# A Laboratory Test of Anaerobic Endurance for Ice Hockey Players

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## Abstract

The purpose was to establish the validity, reliability and objectivity of a cycle ergometer test of anaerobic endurance for ice hockey players. The test consisted of six 15 second repetitions with an exercise to recovery ratio of 1:1. The subjects (n=46 males) were varsity hockey players (n=17), junior varsity hockey players (n=14) and physical education students (n=15). All subjects performed the cycle ergometer test, while the two hockey groups also perfomed an on-ice fitness test. Correlation coefficients of r=-0.87 (p<.001) for peak power/kg on the laboratory test and speed index on the ice test and r=-0.78 (p<.001) for total power/kg on the laboratory test and total time on the ice test provided support for the establishment of criterion related validity. The test discriminated among varsity, junior varsity and non-varsity level players with peak power/kg and total power/kg as predictor variables. Intraclass correlation coefficients of 0.93 and 0.99 attested to the reliability and objectivity of the test. It was concluded that the intermittent cycle ergometer test is a valid, reliable and objective measurement of the anaerobic endurance of ice hockey players.

## Résumé

Le but de cette étude était d'établir la validité, la fiabilité et l'objectivité d'un test de laboratoire visant à déterminer l'endurance anaérobie au hockey. Ce test consistait en 6 séries d'exercise realisées sur bicyclette ergométrique d'une durée de 15 secondes chacune et intercallées de 15 secondes de repos. Quelques 46 joueurs de hockey universitaires seniors et juniors et des étudiants en education physique ont participé à l'étude. Les joueurs des deux groupes ont été soumis a un test d'endurance anaerobie sur glace de Reed ainsi qu'au test en laboratoire. Des coefficients de corrélation de -0.87 ($p<.001$) et de -0.78 ont été obtenu entre la puissance maximale/kg en laboratoire et l'index de vitesse de Reed et la puissance totale/kg mesurée en laboratoire et la durée totale sur glace respectivement et ont servi à établir la validité du test en laboratoire. Le test a permis de distinguer avec precision les joueurs des ligues junior et senior à partir des critères de puissance maximale/kg et de puissance totale/kg. Des coefficients de 0.93 et 0.99 ont été calculés pour les corrélations et ont servi à établir la fiabilité et l'objectivité du test.

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# Chapter I

## Introduction

Ice hockey is a sport in which Canada has consistently been a world power since its inception in 1885, at McGill University, Montreal (Orlick, 1943). Yet in the last ten years the Eastern European countries, notably the Soviet Union and Czechoslovakia, have successfully implemented scientific principles of training and systems of play, that have assisted them to become world champions. Canadian experts have studied these innovative nations in an attempt to regain world supremacy at both amateur and professional levels. An essential aspect of this scientific approach is evaluation of various fitness parameters relevant to the game of hockey. Testing provides feedback to coaches which helps them assess and refine their training programs.

For coaches and athletes to benefit from a test, it should be valid, reliable and objective. When these criteria have been established, fitness norms and athletic profiles can be compiled for later reference. Coaches can subsequently consult this data base to ascertain the potential of their athletes. Specificity theory suggests that a test must simulate the actual competitive activity, in terms of its frequency, intensity and duration. It has been demonstrated that the movements involved in a performance test should mimick the kinetic patterns of the activity (Henriksson, 1981). The ability to run on a treadmill tells the physiologist and coach very little about the potential talents of swimmers, due to the specific nature of treadmill running, yet this evaluation can provide valuable information about various physiological characteristics of runners. The validity, reliability and objectivity of a test, no matter how sophisticated, must be well documented to be accepted by the scientific community. Once this has been accomplished, coaches have a tool at their disposal to gauge the development and progression of their athletes.

## 1.1 Nature and Scope of the Problem

The nature of the game of hockey is characterized by 'shifts' which require repeated short bursts of intense skating. Between shifts, there is a period of passive recovery on the bench. Several researchers have examined the time motion characteristics of ice hockey at various ability levels (Thoden and Jetté, 1975; Green et al., 1976; Montgomery and Vartzbedian, 1977).

Thoden and Jetté (1975) timed the activity patterns of three major junior games and one professional game. Their results indicated that a typical shift (approximately 70-80 seconds in duration) consisted of several short bursts of maximal effort lasting from 2 - 3.5 seconds in duration. They noted that a player can expect to have 5 - 7 bursts per shift and from 15 - 18 shifts per game. Between bursts a player was gliding into position, in preparation for the next explosive burst. The authors noted that the "major junior" players were more anaerobically active than the professionals. This result must be regarded with caution as the data are for one team, participating in one game.

Thoden and Jetté (1975) recommended, based on their observations, that a test to evaluate the 'physical capacity to play hockey,' should include the following concepts:

1) maximal performances of the anaerobic type.
2) work bouts long enough to tax the anaerobic mechanism (i.e. 10 seconds or longer).
3) repetitions which represent as many bursts a player can expect to have on a shift (6 - 10).
4) 10 - 12 seconds of recovery time between work bouts.
5) an assessment of physical capacity in terms of ones ability to perform the final repeats at the same level of performance as the first trial.

These criteria provide the framework for a new laboratory test.

Green et al. (1976) studied the contribution of the anaerobic system versus the aerobic system in the game of hockey. These researchers timed the play of eight university forwards and defensemen. As expected, the defensemen demonstrated longer playing time per shift and for the total game, with less recovery time between shifts. Forwards did more anaerobic work than defensemen. Defensemen required a greater emphasis on the aerobic system while on the ice. Both positions required a sound aerobic base to aid recovery while sitting passively on the bench. The extensive use of the anaerobic system throughout a shift necessitates testing of the player's anaerobic endurance.

Montgomery and Vartzbedian (1977) studied the play characteristics of "old timer" hockey games. Compared to the previous studies, the "old timers" stayed on the ice much longer per shift than junior, college and professionals, 139.1 seconds to 85 seconds (Green et al., 1976) and 68 - 74 seconds (Thoden and Jetté, 1975).

The characteristics of play dictate the need for a high anaerobic fitness level with a good aerobic base. The physiological demands of ice hockey have been well documented by several researchers (Green, 1979; Green and Houston, 1975; Green et al., 1976; Hansen and Reed, 1979; Hockey and Howes, 1979; Houston and Green, 1976; Jetté, 1977; Marcotte and Hermiston, 1975; Montgomery, 1979; Montgomery, 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986; Paterson, 1979; Romet et al., 1978; Seliger et al., 1972; Wilson and Hedberg, 1976). These investigations support the importance of well developed anaerobic and aerobic systems when playing hockey at a high level. Laboratory evaluations of hockey players should examine both of these systems.

## 1.2 Significance of the Study

Fitness assessment is an essential part of a coach's annual training program (Bompa, 1983). The evaluation protocol should employ a valid test which examines the specific fitness components of the sport. The test must also be reproducible by other evaluators thus retaining its objectivity. Daub et al. (1983), Leger et al. (1979), and Montgomery and Brayne (1984) have compared laboratory tests and on-ice tests to determine if selected laboratory tests measured the intended fitness parameters. These authors were also interested in finding out whether the laboratory tests could distinguish among ability levels in the same manner that an on-ice performance test could.

Montgomery and Brayne (1984) examined the relationship among several on-ice tests compared to laboratory tests of hockey fitness. The subjects were 31 varsity and junior varsity players, with a mean age of 20.5 years. One of their results showed low correlations between similar fitness components of an anaerobic laboratory test and the University of Ottawa hockey fitness test (an anaerobic ice test). The laboratory tests were two commonly used protocols examining anaerobic fitness. The first laboratory test was the Wingate cycle ergometer test, which is a maximal 30 second sprint on a cycle ergometer (Ayalon et al., 1975). The second laboratory test was a run until volitional exhaustion on a treadmill tilted to a 20 percent grade and moving at 8 miles per hour

(Cunningham and Faulkner, 1969). Both of these tests are single effort exercise bouts giving no indication of the recovery pattern of the athlete. In hockey, it is important to be able to repeatedly demonstrate high speed outputs. Single effort tests will not differentiate between the ability of two hockey players to recover quickly and perform at a high level in subsequent trials.

This study examines a new laboratory test of anaerobic endurance which is designed to simulate the demands placed on the elite hockey player. Since the test requires repeated efforts at high intensity, it may be a more appropriate protocol for the evaluation of elite hockey players than protocols presently available to the exercise physiologist. If the validity, reliability, and objectivity of the modified test can be established, then hockey coaches will have a laboratory test that has meaningful application in predicting on-ice fitness performance.

## 1.3 Statement of the Problem

The objective of this study is to establish the validity, reliability, and objectivity of a laboratory test of anaerobic endurance of hockey players. The study will seek to test the following hypotheses:

1) A statistically significant correlation will exist between the speed index of the University of Ottawa ice hockey test and peak power/kg output of the laboratory

cycle ergometer test.

2) A statistically significant correlation will exist between total power/kg output on the cycle ergometer and the total time required to complete six repetitions on the University of Ottawa ice hockey fitness test.

3) The laboratory test will discriminate between subjects of three levels of hockey ability (varsity, junior-varsity and non-varsity).

4) A statistically significant, positive correlation will be found between test-retest scores of the laboratory test of anaerobic fitness.

5) A statistically significant correlation will be found between test results of two investigators.

The first and second hypotheses will test criterion related validity while the third hypothesis will test construct validity. Reliability will be verified in the fourth hypothesis. Objectivity will be examined in the final hypothesis.

## 1.4 Operational Definitions

1) Total anaerobic power: The total power output during an intermittent (6 x 15 second) 90 second supramaximal cycle ergometer test.

2) Peak anaerobic power: The highest 15 second power output measured during the 90 second cycle ergometer test.

3) Speed index: The time required to skate one length of the ice (54.9m) on the first repetition of the University of Ottawa hockey fitness test.

4) Anaerobic endurance index (or 'total time'): The total time required to complete six repetitions (91.4m distance for each repetition) of the University of Ottawa fitness test.

5) Construct validity: is concerned with the extent to which a particular measure relates to other measures consistent with theoretically derived hypotheses concerning the concepts (or constructs) that are being measured (Carmines and Zeller, 1984).

6) Criterion related validity: compares test or scale scores with one or more external variables, or criteria, known or believed to measure the attribute under study (Kerlinger, 1964).

7) Reliability: the extent to which a test or any measuring procedure yields the same results on repeated trials (Carmines and Zeller, 1984).

8) Objectivity: an estimation of inter-rater reliability (Baumgartner and Jackson, 1975).

## 1.5 Delimitations

1) The subjects in the study were male students who were: 1) varsity hockey players 2) junior varsity hockey players 3) physical education students.

2) The subjects ranged from 18 to 25 years of age.

3) Generalizations and conclusions could only be made concerning the cycle ergometer and on-ice test used in this study.

## 1.6 Limitations

1) The ice condition may not have been exactly the same for all subjects.

# Chapter II

## Review of the Literature

The review of the literature is divided into five sections:

2.1 Nature of the Game of Ice Hockey

2.2 Energy Source Utilization

2.3 Specificity of Testing

2.4 Anaerobic Testing in the Laboratory

2.5 Anaerobic Testing on the Ice

2.6 Summary

### 2.1 Nature of the Game of Ice Hockey

Thoden & Jetté (1975) monitored three major junior level hockey games and one professional hockey game in an attempt to determine the proportion of time spent in anaerobic or bursting activity, coasting or recovering, and time spent on the bench. Their results indicated that the average player was on the ice for 75 to 90 seconds per shift. Each shift consisted of 5 to 7 bursts with each burst lasting 2 to 3.5 seconds for a total of 15 to 20 seconds of bursting per shift. Each player was on the ice for 5 to 6 shifts per period for a total time of 5 to 7 minutes. The time between shifts was 3 to 4 minutes, the total playing time per game was 15 to 21 minutes with 4 to 6 minutes of that being anaerobic bursting.

In a time motion study, Green et al. (1976) found that the average playing time per game was 24.5 minutes. This playing time was broken down into 17.4 shifts with an average of 85.4 seconds of playing time per shift. There were two to three play stoppages per shift with each stoppage lasting 27.1 seconds with 39.7 seconds of playing time between each stoppage. The average time spent on the bench between shifts was 225 seconds. The average velocity per shift was 227 meters per minute. The average heart rate during a shift was 173 beats per minute. Based on time stoppages per shift, and playing time per shift, the ratio of work to recovery was approximately 1:3.

