University of Alberta

Validation of an Intermittent Sprint Cycle Test for Female Hockey Players

by

Kier R. Wilson ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment for the requirements for the degree of Master of Science

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11431 37A Ave,
Edmonton, Alberta
T6J 0J6

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled, Validation of an Intermittent Sprint Cycle Test for Female Hockey Players, submitted by Kier R. Wilson in partial fulfillment of the requirements for the degree of Master of Science.

Dr. G. Bell

Dr. H. A. Quinney

Dr. D. Voaklander

Dedication

This thesis is dedicated to my dog Lucious.

Lucious,

Sitting with me at the computer for hours on end and listening to all my complaints couldn't have been easy, yet you never complained.

Thank-You.

Abstract

The purpose of this investigation was to validate a hockey specific laboratory and on-ice test that could be utilized to examine anaerobic fitness both off and on the ice. The subjects were active female varsity ice hockey players from the University of Alberta Panda's ice hockey program in Edmonton, Alberta. An on-ice skating test, a 30 second Wingate Anaerobic Test, and an intermittent anaerobic cycle test were completed. Significant correlations were found between the time obtained from the on-ice test and both the intermittent sprint cycle test and the 30 second Wingate Anaerobic Test. The intermittent sprint cycle test and the on-ice test were both found to be reliable in determining anaerobic power and skating speed, respectively. No significant difference and a significant correlation were found between the peak power output obtained from the intermittent sprint cycle test and the peak power output from the 30 second Wingate Anaerobic Test.

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Chapter 1

Introduction

The sport of hockey can be described as one of intermittent anaerobic activity consisting of short sprints, quick turns and explosive starts (Blatherwick, 1994). Depending on the position played, personal skill, and level of play, athletes are required to perform an average of 15 - 28 total minutes over the course of a game, with a typical shift lasting an average of 85.4 seconds (Green, et al., 1976). Time-motion analysis is a technique used to estimate the intensity and determine the duration of a given activity (Wilkins et al., 1991) and has indicated that five to seven intervals of two to three and a half seconds of maximal exertion are performed per shift in hockey (Thoden and Jette, 1975). It is also common to have an all-out race to the puck followed by an extended period of lower intensity skating and/or coasting. This scenario is repeated shift after shift for the duration of the game.

The source of energy for muscular work varies in the sport of ice hockey. The extent to which the aerobic and anaerobic energy systems are utilized is dependent on the duration and intensity of the activity (Green, 1979). The aerobic energy system is primarily responsible for supplying energy for low to moderate intensity activities and assisting with recovery. Anaerobic energy systems, specifically the high energy phosphates including adenosine triphosphate (ATP) and creatine phosphate (CP), are responsible for supplying the majority of energy during the two to three second bouts of all-out exertion found in the sport of ice hockey (Twist, 1993). The provision of energy for quick, explosive movements such as racing for the puck, sharp turns, and body checking are also predominantly supplied through a combination of high energy phosphates and glycolysis (Twist, 1993). The length of time between high intensity exercise determines the extent to which the ATP-PC system recovers in terms of providing the necessary energy for the next sprint. If the time between maximal bursts is short, the glycolytic system becomes increasingly involved in order to provide the required energy. Studies have demonstrated that the rate at which anaerobic glycolysis peaks was approximately 30-40 seconds and this system can predominantly supply energy for 120-180 seconds (Jacobs et al., 1982).

Fitness testing of hockey players is important to provide coaches and trainers with an indication of the current fitness levels of their players, monitor fitness levels throughout the season and to indicate the effectiveness of training programs. Fitness tests to evaluate the anaerobic system are intended to measure the power and/or capacity of both the components of the anaerobic energy systems. Due to the physical demands of ice hockey, the regeneration of ATP through these two energy systems is invaluable (Fox et al., 1969). In order to determine a hockey players' current level of anaerobic fitness, for comparison with previous results and for comparison to their peers, the testing protocol utilized should be as sport and task specific as possible (Macdougall et al., 1991; Inbar et al., 1996). On-ice tests or field tests (Reed et al., 1979; Watson and Sargeant, 1986) may be sport specific and practical but unfortunately are not always valid due to lack of internal control. Therefore, the development of a valid and reliable laboratory test is extremely important.

Some of the laboratory based anaerobic tests may not adequately duplicate the physiological demands of ice hockey. For example, the traditional Wingate Anaerobic Test performed by many elite ice hockey players requires the athlete to cycle maximally for a period of 30 seconds (Bar-Or et al, 1977). Although this test has been validated as an accurate indication of anaerobic fitness, the 30 second work bout is too long to be considered a reasonably ice hockey specific test. The power output decline on the ice during a typical game will not necessarily be as great as that observed with the 30 second Wingate test due to the relatively short and intermittent nature of the high intensity bursts of skating throughout a typical game. The 30 second Wingate provides only one indication of peak power immediately following the initiation of the test. An intermittent anaerobic cycle test of shorter duration separated by a defined recovery period similar to what occurs in a typical game would allow a more sport specific assessment. A five second test bout assesses the maximal rate at which ATP and CP can be utilized and encloses the time spent sprinting on ice as evidenced by time motion analysis (Thoden and Jette, 1975). Recovery periods between each 5 second test bout of 10-12 seconds would be a reasonable approximation of the intermittent on-ice activities (Thoden and Jette, 1975). Furthermore, a repeated sprint test protocol involving a minimum of four sprints separated by appropriate recovery periods would mimic on ice game activities; can be accurately measured using conventional laboratory equipment; and, stress the related energy systems within skeletal muscle. The repeated nature of this type of test would also be useful to measure the decline in power output throughout the test that would be similar to game conditions. The power output during each repeated shorter bout of exercise is indicative of the athlete's ability to recover during the recovery periods of lower intensity cycling. The information obtained from such a test protocol would also be useful when determining optimum shift length and individual training protocols.

Cycle ergometers have been demonstrated to be a valid and reliable means of assessing skating fitness (MacDougall et al., 1991; Cox et al., 1995). Cycling utilizes the same primary muscle groups as the skating movement and cycle ergometers are a valid means of determining power output. Skating ergometers that are capable of quantifying measured power output are not currently available (Montgomery, 1988). Furthermore, a large collection of cycle ergometer data exists and is available for comparison (Quinney, 1990).

Hypothesis

It was hypothesized that there would be a significant, positive relationship between peak power obtained through the intermittent sprint cycle test and sprint times obtained through the on-ice test, as well as a significant positive correlation with between power output and sprint time drop-off over the repeated trials of both tests. It was also hypothesized that power output and power output drop-off obtained through the intermittent sprint cycle test and peak power output and peak power output drop-off obtained through the 30 second Wingate test would also be significantly correlated.

Purpose

The purpose of this study was to examine the validity and reliability of a sport-specific intermittent anaerobic cycle test for female ice hockey players, and to examine the reliability of an on-ice test used to examine the validity of the intermittent sprint cycle test.

Research Questions

Research to date has led to the following research questions: 1) Will peak 5 second anaerobic power output and peak drop-off values obtained from the proposed intermittent test correlate with the peak 5 second power output and power output decline obtained with the traditional Wingate test? 2) Will the 5 second power outputs and power decline over the repeated sprints of the intermittent anaerobic cycle test correlate with on-ice skating sprint time and sprint time decline over the seven sprint trials simulating game conditions?

