EXAMINING THE RELATIONSHIP BETWEEN OFF-ICE TESTING AND ON-ICE PERFORMANCE IN MALE YOUTH ICE HOCKEY PLAYERS

by

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Abstract

Background: In an elite sport setting, physical assessments are administered for talent selection purposes, as well as for continuous monitoring to ensure the effective implementation of training methods to reach optimal sport performance. Physical assessment allows coaches and trainers to determine where an athlete ranks compared to other players, as well as to identify the strengths and weaknesses of the individual. In ice hockey, research has focused on high performance players (e.g., NHL prospects) and the physical characteristics that they possess. To date, the early assessment of youth minor hockey players, and the relationship between off-ice and on-ice performance has received little attention. ***Purpose:*** The purpose of this investigation was to examine the relationship between off-ice physical fitness performance and sport-related performance on on-ice assessments in male, minor ice hockey players. ***Methods:*** Eleven male minor hockey players were recruited across three birth years (2004, 2005, and 2006). Participants completed a battery of 14 off-ice testing protocols that measured body composition, musculoskeletal fitness, aerobic fitness, and anaerobic fitness, as well as 4 on-ice protocols that measured skating speed, skating agility, skating acceleration, and shot velocity. ***Results:*** Older players were taller and heavier than the younger players, and defensemen were taller and heavier when compared to forwards. Across participants, standing long jump was positively correlated to all skating tests (i.e., speed, agility, and acceleration). Players who jumped further demonstrated significantly greater on-ice skating performance. Significant correlations were also found between player weight and maximum speed, agility, and shot velocity. Lighter players were faster and more agile on the ice, while players with a greater mass demonstrated higher scores in shot velocity. A significant relationship was also found between push-ups and off-ice sprinting capability. ***Conclusion:*** These findings were consistent with high performance research with adults revealing that physical measures (such as standing long jump) may have predictive value for on-ice performance even in young, pre-pubertal ice hockey players. While such measures may contribute to the successful identification and selection of players for high performance, utilizing such assessments also has important training implications for the long-term development and performance of all players.

Preface

Mark Stewart Rice conducted this work in the Cognitive and Functional Learning Laboratory, Physical Activity Promotion and Chronic Disease Prevention Unit at the University of British Columbia. Mark Rice performed all data collection, with the assistance of Drs. Warburton and Bredin, along with volunteers of the LEARN Laboratory and CPR Laboratory at the University of British Columbia. Mark Rice performed all data entry, data editing, and data preparation. All statistical analysis was performed by Mark Rice. Dr. Shannon Bredin (supervisor) and committee members (Dr. Darren Warburton and Dr. Veronica Jamnik) provided support, formation, and implementation of research. Dr. Shannon Bredin and Dr. Darren Warburton provided funding for the research and were instrumental in the recruitment of participants.

Ethics approval for this research was obtained through the University of British Columbia Behavioural Research Board. This research was conducted under ethics approval certificate H14-03174.

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1 RM	One Repetition Maximum
LTAD	Long-term Athlete Development
NCAA	National Collegiate Athletic Association
NHL	National Hockey League
OHL	Ontario Hockey League
PHV	Peak Height Velocity
PWV	Peak Weight Velocity
VO_{2max}	Maximum volume of oxygen
WHL	Western Hockey League

Glossary of Operational Definitions

1 RM: One repetition maximum refers to the maximum amount of mass that person can lift in a single attempt (Faigenbaum et al., 2009)

Atom Hockey Division: A minor hockey division that is comprised of players under the age of 11 and over the age of 8 (9-10 years).

Bantam Hockey Division: A minor hockey division that is comprised of players under the age of 15 and over the age of 12 (13-14 years).

Elite: A player or athlete who is at the top echelon of their sport.

House League Team: Teams are made up of players who vary in skill and experience and are balanced for even play. Players that do not make a representative team are often placed on a house league team.

Long-Term Athlete Development (LTAD): Refers to an athlete-centred, seven stage model, put forth by Canadian Sport for Life which serves as a framework for the development of optimal training, competition, and recovery at each stage of athletic development (Balyi, Way, Higgs, Norris & Cardinal, 2014).

National Collegiate Athletic Association (NCAA): An organization comprised of three divisions (Division 1, Division 2, and Division 3) that oversee that athletics of many universities and colleges in the United States and Canada.

National Hockey League (NHL): A professional hockey league comprised of 30 elite hockey teams in Canada and the United States and is considered to be the top hockey league in the world

NHL Combine: A battery of tests developed by Gledhill and Jamnik that takes place in Toronto, Ontario, Canada, every year in June, wherein 110 – 120 of the top draft prospects from around the world participate hockey-related testing protocols.

