $PWC_{170}$

| SOURCE OF VARIANCE | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | ********** | 45 | | | |
| 'A' Main Effects | ********** | 2 | 941065.500 | 8.483 | 0.0007858 |
| Subjects Within Groups | ********** | 43 | 110931.312 | | |
| Within Subjects | ********** | 92 | | | |
| 'B' Main Effects | 664728.500 | 2 | 332364.250 | 20.453 | 0.0000007 |
| 'A*B' Interaction | 203928.500 | 4 | 50982.125 | 3.137 | 0.0185172 |
| 'B'*Subj. Within Groups | ********** | 86 | 16250.043 | | |

TABLE 7

ANALYSIS OF VARIANCE

FOR OXYGEN INTAKE (liters/min.)

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 50.194 | 45 | | | |
| 'A' Main Effects | 14.007 | 2 | 7.033 | 8.392 | 0.0008362 |
| Subjects Within Groups | 35.886 | 43 | 0.835 | | |
| Within Subjects | 17.631 | 92 | 2.754 | | |
| 'B' Main Effects | 5.508 | 2 | 0.381 | 22.114 | 0.0000007 |
| 'A*B' Interaction | 1.522 | 4 | 0.125 | 3.056 | 0.0209395 |
| 'B'.Subj.. Within Groups | 10.711 | 86 | | | |

TABLE 8

ANALYSIS OF VARIANCE

FOR OXYGEN INTAKE (ml/Kg/min.)

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 5495.875 | 45 | | | |
| 'A' Main Effects | 1873.065 | 2 | 936.532 | 11.243 | 0.0001178 |
| Subjects Within Groups | 3581.812 | 43 | 83.298 | | |
| Within Subjects | 3139.437 | 92 | | | |
| 'B' Main Effects | 1122.786 | 2 | 561.393 | 27.294 | 0.0000001 |
| 'A*B' Interaction | 268.983 | 4 | 67.246 | 3.269 | 0.0151687 |
| 'B'·Subj. Within Groups | 1768.875 | 86 | 20.568 | | |

TABLE 9

ANALYSIS OF VARIANCE

FOR ARM STRENGTH

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | ********** | 45 | | | |
| 'A' Main Effects | 504015.312 | 2 | 252007.625 | 2.380 | 0.1046596 |
| Subjects Within Groups | ********** | 43 | 3105896.125 | | |
| Within Subjects | ********** | 92 | | | |
| 'B' Main Effects | 513405.936 | 2 | 256702.937 | 27.895 | 0.0000013 |
| 'A*B' Interaction | 147400.812 | 4 | 36850.203 | 4.004 | 0.0050086 |
| 'B'.Subj. Within Groups | 791408.000 | 86 | 9202.418 | | |

TABLE 10

ANALYSIS OF VARIANCE

FOR STRENGTH INDEX

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | ********** | 45 | | | |
| 'A' Main Effects | 587765.062 | 2 | 293882.500 | 0.842 | 0.4376370 |
| Subjects within Groups | ********** | 43 | 348844.625 | | |
| Within Subjects | ********** | 92 | | | |
| 'B' Main Effects | ********** | 2 | 731029.500 | 18.576 | 0.0000001 |
| 'A*B' Interaction | 749290.187 | 4 | 187322.500 | 4.760 | 0.0016210 |
| 'B' . Subj. Within Groups | ********** | 86 | 39352.555 | | |

TABLE 11

ANALYSIS OF VARIANCE

OF BACK STRENGTH

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 376912.000 | 45 | | | |
| 'A' Main Effects | 8134.465 | 2 | 2067.232 | 0.474 | 0.6254637 |
| Subjects within Groups | 368640.000 | 43 | 8573.020 | | |
| Within Subjects | 166704.000 | 92 | | | |
| 'B' Main Effects | 28965.105 | 2 | 9482.552 | 6.045 | 0.0034984 |
| 'A*B' Interaction | 13297.020 | 4 | 3324.255 | 2.119 | 0.0853131 |
| 'B' . Subj. within Groups | 134912.000 | 86 | 1568.744 | | |

TABLE 12

ANALYSIS OF VARIANCE

FOR LEG STRENGTH

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | ********** | 45 | | | |
| 'A' Main Effects | 193174.437 | 2 | 96587.188 | 0.903 | 0.4127689 |
| Subjects within Groups | ********** | 43 | 106924.625 | | |
| | | | | | |
| Within Subjects | ********** | 92 | | | |
| 'B' Main Effects | 112120.812 | 2 | 45060.406 | 3.648 | 0.0301439 |
| 'A*B' Interaction | 154861.250 | 4 | 38715.312 | 2.520 | 0.0469559 |
| 'B' . Subj. within Groups | ********** | 86 | 15365.578 | | |