Definitions

From Foss and Keteyian, 1997.

Glycolysis

Metabolic pathway that breaks down a molecule of glucose to two molecules of pyruvic acid (aerobically) or two molecules of lactic acid (anaerobically).

Glycogenolysis

Breakdown of stored glycogen to glucose initiating glycolysis as described above.

Aerobic metabolism

Energy provision derived from the oxidation of carbohydrate, fat or protein dependent on oxygen utilization.

Anaerobic metabolism

Energy provision from the breakdown of glucose or glycogen to lactic acid.

Aadenosine triphosphate (ATP)

Major molecule that transfers energy from metabolism to cell functions including muscle contraction during its hydrolysis to adenosine diphosphate and inorganic phosphate.

Creatine phosphate (CP)

Molecule that when hydrolyzed, releases energy used to transfer a phosphate to ADP for the generation of ATP.

Time motion analysis

Observation of an event in order to determine the movement demands on the athletes (Wilkins et al., 1991).

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Chapter 2

Review of Literature

Demands of Ice Hockey

The majority of activity in ice hockey has been reported as intermittent in nature (Carroll, T., R. et al., 1993). Work intensity and duration as well as recovery duration vary from shift to shift within any given period in a game and between games (Green et al. 1976). Time-motion analysis performed by Green et al. (1976) indicated that playing time over the course of a total game averaged between 20.7 minutes and 28 minutes for centermen and defensemen, respectively. Most research suggests that total playing time was between 15 and 28 minutes (Thoden and Jette, 1975; Montgomery, 1988; Cox et al, 1995; Green, 1976). The duration of each shift ranged from 81-88 seconds. Similar observations have been made by Cox et al., 1995; Leger, 1980 and Thoden and Jette (1975) while Montgomery (1988) suggests that the typical shift averages 40 seconds. Thoden and Jette (1975) also observed that within each shift, players averaged 5-7 intense sprints ranging from 2 to 3.5 seconds, followed by 10 to 12 seconds skating at a lower intensity. Dillman et al, (1984) observed similar sprint durations.

Ice hockey has been characterised as a quick, explosive sport with many short high intensity sprints of activity followed by varying amounts of recovery (Quinney, 1990; Blatherwick, 1994). The physiological demands of ice hockey are not limited to a single energy system (Cox et al., 1995; Montgomery, 1988; Twist, 1997). The ATP-PC system, the anaerobic lactic acid system and the aerobic system all play a major role in ice hockey performance.

Energy Systems Used in Ice Hockey

The aerobic energy system primarily functions to supply energy for low to moderate intensity activities not exceeding VO2max and to provide energy for recovery between periods of the game and during extended breaks between shifts in ice hockey (Thoden and Jette, 1975; Twist, 1997). The aerobic energy system may provide approximately 60% of the ATP during moderate exercise (McArdle, Katch and Katch, 1985; Twist and Rhodes, 1993). The aerobic energy system is predominately utilized when the intensity of the activity is at a level where the resynthesis of ATP occurs in the presence of oxygen (MacDougall et al., 1991). While the aerobic energy system is important for hockey and contributes to energy supply up to a maximal aerobic utilization intensity, the majority of work performed during a game derives its energy from the anaerobic energy systems (Twist, 1997).

Heart rate can be used as an indication of the intensity of effort relying on the aerobic energy system (McArdle, Katch and Katch, 1985; Montgomery, 1988). On-ice heart rates have been estimated to be between 85 and 90% (Twist, 1993b); or an average of 92.3% (Paterson, 1977), 78.3% (Wilson and Hedberg, 1976) and 72.5% (Seliger et al., 1972) of maximum, even during the interval of time between bursts of intense exertion. Heart rates have been shown to remain elevated even with stoppages in play ranging from 25-30 seconds (Twist, 1993b). As well, heart rates were observed to be greater than 120 beats per minute prior to the start of play due to anticipation, the effect of catecholamine and psychological stress (Green et al., 1976).

As the intensity of the activity increases, the demand for energy can no longer be met by the aerobic energy system. Therefore, it is essential that the anaerobic system ensures adequate energy supply (Green, 1987). The anaerobic energy system is composed of two separate pathways of ATP production: the anaerobic alactic, ATP-PC or high-energy phosphate system and glycolysis/glycogenolysis or the anaerobic lactic acid system. The anaerobic alactic energy system utilizes localized stores of adenosine triphosphate (ATP) and creatine phosphate (CP) in order to provide the necessary energy. This system is limited to very short duration activities. During anaerobic glycolysis, muscle glycogen stores are the primary substrate and the end product is lactic acid and some ATP resynthesis (Hochachka, 1994). The anaerobic lactic acid system can predominately provide energy for activities lasting 2 (McArdle et al, 1986) to 3 (Jacobs et al., 1982) minutes. It is important to understand that all three energy systems work in concert under complex regulatory mechanisms to provide energy to support cellular work. The intensity and duration of the activity determine the extent to which each energy system is involved (Twist, 1997).

The work performed by an athlete throughout a hockey game can be highly dependent on the two anaerobic energy systems (Twist, 1993). The anaerobic energy supply involves two independent, but overlapping, energy systems (Vanderwalle et al., 1987). During high intensity exercise performed in hockey, the immediate source of energy is derived from the anaerobic alactic system due to the localized stores of ATP and CP in the muscle. Maximal, short duration exercise is dependent on the high energy phosphate or anaerobic alactic system (De Bruyn-Prevost, 1980). Peak energy production occurs in less than 3-5 seconds, and has a capacity estimated between 10 and 20 seconds (Skinner and Morgan, 1985). The anaerobic alactic energy system provides a greater power output than any other energy system (Hochachka, 1994). Therefore, this system is the predominant energy source for the quick, high intensity bursts that characterize ice hockey(Hollering and Simpson, 1977). Unfortunately, muscle is only able to store minimal amounts, 30-50 umol/g of the phosphagens and can only provide energy for 2-5 seconds (Hochachka, 1994) or possibly up to 10 seconds (Skinner et al., 1985) of maximal effort. With rest between shifts averaging 3-4 minutes or slightly less for defensemen (Green, 1976), the anaerobic alactic energy system may not recover completely between shifts. This is because this system requires between 4 to 5 minutes (Green, 1987), or possibly up to 10 full minutes (Fry, 1995) to completely recover once fully depleted.

Providing ATP for continued exercise of high intensity, lasting longer than ten seconds and when the anaerobic alactic system is depleted, becomes the responsibility of glycolysis/glycogenolysis which has been termed the anaerobic lactic acid system (Skinner and Morgan, 1985). With continuous play averaging 30 seconds, the ATP necessary for high intensity exercise between maximal bouts must be supplied by the lactic acid system. The lactic acid system has been shown to be the main source of energy for events lasting up to 45 seconds (Skinner and Morgan, 1985), 60 seconds (Craig et al, 1989), 120 seconds (Medbo et al., 1988), and even up to 180 seconds (Jacobs et al., 1982). Therefore, a typical shift in ice hockey will require the athlete to perform the high intensity aspects of the game relying primarily on the power and capacity of the two anaerobic energy systems. As the intensity of the play increases and the sprints shorten the athlete's energy requirements rely more and more on the high energy phosphate system and less on the lactic acid system (Skinner and Morgan, 1985). Performance will decrease if the intensity level remains at a maximum for an extended period of time due to the depletion of high energy phosphates (Twist, 1997). Subsequently, relying on anaerobic glycolysis results in the accumulation of the end product of lactic acid and performance could be diminished due to muscle acidosis and its relationship to fatigue (Billeter and Hoppeler, 1992; Bertocci and Gollnick, 1985; Fabiato and Fabiato, 1978; Fuchs, Reddy and Briggs, 1970)

Defensemen utilize the high energy phosphate system during one-on-one confrontations and while sprinting after a puck in the corner, and utilize the lactic acid system extensively when the puck remains in the defensive zone for extended periods of time. This occurs, for example, when the team is killing a penalty. Forwards utilize the high energy phosphate system when breaking towards a pass, chasing a loose puck and fighting for the puck in the corners; and the lactic acid system during continuous forechecking and backchecking, as well as penalty killing (Twist, 1993b).