Green et al. (1976) quantified the difference in time-motion characteristics between forwards and defenseman. The defensemen played longer than the forwards (21.2%) which was due to a greater number of shifts (+26.1%) and a much shorter recovery period (-37.1%). For the defensemen the shifts were shorter in duration (-7.4%), shorter in continuous playing time (-10.1%), and longer in the time taken to resume play (+12.9%). The defensemen averaged 61.6% of the velocity of the forwards per shift. The defensemen also averaged 10 to 15 beats per minute lower heart rates per shift (Green et al., 1976).

A later study by Green et al. (1978a) revealed similar time motion characteristics. In this study the average player skated 7 percent less (22.8 minutes) than the study in 1976 (Brayne, 1985). Each player had 25 percent more shifts (21.7) but 26 percent less playing time (63.6 seconds) per shift (Brayne, 1985). The playing time between stoppages (29.1 seconds) was 27 percent less than the earlier study (Brayne, 1985). The time of each play stoppage (29.8 seconds) increased by 10 percent (Brayne, 1985). The recovery time between shifts was 13 percent greater (254 seconds) than the 1976 study (Brayne, 1985). Green (1979) summarized that optimal performance in hockey depended upon the interaction between aerobic and anaerobic systems with the aerobic system determining the tempo of a game.

## 2.2 Energy Source Utilization

The physiological demands of ice hockey have been examined by many researchers (Cunningham et al., 1976; Dulac et al., 1978; Ferguson et al., 1969; Gauthier et al., 1979; Green, 1979; Green and Houston, 1975; Green et al., 1976; Hansen and Reed, 1979; Hockey and Howes, 1979; Houston and Green, 1976; Jetté, 1977; Léger et al., 1979; MacNab, 1979; Marcotte and Hermiston, 1975; Minkoff, 1982; Montgomery, 1979; Montgomery, 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986; Paterson, 1979; Romet et al., 1978; Rusco et al., 1978; Seliger et al., 1972; Smith et al., 1982; Vainikka et al., 1982; Wilson and Hedberg, 1976). Based on the data from these studies, it appears that hockey players have an average maximum oxygen uptake between 50-60 ml/kg·min. The values range as low as 42.3 ml/kg·min for N.H.L. players tested in pre-season to as high as 62.4 ml/kg·min for Eastern European countries tested during mid-season (Enos et al. 1976). It seems that hockey players are fairly similar in terms of max $\dot{V}O_2$ (Cunningham et al., 1976). The aerobic power (max $\dot{V}O_2$) does not seem to change significantly during the hockey season (Green and Houston, 1975)

The adaptation of the aerobic system depends on intensity, duration, and frequency as well as initial fitness level (Astrand and Rodahl, 1981). During game performances, the intensity seems high enough for aerobic improvement, as shown by heart rates frequently exceeding 90 percent of maximal predicted heart rate (Houston and Green, 1976). The authors explain the lack of aerobic improvement by emphasizing that these high heart rates are not maintained for a long enough period of time.

Green and Houston's (1975) results showed that the largest improvements from pre to post tests occurred in the anaerobic systems with the greatest increments in lactate capacity (16.3%). This finding is supported by high lactate values produced during games (Green et al., 1978a,b; Luetsolo, 1976). Time motion studies have also shown that hockey players perform many repeated short bursts of maximal anaerobic activity during a game (Thoden and Jetté, 1975; Seliger et al., 1972). Seliger et al. (1972) measured the oxygen utilization of the Czechoslovakian national team during a model training match. Their findings indicated that 69 percent of the energy expended was derived from anaerobic sources and 31 percent from aerobic sources. The authors reasoned however that the development of the aerobic system was important so as to spare the anaerobic system for the most intensive periods of play.

Green et al. (1978a) investigated the alteration in blood substrates and the depletion pattern of glycogen in the fibres of the vastus lateralis muscle of five forwards and three defensemen, before the game and at the end of each period. The periodic acid - Schiff (PAS) method was used to determine the glycogen concentration in the muscle fibres. The muscle glycogen concentration (MM/kg wet weight) from the vastus lateralis was 89.3 ± 13.6 for the forwards before the game. The defensemen measured 85.0 ± 3.7 before the game. Lactate values for the forwards were as follows; 1.42 MM (pre game), 6.16 MM (after the 1st period), 4.65 MM (after the 2nd period) and 5.63 MM (after the third period). Lactate values for the defensemen were as follows; 1.76 MM (pre game) 2.92 MM (after the first period), 2.77 (after the second period) and 3.12 MM (after the third period). This study by Green et al. (1978a) confirmed the anaerobic nature of the work involved in ice hockey. There is a moderate energy contribution from glycolysis as seen in the venous lactate values sampled at the end of each period.

Green (1978) studied the glycogen depletion patterns from the vastus lateralis muscle during continuous and intermittent exercise consisting of 10 bouts of high intensity work corresponding to 120% of max $\dot{V}O_2$. Each bout consisted of one minute of skating followed by a five minute recovery period. The continuous skating was performed at 55% of max $\dot{V}O_2$ for 60 minutes. Muscle biopsies were taken prior to the first bout of skating, after 30 minutes (5 work bouts) and 60 minutes (10 work bouts).

During the continuous skating, glycogen depletion was 29% with a more pronounced loss from the type I fibres (slow twitch). During the intermittent condition, there was a two-fold greater depletion (70%), with a preferential loss from type II fibres (fast twitch). Of the two types of fast twitch fibres (type IIA - fast twitch oxidative glycolytic, type IIB - fast twitch glycolytic) the greatest depletion was in the type IIB fibres. Green (1978) concluded that glycogen depletion patterns are similar to those seen during cycling at similar percentages of max $\dot{V}O_2$.

Green et al. (1978b) investigated the effect of two intercollegiate games back-to-back within a 24 hour period. During the first game the lactic acid concentration rose from a resting value of 14 mg% (1.56 MM) to 43 mg% (4.78 MM) by the end of the first period. The 43 mg% (4.78 MM) tended to remain constant over the final two periods. There was no difference in lactate response between forwards and defensemen.

Luetsolo (1976) has shown that the hockey player is capable of having high muscle glycogen stores before a game. The researcher stated that during a very hard game, hockey players can lose almost their entire muscle glycogen stores (as much as 40 gm/kg of wet muscle). Muscle glycogen is utilized first from slow twitch fibres and only during strenuous games is it used from the fast twitch fibres (Luetsolo 1976). These data are supported by the work of ~~Green~~ (1978).

## 2.3 Specificity of Testing

If data from various laboratory tests are to be used to evaluate the aerobic and anaerobic skating capabilities of hockey players, these tests must be valid. The concept of specificity in testing has been examined in the literature.

Roberts and Alspaugh (1972), and Pechar et al. (1974) showed that training for cycling is very specific. In the the first study, the training effects of a running, training program were compared with that of a cycling program. An increase in the physical work capacity of the treadmill trained group was demonstrated when tested on both the treadmill and cycle ergometer. In contrast, the bicycle trained group demonstrated an increase in physical work capacity only when tested on the cycle ergometer. When tested on the treadmill, no significant increases could be demonstrated. Roberts and Alspaugh (1972) concluded that training effects of cycling were more specific than those of running; therefore, a treadmill test was not a valid test for measuring cardio-respiratory improvements of cycle trained athletes.

Pechar et al., (1974) examined the specificity of cardiorespiratory adaptation to training. They measured the max $\dot{V}O_2$ of three groups of subjects on both the cycle ergometer and the treadmill, before and after an eight week training program. The three conditions were treadmill training, bicycle training and no training. For the treadmill trained group, the method of evaluation made no difference. The training improvements in max $\dot{V}O_2$ were 6.8 percent when measured on the treadmill and 6.9 percent when measured on the cycle ergometer. In contrast to this, when tested on the treadmill, the cycle trained group demonstrated only a 2.6 percent improvement in max $\dot{V}O_2$. However when tested on the cycle ergometer, an improvement of 7.8 percent was demonstrated. The authors concluded that run training produced a general max $\dot{V}O_2$ improvement whereas cycle training produced a specific training effect.

Pechar et al.'s (1974) finding was not in agreement with Glassford et al. (1965), Hermansen and Saltin (1969), Hermansen et al. (1970), and Pannier et al. (1980) who all examined the effect of run training on max $\dot{V}O_2$ as measured by the treadmill and cycle ergometer tests. In the study by Pannier et al. (1980), the subjects were long distance runners and a control group of active athletes. The difference in max $\dot{V}O_2$ (ml/kg·min) between the two groups was 19.5 percent when measured on the cycle ergometer. This difference increased to 28.8 percent when measured on the treadmill. Pannier and associates concluded that the difference in physical work capacity between runners and controls was underestimated by an unspecific test such as cycling exercise. They stated that in specificly trained runners the max $\dot{V}O_2$ was lower on the cycle ergometer than on the treadmill.

Perhaps the run trained subjects in Pechar's study (1974) were not highly trained runners like those in the study by Pannier et al. (1980) (Brayne, 1985). Examination of the max $\dot{V}O_2$ measured on the treadmill of both groups revealed a max $\dot{V}O_2$ of 58 ml/kg·min (Pechar et al., 1974) and 71 ml/kg·min (Pannier et al., 1980). In summary, the more highly trained the athlete the greater is the need for specific tests of fitness.

Swimming is another sport in which specificity research has been conducted (Gergley et al., 1984; Holmer, 1972; Holmer et al., 1974; Holmer and Astrand, 1972; Magel et al., 1975; McArdle et al., 1978 and Reynett and Montgomery, 1982). These authors stressed that careful attention must be given to the fitness test administered to assess the specific changes in physiological function resulting from training. Magel et al. (1975) suggested that it would be reasonable to expect the largest increase in max $\dot{V}O_2$ when the selected test required the use of the specifically trained muscle groups. Thus changes from a swim training program could be detected in a swimming test but not from a cycle ergometer test (Reynett and Montgomery, 1982).

Three studies (Daub et al., 1983; Léger et al., 1979; Montgomery and Brayne, 1984.) have examined the specificity of on-ice testing versus laboratory testing of hockey players. Daub et al. (1983) found that the adaptive response to training may be specific to the type of work used in training, the type of ergometry used to evaluate training, and the physiological response.

Léger et al. (1979) found a similar max $\dot{V}O_2$ on the ice and in the laboratory for ten hockey players. Although the hockey players had the same max $\dot{V}O_2$ on the treadmill and on the ice, they had a lower mechanical efficiency on the treadmill than runners but a higher efficiency on the ice. The hockey players required 15% less energy to skate at the same speed as the runners yet needed 7% more energy to run on the treadmill. The authors concluded that a performance test is more informative than the max $\dot{V}O_2$ score to establish the ability of a player to perform aerobic skating.

Green (1979) found a large difference in skating efficiency of elite hockey players. Results for three subjects who were characteristic of other elite hockey players were presented. The subject with the lowest max $\dot{V}O_2$ expended the least energy when skating at high velocities. The ability of this subject to maintain skating intensity at high velocities was far superior to the other two subjects in spite of their superiority in maximal oxygen uptake. Green (1979) concluded that skating efficiency may be a more significant indicator of fatiguability than low max $\dot{V}O_2$.

These findings suggest that for hockey players unlike other athletes, maximal oxygen uptake is not the most discriminating factor of a players' aerobic skating capacity. Because a wide variation of mechanical efficiency is a characteristic of hockey players, this factor must be considered important.

This argument was illustrated by Ferguson et al. (1969). Maximal oxygen uptake was measured while skating. The subjects were required to skate around an oval at a certain speed for a three minute workload. The speeds were increased every workload until the point at which subjects could no longer maintain the pace. The subjects carried a gas collection apparatus on their backs and the maximal oxygen uptake was measured by gas analysis. The authors noted a wide variability among the subjects in maximal oxygen uptake (15%). As all subjects were considered trained skaters, it was concluded that considerable differences must have existed in the skill of skating.