TABLE 13

ANALYSIS OF VARIANCE FOR LEFT GRIP STRENGTH

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 20458.000 | 45 | | | |
| 'A' Main Effects | 867.447 | 2 | 433.723 | 0.953 | 0.3937229 |
| Subjects within Groups | 19578.000 | 43 | 455.302 | | |
| Within Subjects | 4410.000 | 92 | | | |
| 'B' Main Effects | 327.447 | 2 | 163.723 | 3.656 | 0.0299236 |
| 'A*B' Interaction | 239.362 | 4 | 59.840 | 1.336 | 0.2630159 |
| 'B' . Subj. within Groups | 3851.000 | 86 | 44.779 | | |

TABLE 14

ANALYSIS OF VARIANCE FOR RIGHT GRIP STRENGTH

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 23696.000 | 45 | | | |
| 'A' Main Effects | 1304.042 | 2 | 652.021 | 1.251 | 0.2964588 |
| Subjects within Groups | 22414.000 | 43 | 521.256 | | |
| | | | | | |
| Within Subjects | 4371.000 | 92 | | | |
| 'B' Main Effects | 428.936 | 2 | 214.468 | 5.518 | |
| 'A*B' Interaction | 382.979 | 4 | 95.745 | 2.303 | 0.0649615 |
| 'B' . Subj. within Groups | 3576.000 | 86 | 41.581 | | |

TABLE 15

ANALYSIS OF VARIANCE FOR CHIN-UPS

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 1519.906 | 45 | | | |
| 'A' Main Effects | 63.655 | 2 | 31.828 | 0.940 | 0.3983272 |
| Subjects Within Groups | 1455.223 | 43 | 33.842 | | |
| Within Subjects | 296.836 | 92 | | | |
| 'B' Main Effects | 92.008 | 2 | 46.004 | 22.251 | 0.0000007 |
| 'A*B' Interaction | 29.236 | 4 | 7.309 | 3.535 | 0.0101559 |
| 'B' . Subj. Within Groups | 177.809 | 86 | 2.068 | | |

TABLE 16

ANALYSIS OF VARIANCE FOR SHOULDER DIPS

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 4604.625 | 45 | | | |
| 'A' Main Effects | 158.398 | 2 | 79.199 | 0.766 | 0.4709254 |
| Subjects Within Groups | 4443.562 | 43 | 103.339 | | |
| Within Subjects | 1097.375 | 88 | | | |
| 'B' Main Effects | 302.972 | 2 | 151.486 | 19.185 | 0.0000008 |
| 'A*B' Interaction | 120.519 | 4 | 30.130 | 3.816 | 0.0066552 |
| Subj. within Groups | 679.063 | 86 | 7.896 | | |

TABLE 17

ANALYSIS OF VARIANCE FOR VITAL CAPACITY

| SOURCE OF VARIATION | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Between Subjects | 157601.000 | 45 | | | |
| 'A' Main Effects | 4217.551 | 2 | 2108.775 | 0.591 | 0.5582623 |
| Subjects within Groups | 153457.000 | 43 | 3568.767 | | |
| Within Subjects | 5877.000 | 92 | | | |
| 'B' Main Effects | 597.447 | 2 | 298.723 | 5.069 | 0.0082965 |
| 'A*B' Interaction | 199.149 | 4 | 49.787 | 0.845 | 0.5005919 |
| 'B' . Subj. within Groups | 5068.000 | 86 | 58.930 | | |

# APPENDIX B

## NEWMAN-KEULS COMPARISON TEST

## FOR TIME EFFECT

LEGEND FOR TABLES IN APPENDIX B

$T_1$ - Trial 1 (Preseason)

$T_2$ - Trial 2 (Midseason)

$T_3$ - Trial 3 (Postseason)

TABLE 18

Newman-Keuls Mean Comparison Test for Time Effect in $PWC_{170}$

| Time | | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|---|
| Means | | 1300 | 1430 | 1460 |
| | 1 | - | 130** | 160** |
| | 2 | | - | 30 |

p = .05 93.1468; 111.9078*
p = .01 123.7569; 148.8848**

TABLE 19

Newman-Keuls Mean Comparison Test for Time Effect in $MVO_2$ (lit/min)

| Time | | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|---|
| Means | | 3.703 | 4.079 | 4.163 |
| | 1 | - | .376** | .46** |
| | 2 | | - | .084 |

p = .05 0.2583; 0.3103*
p = .01 0.3432; 0.3879**

TABLE 20

Newman-Keuls Mean Comparison Test for Time Effect in $MVO_2$ (ml/kg/min)

