A Comparison of Peak $\dot{V}O_2$, EPOC and Lactate Concentration on Three Tests of Anaerobic Endurance

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Thesis Proposal Submitted to
the Faculty of Graduate Studies and Research
in Partial Fulfillment of the Requirements
For the Degree of Master of Arts (Education)

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Montréal, Québec, Canada

September, 1987

Abstract

The purpose was to compare peak $\dot{V}O_2$, EPOC and lactate concentration on three tests of anaerobic endurance. Eleven university hockey players performed two intermittent anaerobic cycle ergometer tests (An-int), two continuous anaerobic cycle ergometer tests (An-cont), two Repeat Sprint Skate tests (RSS) and one continuous aerobic cycle ergometer test (Aer-cont). The An-int test consisted of six 15-second repetitions with an exercise to recovery ratio of 1:1. The RSS test consisted of 6 reps of a 91.4 m skate with each repetition initiated every 30 s. Results indicated that: (1) The An-int produced similar lactate and EPOC values as the An-cont and RSS tests. (2) The An-int test produced similar peak $\dot{V}O_2$ values as that obtained from a $\dot{V}O_2$ max test on a cycle ergometer. (3) The intraclass correlation coefficients for power output/kg, peak $\dot{V}O_2$ and EPOC-total of the Ant-int test were 0.93, 0.86 and 0.71, respectively. (4) The R values for the RSS speed index, total time and drop-off variables were 0.69, 0.93 and 0.94.

Résumé

Le but de cette étude était de comparer la consommation d'oxygène maximale durant un test (Peak $\dot{V}O_2$), la consommation excessive d'oxygène après un test (EPOC) et la concentration d'acide lactique lors de trois tests d'endurance anaérobique. Onze joueurs de hockey de niveau universitaire ont participé à deux tests intermittents de cyclergométrie en anaérobie (int-an), deux tests continus de cyclergométrie en anaérobie (cont-an), deux tests sur glace d'endurance anaérobique RSS (Repeat Sprint Skate de Reed) et un test de $\dot{V}O_2$max en cyclergométrie. Le test intermittent consistait en six séries de quinze secondes d'effort maximal suivi de quinze secondes de repos sur un bicycle ergométrique. Pour le test sur glace, les joueurs devaient effectuer six répétitions de 91.4 m au sprint sur un intervalle de 30 secondes. Les résultats sont les suivants: (1) Des valeurs semblables ont été obtenues pour la concentration d'acide lactique et l'EPOC lors des tests int-an et RSS. (2) Le test int-an a produit des valeurs de consommation d'O_2 maximales semblables aux valeurs obtenues lors du test de $\dot{V}O_2$max sur bicycle ergométrique. (3) Les coefficients de corrélation intra-classe pour la puissance/kg, le peak $\dot{V}O_2$ et l'EPOC total du test int-an furent de 0.93, 0.86 et 0.71 respectivement. (4) Les coefficients de corrélation intra-classe pour l'indice de vitesse, le temps total et l'écart maximal du test RSS furent de 0.69, 0.93 et 0.94.

Acknowledgements

The completion of this investigation would not have been possible without the help of many people. Therefore I would like to recognize the following individuals. I would like to thank all the subjects involved in this study for their participation. I would also like to thank Marek Kaczinski and David McGruer for the many hours they worked collecting the data, and Gary Currie and Tim Gallivin for the help provided with the computer. Many thanks also to Dr René Turcotte who was always there to help. Finally I would like to extend my sincere appreciation to Dr David Montgomery without whom I could not have completed this investigation. Dr Montgomery's knowledge, experience and availability made it all possible. Thank you.

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Chapter 1

Introduction

Hockey is one of the fastest and most exciting sports in the world. The game is comprised of many intricate skills which when blended together produces a very skilled individual (Chambers, 1981). Hockey has also changed greatly in the area of coaching since 1972. As Bob Pulford, one of the National Hockey League coaches remarked, it is no longer enough to simply tell the players what to do; they demand to know why as well. They want to know the difference between aerobic and anaerobic training, they want more information about oxygen uptake and oxygen debt (Taylor, 1978). This is true not only of professional hockey players but of all individuals involved in sports. People want to know.

Because of this craving for knowledge, the scientific approach has been adopted by many sports, including hockey. An essential part of this approach is to evaluate the fitness components involved in the sport. Once these components have been tested, the results will enable the coach to identify the strengths and weaknesses of an athlete or of a training program.

For the test results to have optimum practical significance, the protocols should be as sport specific as possible (MacDougall and Wenger, 1982). Therefore if swimmers are tested on a treadmill, the test results from a running protocol will give little information about the swimmer's aerobic capabilities. However if runners performed the same test, valuable information would be obtained about their physiological state.

Many tests have been designed in order to measure physical fitness parameters specific to the different physical activities. These tests include sophisticated laboratory tests as well as field tests. They aim to simulate, as best as possible, the activity to be evaluated. But in order for a test to be useful to a coach or an athlete, it must be recognized as a valid, reliable and objective test. Will this test always measure what it is supposed to measure? If this is the case, the test becomes a useful tool and a valuable source of information for coaches who want to monitor the development and progression of their athletes.

1.1 Nature and Scope of the Problem

Ice hockey is a game characterized by short bursts of energy output with active or passive recovery periods. Players frequently sprint for the puck as well as coasting into position. The players also spend a significant quantity of time sitting on the bench while waiting for their next shift.

In order to establish the relative importance of the different energy systems, time-motion analysis of ice hockey has been performed by several researchers (Thoden and Jetté, 1975; Green et al., 1976; Montgomery and Vartzbedian, 1977).

Thoden and Jetté (1975) studied the time pattern of three major junior games and one professional game. The researchers noted that the junior players were more anaerobically active than the professionals. However caution should be taken in interpreting the results because of the limited number of teams participating in this study. Thoden and Jette (1975) also made the following recommendations concerning the testing procedures to be used for the evaluation of physical capacity to play hockey;

1) the test should be of maximal performance of the anaerobic type.
2) workbouts should be long enough to tax the anaerobic mechanism (i.e. 10 seconds or longer).
3) the number of repetitions should represent as many bursts a player can expect to have on a shift.
4) there should be 10 to 12 seconds of recovery time between workbouts.
5) the test should provide an assessment of physical capacity in terms of one's ability to perform the final repeats at the same level of performance as the first trial.

Green et al. (1976) also studied the importance of the aerobic and anaerobic system in a hockey game. They recorded the playing time of eight university forwards and defensemen. The results showed that the forwards made more use of their anaerobic system than the defensemen who relied more on their aerobic system to perform longer shifts for a longer total playing time with shorter recovery periods. Both types of players (forwards, defensemen) needed a sound aerobic system to allow them to recuperate on the bench. However, the extensive bursts of energy needed on the ice demonstrated the importance of the anaerobic system.

The physiological requirements of ice hockey have been extensively researched (Astrand, 1973; 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 and Brayne, 1984; Montgomery and Dallaire, 1986; Paterson, 1979; Romet et al., 1978; Seliger, 1968; Seliger et al., 1972; Wilson and Hedberg, 1976; Wilmore and Norton, 1975). These studies support the importance of both the anaerobic and aerobic systems when playing hockey.

Therefore in the fitness evaluation of a hockey player both systems should be evaluated. The protocol used should be specific to the sport and the movement test involved in the performance should mimic the kinetic patterns of the activity (Henriksson, 1981).

Hockey tests have been developed to measure specific physiological fitness parameters of hockey players. These tests have been shown to differentiate among ability levels of hockey players. Daub et al. (1983), Léger et al. (1979) and Montgomery and Brayne (1984) compared laboratory tests to on-ice hockey tests in order to select laboratory tests which could measure these same specific physiological fitness variables. They also examined the effectiveness of laboratory tests to discriminate among several levels of hockey ability.

Montgomery and Brayne (1984) compared several on-ice tests with laboratory tests of hockey fitness. Two laboratory tests were compared to the Repeat Sprint Skate (RSS) hockey fitness test. The results showed that similar fitness components of an anaerobic laboratory test and the Repeat Sprint Skate hockey fitness test (an anaerobic ice test) had low correlations. The laboratory tests included the Wingate cycle ergometer test (a maximum 30 second effort; Ayalon et al., 1975) and a treadmill run to volitional exhaustion at a speed of 8 mph with a 20% grade (Cunningham and Faulkner, 1969). Both of these tests were a single bout effort and did not consider the intermittent type of work performed by a hockey player. A single effort test is not specific for ice hockey and probably does not examine the ability of hockey players to recover between bursts of maximal effort.

1.2 Significance of the Study

Field tests should never replace laboratory tests. Both modes of testing complement each other. Laboratory tests should try to simulate the actual competition in duration, frequency and intensity.

Geijsel et al. (1984) compared maximal power output during cycling and skating and correlated skating performance with cycling performances and skating technique. Twenty-five well-trained speed skaters performed two bicycle tests (of 30 seconds and 2 minutes 30 seconds) and a 500-m and 1500-m ice skating race. The power during skating was calculated from ice and air friction losses. The correlation of the 30 second power bike tests suggested that the inter-individual differences of skating performance at 500-m and 1500-m distances could be attributed substantially to differences in anaerobic power. However, the predictive value of the cycle ergometer test for speed skating performance was low.

Thomson (1981) studied the possibility of developing a practical, easily administered performance test which would provide an accurate prediction of anaerobic energy expenditure. Highly trained sprinters, marathon runners, and untrained male subjects sprinted around a 400-meter track with their running times and speed throughout the sprint being continuously monitored. Through comparison with their anaerobic capacities (pre-determined by laboratory test), a performance test was developed for predicting subjects' anaerobic energy expenditure. Through multiple regression analysis, it was determined that the sprinting time to 256-meters and running speed from 256-meters to 329-meters provided the highest prediction of anaerobic capacity.