If only the max $\dot{V}O_2$ values were examined to make judgements concerning the skating capabilities of these hockey players, errors could have been made. For example two subjects in that study were both able to complete the workload which entailed skating at a velocity of 443 m/min. The max $\dot{V}O_2$ of one subject was computed to be 51.9 m/kg·min while the max $\dot{V}O_2$ of the other subject was 64.4 ml/kg·min. Thus despite large differences in max $\dot{V}O_2$ of these two subjects, they were both able to complete the same final workload. The subject with the lower max $\dot{V}O_2$ was clearly the most efficient skater. This further substantiates the role of skating efficiency as a confounding variable in the analysis of aerobic and anaerobic capacities of hockey players.

Larivière et al. (1978) obtained a significant correlation of .70 between the max $\dot{V}O_2$ obtained in the laboratory and an eight minute skating test. This correlation was only significant when max $\dot{V}O_2$ was expressed in litres/minute. There was no significant correlation when max $\dot{V}O_2$ was expressed in ml/kg·min (Brayne, 1985). Using the max $\dot{V}O_2$ expressed relative to body weight removes the confounding variable weight, and renders a sample more homogeneous. The more homogeneous the sample, the lower the probability of obtaining a significant but irrelevant correlation. Since the results of studies examining the correlations between laboratory and on-ice tests will be utilized by coaches of homogeneous hockey players, care must be taken when selecting samples. The subjects in a study must be homogeneous in age and ability level (Montgomery and Brayne, 1984).

Montgomery and Brayne (1984) examined the specificity of on-ice versus laboratory tests of hockey fitness. The subjects were 31 varsity and junior varsity hockey players tested during the middle of the competitive season ($\bar{X}$ = 20.5 years of age). Two tests that the researchers were interested in comparing; the Wingate cycle ergometer and the University of Ottawa fitness test yielded low relationships between similar components. The speed index (s) was compared with peak anaerobic power in absolute terms and in relation to body weight in kilograms. These comparisons yielded correlations of -0.42 and -0.25 for the varsity and junior varsity, respectively, for the absolute measure of peak anaerobic power. The peak power per kg body weight and speed index comparison yielded correlations of -0.42 and -0.61 for the varsity and junior varsity, respectively. Another comparison between total time (anaerobic endurance index) on the ice (s) and anaerobic 'capacity' per kg body weight evaluated in the laboratory was made. This relationship was found to be low at .08 for the varsity group and -.01 for the junior varsity group.

Montgomery and Brayne (1984) explained the low relationships by stating that players with lower anaerobic endurance in the Wingate test may be able to overcome this weakness by demonstrating superior skating efficiency or better hockey skills. Ferguson et al. (1969) have shown that individual differences in the efficiency of skating may be large even among experienced and highly trained ice hockey players.

## 2.4 Anaerobic Testing in the Laboratory

The anaerobic endurance of hockey players has been measured by sprinting on the treadmill (Green & Houston, 1975; Houston & Green, 1976; Montgomery and Brayne, 1984) and by the Wingate cycle ergometer test (Montgomery, 1982; Smith et al., 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986). The anaerobic test on the treadmill entails a run-to exhaustion. The treadmill is pre-set to a grade of 20 percent and a speed of 215 meters per minute (8 mph). The subject is required to run on the treadmill for as long as possible. The total run time is recorded as a measure of anaerobic lactate capacity.

Some research has indicated that glycogen depletion pattern, and muscles used in cycling are similar to those used in skating (Andersbn and Henriksson, 1977; Green et al., 1978a,b; Geijsel , 1979). A number of "one-shot" short term, high intensity performance tests have been published, which predict anaerobic capacity and power. The Wingate anaerobic test with modifications has been refined to evaluate anaerobic power and capacity of various athletic groups (Bar-Or, 1977,1978; Evans and Quinney, 1981; LaVoie et al., 1984; Montgomery, 1982; Smith et al., 1982).

The Wingate anaerobic test involves a 30 second supramaximal ride on a cycle ergometer. The protocol for the Wingate test has been described by Bouchard et al. (1982). The subject performs a low workload on a modified cycle ergometer increasing the pedal frequency to maximum and within 2 - 3 seconds the test resistance (based on body weight) is applied. The subjects perform at their maximum frequency for the 30 second test period. Pedal frequency is recorded and for each of the (6) five second periods, power outputs are computed. Peak power output, mean power output, and power decrement are calculated. The two former measures are normalized for body weight.

Evans and Quinney (1981), through a series of regression equations, found the average resistance setting to optimize power performance to be 0.096 kp per kg body weight. LaVoie et al. (1984) used the Evans-Quinney formula and found the optimal setting to be 0.099 kp per kg body weight. LaVoie quotes unpublished data by Smith in which the Evans and Quinney formula was again used, to find a setting of 0.094 kp per kg body weight to be optimal. These studies all employed the 30 second test on the cycle ergometer.

In a recent study (Gosilin et al., 1985) questioned whether the Wingate test gives a true representation of measurements which are considered traditionally to reflect alactacid and lactacid components of anaerobic metabolism. Subjects (men n=9 and women n=5) performed an exhaustive cycle ergometer ride at a power output that elicited $\dot{V}O_2$ max. The mean duration of this test was 4.5 minutes. Peak lactate and $O_2$ debt (fast and slow components) were measured. The subjects also performed the Wingate test. All data was normalized for body weight. Both peak lactate and $O_2$ debt had low correlations with either peak or mean power of the Wingate test. The results failed to support the traditional assumptions that both peak and mean power of the Wingate test and peak lactate and $O_2$ debt from a cycling test are measuring the same anaerobic energy systems.

Other anaerobic tests include a 60 second (Thomson, 1981; Thomson and Garvie, 1981) and 120 second (Katch and

Weltman, 1979) cycle ergometer rides. Lactate values obtained during the 60 second test were below maximal values as reported in the literature (Hermansen and Osnes, 1972; Kinderman and Keul, 1977). Katch and Weltman (1979) reported that the 120 second test involved a considerable aerobic contribution during the latter stage of the test. Simoneau et al. (1983) sugested that a test longer than 60 seconds but shorter than 120 seconds in duration would seem appropriate for the evaluation of anaerobic lactate capacity. Newsholme (1981) calculated that the glycogen content of the human muscle could provide sufficient energy for about 80 seconds of sprinting. Katch and Weltman (1979) observed that power output during a 120 second test reached a plateau after 90 seconds. The authors retained the 90 second duration as an indication of anaerobic lactate capacity.

## 2.5 Anaerobic Testing on the Ice

The University of Ottawa fitness test examines the player's ability to recover quickly and perform several maximal work bouts. Reed et al. (1979) have demonstrated the validity, reliability, and objectivity of this test.

Based upon published game analyses, a repeat sprint skate (RSS) test was devised by Reed et al. (1979). The test consisted of six repeated bursts of maximum velocity for 91.4 meters (300 feet), performed on an interval of 30 seconds, included both work and recovery time (Reed et al., 1979). Validation was concentrated on three test scores; (1) drop - off (DO), the maximum difference between RSS times; (2) heart rate recovery (HRR), the difference between the initial and final H.R. counts, and (3) the percentage heart rate recovery (% HRR) (Reed et al., 1979). Midget, Junior A, collegiate and N.H.L. players were subjects in a series of studies which included 48 hour test-retest reliability and validation of RSS scores against off-ice tests such as max $\dot{V}O_2$, peak lactate, mile run time, modified Margaria stair climb, and max HR recovery (Reed et al., 1979). The results showed that the times for the repeated sprints (12.5 - 21.7 seconds; n=227) falls within the anaerobic lactate range (Reed et al., 1979). The mean time of 14.7s, (S.D. = 0.8s) set the work to recovery at approximately a 1:1 ratio. Test-retest correlations (n=22) for DO, HRR, % HRR were 0.78, 0.68, and 0.74, respectively (Reed et al., 1979). Correlations between RSS test scores and laboratory test scores indicated that the drop-off score was more related to anaerobic lactate fitness while the HRR is more related to aerobic fitness (Reed et al., 1979).

The University of Ottawa hockey fitness test has been used to measure both aerobic and anaerobic skating capacities of hockey players (Montgomery, 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986; Smith et al., 1982). Subjects were required to complete six repetitions of 91.4 meters at maximal skating velocity. The repetitions were 30 seconds apart which included both the exercise and recovery time. From this test, a speed index, anaerobic endurance index, and drop-off index are calculated. A reliability coefficient of .77 has been reported for the speed index (Jetté et al., 1975). The speed index is a measure of the alactate system and the anaerobic endurance index (total time) is a measure of the lactate system (Reed et al., 1979).

2.6 Summary

1. A review of the related literature has indicated that hockey is characterized by intermittent periods of activity requiring submaximal and maximal levels of exertion. Both the aerobic and anaerobic energy systems are important in ice hockey.

2. Numerous aerobic and anaerobic tests on the treadmill, cycle ergometer, and on-ice have been utilized to measure aerobic and anaerobic fitness of hockey players.

3. A test duration of 90 seconds has been suggested as optimal for the evaluation of anaerobic lactate endurance.

4. Skating efficiency among trained skaters has a wide variability and because of this, skating efficiency may be a significant indicator of fatiguability in skating along with anaerobic endurance.

5. Correlations between laboratory fitness tests and on-ice tests have produced equivocal results.

6. Questions have been raised concerning the validity of the Wingate test to measure the traditionally accepted components of anaerobic fitness.

# Chapter III

# Methods

This chapter is divided into the following six sections:

3.1 Subjects

3.2 Treatment of the Subjects

3.3 Cycle Ergometer Laboratory Test

3.4 University of Ottawa Hockey Fitness Test

3.5 Experimental Design and Statistical Analysis

3.6 Summary

## 3.1 Subjects

Forty six male subjects were selected for this study. Seventeen of these subjects were members of the McGill University varsity hockey team, while fourteen were members of the junior varsity hockey team. Goaltenders were excluded. The remaining fifteen were male students of McGill University's department of physical education. The age range of the subjects was from 18 to 25 years.

The three groups were treated separately, with the physical education students acting as an athletic control group. Ten of the hockey players had played for both varsity and junior varsity at the time of testing. The grouping of these players was done in terms of time spent with each team. To be in the varsity group, the player must have played 80 percent of his games with the varsity club. Players that did not fall under this category were considered in the junior varsity group.

3.2 Treatment of the Subjects

The hockey players were required to perform both the laboratory and ice tests. The varsity players were tested during the pre-playoff competitive phase of their training. The junior varsity players were tested twice, within a two week period in order to examine the test re-test hypothesis. The physical education students were tested once in the laboratory during this same time period.

Subjects were asked to refrain from eating, drinking (except water), or smoking for two hours prior to testing due to the supramaximal nature of the tests. Testing was conducted on dates which permitted at least two days for recovery prior to a game. All testing in the laboratory occured between 4:00 and 7:00 P.M. All testing on the ice occured between 4:00 and 7:00 P.M. Repeat trials of the same test occured at approximately the same time of day, during the following week.

The subjects made an appointment which was convenient with them on the prescribed testing day. The subjects arrived at the laboratory in proper gym wear. All subjects read and signed an informed consent document prior to the commencement of the first laboratory test. Each laboratory 'slot' of 15 minutes was filled with two athletes. The athlete not on the cycle ergometer was instructed to provide verbal encouragement.

Subjects were encouraged to warm-up before each of the laboratory and ice tests. Verbal explanation combined with a physical demonstration was given by the investigators at the start of each laboratory and ice session. Both the varsity and junior varsity coaches emphasized the importance of the testing sessions to assist the researchers in motivating the subjects. The subjects were encouraged by the investigator and their coach to give maximal effort throughout the test. It was made clear that 'pacing' could be detected and would be considered unacceptable, resulting in a second trial. Pacing was considered to exist if the average of the 5th and 6th repetitions was better than the average of the 3rd and 4th repetitions, or if the average of the 3rd and 4th repetitions was better than the average of the 1st and 2nd repetitions.

For the ice testing the researchers arrived 30 minutes before the hockey teams practice time. The investigator then outlined the testing procedures using a blackboard. The head coach provided the tester with subjects in groups of four. These groups were homogeneous in terms of skating ability in order to provide an optimal competitive environment. Once the ice had been resurfaced, the testing took place as soon as the players had time to perform stretching and warm up exercises. All players wore full hockey equipment and carried a stick. Each test was fully completed during one ice session.