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 49.13 | 54.65 | 55.60 |
| 1 | - | 5.52** | 6.47** |
| 2 | | - | 0.95 |

p = .05 3.3138; 3.9813*
p = .01 4.4028; 3.9813**

TABLE 21

Newman-Keuls Mean Comparison Test for Time Effect in Arm Strength

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 795.7 | 870.8 | 945.1 |
| 1 | - | 75.1* | 149.4** |
| 2 | | - | 74.3* |

p = .05 70.0957; 84.2139
p = .01 93.1307; 105.2674

TABLE 22

Newman-Keuls Mean Comparison Test for Time Effect in Strength Index

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 2717 | 2849 | 2969 |
| 1 | - | 91 | 211* |
| 2 | | - | 120 |

p = .05 144.9530; 1[illegible]485*
p = .01 192.5877; 217.6856**

TABLE 23

Newman-Keuls Mean Comparison Test for Time Effect in Back Strength

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 386.0 | 408.0 | 413.0 |
| 1 | - | 220* | 270* |
| 2 | | - | 50* |

p = .05 28.9412; 34.7703*
p = .01 38.4519; 43.4629**

TABLE 24

Newman-Keuls Mean Comparison Test for Time Effect in Leg Strength

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 1001 | 1031 | 1071 |
| 1 | - | 30 | 70 |
| 2 | | - | 40 |

p = .05 90.5764; 108.8197*
p = .01 120.3418; 136.0246**

TABLE 25

Newman-Keuls Mean Comparison Test for Time Effect in Left Grip

| Time | $T_2$ | $T_3$ | |
|---|---|---|---|
| Means | 121.2 | 121.8 | 124.7 |
| 1 | - | .6 | 3.5 |
| 2 | | - | 2.9 |

p = .05 4.889652565; 5.8744*
p = .01 6.496499521; 7.3431**

TABLE 26

Newman-Keuls Mean Comparison Test for Time Effect in Right Grip

| Time | $T_2$ | $T_3$ | $T_1$ |
|---|---|---|---|
| Means | 124.0 | 125.1 | 128.2 |
| 1 | - | 1.1 | 4.2 |
| 2 | | - | 3.1 |

p = .05 4.7118; 5.6608*
p = .01 6.2602; 7.0160**

TABLE 27

Newman-Keuls Mean Comparison Test for Time Effect in Chin Ups

| Time | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Means | 10.24 | 10.78 | 12.17 |
| 1 | - | .54 | 1.93** |
| 2 | | - | 13.9* |

p = .05 1.05; 1.26*
p = .01 1.40; 1.58**

TABLE 28

Newman-Keuls Mean Comparison Test for Time Effect in Shoulder Dips

| Time | | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|---|
| Means | | 20.33 | 22.47 | 23.94 |
| | 1 | - | 2.14 | 3.61** |
| | 2 | | - | 1.47 |

p = .05 2.053; 2.467*
p = .01 2.728; 3.084**

TABLE 29

Newman-Keuls Mean Comparison for Time Effect in Vital Capacity

| Time | | $T_1$ | $T_3$ | $T_2$ |
|---|---|---|---|---|
| Means | | 290.5 | 294.2 | 295.4 |
| | 1 | - | 3.7 | 4.9 |
| | 2 | | - | 1.2 |

p = .05 5.609; 6.739*
p = .01 7.453; 8.424**

# APPENDIX C

## NEWMAN-KEULS COMPARISON TEST

## FOR GROUP EFFECT

### LEGEND FOR TABLES IN APPENDIX C

C - Control Group

H - Non Weight-Trained Hockey Group

W - Weight-Trained Hockey Group

TABLE 30

Newman-Keuls Mean Comparison Test for Group Effect in $PWC_{170}$

| Group | C | W | H |
|---|---|---|---|
| Means | 1230 | 1460 | 1490 |
| 1 | | 230 | 260 |
| 2 | | - | 30 |

p = .05 243.3752; 292.7311*
p = .01 325.0676; 371.8706**

TABLE 31

Newman-Keuls Mean Comparison Test for Group Effect in $MVO_2$

| Group | C | W | H |
|---|---|---|---|
| Means | 3.534 | 4.162 | 4.249 |
| 1 | - | .628 | .715 |
| 2 | | - | .087 |

p = .05 .6677; .8031*
p = .01 .8918; 1.0202**

TABLE 32

Newman-Keuls Mean Comparison Test for Group Effect in $MVO_2$ (ml/kg/min)

| Group | C | H | W |
|---|---|---|---|
| Means | 47.91 | 55.70 | 55.76 |
| 1 | - | 5.52** | 6.47** |
| 2 | | - | 0.95 |

p = .05 6.6784; 8.0328*
p = .01 8.9201; 10.2044**

TABLE 33

Newman-Keuls Mean Comparison Test for Group Effect in Arm Strength

| Group | C | W | H |
|---|---|---|---|
| Means | 785.3 | 907.9 | 918.4 |
| 1 | - | 122.6 | 133.1 |
| 2 | | - | 10.5 |

p = .05 237.7877; 286.0104*
p = .01 317.6045; 363.3330**

TABLE 34

Newman-Keuls Mean Comparison Test for Group Effect in Strength Index

| Group | C | W | H |
|---|---|---|---|
| Means | 2777 | 2825 | 2933 |
| 1 | - | 48 | 156 |
| 2 | | - | 108 |