Thomson and Garvie (1981) studied a new methodology for determining anaerobic energy expenditure by means of a treadmill sprinting test in the laboratory. The subjects were highly trained sprinters, marathon runners and untrained males. After establishing a workload which elicited exhaustion in just over a minute, each subject performed sprints of 15, 30, 45 and 60 seconds duration in order that their energy expenditure be segmented per 15 seconds of sprinting time. The contribution of each system (aerobic energy, lactacid energy, alactacid energy) was determined by comparing the O_2 consumption and peak lactate values obtained for each 15 second sprint. The results showed that the sprinters expended the greatest anaerobic energy when compared to the marathoners or controls and that both athletic groups (sprinters and marathoners) expended energy from this source past 30 seconds. Only minor differences were observed in aerobic energy expenditure between the three groups throughout the sprint to exhaustion.

Jacobs et al.(1982) examined the changes in selected intramuscular metabolites associated with non-oxidative metabolism after performance of the 30 second Wingate test. Muscle biopsies were taken from the vastus lateralis of nine women before and after the performance of the Wingate test. The absolute changes in CP and lactate were not as large as the ones reported in other studies. Based on the metabolite changes the researchers concluded that the Wingate test was a satisfactory test of the maximal muscular power that can be generated from non-oxidative metabolism, but that the 30 second duration of the test probably did not tax the maximal capacity of such energy metabolism.

Gamble (1986) designed a reliable and valid laboratory test to evaluate the anaerobic endurance of ice hockey players based on the Repeat Sprint Skate hockey fitness test. The test consisted of 6 x 15 seconds of sprint pedaling on a cycle ergometer with 15 seconds rest between each bout. The resistance was set at 0.075 kp per kg of body weight. The number of revolutions were recorded. Peak power and total power were then calculated. Gamble (1986) compared the laboratory test results with the on-ice performance. Peak power and total power were significantly correlated to the speed index and total time or anaerobic endurance of the Repeat Sprint Skate hockey fitness test.

Since the intermittent cycle ergometer test has been shown to be valid, reliable and objective and is a good discriminant of hockey fitness, it is proposed that this study examine physiological variables during the intermittent test as well as during the recovery period in order to establish the intensity and demands of the test.

1.3 Statement of the Problem

The aim of this study was to investigate if an intermittent (6 x 15 seconds of work with 15 seconds recovery) cycle ergometer test designed by Gamble (1986) was a test of high intensity which produced peak lactate, $\dot{V}O_2$ and EPOC (elevated post-exercise oxygen consumption) values. A comparison of these variables was done using three tests of anaerobic endurance: the Repeat Sprint Skate (RSS) hockey fitness test, an intermittent anaerobic cycle ergometer test and a continuous anaerobic cycle ergometer test to exhaustion specially designed for this study. The following hypothesis were examined:

1. There are no significant differences among the peak lactate values following the RSS hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent anaerobic cycle ergometer test.

2. There are no significant differences among the EPOC values following the RSS hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent anaerobic cycle ergometer test.

3. There are no significant differences among the peak $\dot{V}O_2$ values obtained on the continuous anaerobic cycle ergometer test, the intermittent anaerobic cycle ergometer test and the continuous aerobic cycle ergometer test.

4. A statistically significant positive correlation is found between test - retest scores on the RSS hockey fitness test and the intermittent anaerobic cycle ergometer test.

1.4 Operational Definitions

1. EPOC: Elevated (excessive) post-exercise oxygen consumption

   fast component: Oxygen consumption, above the pre-exercise resting $\dot{V}O_2$ value, during the first two minutes of recovery (Sawka et al.,1980).

   slow component: Oxygen consumption, above the pre-exercise resting $\dot{V}O_2$ value, between the third and twelfth minute of the recovery period.

2. Peak $\dot{V}O_2$: Maximum rate of oxygen consumption observed during the test.

3. Peak lactate : Blood lactate concentration taken five minutes after completion of the exercise.

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

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

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

7. Anaerobic endurance index: The total time required to complete six repetitions (6 x 91.4m) of the RSS hockey fitness test.

1.5 Delimitations

Subjects were male hockey players of varsity or junior varsity ability. They were all students at McGill University. The subjects ranged from 18 to 25 years of age.

1.6 Limitations

The ice conditions may not have been the same for all subjects.

Chapter 2

Review of Literature

2.1 Nature of the Game of Ice Hockey

Thoden and Jetté (1975) monitored three major junior hockey games and one professional game to determine the time spent bursting (anaerobic system) or coasting into position or recovering on the bench (aerobic system). A shift on the ice lasted for 75 to 90 seconds. Each burst had a duration of 2.0 to 3.5 seconds for a total of 15 to 20 seconds of bursting per shift. The players were on the ice for five to six shifts per period for a total of five to seven minutes of playing time per period. The total time per game spent on the ice by a player varied between 15 to 21 minutes with four to six minutes of that being anaerobic bursting.

Green et al. (1976) also examined the playing time of hockey players. Their results are similar to those obtained by Thoden and Jetté (1975). The average playing time per game was 24.5

minutes. On the average, the shifts lasted 85.4 seconds with 17.4 shifts per game. The hockey players also spent on the average 225 seconds on the bench between shifts. The work to recovery ratio was 1:3 based on time stoppage per shift and playing time per shift. This study also compared the time motion characteristics of the forwards and the defensemen. The results showed that defencemen played 21.2 percent longer than the forwards and this was due to a greater number of shifts (+ 26.1 percent) and a shorter recovery period (- 37.1 percent). It was also noted that the defensemen averaged 61.6 percent of the velocity of forwards per shift.

The results obtained in two studies by Green et al. (1976; 1978a) were compared by Brayne (1985). In the later study it was observed that the average player skated seven percent less (22.8 min.) than in the 1976 study. The players had 25 percent more shifts (21.7) but 26 percent less playing time per shift (63.6 sec.). Playing time between stoppage (29.1 sec.) was 27 percent less than the earlier study but the time of each play stoppage (29.8 sec.) had increased by 10 percent. It was also noted by Brayne (1985) that the recovery time was 13 percent greater (254 sec.) than in the 1976 study. According to Green (1979) the performance of hockey players depends on the interaction of both the aerobic and anaerobic systems with the aerobic system setting the tempo of the game.

2.2 Energy Source Utilization

Many researchers have studied the physiological demands of ice hockey (Astrand, 1973; Cunningham et al., 1976; Dulac et al., 1978; Ferguson et al., 1969; Gauthier et al., 1979; Green et al., 1973; Green and Houston, 1975; Green et al., 1976; Green, 1979; Hansen and Reed, 1979; Hockey and Howes, 1979; Houston and Green, 1976; Jetté, 1977; Léger et al., 1979; McNab, 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; Rusko et al., 1978; Seliger et al., 1972; Smith et al., 1982; Vainikka et al., 1982; Wilmore and Norton, 1975; Wilson and Hedberg, 1976). Based on these studies, the average $\dot{V}O_2max$ of a hockey player ranged from 50 to 60 ml/kg·min. The values ranged from 42.3 ml/kg.min for N.H.L. players (pre-season) to 62.4 ml/kg·min in players of the Eastern European countries (mid-season) (Enos et al. 1976). Wilson and Hedberg (1976) also reported an average value for Swedish elite hockey players of 65 ml/kg.min in the 1973-74 season.

Studies by Green et al. (1973), Green and Houston (1975) and Seliger et al. (1972) reported a lack of a significant improvement in aerobic power (max $\dot{V}O_2$) over a season of ice hockey. The researchers attributed this lack of improvement to the anaerobic nature of the game. Based on heart rate monitoring, Green et al. (1976) felt that the intensity was high enough during games for aerobic improvement to occur. The heart rate exceeded 90 percent of the predicted maximal heart rate. However according to the researchers, these high heart rates were not maintained for long enough periods of time to produce significant aerobic improvement. Astrand and Rodahl (1981) indicate that adaptation of the aerobic system depends on the intensity, frequency and duration of the exercise. Green and Houston (1975) observed that the largest improvement from pre to post test occured in the anaerobic system. The most improvement (16.3%) was in the lactate energy system. High lactate values during hockey games have been reported by Green et al. (1978 a,b) and Luetsolo (1976) and tend to support the previous findings.

Seliger et al. (1972) examined oxygen utilization of the Czechoslovakian national team during a model game. The results showed that 69 percent of the energy expended was provided by the anaerobic system whereas 31 percent was obtained by aerobic sources. This study is in agreement with Thoden and Jetté's (1975) results from a time-motion analysis study which established that hockey players perform many repeated short bursts of maximal anaerobic activity during a game. Seliger et al. (1972) also pointed out the importance of a good aerobic system in order to spare the anaerobic system for the intense bursts required during the critical moments in a hockey game.

Blood substrates and glycogen depletion pattern during an ice hockey game have been examined by Green et al. (1978a). Alterations in blood lactate concentration were studied for five forwards and three defensemen prior to a game and after each period of play. The forwards obtained the following values 1.42

mmol (pre game), 6.16 mmol (after the 1st period) , 4.65 mmol (after the 2nd period), 5.63 mmol (after the 3rd period), and the defensemen 1.76 mmol (pre game), 2.92 mmol (after the 1st period), 2.77 mmol (after the 2nd period), 3.12 mmol (after the 3rd period). These results indicate that the forwards had higher lactate values than the defensemen.