As with energy system specificity, muscle fibre types are recruited dependent on the nature of the activity. Fast twitch muscle fibres are activated in response to stimuli requiring explosive, powerful, high-intensity work bouts such as sprinting (Fox, Bowers and Foss, 1993). Fast twitch fibres, in relation to the predominantly aerobic slow twitch fibres, contain greater concentrations of phosphocreatine, glycogen and anaerobic enzymes, have faster neural and functional responses and possess favorable structural adaptations in order to provide quick, powerful muscle action (Plowman and Smith, 1997).

Anaerobic Tests

Anaerobic tests for power and capacity are important for athletes involved in sports like ice hockey, where the condition of these energy systems are crucial for performance (MacDougall et al., 1991; Snyder and Foster, 1994). The purpose of any anaerobic test is to provide an indication of the maximal power and/or capacity of the anaerobic energy systems that the test is attempting to evaluate/assess. Maximum power is an indication of the highest power output an athlete can produce. With about 5 to 8 umol of ATP per gram of fast twitch muscle, it is estimated that the greatest rate of muscular power output occurs between 1 and 3 seconds with ATP depletion, or capacity, occuring in less than 5 seconds (Hochachka, 1994). Capacity is representative of the amount of time that the anaerobic energy system can effectively remain the primary source of ATP (Green and Dawson, 1993).

Existing anaerobic tests all involve high intensity exercise or maximal, "all out" effort of various duration (Skinner and Morgan, 1985). The duration of high intensity bouts determines the specificity of the test with respect to both the energy system utilized and individual task. Ideally, the anaerobic test utilized would be sport specific in time, intensity and mode (Manning et al., 1998 ; Macdougall et al., 1991). The validity and reliability of many of these tests has been reviewed (Vandewalle et al., 1987).

Vandewalle et al. (1987) described five key points that affect the validity of maximal anaerobic power tests. First the results of anaerobic tests are highly dependent on the motivation of the subjects. Knowledge of the results of a previous trial, team requirements and verbal encouragement are all motivational factors affecting power output (Geron and Inbar, 1980). Maximal anaerobic power output requires an optimal resistance to obtain a maximal value. It has been recommended that for adult athletes a force of .095 kp/kg (Evans and Quinney, 1981) - .100 kp/kg (Bar-Or, 1987) of bodymass be utilized for cycle ergometer testing of 30 seconds in duration. Third, mean power is evaluated instead of instantaneous power. Tests using friction loaded cycle ergometers utilize mean forces and velocities and not instantaneous values as can be obtained with a force platform. As the duration of the test increases, even marginally, power output rapidly decreases (Wilkie, 1960; Davies, 1971). Therefore, power output measured during certain portions of anaerobic tests may be at a time when muscular power is no longer maximal. Finally, the inertia of the flywheel and body limbs are not taken into account which will result in a slightly inflated power output.

Anaerobic tests are designed to measure the rate of anaerobic energy provision or the capacity of an athlete. The validity of the specific test must be examined both internally and externally. The internal validity of a test is an indication of how accurately the test is measuring the concept it is intending to measure (Slife and Williams, 1995; Kaplan and Saccuzzo, 1997). As well, the inference the researcher is making from the test must be validated. External validity of a test refers to how well the test can be generalized to the intended population (Agnew and Pyke, 1994). Limited external validity has been the major problem with existing laboratory anaerobic tests that are applied to specific sports, including those utilized in ice hockey (Smith et al., 1980). Many of the standard anaerobic tests have shown internal validity (Vandewalle et al, 1987), but do not give a representative indication of anaerobic power and capacity specific to the sport of ice hockey and the physical demands on the ice hockey player.

Existing On-Ice Test Protocols

The Reed Repeat Sprint Skate (RSS) and the Sargeant Anaerobic Skate (SAS40) have been utilized in an attempt to determine anaerobic power and capacity in ice hockey players (Watson and Sargeant, 1986). For the RSS the subject sprinted from goal line to goal line (54.9 metres) where sprint time was recorded. Immediately upon reaching the far goal line the subject changed directions and sprinted back to the blue line closest the starting line. There a total length skate (90.4 metres) time was recorded. The subject repeated this procedure every 30 seconds for a total of six repetitions.

In the SAS40, pylons were placed at 6.1 metre (20 feet) intervals along the length of the ice. The subject sprinted from the first to the last pilon, reversing directions at each end, continuously for 40 seconds. The tester sounded a whistle at 5, 10, 30 and 35 seconds. Markers recorded the position of the support skate at each of the whistle blasts and at the completion of the 40 seconds.

While power measures have been obtained from both these existing on-ice tests the continuous duration of the SAS40 and the extended length of the sprint intervals of the RSS do not concur with observed time-motion analyses of the sport of ice hockey. However, both tests have been used to indicate the anaerobic skating ability of ice hockey players.

In attempt to circumvent sprint lengths and durations which may not be representative of what would occur during a typical game of ice hockey, pilot research was performed at the University of Alberta. This pilot research suggests that a series of skating sprints of 15 metres followed by active recovery back to the starting point would more closely replicate the demands of an actual ice hockey shift. The 15 metre sprint should require 2-4 seconds to complete, allowing the subjects an average of 12 seconds to circle back to the start line and set up for the next sprint. An on-ice test designed around this pilot research and time-motion analysis of the sport of ice hockey could enhance the sport specific nature of testing and should aid in the development of an ice hockey specific sprint cycle testing protocol for the laboratory.

Reliability and Validity

Reliability refers to the effectiveness in reproducing the same results from the same test. Consistency of the data, often determined by test/re-test, is an indication of the reliability of a given test (Vincent, 1995). For example, an athlete should get the same score from the intermittent cycle test on successive tests provided that there was no change in the athlete's actual anaerobic power or capacity between the two tests. The test must also be able to be replicated by other researchers and result in similar findings and interpretations. A test which minimizes measurement error can be thought of as reliable (Kaplan and Saccuzzo, 1997). When attempting to validate and assess the reliability of an anaerobic test, it is usual convention to compare it to the criterion standard test (Bar-Or, 1987). In the context of elite ice hockey, the most often used anaerobic test in ice hockey testing is the 30 second Wingate test as described by Bar-Or, (1977), which is arguably the criterion test of anaerobic fitness.