p = .05 431.5840; 519.1081*
p = .01 576.4514; 659.4484**

TABLE 35

Newman-Keuls Mean Comparison Test for Group Effect in Back Strength

| Group | W | H | C |
|---|---|---|---|
| Means | 394.5 | 399.8 | 412.8 |
| 1 | - | 5.3 | 18.3 |
| 2 | | - | 13.0 |

p = .05 67.6575; 81.3783*
p = .01 90.3677; 103.3783**

TABLE 36

Newman-Keuls Mean Comparison Test for Group Effect in Leg Strength

| Group | W | C | H |
|---|---|---|---|
| Means | 987 | 1038 | 1078 |
| 1 | - | [illegible] | 91 |
| 2 | | - | 40 |

p = .05 238.9396; 287.3959*
p = .01 319.1432; 387.3959**

TABLE 37

Newman-Keuls Mean Comparison Test for Group Effect in Left Grip

| Group | C | H | W |
|---|---|---|---|
| Means | 119.4 | 122.9 | 125.5 |
| 1 | - | 3.5 | 6.1 |
| 2 | | - | 2.6 |

p = .05 15.5919; 18.7439*
p = .01 20.8255; 23.8239**

TABLE 38

Newman-Keuls Mean Comparison Test for Group Effect in Right Grip

| Group | H | C | W |
|---|---|---|---|
| Means | 122.9 | 124.4 | 130.1 |
| 1 | - | 1.5 | 7.2 |
| 2 | | - | 5.7 |

p = .05 16.6830; 20.0663*
p = .01 22.2829; 25.4912**

TABLE 39

Newman-Keuls Mean Comparison Test for Group Effect in Chin-Ups

| Group | C | H | W |
|---|---|---|---|
| Means | 10.16 | 11.21 | 11.81 |
| 1 | - | 1.05 | 1.65 |
| 2 | | - | .60 |

p = .05 4.2509; 5.1129*
p = .01 5.6777; 6.4952**

TABLE 40

Newman-Keuls Mean Comparison Test for Group Effect in Shoulder Dips

| Group | | C | H | W |
|---|---|---|---|---|
| Means | | 20 | 22.50 | 23.41 |
| | 1 | - | 1.68 | 2.59 |
| | 2 | | - | .91 |

p = .05 7.4281; 8.9345*
p = .01 9.9215; 11.3500**

TABLE 41

Newman-Keuls Mean Comparison Test for Group Effect in Vital Capacity

| Group | | W | C | H |
|---|---|---|---|---|
| Means | | 285.9 | 295.0 | 299.2 |
| | 1 | - | 9.1 | 13.3 |
| | 2 | | - | 4.2 |

p = .05 43.6524; 52.5050*
p = .01 58.3050; 66.6997**

# APPENDIX D

## NEWMAN-KEULS COMPARISON TEST

## FOR INTERACTION EFFECT

LEGEND FOR TABLES IN APPENDIX D

C - Control Group; Trial 1

$H_2$ - Non Weight-Trained Hockey Group; Trial 2

$W_3$ - Weight-Trained Hockey Group; Trial 3

TABLE 42
NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN PWC$_{170}$

| Group | | $C_1$ | $C_2$ | $C_3$ | $H_1$ | $W_1$ | $W_3$ | $W_2$ | $H_2$ | $H_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 1200 | 1214 | 1278 | 1339 | 1354 | 1505 | 1526 | 1552 | 1585 |
| | 1 | - | 14 | 78 | 139* | 154* | 305** | 326** | 1352** | 385** |
| | 2 | | - | 64 | 125* | 140* | 291** | 312** | 338** | 371** |
| | 3 | | | - | 61 | 76 | 227** | 248** | 274** | 307** |
| | 4 | | | | - | 15 | 166** | 187** | 213** | 246** |
| | 5 | | | | | - | 151** | 172** | 198** | 231** |
| | 6 | | | | | | - | 21 | 47 | 80 |
| | 7 | | | | | | | - | 26 | 59 |
| | 8 | | | | | | | | - | 33 |

p = .05 92.1; 110.7; 121.8; 129.6; 135.4; 140.3; 144.6; 148.1
p = .01 122.4; 139.3; 149.4; 156.9; 162.5; 167.0; 170.9; 174.5

TABLE 43

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN $MVO_2$ (lit/min)

| Group | | $C_1$ | $C_2$ | $C_3$ | $H_1$ | $W_1$ | $W_3$ | $W_2$ | $H_2$ | $H_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.431 | 3.479 | 3.691 | 3.821 | 3.858 | 4.285 | 4.344 | 4.413 | 4.512 |
| | 1 | - | .048 | .26 | .39* | .427* | .854** | .913** | .982** | 1.018** |
| | 2 | | - | .212 | .342* | .379* | .806** | .865** | .934** | 1.033** |
| | 3 | | | - | .130 | .167 | .594** | .653** | .722** | .821** |
| | 4 | | | | - | .037 | .464** | .523** | .592** | .691** |
| | 5 | | | | | - | .427** | .486** | .555* | .654* |
| | 6 | | | | | | - | .059 | .128 | .227 |
| | 7 | | | | | | | - | .069 | .168 |
| | 8 | | | | | | | | - | .099 |

p = .05 0.255; 0.307; 0.337; 0.359; 0.375; 0.389; 0.401; 0.411
p = .01 0.339; 0.386; 0.414; 0.435; 0.450; 0.463; 0.474; 0.484