Green et al. (1978b) studied the effect of two back-to-back games within twenty four hours on blood lactate concentrations. The lactate values obtained during the first game seem to confirm the moderate involvement of glycolysis in the energy production. The lactate concentrations rose from 14 mg% (1.56 mmol) to 43 mg% (4.78 mmol) by the end of the first period and tended to remain at this value during the last two periods. In this study, Green et al. (1978b) noted no difference in lactate accumulation between forwards and defensemen.

Green (1978) examined the glycogen depletion patterns during intermittent and continuous skating. The subjects in the intermittent group skated ten bouts of high intensity work at 120 percent of $\dot{V}O_2$max. Each work bout was one minute followed by a five minute recovery period. The skaters in the continuous group performed sixty minutes of skating at 55 percent of $\dot{V}O_2$max. Muscle biopsies were taken from the vastus lateralis prior to the first bout, after 30 minutes (5 bouts) and after 60 minutes (10 bouts) to determine the glycogen depletion pattern. The continuous exercise caused a glycogen depletion of 29 percent which was more pronounced in the type I muscle fibers (slow twitch). The glycogen depletion during the intermittent exercise was 70 percent and more pronounced in the type II muscle fibers (fast twitch). Of the two types of fast twitch fibers (fast oxidative - fast glycolytic); the greater depletion appeared in the fast twitch glycolytic muscle fibers. Luetsolo (1976) observed that during intense hockey games players could lose as much as 40 mg of glycogen/kg wet muscle. It was also noted that muscle glycogen was first utilized by slow twitch muscle fibers and only during strenuous games was it used by fast twitch fibers. These results were supported by Green (1978).

2.3 Specificity of Testing

The specificity of a test is essential if the results obtained are to be pertinent to the performances of an activity or sport. A test should try to measure the specific fitness components required in the performance of the sport. In order to achieve this, the test should try to mimic the activity, kinesthetically in duration, frequency and intensity.

Roberts and Alspaugh (1972) studied the training effect of a running versus a cycling program. When the two groups were tested on the treadmill and on the cycle ergometer, the treadmill training group showed an increased physical work capacity on both tests whereas the bike training group only demonstrated an increase on the cycle ergometer test. The researchers concluded that the training effects of cycling were more specific than those of running and that a treadmill test was not valid to evaluate cardiorespiratory improvements of cycling trained athletes. Similar results were obtained by Pechar et al. (1974) after an eight week running or cycling training program. The running training group showed a general $\dot{V}O_2max$ improvement and the cycling training group a more specific training effect.

Pannier et al. (1980) evaluated a group of long distance runners and a group of active athletes on a treadmill and cycle ergometer. The results indicated that for specifically trained athletes (long distance runners), the $\dot{V}O_2max$ was lower when tested on the cycle ergometer than when evaluated on a treadmill test. It was concluded that the more highly trained the athlete the greater the need for specificity of testing.

Léger et al. (1979) examined the specificity of on-ice versus laboratory testing of hockey players. Hockey players were found to have similar $\dot{V}O_2max$ on protocols administered on the ice and on the treadmill. However it was observed that hockey players had a lower mechanical efficiency when running compared to a group of runners but were more efficient on ice. Hockey players required 15 percent less energy to skate at the same speed as the runners. Léger et al. (1979) suggest that a performance test would be more useful than a $\dot{V}O_2max$ test in determining a player's ability to perform aerobic skating.

Green (1979) investigated the skating performance of three elite hockey players. Among the three subjects, the player with the lowest $\dot{V}O_2max$ demonstrated the best mechanical efficiency by expending the least energy at high velocities. His ability to sustain skating intensity at high velocity was far superior to the other two players with higher $\dot{V}O_2max$. Green concluded that skating efficiency may be a more significant indicator of fatiguability than $\dot{V}O_2max$.

In a study by Ferguson et al. (1969), trained skaters performed a $\dot{V}O_2max$ test skating around an oval at a certain speed for three minute workloads while carrying a gas collection apparatus on their backs. The results showed a 15 percent variability among player's $\dot{V}O_2max$. It was concluded that since all subjects were trained skaters the considerable differences were attributed to skating skills. Gamble (1986) also examined the results of the previous study. He noted that two subjects, with large differences in $\dot{V}O_2max$, were both able to perform the same final workload. This study showed that skating efficiency is a confounding variable in the analysis of aerobic and anaerobic capacities of hockey players.

Montgomery and Brayne (1984) compared the Wingate cycling ergometer laboratory test to the on-ice Repeat Sprint Skate hockey fitness test. Thirty one players were tested. A comparison of the on-ice speed index with the cycle ergometer absolute and relative peak power and the on-ice anaerobic endurance index with the cycle ergometer anaerobic endurance index yielded low correlations. The relationship between the on-ice and cycle ergometer anaerobic indexes was low with correlations of $r = .08$ for the varsity group and $r = -.01$ for the junior varsity group. Montgomery and Brayne (1984) suggested that a player with lower anaerobic endurance on the Wingate may be able to overcome this weakness with superior skating efficiency.

Gamble (1986) evaluated thirty one hockey players for anaerobic endurance using the repeat sprint skate hockey fitness test and a cycle ergometer test. The protocol used for the cycle ergometer test consisted of six 15 second repetitions with an exercise to recovery ratio of 1:1. Correlation coefficients of $r = -0.87$ ($p < .001$) for peak power/kg on the laboratory test and speed index of the on-ice test and $r = -0.78$ ($p < .001$) for total power/kg on the laboratory test and total time on the RSS test were found.

The significant correlations obtained in the cycle ergometer intermittent test may be due to the protocol used for testing the players. The six 15 second repetitions with fifteen second recovery may be more representative of the players activity on-ice than a 30 second endurance cycle ergometer test.

Larivière et al. (1978) compared a $\dot{V}O_2max$ obtained in the laboratory to an eight minute skating test. A correlation of $r = 0.70$ was obtained between the two tests when the values were expressed in liters/minute. When the results were expressed in ml/kg·minute there was no significant correlation (Brayne 1985). Accounting for the weight of the subjects rendered the group more homogeneous by eliminating a confounding variable. The more homogeneous a sample is, the less probability of obtaining a significant but meaningless correlation. When comparing laboratory tests to on-ice tests, care should be taken in selecting the sample, since the results of these studies will be utilized by coaches of teams consisting of a homogeneous group of hockey players.

2.4 Anaerobic Testing in the Laboratory

The anaerobic endurance of hockey players has been measured on the treadmill by several researchers (Green and Houston, 1975; Houston and Green, 1976; Montgomery and Brayne, 1984). The anaerobic treadmill test is frequently a run to exhaustion where the treadmill is set at a grade of 20 percent and a speed of 8 miles per hour. The total run time is recorded as a measure of anaerobic lactate capacity.

The anaerobic capacity has also been measured by many researchers using the Wingate cycle ergometer test (Montgomery, 1982; Smith et al., 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986). The Wingate anaerobic test consists of a thirty second supramaximal ride on a cycle ergometer. The protocol used for this test has been described by Bouchard et al. (1982). The subject at first performs low workloads on a modified cycle ergometer. On instruction, the subject increases the pedal frequency to the maximum. Within two to three seconds the test resistance (based on body weight; 0.075 kp per kg body weight) is applied. The subject then performs at maximum frequency for thirty seconds. At the completion of the test, peak power, mean power output and fatigue index are calculated based on the number of revolutions and the time it took to perform these revolutions. The values are then normalized for body weight.

The Wingate test has also been modified to evaluate the anaerobic power and capacity of other sports (Bar-Or et al., 1979; Bar-Or and Inbar, 1978; Evans and Quinney, 1981; Lavoie et al., 1984; Montgomery, 1982).

Andersen and Henriksson (1977), Green et al. (1978 a,b) and Geijsel (1979) reported that muscle glycogen depletion pattern and the muscles used in cycling are similar to those in skating. These results are in agreement with Abler et al. (1986) who stated that the joint velocity in the extension of the leg during cycling correlated well with the movement in skating.

Perez et al. (1986) compared the laboratory response of the Wingate power test to bicycle field tests of 0.3 km and 1.0 km. The lactate value obtained on the Wingate test was statistically different from the peak lactate value of either time trials. The researchers concluded that the Wingate power test be limited as a laboratory evaluation since it's association with actual cycling performance was low.

Evans and Quinney (1981) recommended that the average resistance setting to optimize power output on the cycle ergometer be 0.096 kp per kg of body weight. The Evans-Quinney protocol which considers leg volume as well as body weight in establishing optimal load settings on a cycle ergometer, has been shown to result in significantly higher anaerobic power outputs than the body weight-relative Wingate protocol. It was also noted by Lavoie et al. (1984) that the anaerobic power outputs during cycle ergometer work using the Evans-Quinney protocol with toe stirrups resulted in significantly higher power outputs than any other tests (Wingate protocol with and without toe stirrups, Evans-Quinney protocol without toe stirrups). Lavoie et al. (1984) also applied the Evans-Quinney formula to establish optimum resistance setting on the cycle ergometer. The optimum value obtained was 0.099 kp per kg of body weight. Lavoie quotes unpublished data from Smith who utilized the Evans-Quinney formula and found the optimum setting to be 0.094 kp per kg of body weight. All these studies utilized a thirty second protocol.