Laboratory tests and field tests each have advantages and disadvantages. A laboratory test is ideal because of it's stringent control over internal validity. Most variables can be controlled to minimize the chances of any other factors compounding the effects of the test (MacDougall et al., 1991). Cycle ergometer load and pedaling cadence can be controlled, monitored and accurately measured. The testers are in control of the sprint and recovery intervals. The obvious drawback of many laboratory tests is the sometimes limited external validity. For example, power is necessary on the ice to overcome friction and air resistance, and to support body weight. In the laboratory, on a cycle ergometer, body weight is supported by the bike and muscle activation and patterns differ from cycling to skating (Kumamoto et al. 1972; Mashima et al., 1972; Toyoda et al, 1965; Watson and Sargeant, 1986). Field tests are less internally valid due to the lack of control over such factors as ice conditions, skate sharpness and use of equipment. As well, the researcher has less control over the exact skating speed and interval times of the athlete. They are, however, high in external validity because of their ability to be designed specific to the event or sport (MacDougall et al., 1991).

Summary

Performance in the sport of ice hockey depends on fuel utilization from specific energy systems. This energy system specificity, as well as specificity of muscle groups used and speed of muscular contraction, needs to be replicated during laboratory and on-ice testing conditions. Existing testing protocols may be inadequate at measuring these specific energy systems as they relate to sport specific requirements. Based on the demands of ice hockey, information is available that will allow more sport specific protocols to be designed for both laboratory and field testing situations. As well, there is a lack of information regarding the anaerobic abilities of female ice hockey players.

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Chapter 3

Validation of an Intermittent Sprint Cycle Test for Female Ice Hockey Players

Introduction

The sport of ice hockey is predominately an intermittent, anaerobic activity consisting of short sprints, quick turns and explosive starts as well as other less dominant fitness components (Blatherwick, 1994). Five to seven intervals of two to three and a half seconds of maximal exertion are usually performed per shift in hockey and it is common to have an all-out race to the puck followed by an extended period of lower intensity skating and/or coasting. This scenario is repeated shift after shift for the duration of the game.

Physiological testing of ice hockey players is important to provide coaches and trainers with an indication of the current fitness levels of their players, monitor changes throughout the season and to indicate the effectiveness of training programs. Fitness tests to evaluate the anaerobic system are intended to measure the power and/or capacity of both the components of the anaerobic energy systems. Due to the physical demands of ice hockey, the regeneration of ATP through these two energy systems is invaluable

(Fox et al., 1969). In order to determine an ice hockey players' current level of anaerobic fitness, for comparison with previous results and for comparison to their peers, the testing protocol utilized should be as sport and task specific as possible (Macdougall et al., 1991; Inbar et al., 1996). Therefore, the development of valid and reliable laboratory and field tests is extremely important. An intermittent anaerobic sprint cycle test and matching on-ice protocol consisting of short duration sprints separated by a defined recovery period, similar to that which occurs in a typical game of ice hockey, would allow for a more complete sport specific assessment of the hockey player.

The purpose of this study was to examine the validity and reliability of a sport-specific intermittent anaerobic test for ice hockey players. It was hypothesized that peak 5 second anaerobic power output and peak drop-off values obtained from the proposed intermittent laboratory test would correlate positively with the peak 5 second power output and power output decline obtained with the traditional Wingate test. As well, the 5 second power outputs and power decline over the repeated sprints of the intermittent anaerobic cycle test would also correlate with on-ice skating sprint time and the decline in sprint time over the repeated sprint trials that simulate game conditions.

Methods

Subjects

The subjects were 19 active female varsity hockey players from the University of Alberta Panda's ice hockey program in Edmonton, Alberta. Subjects were injury free and in good health as determined through a questionnaire completed by all participants. All subjects completed an informed consent form and the study was approved by the Faculty of Physical Education and Recreation Ethics Committee.

Experimental Design

A complete fitness assessment consisting of body composition, flexibility, muscular endurance, grip strength, vertical jump, and maximal oxygen consumption was completed in this order to obtain descriptive data. In addition, the on-ice skating test (4 repeats), a 30 second Wingate Anaerobic Test, and the intermittent anaerobic cycle test (3 repeats) were performed by all subjects.

Descriptive Tests

The body composition protocol consisted of 6 skinfolds measurements obtained utilizing Harpenden-like calipers following the protocol as described by the Canadian Physical Activity, Fitness and Lifestyle

Appraisal Manual (Canadian Society for Exercise Physiology, 1996). Two measurements were taken at each site. The values were required to be within .4 millimetre of each other or a third trial was done and the mean of the two closest measures was used. Results were recorded to the nearest millimeter and percent bodyfat was estimated using the Yuhasz formula:
Percent Fat = (sum of 6 skinfolds x 0.097) + 3.64 (Yuhasz, 1966).

A 30 second Wingate Anaerobic Test was performed as outlined by Inbar, Bar-Or and Skinner, (1996), on a cycle ergometer adapted for such testing (Sommerville and Quinney, 1981) modified for resistance setting (Evans and Quinney, 1981). The subjects were permitted to warm up for a period of five minutes on a cycle ergometer alternating between 30 seconds at 100 revolutions per minute and 30 seconds at 60 rpm, equivalent to an intensity of 150 Watts for both. This warm-up protocol was found to be best suited for optimal performance for aerobically fit subjects (Inbar and Bar-Or, 1975; McKenna et al., 1987; Hawley et al., 1989). After a brief period of stretching, the subject cycled for two minutes at 70 revolutions per minute at a resistance setting of 1.5 kiloponds (kp; 100 watts), with one customization trial of 1-2 seconds at a load of 0.095 kp/kg of bodymass occurring within the first 15 seconds of the two minute warm-up. At the testers verbal signal, the subjects began pedaling faster followed by a command to pedal as fast as possible. At top speed a resistance equivalent to 0.095 kp/kg was applied to the cycle ergometer. The subjects were required to pedal as quickly as possible for 30 seconds. Verbal encouragement was provided by instructors and assistants for all subjects in order to standardize external motivation. Conserving energy in order to finish hard was strongly discouraged as this would impact negatively on the results of the test. At the completion of the test the subjects were instructed to continue easy pedaling for a period of at least 10 minutes. The 30 second Wingate Anaerobic Test provided peak 5 second and mean 30 second power output (watts) and displayed power output drop-off [(peak power - mean power) / peak power * 100]. The data from each anaerobic cycle test was captured and reduced using a custom designed software package interfaced with the cycle ergometer.

Flexibility was assessed using a sit and reach protocol on a modified Dillon and Wells flexometer as described by the Canadian Physical Activity, Fitness and Lifestyle Appraisal Manual (Canadian Society for Exercise Physiology, 1996). The subjects were instructed to sit with feet shoulder width resting against the apparatus. Placing one hand on top of the other the subject slowly pushed the slide along the flexometer as far as possible while exhaling and maintaining straight knees. The subjects were given two separate trials with the best score recorded to the nearest centimeter (Canadian Society for Exercise

Physiology, 1996). Muscular endurance of the abdominal muscle group was assessed with a curl-up protocol as reported by Quinney et al., (1984). The subjects were required to lie prone with knees placed at 90 degrees and with hands behind head. The subjects were required to curl-up until the elbows touch the thigh and return until shoulder blades touch the mat. The subjects performed as many curlups as possible up to a maximum to 100 using a cadence of 50 beats per minute set by a metronome (25 curlups per minute).