TABLE 44

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN $MVO_2$ (ml/kg/min)

| Group | | $C_1$ | $C_2$ | $H_1$ | $C_3$ | $W_1$ | $W_3$ | $H_2$ | $W_2$ | $H_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 46.14 | 47.43 | 49.67 | 50.12 | 51.53 | 57.37 | 58.12 | 58.39 | 59.32 |
| | 1 | - | 1.24 | 3.48 | 3.93 | 5.34* | 11.18** | 11.93** | 12.20** | 13.13** |
| | | | - | 2.24 | 2.69 | 4.10 | 9.94** | 10.69** | 10.96** | 11.89** |
| | | | | - | .45 | 1.86 | 7.70** | 8.45** | 8.72** | 9.65** |
| | | | | | - | 1.41 | 7.25** | 8.00** | 8.27** | 9.20** |
| | | | | | | - | 5.84** | 6.59** | 6.86** | 7.79** |
| | | | | | | | - | .75 | 1.02 | 1.95 |
| | | | | | | | | - | .27 | 1.20 |
| | | | | | | | | | - | .93 |

$\alpha$ = .05 3.47; 3.93; 4.33; 4.61; 4.82; 4.99; 5.14; 5.27

$\alpha$ = .01 4.35; 4.95; 5.31; 5.58; 5.78; 5.94; 6.08; 6.21

TABLE 45

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN ARM STRENGTH

| Group | | $C_1$ | $W_1$ | $C_2$ | $C_3$ | $H_1$ | $W_2$ | $H_2$ | $H_3$ | $W_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 740.9 | 794.5 | 795.8 | 819.1 | 851.7 | 883.3 | 933.3 | 970.3 | 1046 |
| | 1 | - | 53.6 | 54.9 | 78.2 | 110.8* | 142 4** | 192.4** | 229.4** | 305.1** |
| | 2 | | - | 1.3 | 24.6 | 57.2 | 88.8 | 138.8** | 175.8** | 251.5** |
| | 3 | | | - | 23.3 | 55.9 | 87.5 | 137.5** | 174.5** | 250.2** |
| | 4 | | | | - | 32.6 | 64.2 | 114.2** | 151.2** | 226.9** |
| | 5 | | | | | - | 31.6 | 81.6 | 118.6** | 194.3** |
| | 6 | | | | | | - | 50 | 87* | 162.7** |
| | 7 | | | | | | | - | 37 | 112.7** |
| | 8 | | | | | | | | - | 75.7* |

p = .05 79.3; 83.3; 91.6; 97.5; 101.9; 105.6; 108.8; 111.5
p = .01 92.1;104.9;112.4;118.1; 122.3; 125.7; 128.6; 131.3

TABLE 46

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN STRENGTH INDEX

| Group | $W_1$ | $C_1$ | $W_2$ | $C_2$ | $H_1$ | $C_3$ | $H_3$ | $H_2$ | $W_3$ |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 26.. | 2696 | 2758 | 2797 | 2833 | 2838 | 2974 | 2992 | 3095 |
| | - | 74 | 136 | 175 | 211* | 216* | 352** | 370** | 473** |
| | | - | 62 | 101 | 137 | 142 | 278** | 296** | 399** |
| | | | - | 39 | 75 | 80 | 216* | 234* | 337** |
| | | | | - | 36 | 41 | 177 | 195 | 298** |
| | | | | | - | 5 | 141 | 159 | 262** |
| | | | | | | - | 136 | 154 | 257** |
| | | | | | | | - | 18 | 121 |
| | | | | | | | | - | 103 |

p = .05 143.4; 172.3; 189.4; 201.7; 210.8; 218.4; 225.0; 230.6
p = .01 190.5; 216.9; 232.6; 244.2; 254.9; 260.0; 266.0; 271.6