## 3.3 Cycle Ergometer Laboratory Test

In a pilot project for this study it was found that the Wingate test resistance of 0.075 kp per kg body weight seemed to elicit higher anaerobic endurance on the proposed test than when using a resistance of 0.096 kp/kg body weight. Several of the athletes tested with a resistance setting of 0.096 kp per kg body weight could not finish the test. Thus, due to the increased length of this new test, it was decided to employ the lighter resistance setting for this project. The resistance setting on the cycle ergometer for each subject was determined by the equation: 0.075 kp x body weight (kg) (Ayalon et al., 1975). Smith et al. (1982) described the set-up of the Monark modified cycle ergometer. The seat height for the subjects was a measure of the distance from the subject's crotch to the floor, or full extension of the leg with the ankle at 90 degrees (normal flexion when the foot is on the ground).

A modified cycle ergometer (Monark) bolted to the floor (for stability) was the testing mode for this investigation. Pedal revolutions completed were monitored by two magnets set at 180 degrees to one another on the crank of the ergometer. A magnetic reed switch was attached to the cycle ergometer frame opposite the crank. The reed switch was connected to an electronic counter. Thus each time the crank completed one revolution, the magnets caused the switch to close twice, therefore generating two impulses (one each). These impulses travelled to an electronic counter which recorded every impulse or half revolution of the crank. The experimenter recorded the pedal revolutions on scoring sheets during the 15 second recovery intervals between repetitions.

A modification was made to the resistance mechanism of the Monark cycle ergometer. It was observed during the pilot study that the resistance seemed to vary slightly throughout a 15 second trial and from repetition to repetition. To apply a constant resistance, a pully system, with a basket to hold mass in was devised. With direct suspension of the mass, the pedal resistance was constant, thereby removing the potential variance in the initial system (see APPENDIX B).

The second modification was to use toe clips on the pedals. This allowed the subjects greater upward pulling on the crank which demands more muscle involvement throughout the whole movement (LaVoie et al., 1978).

The test consisted of six trials, each of 15 second duration, with a total work time of 90 seconds. Between each trial was a recovery interval of 15 seconds. Thus the exercise to recovery ratio was 1:1. The subjects started each repetition from a still position with their feet in the designated starting point. The subject's left foot was at the ten o'clock position, while the right foot was at the four o'clock position, as one looked from the left foot side of the crank. On a verbal command, the subject pedalled the crank as fast as possible for the first 15 second repetition. The investigator also indicated the stopping point. In addition, a clock was visible to the subject. During the 15 second recovery interval, the researcher recorded the revolutions from the electronic counter and reset the counter. The investigator also ensured that the subject's feet were in the proper starting position for the next repetition. The subject was given a five second warning, and then the command 'go' to indicate the start of the repetition. Verbal encouragement was given on each repetition for all subjects, in order to assist in obtaining a supramaximal effort. After the sixth repetition, a two to three minute warm down at low resistance was given.

Two components were computed from the cycle ergometer test: peak anaerobic power, and total anaerobic power.

Peak anaerobic power was the peak power attained from any of the six repetitions. The 15 second interval with the greatest number of revolutions was used in this calculation. The equation used to calculate peak anaerobic power (watts) was:

$$\frac{\text{Rev}}{15\text{s}} \times \frac{60\text{s}}{\text{min}} \times \frac{6\text{m}}{\text{rev}} \times \text{Resistance(kp)} \times \frac{1\ \text{Watt}}{6.12\ \text{kpm/min}}$$

Total anaerobic power was the total power output from the six repetitions of the test (90 seconds). The equation used to caculate this indice was as follows:

$$\frac{\text{Rev}}{90\text{s}} \times \frac{60\text{s}}{\text{min}} \times \frac{6\text{m}}{\text{rev}} \times \text{Resistance(kp)} \times \frac{1\ \text{Watt}}{6.12\ \text{kpm/min}}$$

Both peak and total anaerobic power were also expressed as a relative score by dividing by body weight (kg).

### 3.4 University of Ottawa Hockey Fitness Test

The University of Ottawa hockey fitness test provided the format for the cycle ergometer test discussed in the previous section. Since this ice test has been shown to be a valid and reliable test of fitness for ice hockey players (Reed et al., 1979), its protocol was simulated in the laboratory. This protocol also provided the two criteria to validate the new laboratory test.

Reed et al. (1979) have described the University of Ottawa hockey fitness test. The test was comprised of six repetitions of supramaximal skating. Each work bout consisted of skating 91.4 meters (from goal line to goal line, and then back to the blue line closest to the initial starting point). The distance from goal line to goal line of 54.9 meters was used for the speed index. This indice was timed on the the first repetition of the test. Thus on the first repetition there were two times recorded, one for the speed index (54.9m) and one for the complete distance (91.4m). The times were recorded during the rest interval. The work bouts were started every thirty seconds. Thus if a skater took 13.0 seconds to complete the distance, he had 17.0 seconds of rest before the start of the next repetition. During the rest period, the subjects coasted back to the starting line, and listened for the whistle indicating the start of the next work bout. A five second verbal warning was given prior to the whistle. Verbal encouragement was given throughout the test for all subjects.

The indices to be calculated from the on-ice test were speed index, and total time. Speed index was the time taken to skate the first length of the ice (54.9m). Total time was the sum of the six repetitions, and was termed the anaerobic endurance index.

## 3.5 Experimental Design and Statistical Analysis

The University of Ottawa hockey fitness test and the laboratory test were similar in physiological demands. The difference between the two tests was that the laboratory test held time constant (15 seconds), while the ice test held the distance constant (91.4m). The time of 15 seconds was chosen for the laboratory test, because the 91.4 meters on the ice took approximately 15 seconds to complete. Therefore the reseacher evaluated the relationship between similar indices of the two tests. Speed index on the ice was compared to peak anaerobic power/kg in the laboratory. Total time or anaerobic endurance index on the ice was compared with the power output/kg over 90 seconds on the cycle ergometer.

The two hockey groups performed both the cycle ergometer test and the on-ice fitness test. The junior varsity group performed the cycle egometer test twice within a one week period to evaluate the cycle ergometer test's reliability and objectivity. The physical education students performed the cycle ergometer test once during the same testing period. The experimental design is presented in Table 3.1

Table 3.1: Experimental design

| | | Cycle Ergometer Test | | On-Ice Test | |
|---|---|---|---|---|---|
| Group | n | Peak Power per kg | Total Power per kg | Speed Index (s) | Total Time (s) |
| Varsity Hockey | 1 to 17 | | | | |
| Junior Varsity Hockey | 1 to 14 | * ** | * ** | | |
| P.E. Students | 1 to 15 | | | | |

* Two sets of scores (day1 and day2) to test for reliability
** Two sets of scores (scorer1 and scorer2) on day2 to test for objectivity.

Means and standard deviations were reported for age, height, and weight of all subjects. Pearson Product-Moment correlation coefficients were used to establish criterion related validity. Both hockey groups were tested on-the-ice (University of Ottawa test) and in the laboratory. Correlation coefficients of the proposed comparisons were reported. Table 3.2 provides the comparisons that were analyzed.

Table 3.2: Correlation coefficient comparisions

| University of Ottawa Test | | Cycle Ergometer Test |
|---|---|---|
| Speed Index | vs | Peak Power Output/kg |
| Total Time | vs | Total Power Output/kg |

A multivariate analysis procedure (MANOVA) was used to examine for significant differences among the three groups in the study. The levels of the independant variable were the varsity hockey, junior varsity hockey and physical education students. The dependant variables were the two components of the anaerobic endurance test on a cycle ergometer (peak power/kg body weight, and total power/kg body weight).

Two independant F-test (one way ANOVA) procedures were used to examine for significant differences among the groups in terms of each of the two dependant variables separately. Post hoc analysis of the relevant comparisons was done using Tukey's formula (Keppel, 1973). This formula determined the location of any significant differences.

The discrimination ability of the laboratory test of anaerobic endurance was examined by using multiple discriminant function analysis in order to establish construct validity. The discrimination powers of the laboratory test were evaluated using peak power/kg and total power output/kg as predictors.

The junior varsity players were tested twice within a two week period for determination of test / re-test reliability. The mean power scores per kg body weight for each repetition from day one and day two were used as the data to calculate the intraclass correlation coefficient (R). The intraclass correlation coefficient (R) was determined through the analysis of variance (ANOVA) approach.

The objectivity of the test was also determined by using analysis of variance (ANOVA) and the intraclass correlation coefficient (R). Objectivity of the cycle ergometer test was determined by comparison of mean revolution scores (for each repetition) of the junior varsity group, from the scores of the two testers on day two.

### 3.6 Summary

The statistical procedures that were used to evaluate the five hypotheses are listed in Table 3.3

Table 3.3: Hypotheses analysis

| Comparison | Statistical Analysis |
| --- | --- |
| Hypothesis 1-criterion related validity | |
| speed index (on-ice) versus peak power/kg (lab) | Pearson Product-Moment Correlation Coefficient |
| Hypothesis 2-criterion related validity | |
| total time (on-ice) versus total power output (lab) | Pearson Product-Moment Correlation Coefficient |
| Hypothesis 3-construct validity | |
| differences among the three groups (lab) | MANOVA (with univariate F tests) and Discriminant Function Analysis |
| Hypothesis 4-reliability | |
| lab test 1 versus lab test 2 | Intraclass Correlation Coefficient (R) |
| Hypothesis 5-objectivity | |
| rater #1 versus rater #2 | Intraclass Correlation Coefficient (R) |

# Chapter IV

## Results

This chapter is divided into the following five sections:

4.1 Descriptive Data

4.2 Laboratory and Ice Test Results

4.3 Validity Results

4.4 Reliability Results

4.5 Objectivity Results

### 4.1 Descriptive Data

Means and standard deviations for age, height, and weight of the two hockey groups and the p.e. students are presented in table 4.1.

The ages of the three groups in this investigation were similar: varsity hockey (21.5 years), junior varsity hockey (20.5 years) and p.e. students (22.0 years). The p.e. students were significantly shorter (175.8 cm) than both the varsity (183.2 cm) and junior varsity (180.5 cm) hockey players. The p.e. students were the lightest (74.0 kg) followed by junior varsity (78.4 kg) and varsity players (83.8 kg). The weight differences among the groups were significant.

Table 4.1: Descriptive data ($\bar{X}$ ± S.D.) of subjects (n=46)

| Level | n | Age (yrs) | Height (cm) | Weight (kg) |
|---|---|---|---|---|
| Varsity Hockey | 17 | 21.5 ± 2.0 | 183.2 ± 3.8 | 83.8 ± 5.9 |
| J.V. Hockey | 14 | 20.5 ± 2.4 | 180.5 ± 5.0 | 78.4 ± 9.0 |
| P.E. students | 15 | 22.0 ± 2.7 | 175.8 ± 7.6 | 74.0 ± 7.8 |

## 4.2 Laboratory and Ice Test Results

For the laboratory test, the varsity players exhibited a greater peak power output (970 watts) than the junior varsity players (834 watts). When power was expressed relative to body weight, a similar trend occured: 11.5 watts for the varsity and 10.6 watts for the junior varsity players. The p.e. students exhibited a gross power of 745 watts, and a relative power of 10.1 watts/kg body weight. Since there were significant differences among the three groups in terms of weight, the relative power scores (per kg body weight) were of more relevance than the gross power scores. Relative power was used in all statistical procedures to 'factor out' the possible confounding effect of weight, and thus make the comparisons meaningful.

The same pattern was true for total power. The varsity players demonstrated a total power of 773 watts compared to 646 watts for the junior varsity players. The p.e. students exhibited 541 watts for total power. When power was expressed relative to body weight, the varsity players again demonstrated higher total power (9.2 watts/kg) than either of the junior varsity group (8.2 watts/kg), or p.e. students (7.3 watts/kg). These results are presented in Table 4.2.

An analysis of the power outputs relative to body weight for each of the 15 second intervals during the cycle ergometer test revealed that the varsity players exhibited higher outputs for all six repetitions. These findings are presented in table 4.3.

The differences among the three groups in terms of the two dependant variables (peak power/kg and total power/kg) were significant. Through the MANOVA approch a Hotelling's F ratio of 13.7 was obtained (p<.001). The post hoc analysis of the two univariate F tests revealed F ratios of 15.9 (p<.001) for peak power/kg and 27.6 (p<.001) for total power/kg. These results are presented in Table 4.4.