Grip strength was assessed with the use of a hand dynamometer (Almedic, Montreal), following the protocol designated by the Canadian Physical Activity, Fitness and Lifestyle Appraisal Manual (Canadian Society for Exercise Physiology, 1996). The subjects were given two trials on each hand, with the highest values being recorded and added together to produce a combined score in kilograms.

Vertical jump was measured as a comparison between maximal reach height and maximal jump height (Canadian Physical Activity, Fitness and Lifestyle Appraisal Manual) (Canadian Society for Exercise Physiology, 1996). The subjects were required to stand with dominant side to the wall and reach as high as possible without raising onto the toes, this point was marked on the wall. The subjects were given three trials to jump, from a standing start, and touch as high as possible on the wall. Felt marker was applied to the finger tips in order to mark height position on the wall. The best result (height jumped - standing reach) was used as vertical jump.

The VO_2max cycle ergometer testing protocol followed the procedures previously outlined (Bell et al., 1997) with the exception that 2 minute power output increments were used. Briefly, the subjects were instructed to maintain a cadence of 70rpm at an initial power output of 137 watts followed by a 30 watt increase every 2 minutes until ventilation threshold was estimated as the lowest point followed by a systematic increase in the ratio of VE/VCO2 (Bhambhani and Singh, 1985). Subsequently, the power output was increased by 30 watts every minute until volitional exhaustion. Gas exchange was monitored using a Horizon metabolic measurement cart (Sensormedics, California). The criteria for VO_2max was a peak or plateau (< 100 ml per minute change) with increasing power output. Other criteria for achieving VO_2max were a respiratory exchange ratio in excess of 1.1 and achievement of an age-predicted or known maximum heart rate determined on a Polar Pacer heart rate monitor (Polar Canada, Quebec).

Intermittent Anaerobic Cycle Test

The intermittent anaerobic test was performed on the same modified Monark cycle ergometer using the same computer interface system utilized during the 30 second Wingate. Each subject performed four sets of five second all-out sprints at a resistance setting of 0.095 kp per kilogram of bodymass, followed by 10 seconds of recovery cycling at 60 to 80 revolutions per second at a resistance of 1.5 kp resulting in a power output of approximately 150 Watts. The resistance setting of 0.095 kp per kilogram was estimated based on research performed by Evans and Quinney, (1981) and Dotan and Bar-Or, (1983) as well as recommendations from Inbar et al., (1996). Warm-up and cool-down were identical to that described for the 30 second Wingate test above. At the signal to pedal faster, and then as fast as possible the subjects should have attempted to reach maximum pedaling speed. Once at maximum speed, a load equivalent to 0.095 kp per kilogram was applied to the Monark cycle ergometer and a second tester was instructed to start the test clock. The subjects were required to pedal as fast as possible for five seconds at which time the tester monitoring the time instructed the first tester to release the load and allow the subjects to pedal at a rate of 50 revolutions per minute and a resistance setting of 1.5 kp resulting in a power output of approximately 75 watts. The tester monitoring the time gave the signals to begin pedaling faster and then "all out". The first tester then re-applied the load so that once the subject has achieved top speed the load was present. This procedure was repeated two additional times resulting in a total of four sprint intervals in 60 seconds. Verbal encouragement was consistently provided for each subject. The intermittent anaerobic test was repeated on two separate occasions, (for a total of three tests), to examine test reliability. Reliability was calculated using the results from all three intermittent anaerobic cycle tests. Power output averaged over 5 seconds was obtained from each sprint interval throughout the test. As well, power output drop-off from interval to interval was calculated.

On-Ice Test

An on-ice skating test was performed for the purpose of measuring skating acceleration and speed, as well as the decline in acceleration and speed over repeated trials. The test began with a standing start followed by a 15 metre sprint at maximal speed. Sprint time at five, ten, and 15 metres was recorded with the use of a custom designed electronic light timing system. There was an average of twelve seconds immediately following the completion of their sprint to circle back to the start line and get set for the next sprint. Each sprint and recovery interval required 15 seconds to complete. The subjects performed a total of seven sprints in an attempt to simulate game-like conditions (Thoden and Jette, 1975). Skating times were recorded over the 0-5 metre, 5-10 metre and 0-15 metre distances and skating times over the 10-15 metre and 0-10 metre distances were calculated from the 3 recorded distances. Percentage drop-off over the four trials was calculated by subtracting skating times from sprint 1 from skating times recorded from sprint 7, then dividing the difference by the sprint times from sprint 1 and multiplying the dividend by 100 ((sp7-sp1)/sp1*100). The on-ice test was performed two times per testing session, and on two separate days (four tests in all). Reliability of the on-ice test was calculated from the results obtained from all four tests.

Statistical Analyses

A repeated measures one way ANOVA (Vincent, 1995) was performed to determine the presence of significant differences between both trials for the on-ice test and the intermittent anaerobic test. An intraclass coefficient was calculated from the ANOVA to assess the test - retest reliability of the two tests ((mean square between - mean square within) / (mean square between + mean square within)) (Maguire and Hazlett, 1969). A Pearson's product moment correlation coefficient (Vincent, 1995) matrix was generated to determine the relationship between the intermittent anaerobic cycle test, on-ice test and the 30 second Wingate test. Alpha was preset at $P < 0.05$.

Results

Descriptive data (Table 3-1)

The mean age of the subjects was 24 years with a mean weight of 61.7 kilograms and average height of 166.2 centimeters. Mean sum of the six skinfolds was 110.4 millimetres resulting in a mean percent bodyfat of 19.5 percent and the subjects had mean trunk flexion of 46 centimetres and mean vertical jump of 46 centimeters. A mean of 77 kilograms was measured for combined (left and right) grip strength and the subjects completed a mean of 23 curl-ups. The subjects had a mean relative vo_{2MAX} of 48.0 ml/kg/min and had a mean absolute maximal oxygen uptake of 2.95 liters per minute with a mean maximum heart rate of 190 beats per minute.

Validity of the on-ice test (Table 3-2)

Using Pearson's product moment correlation coefficient, the 5-10 metre, 10-15 metre and the 0-15 metre intervals of the on-ice test significantly correlated with peak relative 5 second power output from the 30 second Wingate ($r = .683$, $r = .664$, $r = .473$, $p < .05$), respectively. No distance interval of the on-ice test significantly correlated with peak absolute 5 second power output from the 30 second Wingate.

Validity of the Intermittent Sprint Cycle Test (Table 3-3)

Peak 5 second power output from the intermittent sprint cycle test was not statistically different from the peak 5 second power output obtained from the 30 second Wingate test. Absolute peak power output from the intermittent sprint cycle test was positively correlated with absolute peak power output from the 30 second Wingate test ($r = .911$, $p < .05$) and relative peak power output from the intermittent sprint cycle test was positively correlated with relative peak power output from the 30 second Wingate test ($r = .746$, $p < .05$). The percent drop-off in peak power output during the intermittent sprint cycle test was positively correlated with the percent drop-off in peak power output during the 30 second Wingate test ($r = .616$, $p < .05$).

Peak relative 5 second power output from the intermittent sprint cycle test was significantly correlated with sprint times over 5-10 metres ($r = .601$, $p < .05$), 10-15 metres ($r = .629$, $p < .05$) and 0-15 metres ($r = .491$, $p < .05$) from the on-ice test. Peak relative power output was not significantly correlated with any other distance interval of the on-ice test. Peak absolute power output from the intermittent sprint cycle test was not significantly correlated with any distance interval of the on-ice test.