TABLE 47

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION IN BACK STRENGTH

| Group | | $W_1$ | $H_1$ | $H_3$ | $W_2$ | $C_1$ | $C_2$ | $H_2$ | $W_3$ | $C_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 365.3 | 390 | 395 | 397 | 402.8 | 412.8 | 414.3 | 421.3 | 422.8 |
| | 1 | - | 24.7 | 29.7 | 31.7 | 37.5 | 47.5* | 49* | 56** | 57.5** |
| | 2 | | - | 5 | 7 | 12.8 | 22.8 | 24.3 | 31.3 | 32.8 |
| | 3 | | | - | 2 | 7.8 | 17.8 | 19.3 | 26.3 | 27.8 |
| | 4 | | | | - | 5.8 | 15.8 | 17.3 | 24.3 | 25.8 |
| | 5 | | | | | - | 10 | 11.5 | 18.5 | 20 |
| | 6 | | | | | | - | 1.5 | 8.5 | 10 |
| | 7 | | | | | | | - | 7 | 8.5 |
| | 8 | | | | | | | | - | 1.5 |

p = .05 28.0; 34.4; 37.9; 40.2; 42.0; 43.6; 44.9; 46.0
p = .01 38.0; 43.3; 46.4; 48.7; 50.4; 51.9; 53.1; 54.2

TABLE 48

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN LEG STRENGTH

| Group | | $W_1$ | $W_2$ | $C_1$ | $C_2$ | $C_3$ | $H_1$ | $H_3$ | $W_3$ | $H_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 921.7 | 952 | 1017 | 1038 | 1060 | 1065 | 1066 | 1087 | 1104 |
| | 1 | - | 30.3 | 95.3 | 116.3 | 138.3* | 143.3* | 144.3* | 165.3** | 182.3** |
| | 2 | | - | 65 | 86 | 108 | 113 | 114 | 135* | 152* |
| | 3 | | | - | 21 | 43 | 48 | 49 | 70 | 87 |
| | 4 | | | | - | 22 | 27 | 28 | 49 | 66 |
| | 5 | | | | | - | 5 | 6 | 27 | 44 |
| | 6 | | | | | | - | 1 | 22 | 39 |
| | 7 | | | | | | | - | 21 | 38 |
| | 8 | | | | | | | | - | 17 |

p = .05 84.6; 107.6; 118.4; 126.0; 131.7; 134.5; 140.6; 144.1
p = .01 119.0; 135.5; 145.3; 152.6; 158.0; 162.4; 166.2; 169.7

TABLE 4.9

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN LEFT GRIP

| | $C_3$ | $C_1$ | $H_2$ | $C_2$ | $H_3$ | $W_2$ | $W_3$ | $H_1$ | $W_1$ |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 119.1 | 119.6 | 120.1 | 120.4 | 122.1 | 123.1 | 125.3 | 126.6 | 128 |
| | - | 1.5 | 3.0 | 3.3 | 4.0 | 5.0 | 7.2 | 8.5* | 9.9* |
| | | - | .5 | .8 | 2.5 | 3.5 | 5.7 | 7.0 | 8.4* |
| | | | - | 0.3 | 2.0 | 3.0 | 5.2 | 6.5 | 7.9* |
| | | | | - | 1.7 | 2.7 | 4.9 | 6.2 | 7.6* |
| | | | | | - | 1.0 | 3.2 | 4.5 | 5.9 |
| | | | | | | - | 2.2 | 3.5 | 4.9 |
| | | | | | | | - | 1.3 | 2.7 |
| | | | | | | | | - | 1.4 |

= .05 ..83; 6.81; 7.39; 6.80; 7.11; 7.36; 7.59; 7.77
.01 8.42; 7.81; 7.84; 8.24; 8.53; 8.77; 8.97; 9.19

TABLE 50

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN RIGHT GRIP

| Group | | $H_3$ | $H_2$ | $C_1$ | $C_2$ | $C_3$ | $W_2$ | $H_1$ | $W_3$ | $W_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 120.3 | 120.3 | 124.1 | 124.5 | 124.7 | 127.3 | 128 | 130.4 | 132.5 |
| | 1 | - | 0 | 3.8 | 4.2 | 4.4 | 7.0* | [illegible] | 10.1** | 12.1** |
| | 2 | | - | 3.8 | 4.2 | 4.4 | 7.0* | 7.7* | 10.1** | 12.2** |
| | 3 | | | - | .4 | .6 | 3.2 | 3.9 | 6.3 | 8.4* |
| | 4 | | | | - | .2 | 2.8 | 3.5 | 5.9 | 8.0* |
| | 5 | | | | | - | 2.6 | 3.3 | 5.7 | 7.8* |
| | 6 | | | | | | - | [illegible] | 3.1 | 5.2 |
| | 7 | | | | | | | - | 2.4 | 4.5 |
| | 8 | | | | | | | | - | 2.1 |

p = .05 4.66; 5.60; 6.16; 6.55; 6.85; 7.10; 7.31; 7.49
p = .01 6.19; 7.05; 7.56; 7.94; 8.22; 8.45; 8.64; 8.83