Goslin and Graham (1985) compared measurements which were considered traditionally to reflect alactacid and lactacid components of anaerobic metabolism. Nine men and five women were administered an exhaustive cycle ergometer ride at $\dot{V}O_2$ max and had peak lactate and O_2 debt (fast and slow components) determined. On a second occasion they performed a Wingate test. All data were normalized for weight. The results showed that peak lactate and the fast O_2 debt component had low non-significant correlations with either peak or mean power. These results failed to support the traditional assumptions that peak and mean power of the Wingate test and peak lactate and O_2 debt of the cycling test measure the same anaerobic systems. Stevens and Wilson (1986) also showed in their study that blood lactate and O_2 debt had low correlation coefficients to the measures of the Wingate anaerobic test. Jacobs et al. (1982)

studied the changes in selected intramuscular metabolites after performance on the Wingate test. They concluded that the Wingate test is a satisfactory test of the maximal muscular power that can be generated from non-oxidative metabolism, however the thirty second test duration does not tax the maximal capacity of this energy system.

Geijsel et al. (1984) compared maximal power output during cycling and skating. Twenty five well-trained speed skaters performed two cycle ergometer tests (0:30 and 2:30) and two ice skating tests (500 meters and 1500 meters). The bike tests were performed on a Mijhardt bike and the brake force during the test was chosen such that no limitation of power delivery through extreme pedal frequencies would occur. The correlation for the 30-second bike test suggested that inter-individual differences in skating performance at 500 meters and 1500 meters could be attributed substantially to differences in anaerobic power.

Other anaerobic tests have varied in duration. Thomson (1981) and Thomson and Garvie (1981) utilized a 60-second cycling test. The lactate values obtained in this test were below the values reported by the literature (Hermansen and Osnes, 1972; Kindermann and Keul, 1977). Katch and Weltman (1979) tested anaerobic capacity with a 120-second cycle ergometer test. It was reported that the test involved a considerable aerobic contribution during its latter stage (Katch and Weltman, 1979). Stevens and Wilson (1986) established the aerobic contribution of the Wingate test to be 44.3 percent of the total energy demand.

Thomson and Garvie (1981) estimated that over one minute of sprinting 30-40 percent of the total energy requirement can be obtained from aerobic sources.

Simoneau et al. (1983) used a 10-second test to measure anaerobic alactacid capacity and a 90-second test for anaerobic lactacid capacity. The optimal load used varied from 0.05 to 0.11 kp/kg for the alactacid test and from 0.03 to 0.06 kp/kg for the lactacid test. The reproducibility of the test was consistently high.

Katch and Weltman (1979) suggested that a test duration between 60 and 120 seconds is appropriate for the evaluation on anaerobic capacity. Newsholme (1981) calculated the glycogen content in human muscle to be sufficient for 80 seconds of sprinting. Finally, Katch and Weltman (1979) during a 120-second test observed that the power output reached a plateau after 90 seconds. The researchers therefore suggested that a 90-second duration be retained as an indication of anaerobic lactate capacity.

2.5 Anaerobic Testing on the ice

Based on the results of game analysis, Reed et al. (1979) developed a repeat sprint skate test (RSS). The test consisted of six repeats of 91.4 meters of maximal skating on a thirty second interval including work and recovery time (Reed et al., 1979).

The repeat sprint skate hockey fitness test has been established by Reed et al. (1979) to be a reliable, valid and objective test. This test measures a player's ability to recover quickly between bouts of maximal intensity.

The validation of the test was based on three test scores; (1) drop-off (DO), the maximal difference between RSS times; (2) heart rate recovery (HRR), the difference between initial and final heart rate counts and (3) the percent heart rate recovery (% HRR) (Reed et al., 1979). Midget, junior A, collegiate and NHL players participated in a series of studies using the RSS test which included a 48 hour test-retest for reliability and validation of RSS scores against off-ice tests such as $\dot{V}O_2$ max, peak lactate , mile run time, modified Margaria stair climb and max HRR (Reed et al., 1979).

The on-ice results obtained for the RSS ranged from 12.5 seconds to 21.7 seconds which was within the anaerobic lactate range (Reed et al., 1979). The average time (14.7 sec) required to perform the 91.4 meter sprint set the work to recovery ratio at approximately 1:1. The test-retest correlations of DO, HRR and % HRR were 0.78, 0.68 and 0.74 (Reed et al., 1979). The correlation between the RSS test scores and the laboratory test scores indicated that the DO score was more related to anaerobic lactate fitness while HRR score was more related to aerobic fitness (Reed et al., 1979).

The repeat sprint skate hockey fitness test has been utilized by many researchers to measure aerobic and anaerobic skating capacities (Montgomery, 1982; Montgomery and Brayne, 1984; Montgomery and Dallaire, 1986; Smith et al., 1982; Watson and Sargeant, 1986). From this test, speed index, anaerobic endurance index (total time) and drop-off can be calculated. Jetté et al. (1975) found a reliability coefficient for speed index of 0.77. The speed index is considered a measure of the alactate system and the anaerobic endurance index of the lactate system (Reed et al., 1979)

Watson and Sargeant (1986) compared two on-ice tests (the RSS and the Sargeant anaerobic skate) to a 40 second Wingate test. Even though the inter-test correlations of anaerobic endurance were significant, the highest predictive estimate was only 53%. It was concluded that the 40 second Wingate test does not demonstrate a high relationship with on-ice measures of anaerobic power and endurance.

2.6 EPOC and Lactate Measurements

Graham and Andrew (1973) studied the intra-individual variability of O_2 debt. On five to seven occasions, six physical education students exercised at three progressive continuous workloads for 15 to 19 minutes and O_2 debt was measured. The results showed that the intra-individual variability for O_2 debt was greater than that for max $\dot{V}O_2$. Among the different athletes tested, no significant difference could be shown between any of the groups for O_2 debt. It was concluded that training was not a major factor to account for the diversity in debt.

Hagberg et al. (1980) studied the effect of work intensity and duration on recovery O_2. Eighteen men exercised at 50, 65 and 80 percent of $\dot{V}O_2max$ for five and twenty minutes. It was established from this study that the magnitude of the rapid component of recovery O_2 was proportional to exercise intensity and not altered by exercise duration. The slow component of the O_2 recovery was not significantly altered by exercise intensity or duration at 50 and 65 percent of $\dot{V}O_2max$. However after 20 minutes at 80 percent of $\dot{V}O_2max$ the slow component of recovery O_2 was five times larger than after the five minute exercise at 80 percent of $\dot{V}O_2$ max. The researchers noted that the Q_{10} effect of temperature (resulting change of rates of biological or enzymatic reactions caused by the effect of temperature) could account for 60 to 70 percent of the slow component of recovery at all work rates and durations. It could also account for the remaining 70 percent of the increase in the slow component of recovery O_2 after the 20 minute exercise at 80 percent of $\dot{V}O_2$ max.

Fox (1973) utilized the two minute recovery O_2 to estimate the alactic portion of oxygen debt. This test consisted of three to five minutes of running to exhaustion on a treadmill. The recovery O_2 was then used in an equation to calculate the alactic portion of O_2 debt.

Brooks et al. (1973) tested the hypothesis that post-exercise O_2 consumption was related to the re-conversion of lactic acid to glycogen. The results of this study were converse to those expected according to the lactacid O_2 debt hypothesis. The primary fate of lactic acid after exercise appeared to be oxidative.

Hermansen and Stensvold (1972) studied the production and removal of lactate during exercise. The highest removal rate was 8 mg lactate/100 mg x min at 63 % of $\dot{V}O_2$ max. The lactate removal rate was higher during exercise than during rest. These results indicated the pronounced capacity of the human skeletal muscles to oxidize lactate.

2.7 Summary

1. A review of literature has indicated that hockey is an intermittent sport requiring both the aerobic and anaerobic energy systems.
2. Many aerobic and anaerobic tests on the treadmill, cycle ergometer and on-ice have been used to evaluate the aerobic and anaerobic fitness of hockey players. However, specificity of testing seem to be essential if the results are to be pertinent to the performances of an activity or sport.
3. A test duration of 90 seconds has been suggested for measuring anaerobic capacity. It was also recommended that

a resistance setting of 0.96 kp per kg of body weight be used to optimize power output on the cycle ergometer.

4. The repeat sprint skate hockey fitness test has been utilized by many researchers to measure aerobic and anaerobic skating capacities.

5. The O_2 consumption post exercise can be divided in two components: fast and slow. The slow component is influenced by the intensity and the duration of the exercise and possibly by the Q_{10} effect of temperature.

6. The primary fate of lactic acid after exercise appears to be oxidative.

Chapter 3

Methods

This chapter is divided into the following sections:

1) Selection of Subjects
2) Cycle Ergometer Laboratory Tests
   - Continuous Cycle Ergometer $\dot{V}O_2$ max Test
   - Intermittent Cycle Ergometer Test of Anaerobic Endurance
   - Continuous Cycle Ergometer Test of Anaerobic Endurance
3) Repeat Sprint Skate Hockey Fitness Test
4) Collection of Data
5) Experimental Design and Statistical Analysis

3.1 Selection of Subjects

The subjects for this study consisted of eleven male hockey players of varsity or junior varsity level. They were all students at McGill University and ranged in age between 18 and 25 years.

All subjects were asked to participate in seven testing sessions (two intermittent cycle ergometer tests of anaerobic endurance, two continuous cycle ergometer tests of anaerobic endurance, one $\dot{V}O_2$ max cycle ergometer test, and two on-ice anaerobic endurance tests). Five of these testing sessions were performed on a cycle ergometer in a laboratory setting and two sessions were performed on the ice. There was at least one day of recovery between each test.

Subjects were asked to refrain from eating, drinking (except water) and smoking for two hours prior to testing. Subjects were also asked to make an appointment which was convenient for them on the testing day. They were also asked to report to the laboratory wearing proper gym wear. Each subject read and signed a consent document prior to the first laboratory test.