For the University of Ottawa skating test, the varsity players were significantly faster (7.32 s) than the junior varsity players (7.71 s). The anaerobic endurance of the varsity players was 4.19 seconds superior to that of the junior varsity players.

An analysis of the time to complete each repetition of the University of Ottawa skating test revealed that the varsity compared to the junior varsity group demonstrated superior speed for every repetition. This result was consistent with the power outputs demonstrated on the laboratory test. These findings are listed in table 4.6.

Table 4.2: Cycle ergometer tests of the varsity players (n=17), junior varsity players (n=14) and p.e. students (n=15)

| Variable | Mean | S.D. | Range |
|---|---|---|---|
| Peak Power (watts) | | | |
| Varsity hockey | 970 | 78 | 856 - 1125 |
| Jr. varsity hockey | 834 | 94 | 677 - 1029 |
| P.E. students | 745 | 119 | 608 - 1016 |
| Peak Power (watts/kg) | | | |
| Varsity hockey | 11.5 | 0.6 | 10.3 - 12.8 |
| Jr. varsity hockey | 10.6 | 0.6 | 9.4 - 11.2 |
| P.E. students | 10.1 | 0.9 | 9.0 - 11.8 |
| Total Power (watts) | | | |
| Varsity hockey | 773 | 51 | 663 - 855 |
| Jr. varsity hockey | 646 | 64 | 533 - 772 |
| P.E.students | 541 | 101 | 318 - 737 |
| Total Power (watts/kg) | | | |
| Varsity hockey | 9.2 | 0.5 | 8.4 - 10.2 |
| Jr. varsity hockey | 8.2 | 0.6 | 7.0 - 9.5 |
| P.E.students | 7.3 | 1.0 | 4.5 - 8.7 |

Table 4.3: Cycle ergometer power outputs ($\bar{x} \pm$ S.D.) for the six repetitions

| Repetition | Varsity Hockey | | Junior Varsity Hockey | | P.E. Students | |
|---|---|---|---|---|---|---|
| Watts | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. |
| 1 | 970 | 78 | 834 | 94 | 745 | 119 |
| 2 | 882 | 63 | 751 | 67 | 645 | 100 |
| 3 | 748 | 59 | 629 | 70 | 542 | 88 |
| 4 | 711 | 56 | 616 | 80 | 491 | 82 |
| 5 | 667 | 53 | 554 | 60 | 454 | 77 |
| 6 | 659 | 53 | 543 | 65 | 427 | 76 |
| Watts/kg | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. | $\bar{x}$ | S.D. |
| 1 | 11.5 | 0.6 | 10.6 | 0.6 | 10.1 | 0.9 |
| 2 | 10.5 | 0.7 | 9.6 | 0.7 | 8.7 | 0.8 |
| 3 | 9.0 | 0.8 | 8.1 | 0.6 | 7.3 | 0.7 |
| 4 | 8.5 | 0.7 | 7.9 | 0.6 | 6.7 | 0.7 |
| 5 | 8.0 | 0.7 | 7.1 | 0.7 | 6.1 | 0.7 |
| 6 | 7.9 | 0.7 | 7.0 | 0.7 | 5.8 | 0.7 |

Table 4.4: Manova results for the three groups (n=46)

| Effect | df | F | P |
|---|---|---|---|
| Multivariate Analysis (Hotellings) | | | |
| Groups (3) | 2,42 | 13.7 | .001 |
| Univariate Analysis | | | |
| Peak Power/kg | 2,43 | 15.9 | .001 |
| Total Power/kg | 2,43 | 27.6 | .001 |

Table 4.5: University of Ottawa fitness test for the varsity (n=17) and junior varsity (n=14) players

| Variable | Mean | S.D. | Range |
|---|---|---|---|
| Speed Index (s) | | | |
| Varsity | 7.32 | 0.20 | 7.05 - 7.60 |
| Jr. varsity | 7.71 | 0.29 | 7.30 - 8.40 |
| Anaerobic Endurance Index (s) | | | |
| Varsity | 89.26 | 2.70 | 83.20 - 94.50 |
| Jr. varsity | 93.45 | 1.93 | 90.34 - 97.10 |

Table 4.6: Results ($\bar{X} \pm$ S.D.) of the University of Ottawa fitness test for the varsity (n=17) and junior varsity (n=14) players

| Rep | Varsity | | Jr. Varsity | |
|---|---|---|---|---|
| | $\bar{X}$ | S.D. | $\bar{X}$ | S.D. |
| 1 | 13.39 | 0.45 | 13.59 | 0.39 |
| 2 | 14.18 | 0.46 | 14.40 | 0.53 |
| 3 | 14.81 | 0.45 | 15.39 | 0.43 |
| 4 | 15.26 | 0.52 | 16.19 | 0.43 |
| 5 | 15.62 | 0.66 | 16.68 | 0.42 |
| 6 | 15.94 | 0.76 | 17.22 | 0.56 |

## 4.3 Validity Results

One of the purposes of this investigation was to establish two kinds of validity: criterion related validity and construct validity. Pearson Product-Moment correlation coefficients were determined between two laboratory and two on-ice variables. The laboratory variables were peak anaerobic power (watts/kg) and total anaerobic power (watts/kg) on the cycle ergometer test. These two variables were compared to the speed index and the total time (anaerobic endurance index) scores on the University of Ottawa hockey fitness test. Peak power (watts/kg) correlated significantly with speed index and total power (watts/kg) correlated significantly with the total time (anaerobic endurance index) variable of the University of Ottawa hockey fitness test. The statistical analysis to examine the validity of the laboratory test for ice hockey players is presented in the next table.

Table 4.7: Correlation coefficients - Laboratory test versus on-ice test (n=31 hockey players)

| Laboratory Variable | | On-Ice Variable | Rank-Order correlation | Pearson correlation |
|---|---|---|---|---|
| 1. Peak Power (watts/kg) | vs | Speed Index (s) | -.79 | -.87 * |
| 2. Total Power (watts/kg) | vs | Total Time (s) | -.62 | -.78 * |

* p<.001

Construct validity was tested by examining the discriminant powers of the cycle ergometer test using peak power (watts/kg) and total power (watts/kg) as predictor variables. The nominal variable consisted of three categories: varsity hockey, junior varsity hockey and physical education students. The discriminant function analysis for the laboratory test was found to be significant at the p<.001 level. Tables 4.8 to 4.11 present the discriminant function analysis for the laboratory test.

Table 4.8: Canonical discriminant functions for the cycle ergometer test

| Function | % Var. | Chi squared | df | sig. |
|---|---|---|---|---|
| 1 | 97.4 | 36.8 | 4 | 0.001 |
| 2 | 2.6 | 1.4 | 1 | 0.23 |

Table 4.9: Standardized canonical discriminant function coefficients (cycle ergometer test)

| | Function 1 | Function 2 |
|---|---|---|
| Peak Power (watts/kg) | 0.15 | 1.32 |
| Total Power (watts/kg) | 0.89 | -0.99 |

Table 4.10: Canonical discriminant functions evaluated at group means-group centroids (cycle ergometer test)

| Level | Function 1 | Function 2 |
|---|---|---|
| Varsity hockey | 1.28 | 0.11 |
| Jr varsity hockey | -0.08 | -0.27 |
| P.E. students | -1.37 | 0.13 |

Table 4.11: Classification results (cycle ergometer test)

| | | Predicted group membership | | |
|---|---|---|---|---|
| Level | n | Varsity hockey | Jr varsity hockey | P.E. students |
| Varsity hockey | 17 | 14<br>82.4% | 3<br>17.6% | 0<br>0.0% |
| Jr varsity hockey | 14 | 1<br>7.1% | 10<br>71.4% | 3<br>21.4% |
| P.E. students | 15 | 1<br>6.7% | 3<br>20.0% | 11<br>73.3% |

For the cycle ergometer test, the first function accounted for 97.4% of the total variance while the second function accounted for 2.6% of the total variance. In terms of the two predictors used, the first function had a higher weighting on total power (0.89), than on peak power (0.15). Table 4.9 demonstrates that the group centroids are more dispersed: function one (1.28, -0.08, -1.37) compared to function two (0.11, -0.27, 0.13). Function one provides the largest linear separation of the three groups and thus would be the preferred equation.

The discriminant function analysis revealed that when using peak and total power/kg body weight as predictor variables, 76.1% (35/46) of the subjects were correctly classified. Discriminant function analysis is a statistical technique in which linear combination of variables are used to distinguish between two or more categories of subjects (SPSS Inc., 1986). In this study, the three categories were varsity hockey, junior varsity hockey and physical education students. The chosen predictor variables (peak power/kg and total power/kg) discriminated among groups of subjects and predicted the group to which a subject would fall, based upon the values of these variables (SPSS Inc., 1986). The procedure found the linear combination of variables (function one) that best discriminated among, or separated the groups (SPSS Inc., 1986). After the discriminant functions have been computed, the coefficients are used to predict group membership just as in regression analysis.

In terms of the individual group breakdown of the classification results, the varsity team placed 82.4% of its members into the proper category (its own) while the junior varsity placed 71.4% and the p.e. students placed 73.3% correctly into their respective groups.

Of the varsity group, three of its 17 members were predicted to be in the junior varsity group while none were predicted to fall in the p.e. student's group. Of the junior varsity group, three of its 14 members were predicted to be in the p.e. students group while one of its members was predicted to be in the varsity hockey group. Finally, of the physical education students, three of its 15 members were predicted to be in the junior varsity group, and one of its members in the varsity hockey group.

## 4.4 Reliability Results

The power/kg scores for each repetition on two separate days were used to determine the cycle ergometer's test re-test reliability. Table 4.12 includes the power output for the six repetitions of the cycle ergometer test on days one and two. Of the 14 junior varsity players tested on day one, three players were not tested on day two. One player quit the team, and two others had sustained injuries which prevented them from being re-tested. Thus the excluded subject's data (collected on the first day) were not used in the calculation for reliability (on day two). The adjusted mean weight of the junior varsity (n=11) for day one was 79.83 kg. The mean weight (79.43 kg) for day two was similar. These two values were slightly higher than the mean weight (78.4 kg) of the whole junior varsity team (n=14). The intraclass correlation coefficient (R), as determined by the analysis of variance approach was 0.93.

Table 4.12: Power outputs ($\bar{x} \pm$ S.D.) for the six repetitions of the cycle ergometer test on days 1 and 2. (n=11 junior varsity hockey players)

| Rep | Day 1 | | Day 2 | |
|---|---|---|---|---|
| | watts/kg | S.D. | watts/kg | S.D. |
| 1 | 10.6 | 0.7 | 11.1 | 0.6 |
| 2 | 9.7 | 0.7 | 9.7 | 0.7 |
| 3 | 8.0 | 0.7 | 8.2 | 0.6 |
| 4 | 7.8 | 0.6 | 7.7 | 0.7 |
| 5 | 6.9 | 0.6 | 7.1 | 0.6 |
| 6 | 6.8 | 0.6 | 7.2 | 0.5 |
| Total | 49.8 | 2.9 | 51.0 | 2.5 |

4.5 Objectivity Results

In order to determine the objectivity of the laboratory test, two scorers were present during the second testing session of the junior varsity players. For each of the six repetitions, pedal revolutions were recorded independantly by the two scorers. The results for each scorer on the six repetitions of the cycle ergometer test are presented in table 4.13. The results are presented as pedal revolutions per repetition instead of power output since pedal revolutions are the only potential source of scoring error in the equation:

$$\frac{\text{Rev}}{15\text{s}} \times \frac{60\text{s}}{\text{min}} \times \frac{6\text{ m}}{\text{Rev}} \times \text{resistance (kp)} \times \frac{1\text{ Watt}}{6.12\text{ kpm/min}}$$

The other components in the equation are calculated constants, which remain the same for both scorers. The intraclass correlation coefficient (R), derived from analysis of variance procedures, for the two testers was 0.99.