TABLE 51

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN CHIN UPS

| Group | | $C_1$ | $C_2$ | $W_1$ | $H_2$ | $C_3$ | $H_1$ | $W_2$ | $H_3$ | $W_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 9.812 | 10.09 | 10.23 | 11.57 | 10.59 | 10.67 | 11.67 | 12.40 | 13.53 |
| | 1 | | .278 | .418 | .758 | .778 | .858 | 1.858* | 2.588** | 3.718** |
| | 2 | | - | .14 | .48 | .50 | .58 | 1.58* | 2.31** | 3.44** |
| | 3 | | | - | .34 | .36 | .44 | 1.44 | 2.17** | 3.30** |
| | 4 | | | | - | .02 | .10 | 1.10 | 1.83** | 2.96** |
| | 5 | | | | | - | .08 | 1.08 | 1.81** | 2.94** |
| | 6 | | | | | | - | 1.00 | 1.73** | 2.86** |
| | 7 | | | | | | | - | .73 | 1.86** |
| | 8 | | | | | | | | - | 1.13* |

p = .05 1.03; 1.24; 1.37; 1.46; 1.52; 1.58; 1.63; 1.67
p = .01 1.38; 1.57; 1.68; 1.77; 1.83; 1.88; 1.92; 1.96

TABLE 52

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN SHOULDER DIPS

| Group | | $C_1$ | $H_1$ | $W_1$ | $C_2$ | $C_3$ | $W_2$ | $H_3$ | $H_2$ | $W_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 19.28 | 20.77 | 20.93 | 21.37 | 21.81 | 22.40 | 23.10 | 23.63 | 26.90 |
| | 1 | - | 1.49 | 1.65 | 2.09 | 2.53 | 3.12* | 3.82** | 4.35** | 7.62** |
| | 2 | | - | .16 | .60 | 1.04 | 1.63 | 2.33 | 2.86 | 6.13** |
| | 3 | | | - | .44 | .88 | 1.47 | 2.17 | 2.7 | 5.97** |
| | 4 | | | | - | .44 | 1.03 | 1.73 | 2.26 | 5.53** |
| | 5 | | | | | - | .59 | 1.29 | 1.82 | 5.09** |
| | 6 | | | | | | - | .7 | 1.23 | 4.50** |
| | 7 | | | | | | | - | .53 | 3.80** |
| | 8 | | | | | | | | - | 3.27** |

p = .05 2.03; 2.44; 2.68; 2.85; 2.98; 3.09; 3.18; 3.26
p = .01 2.69; 3.07; 3.29; 3.46; 3.58; 3.68; 3.79; 3.84

TABLE 53

NEWMAN-KEULS MEAN COMPARISON TEST FOR INTERACTION EFFECT IN VITAL CAPACITY

| Group | | $W_1$ | $W_2$ | $W_3$ | $C_1$ | $C_3$ | $H_1$ | $C_2$ | $H_2$ | $H_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | | 282.8 | 287.3 | 287.7 | 290.9 | 295 | 297.9 | 299.1 | 299.8 | 300 |
| | 1 | - | 4.2 | 4.0 | 8.1* | 12.2** | 15.1** | 16.3** | 17** | 17.2** |
| | 2 | | - | .4 | 3.6 | 7.7* | 10.6** | 11.8** | 12.5** | 12.7** |
| | 3 | | | - | 3.2 | 7.3* | 10.2** | 11.4* | 12.1** | 12.3** |
| | 4 | | | | - | 4.1 | 7.0* | 8.2* | 8.9* | 9.1* |
| | 5 | | | | | - | 2.9 | 4.1 | 4.8 | 5 |
| | 6 | | | | | | - | 1.2 | 1.9 | 2.1 |
| | 7 | | | | | | | - | .7 | 0.9 |
| | 8 | | | | | | | | - | 0.2 |

p = .05 5.55; 6.66; 7.33; 7.80; 8.15; 8.45; 8.70; 8.92
p = .01 7.37; 8.39; 9.00; 9.45; 9.78;10.06;10.29;10.51

# APPENDIX E

## TABLE OF MEANS

TABLE 54

MEANS FOR $PWC_{170}$

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 1200 | 1214 | 1287 | 1230 |
| Hockey Group | 1339 | 1552 | 1585 | 1490 |
| Weight Group | 1354 | 1526 | 1505 | 1460 |
| Trial Means | 1300 | 1430 | 1460 | |

TABLE 55

MEANS FOR $MVO_2$ (liters/min)

| | T | T | T | Group Means |
|---|---|---|---|---|
| Control Group | 3.43 | 3.48 | 3.69 | 353 |
| Hockey Group | 3.82 | 4.41 | 4.51 | 424 |
| Weight Group | 3.86 | 4.34 | 4.29 | 416 |
| Trial Means | 3.70 | 4.07 | 4.16 | |

TABLE 56

MEANS FOR $MVO_2$ (ml/kg/min)

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 46.19 | 47.43 | 50.12 | 47.91 |
| Hockey Group | 49.67 | 58.12 | 59.32 | 55.70 |
| Weight Group | 51.53 | 58.39 | 57.37 | 55.76 |
| Trial Means | 49.13 | 54.65 | 55.60 | |