Subjects were encouraged to warm-up before each of the laboratory tests as well as the on-ice tests. Verbal explanations were given by the investigators at the start of each laboratory and on-ice testing session. The subjects were encouraged by the investigators to give a maximal effort throughout the test. The subjects were informed that if any "pacing" was detected, the test would be considered unacceptable and would result in a second trial. Pacing was considered to exist if the average of the fifth and sixth repetitions of the on-ice and intermittent cycle ergometer anaerobic endurance test was higher than the third and fourth repetitions or if the average of the third and fourth repetitions was higher than the first and second repetitions.

The subjects for the on-ice test were required to carry their hockey sticks.

3.2 Cycle Ergometer Laboratory Tests

For the cycle ergometer tests, with the exception of the $\dot{V}O_2$ max test, the resistance setting was determined by the equations: 0.075 kp x body weight (kg) (Ayalon et al., 1975) and 0.090 kp x body weight (kg). A modified Monark cycle ergometer was used as described by Smith et al. (1982). The Monark cycle ergometer was bolted to the floor for stability. Pedal revolutions 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 frame of the cycle ergometer opposite the crank. The reed switch was connected to an electronic counter which recorded each closing of the switch by the magnets. Therefore for one revolution there were two impulses generated. A modification was also made to the cycle ergometer resistance mechanism. Due to variation in the resistance from repetition to repetition during the 15 second trials, Gamble (1986) constructed a basket to hold the mass so that a constant resistance was applied to the flywheel. The mass was suspended from the flywheel. This modification removed a potential source of variance.

For all cycle ergometer tests, the toe stirrups were used in order to allow the subjects greater upward pull on the crank thereby enabling the involvement of more muscle mass in the whole movement (Lavoie et al., 1978). The seat height was adjusted in order to enable full extension of the subject's leg with the ankle at 90 degrees. During the cycle ergometer tests, the subjects were required to remain seated at all times.

3.2.1 Continuous Cycle Ergometer $\dot{V}O_2max$ Test

All subjects underwent an exercise test to exhaustion on the cycle ergometer. The protocol was as follows: The subject pedaled at a rate of 60 rpm for the duration of the test. The workload was changed every 2 minutes. The initial load was at 2 kp and was increased by 0.5 kp every two minutes until the subject was exhausted. Verbal encouragement was offered by the investigator throughout the test. At the completion of the test, the subject remained seated for 12 minutes of recovery. Throughout the test and during 12 minutes of recovery, the subject's oxygen consumption was measured using a Roxon Metabolic Cart.

3.2.2 Intermittent Cycle Ergometer Test of Anaerobic Endurance

The test consisted of six repetitions of 15 seconds duration with a 15 second recovery period between each repetition for a total work time of 90 seconds. The exercise to rest ratio was 1:1. The subject started each repetition from a stationary position with his feet in a designated start position. The subject's favored foot was placed at a one o'clock (right foot - right side view) or 11 o'clock (left foot - left side view) position. The subject was given a five second warning and on the command "go" he pedaled the crank as fast as possible for 15 seconds. The investigator also gave a verbal command "stop" after 15 seconds. A clock was also visible to the subject. During the recovery period the investigator recorded the number of impulses from the electronic counter and reset it. The investigator also ensured that the subject was in the proper position for the next bout. Verbal encouragement was provided throughout the test. After completion of the sixth and final repetition, the subject was seated on a chair for twelve minutes of recovery and remained silent. Throughout the test the subject was wearing a nose clip and a mouthpiece which was connected to a Roxon metabolic cart in order to establish his O_2 consumption prior, during and after the test. Twelve minutes of recovery O_2 consumption were broken down into fast (first two minutes of recovery) and slow (from the third to the twelfth minute of recovery) components. Finger tip blood samples were taken five minutes into the recovery and were analyzed for lactate concentration.

Two variables 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 computation. 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 calculate this indice was:

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

Both peak anaerobic power and total anaerobic power were also expressed as a relative score by dividing by the subject's body mass. These variables were abbreviated as: PAP/kg

TAP/kg

The drop-off score was also calculated as an absolute and relative score. The relative score were obtained by dividing the drop-off score by body mass.

$$\underset{\text{(Watts)}}{\text{Drop-off}} = \underset{\text{(Watts)}}{\text{Peak power output}} - \underset{\text{(Watts)}}{\text{lowest power output}}$$

The lowest power output was calculated from the repetition with the lowest number of pedal revolutions.

3.2.3 Continuous Cycle Ergometer Test of Anaerobic Endurance

This test consisted of a cycle ergometer ride to volitional exhaustion. The subjects were required to pedal at a rate of 90 rpm at resistance settings equivalent to 0.075 kp x body weight and 0.09 kp x body weight until the point of fatigue had been reached. The number of pedal revolutions for every 5-second interval were monitored throughout the test. The subjects received continuous feedback of their performance (e.g. ahead of pace - slow down; or behind pace - speed up). When the subjects fell 10 impulses (5 revolutions) behind the recommended cadence, a warning was given. If the subject could not pick-up the pace but continued to be 10 impulses (5 revolutions) behind the pace at the next interval, the test was stopped.

The subject started the test from a still position with the preferred foot in the 1 o'clock position (right foot - right side view) or 11 o'clock (left foot - left side view). At the verbal signal "go" he pedaled at a rate of 90 rpm until the point of fatigue was reached (10 impulses behind recommended rate). When fatigue had been reached and the test stopped, the subject was seated on a chair for a 12 minute recovery and remained silent.

Throughout the test, the subject was wearing a nose clip and was breathing through a low resistance valve which was connected to a Roxon metabolic cart in order to establish his O_2 consumption prior, during and after the test. Twelve minutes of recovery O_2 consumption were broken down into fast (first two minutes of recovery) and slow (from the third to the twelfth minute of recovery) components. Finger tip blood samples were taken five minutes into recovery and were analyzed for lactate concentration.

The variables which were calculated from this test were:

Time to fatigue (s) - amount of time required for the subject to reach volitional exhaustion.

Anaerobic endurance (Watts):

$$\frac{\text{total rev}}{\text{time of fatigue}} \times \frac{60\text{ s}}{\text{min}} \times \frac{6\text{ m}}{\text{rev}} \times \text{resistance(kp)} \times \frac{1\text{ Watt}}{6.12\text{ kpm/min}}$$

3.3 Repeat Sprint Skate Hockey Fitness Test

Reed et al. (1979) described the repeat sprint skate (RSS) hockey fitness test. The test consists of six repetitions of supramaximal skating. Each subject was required to sprint 91.4 m (from goal line to goal line and back to the blue line closest to the starting point) on an interval of 30 seconds. In other words, the work bouts were started every 30 seconds. For example, if a subject completed the 91.4 m in 14 seconds he had 16 seconds of recovery during which he skated to the initial starting point. On the first repetition, speed index was measured by timing the subject for 54.9 m (goal line to goal line). Therefore on the first repetition, two times were taken; one for the speed index (54.9 m) and one for the complete distance (91.4 m). Before every repetition, a 5-second warning was given. At the completion of the test, the subject immediately put on the nose clip and mouthpiece which was connected to the Roxon metabolic cart, and were seated and kept silent for 12 minutes in order to allow the collection of EPOC (elevated post-exercise oxygen consumption) which was divided into fast (first two minutes of recovery) and slow (from the third to the twelfth minute of recovery) components. Finger tip blood samples were taken five minutes into recovery and were analyzed for lactate concentration.

The components which were computed for the on-ice test were:

Speed index: Time to skate 54.9 meters.

Anaerobic endurance index: Sum of the times for the 6 repetitions.

3.4 Collection of Data

Data collection were performed in a systematic manner. The administration of the five laboratory tests (two intermittent cycle ergometer anaerobic tests, two continuous cycle ergometer anaerobic endurance tests, one aerobic $\dot{V}O_2$ max test) were done on a modified Monark cycle ergometer. Expired gas volumes were analyzed using a Roxon Metabolic Cart. The following variables were collected: $\dot{V}E$, $\dot{V}O_2$, Mets, $\dot{V}CO_2$, RQ and ventilatory equivalent for oxygen.

Measurements were continuously recorded every 15 seconds starting with five minutes of resting data, followed by the exercise tests and ending with twelve minutes of recovery data. The fast component of EPOC was calculated from O_2 consumption during the first two minutes of recovery and the slow component from the O_2 consumption of the third to twelfth minutes. Fifteen second values were displayed on-line with the use of an Apple IIe computer and Okidata micro-82A printer.

EPOC for the ice hockey fitness test was calculated on only one occasion using the Roxon metabolic cart. The fast component was calculated from the O_2 consumption of the first two minutes of recovery and the slow component from the O_2 consumption of the third to the twelfth minutes. Data collection was initiated within 10 seconds of test termination. The first value of the fast EPOC was estimated with a regression computer program that utilized the recovery data points.

Finger tip blood samples (100 ul) were taken for the cycle ergometer tests as well as for the on-ice tests five minutes into recovery. The samples were immediately analyzed by a YSI Model 27 lactate analyzer.

3.5 Experimental Design and Statistical Analysis

The validity, reliability and objectivity of the Repeat Sprint Skate hockey fitness test and the intermittent cycle ergometer test of anaerobic endurance have been demonstrated by Reed et al. (1979) and Gamble (1986), respectively. Pearson product-moment correlation coefficients examined the association between the laboratory and on-ice tests. Comparisons between peak power versus speed index and total power output versus total time were made in order to establish if the data in this study coincided with the correlations ($r = -.87$ and $r = -.78$) obtained by Gamble (1986).

This study was concerned with the following physiological parameters; peak lactate, peak $\dot{V}O_2$, EPOC and with the day-to day variability between the same test. The following experimental design was used.