The percent drop-off in peak 5 second power output from the first sprint of the intermittent sprint cycle test to the fourth did not significantly correlate with skating time drop-off from the first sprint of the on-ice test to the seventh over any distance interval.

Reliability of the on-ice test and the Intermittent Sprint Cycle Test (Table 3-4)

The sprint times of the on-ice test were reliable over all measured distances. (0 to 5 metre time ICC =.796; 5 to 10 metre time ICC =.963; 10 to 15 metre time ICC =.944; 0 to 15 metre time ICC =.952, $p < .05$). On-ice sprint time drop-offs were also reliable at the 10 to 15, and the 0 to 15 metre distances (ICC =.632 and ICC =.677, $p < .05$, respectively). On-ice sprint time drop-off over distances of 0 to 5 metres and 5 to 10 metres were not reliable (ICC =.436 and ICC =.288, $p < .05$, respectively).

The test / retest reliability of peak 5 second power output and percent drop-off for the intermittent sprint cycle test was found to be significantly reliable (ICC = .994 and ICC= .901, respectively, $p < .05$).

Discussion

Descriptive Data

There is little available data on the fitness levels of female ice hockey players. However, fitness levels of athletes in other similar female sports such as ringette (Webster et al., 1999, see Table 3-1) may be used for comparative purposes. Webster (et al., 1999) has published fitness indices of the Canadian National Ringette team recently, and despite differences in the nature of the two sports, they are similar in many respects. It is interesting to note that age and body composition of both groups were similar (Table 3-1). Indicators of flexibility and aerobic fitness were also very similar between the two teams. The largest difference between the National Ringette team and the Pandas varsity hockey team were illustrated in anaerobic power. Peak absolute and relative anaerobic power output values from the 30 second Wingate test were considerably higher for the National Ringette team. Power output drop-off from the 30 second Wingate test was also higher for the National Ringette team which was likely due to higher peak power output values by the latter group. Despite the larger drop-off among the ringette team, mean power output over the 30 second Wingate test was similar for both groups. Overall, the fitness results reported by Webster et al., (1999) show remarkable similarity to the varsity hockey players and also suggest that the hockey players may benefit from further development of anaerobic fitness. However, the difference in anaerobic fitness between the two sports may also indicate a difference in the nature of the game and may not reflect a limitation in anaerobic power output of female hockey players.

On-Ice Test Validity

The validity of the on-ice test is based on the review of time-motion analyses from previous research (Green et al, 1976). The important validation determined through this experiment was whether sprint time over the 15 metre distance, or a portion of the 15 metre distance, would be a valid indication of peak power as assessed by the 30 second Wingate test. The on-ice test sprint times over the 5-10 metre, the 10-15 metre and the 0-15 metre distances correlated highly with peak 5 second power output from the 30 second Wingate test when the power outputs were expressed relative to the subject's bodyweight. These findings indicate that the on-ice test is a valid indicator of skating power once the variability in technique due to acceleration from a complete stop is corrected (at the 5 metre distance). Since skating is a weight bearing event it was anticipated that the relative measure of peak power from the 30 second Wingate test would be more skating specific than the absolute value. It can be concluded that sprint times obtained from the on-ice test are valid indicators of anaerobic power in female ice hockey players. Elimination of the first 5 metres from the analysis improved the validity of the on-ice test.

Intermittent Sprint Cycle Test Validity

The validity of the intermittent sprint cycle test was based on 1) the observation of no significant difference between peak power output obtained from the intermittent sprint cycle test and the peak power output obtained from the 30 second Wingate Anaerobic Test, and 2) a significant correlation between the peak power output observed in the intermittent sprint cycle test and skating speed observed during the on-ice test. In addition, a significant correlation between the percent drop-off in peak power output over the 4 five second sprints in the intermittent sprint cycle test and skating time drop-off over the 7 fifteen metre skating sprints during the on-ice test would support validity of percent drop-off values obtained.

The protocol utilized to determine peak 5 second power was identical over the first 5 seconds of both the intermittent sprint cycle test and the Wingate Anaerobic Tests. As hypothesized, the peak 5 second power output from the intermittent sprint cycle test was not significantly different than peak 5 second power output from the 30 second Wingate Anaerobic Test. In addition, power output from the intermittent sprint cycle test correlated strongly with the peak power output from the 30 second Wingate Anaerobic Test. It can be concluded that the intermittent sprint cycle test was a valid test of peak 5 second anaerobic power.

The 5-10 metre, 10-15 metre and 0-15 metre distances of the 15 metre sprint were found to be valid measures of the subject's skating power as indicated by significant correlations with peak 5 second power output from the 30 second Wingate Anaerobic Test. Peak power output expressed relative to bodymass from the intermittent sprint cycle test was significantly correlated with the 5-10, 10-15 and 0-15 metre distances of the on-ice test. It is assumed that this is due to the weight bearing nature of the action of skating. The percent drop-off in peak power output over the four five second sprints of the intermittent sprint cycle test did not significantly correlate with skating time percent drop-off over any of the examined distances, but did significantly correlate with power output drop-off over the 30 second Wingate Anaerobic Test. Thus the present study provides evidence to indicate that the intermittent sprint cycle test was a valid indicator of anaerobic performance specific to the sport of hockey and can be utilized as a valid laboratory test. It can be argued that the drop-off values from the intermittent sprint cycle test do indicate a drop in power output due to fatigue which is similar in response compared to other laboratory anaerobic cycle tests such as the Wingate Anaerobic Test, but it may be different from the type of fatigue induced drop in sprint time observed on ice. This is probably due to a difference in time of work intervals and recovery intervals as well as the inherent difference comparing the exercise form of skating to that of cycling. As well, the fatigue induced by the on-ice skating test, although a maximal effort test, is not as severe as that experienced during the intermittent sprint cycle test.

On-Ice and Intermittent Sprint Cycle Test Reliability

The on-ice test was found to be statistically reliable, as indicated by high intraclass correlation values, over the entire 15 metre distance as well as over each of the 5 metre intervals measured throughout the test. The initial 5 metre segment of the skating test showed a lower intraclass correlation when the test was repeated compared to other segments of the sprint test. This suggests a greater variability in skating technique during the acceleration phase of the sprints, and helps to explain the lack of validity observed for the initial phase of the on-ice sprint test and the lower intraclass correlation over the entire 15 metre distance. Skating sprint time drop-off was reliable over the 10-15 metre and entire 15 metre distances. Both peak 5 second power output and peak 5 second power output drop-off over the 4 five second sprints during the intermittent sprint cycle test were found to be reliable as indicated by high intraclass correlations.

In summary, The present study showed that the on-ice test and the intermittent sprint cycle test are valid and reliable measures of peak anaerobic power relative to the sport of ice hockey. The on-ice test was shown to be a valid indicator of skating power as indicated by high correlations with relative peak power output from the 30 second Wingate Anaerobic Test. Removal of the variability due to acceleration from a complete stop, exclusion of the results from the initial 5 metres of the 15 metre sprint, increased the validity of the on-ice test. The intermittent sprint cycle test was shown to be a valid indicator of ice hockey specific anaerobic power as indicated by significant correlations between peak power output from the intermittent sprint cycle test and skating times observed during the on-ice test.