Table 4.13: Pedal revolutions ($\bar{X} \pm$ S.D.) on the six repetitions of the cycle ergometer test for two scorers (n=11)

| Repetition | Scorer 1 | | Scorer 2 | |
|---|---|---|---|---|
| 1 | 37.8 | 2.1 | 38.0 | 2.1 |
| 2 | 32.9 | 2.3 | 32.8 | 2.0 |
| 3 | 27.9 | 2.0 | 28.0 | 1.9 |
| 4 | 25.9 | 2.2 | 25.7 | 2.1 |
| 5 | 24.0 | 2.0 | 23.8 | 2.0 |
| 6 | 24.3 | 1.7 | 24.0 | 1.7 |
| Total | 172.8 | 8.5 | 172.2 | 8.2 |

# Chapter V

# Discussion

The following sections are included in this chapter:

5.1 Laboratory Test Findings

5.2 Ice Test Findings

5.3 Validity Findings

5.4 Reliability and Objectivity Findings

## 5.1 Laboratory Test Findings

When comparing results from the cycle ergometer test with those of Wingate test, caution must be exercised. Although both tests have a peak power and a total power score which are calculated in a similar fashion, the nature of the two tests are slightly different. The Wingate test is a one repetition 30 second test, while the new test is intermittent in nature, having six repetitions of 15 seconds work followed by 15 seconds of recovery. Peak power in the Wingate test is calculated using the highest five second revolution count whereas the new test uses the highest 15 second revolution count. Total power in the Wingate test uses the revolution count for the entire test (30 s) while the new test takes the total revolutions for the six repetitions (90 s). These two time frames scores reflect different energy demands.

If exercise is less than 10 seconds in duration, which the peak power period is for the Wingate test, only an alactic oxygen debt would occur (Margaria et al., 1969). The authors assumed that lactic acid did not accumulate until 10-15 seconds after the beginning of exercise, presumably when the phosphate stores were diminished. Thus the peak power indice of the Wingate test is a reflection of the subject's ATP-CP system. The alactic oxygen debt was defined by Margaria et al. (1969) as an anaerobic process responsible for the splitting of ATP-CP. The new test takes 15 seconds as the duration for the peak power calculation, which may not be entirely a reflection of the ATP-CP system.

Christensen et al. (1960), examined various physiological measures during continuous and intermittent work. Two trained male subjects ran on the treadmill with 0 percent grade at a speed of 20 km/hr. Work periods of 5, 10, and 15 seconds were used with recovery periods from 5 to 45 seconds. Blood samples were taken every five minutes and analyzed for lactic acid concentration. There was a strong trend toward increased lactic acid concentrations when the work periods were 15 seconds compared to five or ten seconds. Thus the first 15 second exercise bout of the new test would reflect ATP-CP splitting, with a relatively small component of anaerobic glycolysis.

The anaerobic endurance of the Wingate test and total power of the new test would seem to reflect the same physiological conditions. The main difference between the two indices is that one reflects a 'one shot' exercise bout while the new test reflects six intermittent exercise bouts. The effect of the 15 second recovery periods between work bouts, on the nature of the new test is worth discussing.

Several reseachers have examined the importance of the recovery period in exercise (Astrand et al., 1960a,b; Fox et al., 1969; Margaria et al., 1969; Saltin et al., 1977; Saltin 1973; Saltin and Essen, 1971). Margaria et al. (1969) tested three subjects running a series of trials on the treadmill. The experimental conditions consisted of running at 18 km/hr on a 15 % grade with work periods of 10 seconds alternated with rest periods of 10, 20, or 30 seconds. During the first session the subjects reached exhaustion after 30-40 seconds with maximum blood lactate concentrations of 50-60 mg% (5.5-6.0 mmol/l). The results showed that no lactic acid accumulated if the period of recovery was 30 seconds. Also the increase in blood lactic acid concentration, due to 10 seconds of running, increased when the recovery period was decreased from 20 to 10 seconds. Finally, the blood lactic acid concentration was dependant on the number of runs (Margaria et al., 1969).

The importance of the recovery periods in an intermittent activity, with relatively short work periods, has been associated with the process of phosphagen resynthesis. Fox and Mathews (1981) have related the duration of the relief interval to the percentage of ATP and CP resynthesized. When the recovery period was less than ten seconds, very little ATP and CP were restored. When the recovery interval was 30, 60 and 120 seconds, the resynthesis of ATP and CP was 50%, 75% and 94%, respectively.

During recovery periods of less than 20 seconds, the reloading of ATP-CP has an insignificant role in energy supply during intermittent exercise (Saltin and Essen, 1971). Thus the new test, with the exception of the first repetition, is an indication of the capabilities of the lactate system, since 15 seconds is not enough time for complete replenishment of the ATP-CP stores.

The total work time (90s) is in accordance with Simoneau et al. (1983) who stated that a test longer than 60 seconds but shorter than 120 seconds in duration would seem appropriate for the evaluation of anaerobic lactate capacity. The duration of 90 seconds employed in the new test is an optimal time for a consistent indication of anaerobic lactate capacity (Katch and Weltman, 1979).

Another small difference between the Wingate and the new test is in the calculation of the two physiological indices. Greater mathematical precision in determing peak power can be obtained in the new test. The new test calculates peak power using the highest revolutions during a 15 second period as compared with highest revolutions during a 5 second period for the Wingate. A one revolution count error in five seconds can mean a difference of 12 revolutions/min in the final calculation. This difference is reduced to 4 revolutions/minute when a one count error is made during a 15 second interval. The method in this investigation was subject to a 0.5 to 1.0 revolution count difference between independant scorers. The same phenomenon may be reversed for total power. Since the 90 second test has six separate scores, the error of 4 revolutions/minute might accummulate six times, and thus be a greater error than the total score of the 30 second Wingate test.

Another reason why comparisons between the two tests must be done with caution, is that some studies use weight relative protocols for determining load resistance while others employ the leg volume and body weight protocol. This investigation utilized a resistance setting of 0.075 (kp) per kg of body weight which was similar to the original Wingate resistance setting. Other investigations in the literature have used resistances of 0.096 kp/kg body weight (Evans and Quinney, 1981) 0.094 kp/kg body weight (Smith et al., 1982) 0.099 kp/kg body weight (LaVoie et al., 1984). These settings are significantly higher than the original Wingate setting of 0.075 kp/kg body weight. Despite the differences between the two tests, comparison of similar indices can be made. The cycle ergometer test of anaerobic endurance for hockey players and the Wingate test require similar physiological responses.

The results from the new test are compared in table 5.1 to data from various studies that have used the 30 second Wingate test. Montgomery and Brayne (1984) used the Evans and Quinney protocol and obtained a peak power of 11.5 (watts/kg) and 11.4 (watts/kg) for the varsity and junior varsity hockey players, respectively. Montgomery and Dallaire reported values of 10.1 watts/kg and 10.3 watts/kg for the forwards of a professional hockey team during two consecutive pre-seasons (81-82, 82-83). The authors reported values of 9.7 and 9.8 watts/kg for the defensemen on the team during the same pre-season testing sessions. Smith et al. (1982) used the Evans and Quinney protocol and obtained a mean peak power output of 11.7 watts/kg for the Canadian Olympic (1980) hockey team. Two other studies using the same protocol, with active subjects, yielded similar results. Peak power outputs of 11.3 watts/kg (Evans and Quinney, 1981) and 11.5 watts/kg (LaVoie et al., 1984), have been reported. Other studies which used the Wingate protocol have reported lower peak power outputs for active subjects, 10.3 watts/kg (Chomay et al., 1982). Kaczkowski et al. (1982), using the Wingate protocol, reported a peak power output of 11.8 watts/kg for active subjects. In this study a peak power of 11.5 watts/kg and 10.6 watts/kg for the varsity and junior varsity are in this range. The p.e. students peak power (10.1 watts/kg) is similar to results (10.3 watts/kg) reported for active subjects (Chomay et al., 1982) and is less than results (10.8 watts/kg) reported by Kaczkowski et al. (1982).

Total power of the 90 second test was calculated in a similar fashion as anaerobic endurance of the Wingate test to allow for comparison of the two indices. The results from the new test are compared in table 5.2 to data from studies that have used the 30 second Wingate test. In this investigation, the varsity (9.2 watts/kg) and junior varsity (8.2 watts/kg) demonstrated higher total power/kg values respectively, compared to the p.e. students (7.3 watts/kg). Values for anaerobic endurance of 8.6 watts/kg (Chomay et al., 1982) have been reported for the Wingate test using a resistance of 0.075 kp/kg of body weight. Montgomey and Brayne (1984) reported an anaerobic endurance of 9.0 watts/kg for varsity hockey players and 9.2 watts/kg for junior varsity players while employing the Evans and Quinney resistance. Montgomery and Dallaire (1986) reported values of 8.5 and 8.7 watts/kg for Montreal Canadien forwards over two consecutive pre-seasons (81-82, 82-83). The authors reported a value of 8.2 watts/kg for the defensemen during these two pre-season testing sessions. Some other values reported in the literature for anaerobic endurance include; 9.4 watts/kg for the Olympic hockey team (Smith et al., 1982) 9.1 watts/kg for active subjects (LaVoie et al., 1984) and 8.9 watts/kg for active subjects (Evans and Quinney, 1981).

Table 5.1: A comparison of peak power from various studies using a cycle ergometer test

| Level | Power (watts) | Power/kg (watts/kg) | Reference |
|---|---|---|---|
| varsity hockey | 970 | 11.5 (W) | Present study |
| jr varsity hockey | 833 | 10.6 (W) | Present study |
| p.e. students | 745 | 10.1 (W) | Present study |
| varsity hockey | 951 | 11.5 (EQ) | Montgomery & Brayne, 1984 |
| jr varsity hockey | 877 | 11.4 (EQ) | Montgomery & Brayne, 1984 |
| active subjects | 918 | 11.8 (W) | Kaczkowski et. al., 1982 |
| Olympic | 949 | 11.7 (EQ) | Smith et al., 1982 |
| active subjects | 860 | 11.5 (EQ) | LaVoie et al., 1984 |
| active subjects | 839 | 11.3 (EQ) | Evans & Quinney, 1981 |
| recreational hockey | 771 | 10.3 (W) | Chomay et al., 1982 |
| Montreal Canadiens | | | |
| forwards, 81-82 | 857 | 10.1 (EQ) | Montgomery & Dallaire, 1986 |
| defensemen, 81-82 | 894 | 9.7 (EQ) | "" "" |
| forwards, 82-83 | 875 | 10.3 (EQ) | "" "" |
| defensemen, 82-83 | 918 | 9.8 (EQ) | "" "" |

(EQ)=Evans & Quinney resistance

(W)=Wingate resistance

Table 5.2: A comparison of total power from various studies using a cycle ergometer test.

| Level | An. Endurance (watts) | An. Endurance/kg (watts/kg) | Reference |
|---|---|---|---|
| varsity hockey | 772 | 9.2 (W) | Present study |
| jr varsity hockey | 646 | 8.2 (W) | Present study |
| p.e. students | 541 | 7.3 (W) | Present study |
| varsity hockey | 747 | 9.0 (EQ) | Montgomery & Brayne, 1984 |
| jr varsity hockey | 710 | 9.2 (EQ) | Montgomery & Brayne, 1984 |
| active subjects | 750 | 9.6 (W) | Kaczkowski et al., 1982 |
| Olympic | 762 | 9.4 (EQ) | Smith et al., 1982 |
| active subjects | 680 | 9.1 (EQ) | LaVoie et al., 1984 |
| active subjects | 662 | 8.9 (EQ) | Evans & Quinney, 1981 |
| recreational hockey | 643 | 8.6 (W) | Chomay et al., 1982 |
| Montreal Canadiens | | | Montgomery & Dallaire, 1986 |
| forwards 81-82 | 723 | 8.5 (EQ) | "" "" |
| defensemen 81-82 | 760 | 8.2 (EQ) | "" "" |
| forwards 82-83 | 732 | 8.7 (EQ) | "" "" |
| defensemen 82-83 | 764 | 8.2 (EQ) | "" "" |

(EQ)= Evans & Quinney resistance

(W)= Wingate Resistance

## 5.2 Ice Test Findings

The speed index displayed by the varsity players in the University of Ottawa test (7.32 s) was inferior to the 1980 Canadian Olympic team (7.09 s), yet slightly superior to junior A and professional hockey players (7.40 s) as cited by Smith et al. (1982). The varsity players were faster (7.32 s) while the junior varsity players (7.71 s) were similar to the varsity hockey players (7.69 s) reported by Montgomery and Brayne (1984). Both the varsity and junior varsity players were faster than college and junior players (7.96 s) and recreational players (8.14 s) reported by Montgomery (1982) and Chomay et al. (1982)

The varsity team exhibited superior anaerobic endurance (89.26 s) and the junior varsity similar anaerobic endurance (93.45 s) to the varsity hockey players (93.3 s) reported by Montgomery and Brayne (1984). Both teams were superior compared with junior and college (95.5 s - Montgomery, 1982), junior varsity players (95.8 s - Montgomery and Brayne, 1984) and recreational players (99.3 s - Chomay et al., 1982).