Table 3.1: Experimental Design

Test	On-ice anaerobic	Intermittent anaerobic	Continuous anaerobic
Subjects 1 2 3 . . . 11			

Peak lactate and EPOC (fast and slow components) were analyzed using a one-way ANOVA applying the above design in order to examine hypothesis 1.3.1 and 1.3.2, respectively.

Hypothesis 1.3.3 which examined peak $\dot{V}O_2$ scores was analyzed using the same design but the results from the continuous cycle ergometer $\dot{V}O_2max$ test replaced the results from the on-ice hockey fitness test in the above design. This analysis used the peak $\dot{V}O_2$ scores from the three cycle ergometer tests. The peak $\dot{V}O_2$ score from the two trials of the intermittent and the two trials of the continuous cycle ergometer tests of anaerobic endurance were averaged and compared with the peak $\dot{V}O_2$ from the continuous cycle ergometer $\dot{V}O_2$ max test. The experimental design for this hypothesis is shown in table 3.2. The statistical analysis was a one-way ANOVA.

Table 3.2: Experimental Design

Test	Continuous anaerobic	Intermittent anaerobic	Continuous aerobic
Subjects 1 2 3 . . . 11			

Hypothesis 1.3.4 examined the day-to-day variability on the repeat sprint skate hockey fitness test, and the intermittent cycle ergometer test. Results from trials 1 and 2 of each test were compared using the intraclass correlation coefficient (R) obtained from the ANOVA test.

The statistical procedures that were used to evaluate the four hypothesis are summarized in the following table.

Table 3.3: Summary of Hypothesis and Statistical Analysis

Comparison	Statistical Analysis
Hypothesis 1 - Peak Lactate	
RSS (on-ice) Continuous anaerobic cycle ergometer Intermittent anaerobic cycle ergometer	One-way ANOVA
Hypothesis 2 - EPOC	
RSS (on-ice) Continuous anaerobic cycle ergometer Intermittent anaerobic cycle ergometer	One-way ANOVA
Hypothesis 3 - Peak $\dot{V}O_2$	
Continuous anaerobic cycle ergometer Intermittent anaerobic cycle ergometer Continuous aerobic cycle ergometer	One-way ANOVA
Hypothesis 4-variability	
Day 1 versus Day 2	Intraclass Correlation Coefficient (R)

Chapter 4

Results

This chapter is divided into the following four sections:

4.1 Descriptive Data

4.2 Criterion Related Validity Results

4.3 ANOVA Results

4.4 Reliability Results

4.1 Descriptive Data

The subjects for this study were eleven male hockey players of varsity or junior varsity level. The average age, height and weight of the subjects were, 22.5 years (S.D.=3.5), 180.6 cm (S.D.=5.0) and 82.7 kg (S.D.=5.03), respectively.

The results obtained for the different variables on the intermittent and the continuous cycle ergometer tests are presented in tables 4.1 and 4.2 while the results for the $\dot{V}O_2$ max continuous cycle ergometer test are presented in table 4.3. The data recorded for the repeat sprint skate hockey fitness test are listed in table 4.4.

Table 4.1: Intermittent Cycle Ergometer Test ($\bar{X} \pm S.D.$)

Variable	Day 1		Day 2	
Peak power (watts)	922.2	60.4	898.2	69.1
Peak power (watts/kg)	11.2	0.8	10.9	0.7
Total power (watts)	727.8	51.0	745.2	46.7
Total power (watts/kg)	8.8	0.7	9.0	0.6
Drop-off (watts)	289.0	106.4	230.6	96.3
Drop-off (watts/kg)	3.5	1.1	2.8	1.1
Drop-off (%)	31.1	10.1	25.2	9.0
Peak $\dot{V}O_2$ (l/min)	4.3	0.5	4.5	0.5
EPOC-total (l)	6.6	1.1	7.1	1.0
EPOC-fast (l)	3.1	0.5	3.2	0.5
EPOC-slow (l)	3.5	0.9	3.9	0.9
Lactate (mg %)	-	-	120.1	17.9

Table 4.2: Continuous Cycle Ergometer Test ($\bar{X} \pm$ S.D.)

Variable	Day 1		Day 2	
Resistance (kp/kg body wt)	.075		.090	
Total power (watts)	532.0	31.9	641.0	41.6
Total power (watts/kg)	6.5	0.2	7.8	0.4
Time to fatigue (s)	178.6	76.3	86.4	46.9
Peak $\dot{V}O_2$ (l/min)	4.4	0.9	4.1	0.7
EPOC-total (l)	6.7	1.6	5.8	1.3
EPOC-fast (l)	3.2	0.7	3.0	0.6
EPOC-slow (l)	3.5	1.1	2.8	0.8
Lactate (mg %)	-	-	106.0	22.6

Table 4.3: Continuous Cycle Ergometer $\dot{V}O_2$ max Test

Variable	Mean	S.D.
Cycling time (min)	16.3	2.8
VE max-BTPS	169.6	21.7
$\dot{V}O_2$ max (l/min)	4.6	0.7
$\dot{V}O_2$ max (ml/kg.min)	56.1	8.0

Table 4.4: The RSS Test Results ($\bar{X} \pm$ S.D.)

Variable	Day 1		Day 2	
Speed index (s)	7.6	0.3	7.6	0.3
Total time (s)	91.4	5.2	91.9	5.3
Drop-off (s)	3.2	1.6	2.8	1.5
EPOC-total (l)	8.4	1.2	-	-
EPOC-fast (l)	3.8	0.6	-	-
EPOC-slow (l)	4.6	0.7	-	-
Lactate (mg %)	96.5	20.9	-	-

4.2 Criterion Related Validity Results

Pearson product-moment correlation coefficients were determined between the two laboratory and the two on-ice variables in order to establish if the data obtained in this study produced similar correlations ($r = -.87$ and $r = -.78$) as those obtained by Gamble (1986). The variables compared were the peak anaerobic power (watts/kg) and the total anaerobic power (watts/kg) of the intermittent cycle ergometer test versus the speed index (s) and the anaerobic endurance index (s) of the repeat sprint skate hockey fitness test. Total anaerobic power (watts/kg) correlated significantly with the anaerobic endurance index (s) but a significant correlation failed to be established between peak anaerobic power and speed index. The statistical analysis is presented in table 4.5.

Table 4.5: Correlation coefficients - laboratory test versus on-ice test (n=11)

Laboratory Variable		On-ice Variable	Pearson correlation
1. Peak power (watts/kg)	vs	Speed index (s)	- .07
2. Total power (watts/kg)	vs	Anae. end. index (s)	- .71 *

*p < .001

4.3 ANOVA Results

A one-way analysis of variance was applied in order to establish if there were significant differences among the peak lactate values and the EPOC values (fast, slow and total) following the repeat sprint skate hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent anaerobic intermittent cycle ergometer test. No significant differences ($p<.05$) were obtained for the lactate and the EPOC-fast values as shown in tables 4.6 and 4.7. However, the analysis of the EPOC-slow and EPOC-total values indicated a significant difference among the values obtained for the three tests as presented in tables 4.8 and 4.9. A post hoc Tukey test established that the significant difference for both the EPOC-slow and EPOC-total variables was attributed to the differences between the on-ice and the continuous anaerobic cycle ergometer test. There was no significant difference between the intermittent cycle ergometer test and the on-ice test for EPOC-slow and EPOC-total. The values obtained for the intermittent and continuous cycle ergometer test were not significantly different.

Another one-way analysis of variance was also applied to determine if there were significant differences among the peak $\dot{V}O_2$ values obtained following the continuous anaerobic cycle ergometer test, the intermittent anaerobic cycle ergometer test and the continuous aerobic test ($\dot{V}O_2$ max). No significant difference ($p<.05$) was obtained for the peak $\dot{V}O_2$ values for the three tests. These results are presented in table 4.10.

Table 4.6: ANOVA for Lactate

Source	D.F.	SS	MS	F-ratio	Prob.
Between groups	2	2835.2	1417.0	3.04	0.06
Within groups	28	13058.9	466.4		
Total	30	15894.1			

Table 4.7: ANOVA for EPOC-fast

Source	D.F.	SS	MS	F-ratio	Prob.
Between groups	2	1.7	0.9	3.12	0.07
Within groups	21	5.7	0.3		
Total	23	7.4			

Table 4.8: ANOVA for EPOC-slow

Source	D.F.	SS	MS	F-ratio	Prob.
Between groups	2	9.5	4.7	7.80	0.01
Within groups	21	12.8	0.6		
Total	23	22.3			

Table 4.9: ANOVA for EPOC-total

Source	D.F.	SS	MS	F-ratio	Prob.
Between groups	2	18.8	9.4	8.72	0.01
Within groups	21	22.6	1.1		
Total	23	41.4			

Table 4.10: ANOVA for Peak $\dot{V}O_2$

Source	D.F.	SS	MS	F-ratio	Prob.
Between Groups	2	0.6	0.30	0.59	0.56
Within Groups	30	15.2	0.51		
Total	32	15.8			

4.4 Reliability Results

The scores for the power output/kg, the peak $\dot{V}O_2$ and the EPOC-total were used to determine the intermittent anaerobic cycle ergometer test-retest reliability. The values obtained for these variables on day one and day two were compared for 11 hockey players. The intraclass correlation coefficients (R), as determined by the analysis of variance were .93, .86 and .71 for the power output/kg, the peak $\dot{V}O_2$ and the EPOC-total respectively.