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Tables

Table 3-1 Descriptive Data

	Panda Average	1996 Canadian Ringette Team (Webster et al., 1999)
AGE (Yrs)	21	20.6
BODY COMPOSITION		
WEIGHT (kg)	61.7	62.3
HEIGHT (cm)	166.2	165.9
SKINFOLDS (mm)		
SUBSCAPULAR	14.0	11.3
TRICEP	14.1	15.6
ILIAC CREST	16.6	19.7
ABDOMEN	16.5	16.4
FRONT THIGH	25.5	22.9
REAR THIGH	23.7	24.2
SUM	110.4	110.1
% BODYFAT	19.5	
ANAEROBIC POWER		
PEAK 5s (W)	592.4	773.5
MEAN 30s (W)	517.4	518.9
RELATIVE PEAK 5s (W/kg)	10.1	12.4
RELATIVE MEAN 30s (W/kg)	8.4	8.4
% DROP-OFF	35.7	52.9
FLEXIBILITY		
TRUNK FLEXION (cm)	40.5	40.7
MUSCULAR STRENGTH, POWER AMD ENDURANCE		
VERTICAL JUMP (cm)	40	
GRIP STRENGTH (kg)	77	63.6
CURL-UPS (#)	23	33.4
AEROBIC FITNESS		
VO2 ABSOLUTE (l/min)	2.95	2.98
VO2 RELATIVE (ml/kg/min)	48.0	47.0
MAX HEART RATE (bpm)	190	192

Table 3-2 On-Ice Validity

Sprint time validity	30 second Wingate peak absolute power output	30 second Wingate peak relative power output
Mean 0-5m sprint time	-0.1154	-0.0803
Mean 5-10m sprint time	-0.3590	-0.6826*
Mean 10-15m sprint time	-0.3755	-0.6640*
Mean 0-10m sprint time	-0.2326	-0.3374
Mean 0-15m sprint time	-0.2984	-0.4734*
	30 second Wingate drop-off	
Sprint time drop-off validity		
Mean 0-5m sprint time	0.0592	
Mean 5-10m sprint time	-0.3594	
Mean 10-15m sprint time	-0.1760	
Mean 0-10m sprint time	-0.1995	
Mean 0-15m sprint time	-0.1184	

*significant, p<.05

Table 3-3 Intermittent Sprint Cycle Test Validity

P.O. validity	30s Wingate absolute peak power	30s Wingate relative peak power	Mean on-ice 0-5m time	Mean on-ice 5-10m time	Mean on-ice 10-15m time	Mean on-ice 0-10m time	Mean on-ice 0-15m time
ISCT Peak po							
Mean Absolute	0.9106*	0.4741*	-0.1652	-0.2749	-0.3150	-0.2360	-0.2804
Mean Relative	0.5542*	0.7455*	-0.1766	-0.6010*	-0.6291*	-0.3769	-0.4906*
P.O. drop-off							
ISCT po drop-off validity	0.6162*	0.6162*	0.2731	0.1278	-0.2441	0.1677	0.0780

*significant, p<.05

Table 3-4 Intermittent Sprint Cycle Test and On-Ice Test Reliability

ISCT average peak 5s power-output	0.994*
ISCT average peak 5s power-output drop-off	0.901*
On-ice zero to five metre time	0.796*
On-ice five to ten metre time	0.963*
On-ice ten to fifteen metre time	0.944*
On-ice zero to fifteen metre time	0.952*
On-ice zero to five metre time drop-off	0.437
On-ice five to ten metre time drop-off	0.288
On-ice ten to fifteen metre time drop-off	0.632*
On-ice zero to fifteen metre time drop-off	0.678*

*significant, p<.05

Chapter 4

General Discussion

The purpose of this investigation was to validate hockey specific laboratory and on-ice tests which may be utilized to examine anaerobic fitness both off and on the ice.

The intermittent sprint cycle test and the on-ice test were both found to be highly reliable in determining anaerobic power and skating time over a specified distance, respectively. The repeatability of the on-ice test increased after the first five metres of the test, possibly due to inconsistent acceleration from a standing start. The times recorded were measured in hundreds of seconds, therefore, any variation in technique, as well as any minor slip would be reflected in the time recorded over the first five metres.

A significant correlation was found between the power output obtained from the intermittent sprint cycle test and the 30 second Wingate Anaerobic Test. Significant correlations were also observed between the skating time obtained from the on-ice test and both the intermittent sprint cycle test and the 30 second Wingate Anaerobic Test, when the first five metres of the on-ice test was excluded. However, these significant correlations were limited to the power output that was expressed relative to body mass. Absolute power output value correlations with the on-ice test increased after the first five metres of the on-ice test but were not statistically significant.

It is hypothesized that the first five metres of the on-ice test was too variable from one sprint to the next by the same subject. This could possibly be attributed to the skating ability of the subject pool. Examining more elite level skaters could minimize the variability over the initial five metres of the test. Once the subject was near maximal skating speed less variation in skating technique may occur thereby providing more consistent, and therefore reliable, data. This was different from the performance of both bike tests where the protocol ensured that acceleration to top speed was reached before the test was initiated.

The intermittent sprint cycle test requires no additional laboratory equipment other than is necessary to complete the more widely reported 30 second Wingate Anaerobic Test, making it a realistic test to implement at locations already performing fitness testing. The on-ice test is relatively easy to administer and even coaches during regular practice sessions may be able to implement it. As well, teams with a limited testing budget may use the on-ice test with little additional expense. Although more research is needed, the results from this study indicate that an on-ice test, possibly consisting of a five to ten metre sprint with a five metre flying start, could easily be performed by an entire team during practice sessions. Although the times recorded are relatively short, (hundredths of seconds), the distance used during the on-ice test could be manipulated in order to measure with hand held timers. Modifying the test to flying start, 10 or 15 metre test would increase overall test time and possibly allow for accurate hand held timer measurement. This would allow for a valid and reliable test of anaerobic fitness that is sport specific. It could be used to evaluate changes in anaerobic fitness due to training, and seasonal game and practice schedules.

On the whole, subjects preferred the format of the intermittent sprint cycle test, when compared to the existing 30 second Wingate Anaerobic Test. Although still exhausting, the subjects were more positive in how they perceived they performed on the test and generally felt better, and recovered quicker, following the intermittent sprint cycle test.

Future Research

Future research needs to be conducted with a greater range of subjects. Research involving an on-ice test with a flying start and possibly a bike test where acceleration to maximal power output is recorded would enhance the findings of the current study. As well, subjects need to be highly motivated to produce the most accurate data. Possibly collecting data at a training camp or try-out where athletes are vying for a team would be ideal. Data also needs to be collected over varying age and skill levels of players, as well as players of both genders. Currently only female, collegiate hockey players have been used to examine these new test protocols.

Appendix A

Informed Consent

Title: Validation of an Intermittent Sprint Cycling Test for Hockey Players

Investigators:

	Kier Wilson	436-9341
	Gordon Bell	492-2018
	Art Quinney	492-3364

Purpose: To determine the reliability and validity of a repeated sprint cycling test for hockey players. The development of a more task specific test protocol will be beneficial in both training program design and hockey specific testing.