## 5.3 Validity Findings

Validation of performance tests and various field tests can be determined by correlating field test results with already established laboratory tests (Burke, 1976; Cooper, 1968; Doolittle and Bigbee, 1968; Léger and

Boucher, 1980; Léger and Lambert, 1982).

In the present investigation the procedure was reversed. A new cycle ergometer test of anaerobic endurance designed to test the physiological demands of a hockey 'shift' was compared to an established on-ice hockey fitness test. Pearson Product-Moment correlation coefficients were determined between two laboratory variables (peak power/kg and total power/kg) and two on-ice performance variables (speed index and total time).

The first hypothesis of this investigation stated that there would be a statistically significant correlation between the speed index of the University of Ottawa ice hockey test, and peak power/kg of the laboratory cycle ergometer test. Results revealed a significant r value of -0.87 ($p<.001$). This provides evidence of the association between peak power on the cycle ergometer with speed index of the University of Ottawa ice hockey test. This finding is in agreement with Montgomery and Brayne (1984) who also obtained a significant correlation of -0.61 between peak power of the Wingate test and speed index of the same on-ice test used in this investigation. Bar-Or (1978) obtained a significant correlation of -0.84 between the peak power on the Wingate test and the 40 meter run. Kaczkowski et al. (1982) also found a significant correlation of -0.91 between maximal anaerobic power and a 50 meter run.

The second hypothesis predicted that there would be a statistically significant correlation between total power/kg on the cycle ergometer and total time required to complete six repetitions on the University of Ottawa ice hockey test. Total power/kg output was negatively correlated with total time of the ice test (r=-0.78, p<0.001). Considering the potential for skating efficiency to reduce the relationship (Ferguson et al., 1969), this finding demonstrates a strong association between these two variables.

The varsity players in this study were found to have a significantly greater peak power per kg of body weight and total power per kg of body weight than the junior varsity players and the control group. This trend was also evident in the on-ice variables (speed index, total time). The varsity players were significantly faster than the junior varsity players. Since skating speed and skill were main criteria used in the selection of the varsity team, this result is not suprising. Also, since the testing was done during the middle portion of the competitive season for both teams, it seems reasonable to assume that the varsity players would demonstrate superior anaerobic endurance than the junior varsity players due to the differences in volume and intensity of practice times.

There were major differences between the two hockey teams in terms of time spent on the ice, and intensity during training sessions. The varsity team was on the ice six days a week for a minimum period of one hour and 45 minutes per session. If a player missed a practice he was expected to replace this work-out with a session on a cycle ergometer for a minimum of 40 minutes, at a heart rate of 160 beats/minute. The other option offered to the player was 40 minutes on a 'slide board' at the same heart rate. The junior varsity team's training program was qualitatively, as well as quantitatively different to that of the varsity team's program. The players on this team were required to practice twice a week for a duration of 50 minutes per workout. If a player missed a practice he was not required to do any off-ice work. In addition to the volume of training difference between the two teams, the intensity was different as well. Due to the 'club' nature of the junior varsity team and the practice time restraints, little anaerobic work was incorporated into the workouts. The junior varsity coach preferred to concentrate on team skills during the limited ice time available to the team.

The second major difference between the varsity and junior varsity hockey teams was that the varsity players followed an intense leg training program both before and during the season. The players were required to perform various ballistic jumping exercises which were designed to provide an overload to the quadriceps. They performed these exercises until local fatigue was experienced. Many of the players on the varsity team had been following this training regime for several years. These players may have been better equipped to deal with local fatigue in the quadiceps having had to endure this type of training both on-ice and off-ice. Most of both team's fitness training on-ice and off-ice was of the alactic and lactic type, which was appropriate for the nature of the laboratory test.

Construct validity is concerned with the extent to which a particular measure relates to other measures consistent with theoretically derived hypotheses concerning the concepts that are being measured (Carmines and Zeller, 1984). The constructs used in this study were the three levels of hockey playing experience (varsity, jr varsity and non-varsity). The predictors used for the cycle ergometer test were peak power/kg and total power/kg. The predictors were chosen based on their association with similar variables in previous studies of hockey players. The discriminant function analysis showed that 76% of the subjects were correctly categorized when the predictor variables were peak and total power (watts/kg). The question as to why the cycle ergometer would be a valid 'mode' for the testing of hockey players will be addressed.

Geijsel (1979,1980) examined the use of cycling as a pre-season training mode and the cycle ergometer as a testing instrument in marathon speed skating. Geijsel (1979) cites Enschede (1960) and Geijsel (1976,1977) stating that endurance time with a maximal load on a cycle ergometer at the beginning of the competitive season was very low compared with scores at the end of the season. These authors concluded that the traditional pre-season training of 'running through the woods', combined with 'skating simulations' was not optimal. It was observed that those skaters who cycled during the pre-season enjoyed very good results in the first month of competition. It was also shown that endurance times on a cycle ergometer for marathon speed skaters increased; 1) in preseason, only if training consisted mainly of cycling and 2) in the competitive season (when the training was on-ice). Geijsel (1979) therefore concluded that speed skaters should train on racing bicycles from June until November, to optimize performance at the beginning of the competitive season. Geijsel (1979) also suggested that cycle ergometer testing would demonstrate the increments or decrements in skating performance made by a skater throughout the competitive season.

To further substantiate these conclusions Geijsel (1980) studied whether superior marathon speed skaters (in terms of points awarded for race results) have better endurance times at a continuous workload on a cycle ergometer, than inferior skaters. Ten of the best and ten of the worst skaters (senior mens) in the Netherlands cycled at a resistance of 5 watts/kg and a pedalling rate of between 60 and 80 revolutions per minute. Results indicated that the better skaters had significantly longer endurance times than the worst skaters ($p<0.01$). No significant differences existed in the values of heart rates (at 200 watts, and 5 watts/kg workloads), maximum oxygen uptake (ml/kg·min), number of years of training, and training frequency in both pre-season and competitive season. The superior skaters although homogeneous in terms of these variables, were able to produce more power for a longer period of time than the inferior skaters on the cycle ergometer test. It seems that for 'skaters' the appropriate mode for laboratory testing is a cycle ergometer.

The protocol in this investigation followed the guidelines outlined by Thoden and Jetté, (1975) to test the 'physical capacity to play hockey.' These guidelines were a result of the time motion characteristics of ice hockey. The main criteria included maximal work bouts long enough to tax the anaerobic mechanism (10 seconds or longer) with 10-12 seconds of recovery between repetitions, and numbering as many bursts as a player can expect to have per shift (5-7). Green et al. (1976) and Green et al. (1978a) further substantiate these time motion characteristics. Reed et al. (1979) designed an on-ice test which satisfied these guidelines and was shown to be a valid hockey fitness test. All these findings provided the structure for the new cycle ergometer test.

The results indicate that, although the new test is not an on-ice hockey fitness test, it can provide useful information concerning the readiness of players to meet the demands of ice hockey.

## 5.4 Reliability and Objectivity Findings

The three important qualities of a good test are validity, reliability and objectivity (Baumgartner and

Jackson, 1975). If any of these qualities are missing the test cannot be considered to have scientific use.

The concept of reliability has been present for over 50 years (Safrit, 1976). According to Carmines and Zeller (1984) reliability can be defined as the extent to which an experiment, test or any measuring procedure, yields the same results on repeated trials. Synonyms for reliability are: dependability, stability, consistency, predictability and accuracy (Kerlinger, 1964). A correlation coefficient is used to determine the degree of agreement between trials.

Objectivity is a concept closely related to reliability. It is defined as rater reliability (Baumgartner and Jackson, 1975; Safrit, 1976). If a test is objective there will be a close agreement between the scores assigned to each subject by two or more judges. A correlation coefficient is calculated which indicates the degree of agreement between the two scorers.

In the present investigation, the laboratory test was administered on two separate days in order to establish its reliability. For the second testing session there were two scorers present to record the results during the test. The results from the two scorers were then analysed to determine the test's objectivity.

In the past, the commonly accepted practice for estimating test reliability involved the product-moment correlation coefficient or some variation of it (Feldt and McKee, 1958; Kroll, 1962; Liba, 1962). However an important limitation of this estimation method is that it is a bivariate statistic and should be used when determining the relationship between two independant variables (Safrit, 1976). When subjects are tested twice on the same test, only one variable is measured, and a univariate statistic should be used (Safrit, 1976).

In the present investigation, the estimation of reliability and objectivity was determined by the intraclass correlation coefficient (R) through the analysis of variance approach (a univariate statistic). The intraclass correlation coeficient for reliability was found to be 0.93. The correlation coefficient for objectivity was 0.99. These values provide strong support for the establishment of reliability and objectivity of the new cycle ergometer test of anaerobic endurance for hockey players.

# Chapter VI

## Summary, Conclusions and Recommendations

### 6.1 Summary

The purpose of this investigation was to establish the validity, reliability and objectivity of a laboratory test of anaerobic endurance for ice hockey players. The protocols of existing laboratory tests of anaerobic endurance consisted of one work bout. The modified laboratory test of anaerobic endurance used six work bouts, totalling 90 seconds in duration (15 seconds per work bout). This modification was based on prior studies of time analysis during hockey play, in which number of maximal bursts per shift were found to be from five to seven. It was believed that the new laboratory test of anaerobic endurance would be more representative of a typical shift in hockey, than the present laboratory protocols and could be applied to all levels of hockey players.

The subjects in this study were 46 males from varsity hockey, junior varsity hockey and physical education. All subjects performed a cycle ergometer test. In addition, the hockey groups also performed the University of Ottawa ice hockey fitness test (Reed et al. 1979). The junior varsity group performed the cycle ergometer test twice in order to establish the test's reliability. Two investigators scores were compared in order to establish the test's objectivity.

The first hypothesis of this study stated that there would be a statistically significant correlation between the speed index of the University of Ottawa ice hockey fitness test, and peak power/kg output of the laboratory cycle ergometer test. The Pearson Product-Moment correlation coefficient revealed an r value of -0.87 which was significant at the 0.001 level. This provides strong evidence of the association between these two variables as well as lending support for the establishment of criterion related validity.

The second hypothesis predicted that there would be a statistically significant correlation between the total time required to complete the University of Ottawa hockey fitness test and total power/kg output on the cycle ergometer test. The Pearson Product-Moment correlation coefficient yielded an r value of -0.78 which was significant at the $p<0.001$ probability level. This finding demonstrates a strong association between these two variables and again provides support for the establishment of criterion related validity for the new test.

It was hypothesized that the new laboratory test of anaerobic fitness for hockey players would discriminate between hockey players of varying ability (varsity, junior varsity, non-varsity). The assumption was made that the performance scores on the cycle ergometer test would vary according to the level the players had attained. This did prove to be the case. The laboratory test had discriminant powers, with peak and total power/kg as predictor variables. This result provides support for the establishment of construct validity.

The fourth and fifth hypotheses were concerned with reliability and objectivity of the laboratory test. The intraclass correlation coefficients, using the ANOVA approach, revealed values of 0.93 for test-retest reliability and 0.99 for objectivity (test scores of two investigators). These values confirmed the reliability and objectivity of the new laboratory test.

## 6.2 Conclusions

Within the delimitations and limitations of this study, the following conclusions seemed justified:

1) The peak power/kg variable from the 90 second intermittent cycle ergometer test is a valid measure of the skating speed of ice hockey players.

2) The total power/kg variable from a 90 second intermittent cycle ergometer test is a valid measure of the anaerobic endurance of ice hockey players.

3) The 90 second intermittent ergometer test discriminated among subjects of varsity, junior varsity and non-varsity playing experience. This finding provides support for the establishment of construct validity.

4) The cycle ergometer test is reliable and objective.