Test-retest reliability was also measured for the Repeat Sprint Skate hockey fitness test. The intraclass correlation coefficients (R), as determined by the analysis of variance approach, were obtained for speed index, total time and drop off variables using results for the hockey players. The analysis revealed R values of .69, .93 and .94 for speed index, total time and drop off values. These results are presented in table 4.11.

Table 4.11: Intraclass Correlation Coefficients

Variables	Intraclass correlation coefficients (R)
Intermittent Cycle Test	
Power Output/kg	.93
Peak $\dot{V}O_2$	.86
EPOC-total	.71
Repeat Sprint Skate Test	
Speed Index	.69
Total Time	.93
Drop Off	.94

Chapter 5

Discussion

5.1 Laboratory Test Findings

When comparing the results from the intermittent anaerobic cycle ergometer test to the Wingate test, caution must be taken because of the slightly different nature of both tests (Gamble, 1986). The Wingate test is a single 30 second effort whereas the intermittent anaerobic cycle ergometer test is six repeats of 15 seconds, followed by 15 seconds of rest. The peak power for the Wingate test is calculated using the highest five second revolution count and its total power is measured from the number of revolutions for the 30 second test. The peak power for the intermittent anaerobic cycle ergometer test uses a longer interval of 15 seconds. The total power is calculated from the number of revolutions for the duration of the entire test which is 90 seconds.

The resistance setting is another factor which must be considered when comparing results of anaerobic tests. While some studies use the weight relative protocol, others utilize leg volume and body weight. Evans and Quinney (1981) and Lavoie et al., (1984) reported greater power output using the leg volume and body weight protocol.

The results for the peak and the total anaerobic power of the intermittent anaerobic cycle ergometer test of this investigation are compared in table 5.1 to data from various studies. Smith et al., (1982) obtained peak power values of 11.7 (watts/kg) and 11.5 (watts/kg) for forwards and defense of the 1980 Canadian Olympic players and total anaerobic power values of 9.6 (watts/kg) for both groups. Montgomery and Brayne (1984) using the Evans and Quinney protocol obtained a peak power of 11.5 (watts/kg) and 11.4 (watts/kg) for varsity and junior varsity hockey players. The anaerobic power for these two groups was 9.0 (watts/kg) for varsity players and 9.2 (watts/kg) for the junior varsity group. Brayne (1985), using a resistance setting of .095 kp x body weight, reported values of 11.5 (watts/kg) and 9.0 (watts/kg) for peak power and total anaerobic power, respectively of varsity and junior varsity hockey players. Watson and Sargeant (1986) using a 40 second Wingate test with university and junior players reported values of 10.1 (watts/kg) for peak power and 7.7 (watts/kg) for anaerobic endurance. During the present study, values of 11.0 (watts/kg) and 8.9 (watts/kg) were found for peak power and total anaerobic endurance as compared to 11.5 (watts/kg) and 9.2 (watts/kg) obtained by Gamble(1986) which used the same protocol. There was also a continuous anaerobic test conducted in this investigation. Values of 6.5 (watts/kg) and 7.8 (watts/kg) for total anaerobic power were obtained when the resistance was set using .075 kp x body weight and .09 kp x body weight, respectively. The players were required, for this test, to pedal at a rate of 90 rpm until fatigue was reached.

Table 5.1: Comparison of Anaerobic Results from various Studies

Group	Peak Power (watts/kg)	Anaerobic endurance (watts/kg)	Reference
Can. Olympic forwards	11.7	9.6	Smith et al., 1982
Can Olympic defense	11.5	9.6	Smith et al., 1982
Varsity hockey	11.5	9.0	Montgomery & Brayne, 1984
Junior varsity hockey	11.4	9.2	Montgomery & Brayne, 1984
University	11.5	9.0	Brayne, 1985
University and junior	10.1	7.7	Watson and Sargeant, 1986
University	11.5	9.2	Gamble, 1986
Varsity and junior varsity	11.0	8.9	Present study

A continuous aerobic cycle ergometer test was also performed by all players in this study. A $\dot{V}O_2$ max of 56.1 (ml/kg.min) was achieved. This score is similar to the $\dot{V}O_2$ max values for university level players tested on a cycle ergometer reported by Thoden and Jetté, 1975, Romet et al., 1978, Daub et al., 1983. $\dot{V}O_2$ max values are reported in table 5.2.

Table 5.2: Comparison of $\dot{V}O_2$ max Results from various Studies

Group	n	$\dot{V}O_2$ max (ml/kg.min)	Reference
University	15	54.5	Thoden and Jetté, 1975
University	18	55.2	Romet et al., 1978
University	5	54.3	Daub et al., 1983
University	21	58.4	Krotee et al., 1979
University	11	56.1	Present study

5.2 Comparison of RSS Studies

The speed index (7.6 s) obtained from the repeat sprint skate test by the hockey players in this study was slower than the value reported by Smith et al., (1982) for the Canadian Olympic Team forwards (7.0 s) and defense (7.3 s). Reed, as cited by Smith et al., (1982), also reported a faster speed index for professional and junior hockey players (7.4 s). The speed index in this investigation is comparable to the 7.6 s obtained by the university and junior hockey players in the study by Watson and Sargeant (1986) and faster than the values reported by Brayne (1985) for the varsity (7.7 s) and junior varsity (8.0 s) hockey players. Speed indexes for various studies are reported in table 5.3.

The hockey players in this study showed superior anaerobic endurance (91.7 s) to the university and junior hockey players reported by Watson and Sargeant (1986), Brayne (1985) and Montgomery (1982). Anaerobic endurance values for various studies are reported in table 5.3.

The drop-off score for the players in this investigation was 3.0 s. This value is lower than the 3.2 s obtained by the Canadian Olympic Team forwards (Smith et al., 1982), as well as 3.4 s and 3.6 s obtained by the junior varsity players reported by Brayne (1985) and Gamble (1986). Other drop-off values are reported in table 5.3.

Table 5.3: Comparison of RSS Results from various Studies

Group	Speed Index (s)	Anae. End. (s)	Drop-off (s)	Reference
Can. Olympic Team				
forwards	7.0	-	3.2	Smith et al., 1982
defense	7.3	-	2.8	Smith et al., 1982
Prof. & junior	7.4	-	2.9	Reed - cited by Smith et al., 1982
University & Junior	7.6	94.6	1.1	Watson & Sargeant, 1982
University - Varsity	7.7	93.3	2.9	Brayne, 1985
University - J.V.	8.0	95.8	3.4	Brayne, 1985
University	8.0	95.5	2.2	Montgomery, 1982
University - Varsity	7.3	89.3	2.6	Gamble, 1986
University - J.V.	7.7	93.5	3.6	Gamble, 1986
Varsity and J.V.	7.6	91.7	3.0	Present study

5.3 Comparison of Peak Lactate Values

The peak lactate value obtained for the intermittent anaerobic cycle ergometer test in this study was 120.1 mg % (13.5 mmol/l). This value was higher than the values obtained for the continuous anaerobic cycle ergometer test (106.0 mg % or 11.9 mmol/l) and the repeat sprint skate hockey fitness test (96.5 mg % or 10.8 mmol/l). This value is also higher than the peak lactates (10.8 mmol/l) reported by Watson and Sargeant (1986) for a 40 second Wingate test with junior A and university players. Goslin and Graham 1985, while using an exhaustive cycle ergometer ride at $\dot{V}O_2$ max obtained a comparable peak lactate value (13.3 mmol/l) to the intermittent lactate value. Contrary to the findings reported by Watson and Sargeant, (1986), the peak lactate value for the RSS on-ice test is lower than the peak lactate value obtained for the laboratory tests. Vogelaere et al., 1986, observed that blood lactate concentrations were significantly lower at 0°C than they were at 20°C. When peak lactate values for the intermittent anaerobic cycle ergometer test, the continuous anaerobic cycle ergometer test and the RSS hockey fitness test were compared in this study, a value of .06 was obtained indicating no significant difference at the .05 level. Since only one lactate measure was taken for each test on a small sample, and because of the small margin separating the value obtained to a significant difference, caution should be taken in interpreting the result. Even though care was taken to minimize error by using the same operator and analyzer for all lactate analysis, studies using at least two readings are needed to establish the validity of this conclusion.

5.4 Comparison of EPOC values

The fast component of EPOC was calculated from the first two minutes of recovery for the intermittent anaerobic cycle ergometer test (3.2 l), the continuous anaerobic cycle ergometer test (3.1 l) and the on-ice test (3.8 l). All three values were higher than the 2-min O_2 debt (2.71 l) reported by Goslin and Graham (1985) following an exhaustive cycle ergometer ride at $\dot{V}O_2$ max. When the three EPOC-fast values were compared, no significant differences were obtained. Therefore all three tests would seem to reflect the same anaerobic intensity. However, it has been suggested (Brooks and Fahey, 1984) that EPOC or O_2 debt is not an adequate measure of anaerobic metabolism during exercise.

The slow and total components of EPOC were also calculated for all three anaerobic tests. When the slow component scores (int=3.7 l, cont=3.1 l, on-ice=4.6 l) were analyzed, the on-ice value was found to be significantly different only from the continuous anaerobic EPOC-slow value. The same results were obtained when the EPOC-total values for the three tests were compared. There was a significant difference between the total EPOC value for the on-ice test (8.4 l) and the continuous anaerobic cycle ergometer test (6.3 1) but not from the intermittent anaerobic cycle ergometer test (6.91).

When comparing the EPOC values of all three tests, the the on-ice test had the highest values. The temperature at the arena may have been a factor. According to Vogelaere et al. 1986, $\dot{V}O_2$, during and after exhaustive cycle ergometer tests at low temperature (0°C), have higher values than the $\dot{V}O_2$ achieved during the same test at 20°C.