Procedures: The following tests will be performed.

1. Body composition: tricep, subscapular, chest, iliac crest, abdomen, and front thigh skinfolds will taken using standard skinfold calipers.
2. Wingate Anaeorbic Test: 30s sprint on a cycle ergometer at a resistance of 95g/kg body mass.
3. Sit and reach test: seated toe touch
4. Curl-up test: the maximal number of repetitions that can be performed to a cadence of 50 beats per minute will be determined.
5. Grip strength test: maximal force applied to a hand grip dynamometer will be determined.
6. VO2max test: cycle ergometer test to volitional exhaustion over an increasing workload.
7. Intermittent anaerobic cycle test: 4x5s sprints on 15s will be performed at a resistance of 95g/kg body weight. This test will be performed twice on separate days.
8. On-ice test: 7 repeats of 20m maximal sprint on 15s in full equipment and holding stick. This test will be performed twice on separate days.

Possible Side Effects: The cycling tests may induce feelings of nausea and/or dizziness which may be accompanied by vomiting. All tests could result in muscle cramps, strains, or pulls and secondary soreness. During the skating test, the possibility of falling with/without hitting the boards and subsequent injury exists. The probability of these side effects decreases with experience performing these tests and adequate warm-up.

Results: You will be provided with your own test results and the mean data for the group. All results will be published and presented as mean data so that personal identification will not be possible.

All procedures for each test will be thoroughouly explained to you before each test. You will have the opportunity to ask questions at that time and ensure you understand what is expected before performing any test. You may also ask any question to receive any clarification on any of the procedures before completing this consent form. **YOU MAY DECLINE TO PARTICIPATE, OR WITHDRAW FROM THIS STUDY AT ANY TIME, FOR ANY REASON, WITHOUT ANY CONSEQUENCES.**

I have read the above and understand the requirements of participation of this study. I know that I may decline to participate or withdraw from this study at any time, for any reason, without any consequences.

Signature____
Date_______________

Witness____
Date_______________

Investigator or Designee____________________________

Appendix B

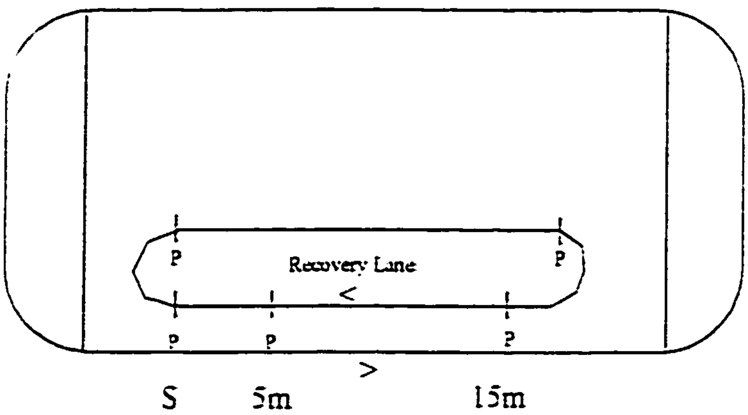
On-Ice Test Description

One player begins from a dead stop at the start line and on command, sprints as fast as possible through the last marking cone. The player immediately enters the recovery lane and skates back to the starting cone at a low intensity to begin the next sprint **at a <u>dead stop</u> every 15 seconds.** This is repeated 7 times.

Equipment:

Fresh ice surface
5 marker cones or pylons
3 stop watches
Tape measure
4 assistants: Starter, two distance timers and one recorder.
Note: Players should wear full equipment

Setup:



P = Pylon or Cone
S = Start
5m = 5 metre mark
15m = 15 metre mark

Table C-1 On-Ice Sprint Times and Intermittent Sprint Cycle Test 5s Average Peak Power

Subject	0-5M (s)	5-10M(s)	10-15M(s)	0-15M (s)	0-10M (s)	x isct abs	x isct rel	30s W abs	30s W rel
1	1.28	0.83	0.73	2.85	2.11	694.3	12.2	662.6	11.7
2	1.27	0.91	0.81	2.98	2.18	453.3	8.5	435.5	8.2
3	1.37	0.94	0.85	3.16	2.31	643.1	9.9	590.3	9.2
4	1.17	0.85	0.75	2.77	2.02	725.5	11.6	607.5	9.7
5	1.23	0.87	0.80	2.90	2.11	727.3	11.2	700.9	10.8
6	1.35	0.89	0.79	3.03	2.24	629.4	12.1	557.6	10.8
7	1.29	0.90	0.81	3.00	2.19	667.7	10.1	586.4	9.1
8	1.29	0.89	0.83	3.02	2.19	604.1	10.4	504.6	8.7
9	1.30	0.90	0.84	3.05	2.20	725.7	10.4	712.3	10.2
10	1.30	0.93	0.83	3.05	2.22	672.2	11.0	613.3	9.7
11	1.28	0.89	0.79	2.95	2.17	884.3	11.8	807.4	10.8
12	1.29	0.90	0.82	3.00	2.19	611.6	9.5	626.7	9.7
13	1.30	0.89	0.80	2.99	2.19	585.4	10.5	516.2	9.2
14	1.31	0.88	0.79	2.97	2.18	598.4	11.3	609.7	11.5
15	1.25	0.85	0.77	2.86	2.09	575.8	10.9	629.8	11.9
16	1.27	0.85	0.75	2.87	2.12	893.4	11.9	901.7	11.8
17	1.41	0.88	0.79	3.07	2.28	664.6	10.4	652.2	10.3

Table D-1 On-Ice Sprint Time and Intermittent Sprint Cycle Test Drop-Offs

Subject	0-5M (s)	5-10M (s)	10-15M (s)	0-15M (s)	0-10M (s)	mean isct	30s Wingate
1	-1.98%	7.47%	10.12%	3.78%	1.62%	24.28%	34.01%
2	3.92%	7.71%	15.99%	8.27%	5.50%	4.94%	19.74%
3	3.80%	5.01%	8.27%	5.32%	4.28%	19.31%	43.61%
4	4.07%	3.65%	3.83%	3.85%	3.88%	17.42%	27.96%
5	1.65%	5.56%	6.13%	4.06%	3.27%	27.59%	32.36%
6	3.29%	5.11%	0.58%	3.09%	3.97%	22.52%	33.58%
7	9.95%	6.88%	15.76%	10.53%	8.64%	28.62%	39.80%
8	3.52%	7.87%	8.24%	6.03%	5.23%	22.65%	21.62%
9	4.98%	5.33%	1.82%	4.12%	5.03%	31.22%	35.04%
10	6.18%	6.31%	7.30%	6.48%	6.21%	29.33%	37.39%
11	2.21%	3.70%	7.70%	4.04%	2.79%	21.16%	38.44%
12	0.64%	1.28%	5.81%	2.18%	0.90%	10.15%	31.51%
13	0.83%	4.33%	2.30%	2.23%	2.37%	18.83%	26.99%
14	3.81%	4.29%	7.30%	4.84%	3.31%	21.82%	38.58%
15	-2.78%	3.84%	2.08%	0.45%	1.69%	23.89%	47.05%
16	-0.57%	2.37%	5.56%	1.88%	0.58%	29.79%	49.85%
17	9.95%	5.78%	6.68%	7.92%	4.33%	32.15%	49.46%