TABLE 57

MEANS FOR ARM STRENGTH

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 740.9 | 795.8 | 819.1 | 785.3 |
| Hockey Group | 851.7 | 933.3 | 970.3 | 918.4 |
| [illegible] | 794.5 | 883.3 | 104.6 | 907.9 |
| [illegible] | 795.7 | 870.8 | 945.1 | |

TABLE 58

MEANS FOR STRENGTH INDEX

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 2606 | 2797 | 2838 | 2777 |
| Hockey Group | 2833 | 2992 | 2974 | 2933 |
| Weight Group | 2622 | 2758 | 3095 | 2825 |
| Trial Means | 2717 | 2849 | 2969 | |

TABLE 59

MEANS FOR BACK STRENGTH

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 402.8 | 412.8 | 422.8 | 412.8 |
| Hockey Group | 390.0 | 414.3 | 395.0 | 399.8 |
| Weight Group | 365.3 | 397.0 | 421.3 | 394.5 |
| Trial Means | 386.0 | 408.0 | 413.0 | |

TABLE 60

MEANS FOR LEG STRENGTH

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 1017 | 1038 | 1060 | 1038 |
| Hockey Group | 1065 | 1104 | 1066 | 1078 |
| Weight Group | 9217 | 9520 | 1087 | 987 |
| Trial Means | 1001 | 1031 | 1071 | |

TABLE 61

MEANS FOR LEFT GRIP STRENGTH

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 119.6 | 120.4 | 118.1 | 119.4 |
| Hockey Group | 126.6 | 120.1 | 122.1 | 122.9 |
| Weight Group | 128.0 | 123.1 | 125.3 | 125.5 |
| Trial Means | 124.7 | 121.2 | 121.8 | |

TABLE 62

MEANS FOR RIGHT GRIP STRENGTH

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 124.1 | 124.5 | 124.7 | 124.4 |
| Hockey Group | 128.0 | 120.3 | 120.3 | 122.9 |
| Weight Group | 132.5 | 127.3 | 130.4 | 130.1 |
| Trial Means | 128.2 | 124.0 | 125.1 | |

TABLE 63

MEANS FOR CHIN UPS

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 9.81 | 10.09 | 10.59 | 10.16 |
| Hockey Group | 10.67 | 10.57 | 12.40 | 11.21 |
| Weight Group | 10.23 | 11.67 | 13.53 | 11.81 |
| Trial Means | 10.24 | 10.78 | 12.17 | |

TABLE 64

MEANS FOR SHOULDER DIPS

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 19.28 | 21.37 | 21.81 | 20.82 |
| Hockey Group | 20.77 | 23.63 | 23.10 | 22.50 |
| Weight Group | 20.93 | 22.40 | 26.90 | 23.41 |
| Trial Means | 20.33 | 22.47 | 23.94 | |

TABLE 65

MEANS FOR VITAL CAPACITY

| | $T_1$ | $T_2$ | $T_3$ | Group Means |
|---|---|---|---|---|
| Control Group | 290.9 | 299.1 | 295.0 | 295.0 |
| Hockey Group | 297.9 | 299.8 | 300.0 | 299.2 |
| Weight Group | 282.8 | 287.3 | 287.7 | 285.9 |
| Trial Means | 290.5 | 295.4 | 294.2 | |

# APPENDIX F

## PERFORMANCE - FITNESS CORRELATION MATRIXES

TABLE 66

FITNESS - PERFORMANCE CORRELATION MATRIX - Junior Team

| Variable | $PWC_{170}$ | $MVO_2$ (lit/min) | $MVO_2$ (ml/kg/min) | Arm Strength Index | Strength Index | Body Weight | Performance Score |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | - | 0.998* | 0.776* | 0.189 | 0.562* | 0.666* | 0.203 |
| 2 | | - | 0.760* | 0.179 | 0.575* | 0.683* | 0.204 |
| 3 | | | - | 0.256 | 0.355 | 0.098 | 0.024 |
| 4 | | | | - | 0.727* | 0.006 | 0.218 |
| 5 | | | | | - | 0.472 | 0.238 |
| 6 | | | | | | - | 0.109 |
| 7 | | | | | | | - |

p = .05 .514

TABLE 67

FITNESS - PERFORMANCE CORRELATION MATRIX - Senior Team

| Variable | $PWC_{170}$ | $MVO_2$ (lit/min) | $MVO_2$ (ml/kg/min) | Arm Strength | Strength Index | Body Weight | Performance Score |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | - | 0.806* | 0.725* | 0.349 | 0.464 | 0.496 | 0.132 |
| 2 | | - | 0.902* | 0.271 | 0.226 | 0.574* | 0.047 |
| 3 | | | - | 0.233 | 0.104 | 0.168 | 0.226 |
| 4 | | | | - | 0.345 | 0.125 | 0.143 |
| 5 | | | | | - | 0.316 | 0.006 |
| 6 | | | | | | - | 0.552* |
| 7 | | | | | | | - |

p = .05 0.532