Ontario Hockey League (OHL): A major junior hockey league based in Ontario, Canada, and is one of three leagues that make up the Canadian Hockey League (highest level of junior hockey).

Peak Height Velocity: Maximal rate of growth during the adolescent growth spurt (Yague & De La Fuente, 1998)

Peak Weight Velocity: Maximum growth in body weight during adolescence (Beunen & Malina, 1998).

Relative Age Effect: The overrepresentation of players on a team who are born in the first quarter or first half of the year and the simultaneous underrepresentation of players born later in the calendar year (Hancock et al., 2013)

Representative Team: Teams that require tryouts to select players to represent their respective communities, cities, provinces, and so forth. In theory, only those players with the best skills will be selected for the team.

VO_{2max}: Maximum volume of oxygen that can be transported throughout the body and used by working muscles (Warburton et al., 2006)

Western Hockey League (WHL): A major junior hockey league based in Western Canada and the Northwestern United States, and is one of three leagues that make up the Canadian Hockey League (highest level of junior hockey).

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CHAPTER ONE: INTRODUCTION TO THE THESIS

The purpose of this chapter is to provide an introduction to the thesis, an overview of the research, and outline the format of the thesis document.

1.1. Introduction

There are more than 600,000 youth registered in minor hockey in Canada (Hockey Canada, 2013), and the majority of them have dreams of one day playing in the National Hockey League (NHL). For some children, participation in hockey starts as early as 4 years of age, when they are first registered in minor hockey at the pre-novice level (Hockey Canada, 2013). By the age of six, hockey is already a year-round sport for some, with spring hockey and summer camps available and heavily promoted to parents in an effort to develop the skills necessary to compete at the higher levels. Unfortunately, only a few ever realize the dream of playing in the NHL as one of the worlds best.

Statistically the odds of '*making it'* to the elite level are low. For example, when following 22,000 ten-year old Canadian hockey players in Ontario, Kesselring (2014) found that only 132 (<1%) of players actually made it into the top feeder leagues for the NHL (e.g., Canadian Hockey League and National Collegiate Athletic Association Division 1 Schools); while only seven of the 132 players (5%; or 0.03% of 22,000) ever played a game in the NHL (Kesselring, 2014). Statistically, being from Ontario, does increase your odds if you are from Canada. In the 2011 – 2012 season, 525 Canadians (53.1% of all NHL players) played in the NHL. Of the 525 players from Canada, 197 players (37.5%) were from Ontario. This is more than the next three provinces combined (Alberta = 72; Quebec = 58; British Columbia = 53) (Langager, 2013). While being drafted earlier in the NHL's annual entry draft selection process increases one's likelihood of playing in the NHL, being drafted itself still does not guarantee success. For instance, Fitzpatrick (2014) examined players selected in the NHL entry draft between 1990 and 1999. During these years, 2,600 players were drafted. Those players selected in the first round had a 63% chance of playing in the NHL, those selected in the second round had a 25% chance, and those players selected in the third and subsequent rounds had only a 12% chance (Fitzpatrick, 2014). Further, of the 5,981 players drafted between 1981 – 2003, the average career length was 5.6 years, wherein the career of 20.1% of players lasted more than 160 games, and 64.9% of players played less than 10 games. In fact, only 5% (290 players) played more than one NHL game in their career (Tingling, Masri, & Martell, 2011). In short, a great number of players will dedicate themselves to the sport of ice hockey from the earliest of years, investing significant amounts of time and resources. Unfortunately, the reality is that only a select few will ever realize the dream of what so many young Canadians aspire to achieve.

Part of the selection process in ice hockey involves rigorous testing in an attempt to identify those with and without the capabilities to play hockey and succeed at a high level. This is a common approach in high performance sport; wherein identifying successfully elite versus non-elite players is critical for a team's success (Vescovi, Murray, Fiala, & VanHeest, 2006). As such, a critical analysis of the qualities deemed important for a particular sport is required, as well as the subsequent selection and implementation of appropriate, valid, and reliable tests to assess those attributes in individuals. The annual

NHL combine (as developed by Gledhill and Jamnik) took place in Toronto, Ontario, Canada (up until 2014), wherein 110 – 120 of the top draft prospects from around the world participate in a battery of hockey-related testing protocols. The battery is designed to assess the athlete's level of physical fitness. The scores achieved by the prospect is then used by NHL teams to assist in making entry draft decisions, whereby the information provided is considered to be a predictor of hockey playing potential (Burr et al., 2008).