## 6.3 Recommendations

The following recommendations are proposed for future investigations:

1) Further studies should be conducted to evaluate the optimal resistance setting for the new protocol.

2) Follow-up studies should be conducted using players with a wider range of ability, including professionals and younger players, in order to further test the construct validity of the new laboratory test of anaerobic endurance for ice hockey players.

3) Follow-up studies should be conducted comparing the cycle ergometer test to other tests of anaerobic endurance to further examine criterion related validity.

4) Studies with other athletic groups (eg. speed skaters, cyclists, wrestlers) should be examined to determine the suitability of this protocol for athletes in these sports.

5) Refinement of the test protocol to include an aerobic recovery component (ie. two sets of four repetitions with a five minute recovery period between repetitions). This test protocol takes into consideration time spent on the bench between shifts, and would give the coach an additional piece of information that the present protocol cannot state.

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# APPENDIX A

## Cycle Ergometer Test Protocol

1) Take subject's weight in kilograms and multiply by 0.075 to get the subject's test resistance.
2) Set proper seat height (full extension of the leg with feet in a 90 degree flexed position).
3) Subject warms up for 3 minutes at 2 kp resistance.
4) Investigator explains test protocol:
   a) Six maximal bursts each of 15 seconds duration.
   b) Each repetition is followed by a 15 second recovery period.
   c) Subjects must return feet to the starting position during each recovery interval.
   d) Subjects must not pace. They must pedal all-out on each repetition.
   e) There will be the command "GO" to start each repetition and "STOP" to indicate the end of each repetition. There will be a five second warning prior to the start of each successive repetition.
5) Resistance is added to the flywheel by adding mass into the basket.
6) Tester shows the subject the proper foot position for the start of each repetition. Left foot at 10 oclock and right foot at 4 oclock as one looks from the left foot side of the crank.
7) Ensure that the toeclips are tightened.
8) Investigator starts the test.

9) Verbally ensure that the subject does not raise off the seat during the work bouts.

10) Investigator records the number of revolutions from the electronic counter onto the score sheet during each recovery period.

11) Provide the subject with verbal motivation.

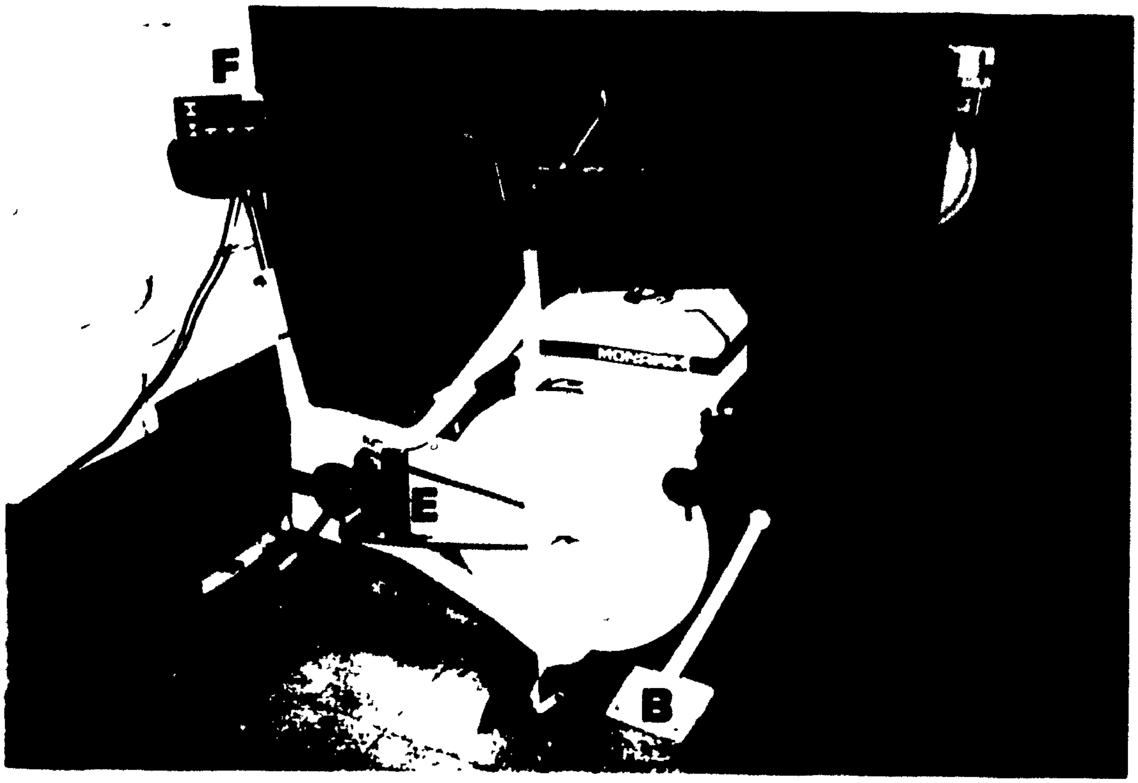
12) Allow a three minute warm down after the completion of the test.

# APPENDIX B

## Cycle Ergometer Set-Up

Modified Monark Stationary

Cycle Ergometer




A - Cycle ergometer bolted to the floor for stability

B - 17 inch pully bolted at an angle to the floor

C - Basket to suspend mass of known quantity

D - Two magnets 180 degrees to one another (on underside of the crank)

E - Impulse generator (magnetic reed switch, Smith et al., 1982)

F - Electronic counter

# APPENDIX C

## Sample Data Sheet

Date ____________ TEAM ____________

| | Cycle Ergometer Test | | | | | | On-Ice test | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub # | Revolution Counts | | | | | | Speed Index | Time (s) | | | | | |
| kp | 1 | 2 | 3 | 4 | 5 | 6 | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | |

# APPENDIX D

## Sample Calculations

Raw data on player #00

Weight= 187 lbs =85 kg

Test resistance=0.75 x 85 = 6.4 kp

Table: Revolutions/repetition

| 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|
| 37.5 | 32.5 | 29.5 | 27.0 | 25.5 | 24.5 | 176.5 |

The equation:

$$\frac{\text{Rev}}{15\text{ s}} \times \frac{60\text{ s}}{\text{Min}} \times \frac{6\text{ m}}{\text{Rev}} \times \text{Resistance (kp)} \times \frac{1\text{ watt}}{6.12\text{ Kpm/min}}$$

Peak Power

$$\frac{37.5}{15\text{s}} \times \frac{60}{1\text{ min}} \times \frac{6\text{ m}}{1\text{ rev}} \times 6.4\text{ kp} \times \frac{1\text{ watt}}{6.12\text{ kpm/min}} = 941\text{ watts}$$

$$\frac{941\text{ watts}}{85\text{ kg}} = 11.07\text{ watts/kg}$$

Total Power

$$\frac{176.5}{90\text{s}} \times \frac{60}{1\text{ min}} \times \frac{6\text{ m}}{1\text{ rev}} \times 6.4\text{ kp} \times \frac{1\text{ watt}}{6.12\text{ kpm/min}} = 738\text{ watts}$$

$$\frac{738\text{ watts}}{85\text{ kg}} = 8.68\text{ watts/kg}$$

APPENDIX E
Summary Data

| Subject | Weight lbs | Weight kgs | Speed Index | Sum of six reps | Peak Power/kg | Total Power/kg |
|---|---|---|---|---|---|---|
| Varsity | | | | | | |
| 1 | 179 | 89.5 | 7.16 | 85.67 | 11.9 | 10.1 |
| 2 | 167 | 75.9 | 7.18 | 87.55 | 11.8 | 9.8 |
| 3 | 184 | 83.6 | 7.39 | 89.91 | 11.6 | 8.9 |
| 4 | 171 | 77.7 | 7.60 | 90.18 | 10.3 | 8.5 |
| 5 | 183 | 83.2 | 7.54 | 91.40 | 11.3 | 8.4 |
| 6 | 187 | 85.0 | 7.16 | 85.58 | 11.5 | 9.5 |
| 7 | 177 | 80.5 | 7.40 | 90.08 | 11.4 | 9.2 |
| 8 | 168 | 76.4 | 7.15 | 87.00 | 12.8 | 10.2 |
| 9 | 167 | 75.9 | 7.52 | 91.61 | 11.3 | 9.4 |
| 10 | 185 | 84.1 | 7.53 | 89.10 | 11.3 | 9.5 |
| 11 | 173 | 78.6 | 7.08 | 83.20 | 12.0 | 9.6 |
| 12 | 190 | 86.4 | 7.40 | 90.08 | 11.5 | 9.2 |
| 13 | 200 | 90.9 | 7.06 | 91.00 | 12.2 | 9.4 |
| 14 | 203 | 92.3 | 7.05 | 90.30 | 12.2 | 8.9 |
| 15 | 201 | 91.4 | 7.20 | 94.50 | 11.4 | 8.8 |
| 16 | 194 | 88.2 | 7.60 | 90.20 | 10.4 | 8.8 |
| 17 | 204 | 92.7 | 7.50 | 90.10 | 11.4 | 9.0 |
| Jr Varsity | | | | | | |
| 1 | 165 | 75.0 | 7.54 | 90.34 | 11.1 | 9.5 |
| 2 | 205 | 93.2 | 7.50 | 93.27 | 10.3 | 8.3 |
| 3 | 159 | 72.3 | 7.30 | 92.80 | 11.2 | 8.5 |
| 4 | 168 | 76.4 | 7.83 | 91.70 | 9.8 | 8.1 |
| 5 | 172 | 78.2 | 8.14 | 96.55 | 9.5 | 7.4 |
| 6 | 169 | 76.8 | 7.90 | 95.55 | 11.0 | 8.6 |
| 7 | 160 | 72.7 | 7.53 | 92.10 | 11.1 | 8.5 |
| 8 | 185 | 84.1 | 8.40 | 94.00 | 9.4 | 7.9 |
| 9 | 137 | 62.3 | 7.59 | 93.37 | 10.9 | 8.6 |
| 10 | 160 | 72.7 | 7.55 | 94.50 | 11.0 | 8.1 |
| 11 | 205 | 93.2 | 7.80 | 97.10 | 11.1 | 7.9 |
| 12 | 200 | 90.9 | 7.72 | 93.13 | 10.3 | 7.0 |
| 13 | 157 | 71.4 | 7.58 | 91.90 | 10.8 | 8.9 |
| 14 | 174 | 79.1 | 7.53 | 92.04 | 11.2 | 8.6 |
| P.E. Students | | | | | | |
| 1 | 171 | 77.7 | | | 10.9 | 8.7 |
| 2 | 206 | 93.6 | | | 10.8 | 7.8 |
| 3 | 153 | 69.6 | | | 9.2 | 7.1 |
| 4 | 154 | 70.0 | | | 11.6 | 7.9 |
| 5 | 170 | 77.3 | | | 11.8 | 8.5 |
| 6 | 157 | 71.4 | | | 9.1 | 4.5 |
| 7 | 193 | 87.7 | | | 10.3 | 7.0 |
| 8 | 154 | 70.0 | | | 11.1 | 8.2 |
| 9 | 162 | 73.6 | | | 9.0 | 7.6 |
| 10 | 146 | 66.4 | | | 10.4 | 7.6 |
| 11 | 148 | 67.3 | | | 9.1 | 6.8 |
| 12 | 169 | 76.8 | | | 9.5 | 7.4 |
| 13 | 161 | 73.2 | | | 9.6 | 7.0 |
| 14 | 150 | 68.2 | | | 9.6 | 7.0 |
| 15 | 146 | 66.4 | | | 9.7 | 6.8 |

# APPENDIX F

## Informed Consent

Date: ________________

Name: ________________

I hereby give consent to Fraser W. Gamble to administer and supervise the following investigation:

1. Record anthropometric data (standing height, body weight).
2. Administer a cycle ergometer test.
3. Administer an on-ice fitness test.

I have heard and seen a clear explanation and understand the purpose and demands of the procedure and am fully cognizant of the risks involved and the complications that might arise. I have heard a clear explanation and understand the benefits to be expected from the procedure. I understand that the procedure to be administered is investigational and that I might withdraw my consent for my participation at any time. Having received this information, and satisfactory answers to the questions I have asked, I voluntarily consent to the procedure designated in the first paragraph.

Signature: ________________

Witness: ________________