5.5 Comparison of Peak $\dot{V}O_2$ Values

When comparing the peak $\dot{V}O_2$ values of the intermittent anaerobic cycle ergometer test (4.4 l/min) and the continuous anaerobic cycle ergometer test (4.3 l/min) to the continuous aerobic cycle ergometer test (4.6 l/min), no significant differences were found. The intermittent anaerobic cycle ergometer test produced an intensity equivalent to 95 % of $\dot{V}O_2$ max. The continuous anaerobic test achieved 92 % of $\dot{V}O_2$ max obtained from a continuous protocol.

5.6 Reliability

Reliability as defined by Carmines and Zeller (1984) is the extent to which an experiment, test or any measuring procedure, yields the same results on repeated trials. In this study, the same tests were performed on two separate days. The reliability was measured using the intraclass coefficient (R) through the analysis of variance. The intraclass coefficients of reliability were measured for peak power/kg, peak $\dot{V}O_2$ and EPOC-total for the intermittent anaerobic cycle ergometer test with values of .93, .86 and .80, respectively. These results support the reliability of the intermittent anaerobic cycle ergometer test. The intraclass correlation coefficient was not calculated for the continuous anaerobic cycle ergometer test because resistance setting was changed from .075 kp x body weight for day 1 to .09 kp x body weight for day 2. The intraclass coefficient of reliability was also performed for the speed index, the total time and the drop-off time for the repeat sprint skate hockey fitness test. Values of .69 for speed index, .93 for total time and .94 for drop-off time were obtained and suggest that the RSS test is reliable for the total time and drop off time variables. Only a moderate reliability was obtained for the speed index.

The aim of this study was to establish that the intermittent (6 x 15 seconds of work with 15 seconds recovery) anaerobic cycle ergometer test designed by Gamble (1986) was a test of high intensity producing peak lactate, $\dot{V}O_2$ and EPOC values. By comparing the intermittent test to tests which produce peak values for each of the variables mentioned earlier, a relative comparison of intensity could be achieved. Since no significant differences were found in the physiological response between the anaerobic intermittent cycle ergometer test and the Repeat Sprint Skate hockey fitness test and since the intermittent cycle ergometer test achieves a peak $\dot{V}O_2$ similar to the continuous aerobic cycle ergometer test, it is concluded that the test designed by Gamble (1986) is a test of high intensity which produces peak lactate, $\dot{V}O_2$ and EPOC values.

A Pearson product-moment correlation was also performed between two laboratory variables (peak power/kg and total power/kg) of the intermittent anaerobic cycle ergometer test and two on-ice performance variables (speed index and total time) to determine if the data in this study could replicate the correlations (r= - .87 and r= - . 78) obtained by Gamble (1986). The correlations calculated in this study were of r= - .07 (peak power/kg and speed index) and r= - .71 (total power/kg and total time). The small number of subjects (n=11) may have allowed factors such as fatigue to influence the results of the peak power and speed index scores resulting in the low correlation for these variables.

Chapter 6

Summary, Conclusions and Recommendations

6.1 Summary

The purpose of this investigation was to determine if the intermittent anaerobic cycle ergometer test designed by Gamble (1986) was a high intensity test which would produce peak lactate, $\dot{V}O_2$ and EPOC values. A comparison of these variables was done using three tests of anaerobic endurance: the RSS hockey fitness test, an intermittent anaerobic cycle ergometer test and a continuous anaerobic cycle ergometer test to exhaustion.

The subjects in this study were 11 male hockey players of varsity or junior varsity level. All subjects performed two intermittent anaerobic cycle ergometer tests, two continuous anaerobic tests, two RSS hockey fitness tests (Reed et al., 1979) and one continuous aerobic cycle ergometer test ($\dot{V}O_2$ max).

The first hypothesis of this study stated that there would be no significant differences among the peak lactate values following the RSS hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent anaerobic cycle ergometer test. The one-way analysis of variance revealed an F ratio of 3.04 which was not significant at the 0.05 level. Thus the intermittent anaerobic cycle ergometer test produces peak lactate values that are comparable to the RSS hockey fitness test and a continuous cycle ergometer test taking into account the limitations of this study.

The second hypothesis stated that there would be no significant differences among the EPOC values following the RSS hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent anaerobic cycle ergometer test. The one-way analysis of variance revealed F ratios of 3.12, 7.80 and 8.72 for EPOC-fast, EPOC-slow and EPOC-total. The F ratio for EPOC-fast indicated that there were no significant difference at the 0.05 level among the three groups for the fast component of EPOC. Significant F values were found for EPOC-slow and EPOC-total. These differences were further analyzed using the post hoc Tukey test. The results of the post hoc test revealed that the values for the on-ice test were significantly different from the values of the continuous anaerobic cycle ergometer test but not from the intermittent anaerobic cycle ergometer test. These results demonstrate that the intermittent anaerobic cycle ergometer test produces an EPOC-fast value that is similar to the value obtained from the RSS test.

The third hypothesis stated that there would be no significant differences among peak $\dot{V}O_2$ values obtained on a continuous anaerobic cycle ergometer test, the intermittent anaerobic cycle ergometer test and the continuous aerobic cycle ergometer test. The one-way analysis of variance revealed an F ratio of 0.59 which was not significant at the .05 level. These results demonstrate that the intermittent anaerobic cycle ergometer test produces peak $\dot{V}O_2$ values that are similar to the values obtained on a continuous anaerobic cycle ergometer test and the RSS test.

The fourth hypothesis was concerned with the reliability of the test - retest scores on the RSS hockey fitness test, the continuous anaerobic cycle ergometer test and the intermittent cycle ergometer test. The intraclass correlation coefficients, using the ANOVA approach, revealed values of .69 (speed index), .93 (total time) and .94 (drop off) for the on-ice test. These values attest to the reliability of the total time and drop off values obtained during the RSS hockey fitness test. The intraclass coefficients were also calculated for the intermittent anaerobic cycle ergometer test. Values of .93 (power output), .86 (peak $\dot{V}O_2$) and .76 (EPOC-total) were obtained. These intraclass correlation coefficients indicate the reliability of the intermittent anaerobic cycle ergometer test to replicate power output. Intraclass correlation coefficients were not performed for the continuous anaerobic cycle ergometer test because resistance settings were changed from day 1 to day 2.

6.2 Conclusions

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

1) The intermittent anaerobic cycle ergometer test produces similar lactate values to a continuous anaerobic cycle ergometer test and to the RSS test.

2) The intermittent anaerobic cycle ergometer test produces similar EPOC values as the RSS test and a continuous anaerobic cycle ergometer test. Significant differences in EPOC values exist between the RSS test and the continuous anaerobic cycle ergometer test.

3) The intermittent anaerobic cycle ergometer test produces a similar peak $\dot{V}O_2$ as that obtained from a $\dot{V}O_2$ max test on a cycle ergometer

4) Test re-test values for power output on the intermittent cycle ergometer test are similar.

5) Test re-test values for the RSS variables, total time and drop-off score, are similar.

The results from this investigation suggest that the intermittent anaerobic cycle ergometer test is a test of high intensity which produces peak lactate, $\dot{V}O_2$ and EPOC values.

6.3 Recommendations

The following recommendations are proposed for future investigations:

1) Further studies should be done using athletes from other sports to establish the suitability of this protocol for different athletic populations.

2) Studies using this protocol should be done on à homogeneous group of hockey players of different caliber in order to establish base line data for comparison.

3) Future studies should examine the optimum resistance setting for the anaerobic intermittent cycle ergometer test.

4) Future studies should examine the appropriate time to take a single blood sample during the recovery period using the anaerobic intermittent cycle ergometer test.

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APPENDIX A

Informed Consent

Date:_______________

Name:_______________

I hereby give consent to Ginette Ladouceur to administer and supervise the following investigation:

1. Record anthropometric data (standing height, body weight).
2. Administer five cycle ergometer tests.
   - one max $\dot{V}O_2$ cycle ergometer test; subject will be required to cycle at a certain cadence and at an initial resistance of 2kp for two minutes. For every subsequent two minutes the resistance will be increased by 0.5kp until the subject can no longer keep up to the cadence. During the test and the twelve minute recovery period, gas analysis will be done through the collection of gas by a mouthpiece worn by the subject and connected to a Roxon metabolic cart.
   - two intermittent cycle ergometer tests; subject will be required to cycle as fast as possible at a predetermined resistance (according to the weight of the suject) for 6 bouts of 15 seconds with 15 seconds recovery between bouts. During the test and the twelve minute recovery period, gas analysis will be done through the collection of gas by a mouthpiece worn by the subject and connected to a Roxon metabolic cart.

- two continuous cycle ergometer tests; subject will be required to cycle at a predetermined cadence (90 rpm) and resistance (according to the subject's weight) for as long as he can keep up to the cadence. When the subject falls too much behind the cadence (5 rpm for two intervals) the test will be stopped. During the test and the twelve minute recovery period, gas analysis will be done through the collection of gas by a mouthpiece worn by the subject and connected to a Roxon metabolic cart.

3. Administer two on-ice fitness tests.
   - subject will be required to skate as fast as possible, from goal line to goal line and back to the blue line closest to the starting point, six times on a 30 second interval. After the test the subject will put on a mouthpiece which will be connected to a Roxon metabolic cart for gas analysis during the twelve minute recovery period.

4. Take finger tip blood samples for lactate analysis.
   - Five minutes after the completion of each test (with the exception of the max $\dot{V}O_2$ cycle ergometer test) finger tip blood samples will be collected from the subject to determine lactate concentration.

I have heard 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 voluntary consent to the procedure designated in the first paragraph.

Signature:________________