For skating players (forwards and defensemen), a number of physical fitness tests have been shown to be significant predictors of draft selection order. These include measurements of peak power achieved during a 30-second standard Wingate test, body index, fatigue index, and standing long jump (Burr et al., 2008). These tests are particularly important to the sport of ice hockey. Peak power output reflects the player's capacity for spurts of speed or to clear opponents from the net. Body index refers to the amount of body fat a player has. This is important to know because high body fat mass can slow a player down, as well as make them fatigue more quickly. In contrast, the fatigue index reflects the capability of a player to maintain high intensity levels throughout a shift on the ice. Finally, standing long jump reflects the player's muscular strength and his or her potential to skate powerfully (Gledhill & Jamnik, 2007). While, there is some evidence that physical fitness testing has utility and predictive value in draft eligible hockey players, there is no research to date that has examined such physical fitness measures in young hockey players in the early developmental years of ice hockey. That is, do physical fitness scores hold predictive value for hockey performance across minor hockey divisions? Stated more specifically, do players selected for the competitive ‘travel’ or ‘representative (rep)’ teams (at Atom, Pee Wee, Bantam, and Midget) exhibit better physical fitness scores versus same-aged youth playing in lower division, recreational, house league teams? Further research is needed to examine the effect of physical fitness across hockey divisions and player skill level.

An important methodological issue that is raised when administering off-ice testing measures for the selection and identification of hockey players is the relationship between off-ice testing and on-ice performance measures. That is, is off-ice performance predictive of one’s on-ice performance? In previous research, Potteiger et al. (2010) have shown that National Collegiate Athletic Association (NCAA) Division One hockey players on-ice skating times were significantly correlated with Wingate anaerobic power and capacity measures. Similarly, Mascaro et al. (1992) found that the sprint skating speed of professional hockey players was significantly correlated with vertical jump and anaerobic power, with anaerobic power being the best predictor. While this research provides support for the predictive capabilities of select off-ice physical fitness measures for on-ice performance, these investigations have focused on varsity and/or professional levels of play. To date, little is known about the relationship between on-ice and off-ice performance in minor hockey-age youth.

Examining the relationship of physical fitness to hockey performance is a relevant contemporary issue for both the selection process and the development of effective training programs at the minor hockey level. In the current system, the selection process into higher-level rep teams and lower level house league teams already begins at the Atom division (players 9 and 10 years of age as of December 31). Typically starting in August, tryouts are held in minor hockey associations across Canada and teams are selected most commonly based on a coaches' interpretation of on-ice sessions. A coach's capability to accurately assess and justify interpretations of an athlete's skill and hockey capabilities determines if an athlete will be selected to a particular team (Wiseman, Bracken, Horton, & Weir, 2014). Tryouts, especially at the younger ages, are often a subjective process with very few objective measures. Due to the lack of other valid and reliable measurement tools coaches fall back on their perception of performance to judge their players contribution to play, a perception that takes into account their experience and training (Nadeau, Godbout, & Richard, 2008). Implementing another evaluation protocol in minor hockey, such as off-ice testing, could help distinguish between those players who are aerobically and anaerobically more fit, as well as, physically stronger, which may not be readily noticeable in on-ice testing alone. In addition, having minor hockey players go through off-ice testing could identify potential areas for the athlete to improve upon, which could help them better focus their training and ultimately, facilitate their long-term development and advancement in the sport of ice hockey.

1.2 The Thesis Research

The purpose of the research was to investigate the relationship between off-ice physical fitness performance and sport-related performance on on-ice assessments in male, minor ice hockey players. A total of eleven male minor hockey players were recruited across three birth years (2004, 2005, and 2006). Players were assessed on 14 off-ice tests examining both health-related and performance-related physical fitness measures. Health related physical fitness measures refer to those components that affect a person's health and quality of daily living, while performance related physical fitness measures correspond to those components that affect an individual's athletic performance.

In total, participants completed a battery of 14 off-ice testing protocols that measured body composition, musculoskeletal fitness, aerobic fitness, and anaerobic fitness, as well as 4 on-ice protocols that measured skating speed, skating agility, skating acceleration, and shot velocity. All off-ice tests are used currently in the NHL combine (Gledhill & Jamnik, 2007) and served as the basis for selection of off-ice testing measures in the youth hockey players. The choice in on-ice measures was based on research by Bracko (2001) in elite and non-elite Women's ice hockey and Farlinger et al. (2007) in competitive ice hockey players.

We hypothesized that players who exhibit higher scores on off-ice measures will also demonstrate better scores on on-ice measures. Previously, it has been shown that elite women ice hockey players outperform non-elite players in on-ice testing (Bracko, 2001). In addition, it was also postulated that off-ice measures requiring high power output from the legs such as vertical jump, standing long jump, Wingate, and the 30-meter sprint will be particularly salient in predicting on-ice performance, even in young players. Farlinger et al. (2007) have shown that such tests are strongly related to on-ice sprint skating speed in competitive hockey players.

1.3 Overview of the Thesis Document

This document is comprised of five chapters. The first chapter introduces and identifies the research underlying the work. The second chapter includes a narrative review of key concepts to the research. The third chapter includes a summary of the research to date on elite performance markers of male individuals in the sport of ice hockey. The empirical work is presented in chapter four. Last, chapter five discusses the relevant findings and provides a summary of the thesis document.

CHAPTER TWO: FOUNDATIONAL CONCEPTS UNDERLYING THE RESEARCH

The purpose of this chapter is to present the basic underlying concepts that are central to the thesis research. This chapter provides a summary of the divisions of minor hockey and the selection process involved (presented first), followed by discussion of on- and off-ice testing protocols, long term athlete development, growth and maturation, as well as the relative age effect.

2.1 Introduction

At the beginning of each hockey season, 3,500 minor hockey associations across Canada prepare to evaluate and select players for placement on hockey teams (Hockey Canada, 2013). Evaluation is carried out to assess the physical skill level of the player in an attempt to determine his or her individual strengths and weaknesses (Gilenstam, Thorsen, & Henriksson-Larsen, 2011). The athlete's performance depends on several factors, including (but not limited to): genetic endowment, physical fitness, and hockey-specific skill (Hoff, Kemi, & Helgerud, 2005). These evaluations are often considered to be the most difficult and stressful process of the hockey year for athletes and coaches alike. For the coach, these evaluations and the decisions that result set up a team for a successful season or conversely, can lead to a season with less than desirable outcomes. For the athlete, his or her ranking in the evaluation process will determine the tier that (s)he will play and ultimately the level of coaching, practice and game quantity, and the level of play (s)he will be exposed to.

2.2 Age Divisions

In Canada, minor hockey athletes are grouped together in two-year age increments. The first division is called initiation where the players are seven years and younger and are represented as “Hockey 1” and “Hockey 2”. The second of the development stages is called Novice where players aged seven to eight are grouped into divisions referred to as “Hockey 3” and “Hockey 4”. In these divisions, teams are called “squads” and players are grouped so that there is a balance of abilities amongst players and no one team should be better than another. During the grouping stage of the season, tryouts are not held, but rather inter-squad games are played and players are moved around to make squads as equal as possible. At this age, hockey is played with the mandate that all playing time is equal amongst athletes and that all players will be provided the opportunity to experience all positions including forward, defense, and goalie keeping.

Once a player reaches the age of 9, they move to the Atom division, where tryouts are conducted to select players to play on representative (or ‘rep’) teams (Hockey Canada, 2013). These players are put through a number of on-ice tests that measure their capabilities to skate, pass, shoot, handle the puck, and play 1 on 1 (Hockey Canada, 2013). Hockey Canada’s individual evaluation sheet has 90 individual categories in which a player can be rated on. Only 3 of these categories assess fitness level, which include heading topics of physically fit, physically tough, and not prone to injury.

As a player continues on in minor hockey, they proceed through the Peewee division (under 13 years of age), the Bantam division (under 15 years of age), and the Midget division (under 18 years of age) (Hockey Canada, 2013). The selection criteria for these divisions does not change according to Hockey Canada's Individual Player Evaluation Sheet, and only three categories assess fitness level.

2.2.1 Selection Process

To generate better athletes and achieve higher performances, it has been suggested that a greater concerted effort be placed on improving the selection process (Brodani & Simonek, 2012). More specifically, it is suggested that more effort should be focused on administering valid and reliable tests to identify those athletes with the greatest potential of success. While the purpose of the current NHL combine protocol is to evaluate the physical attributes of athletes using off-ice testing measures, little is known about correlative values of these off-ice testing protocols and the athlete's on-ice performance (Vescovi et al., 2006). Skating is a dynamic and complex skill; therefore, it is difficult to meet the physical demands associated with skating by administering off-ice tests (Bracko, 2001). However, it is suggested that off-ice testing may be used to identify players with strengths and/or weaknesses that can set them apart from other athletes (Burr et al., 2008).

While NHL draft prospects are tested using off-ice measures, little off-ice testing is implemented in youth ice hockey. This may be due to a lack of time, a lack of qualified personnel, a lack of equipment availability, a lack of knowledge, a fear that an athlete may sustain an injury, or even more simply, an evaluator may think that off-ice testing is not important. While research is limited in this area (especially as it relates to ice hockey), Faigenbaum, Milliken & Wescott (2003) reported that no injuries were sustained in healthy youth performing one-repetition maximum (1RM) tests under the supervision of qualified personnel. Furthermore, the National Strength and Conditioning Association suggests that resistance training, in addition to aerobic exercise, offers unique benefits for children and adolescents when appropriately prescribed and supervised (Faigenbaum et al., 2009). As well, prospective studies on resistance training in youth indicate a low risk of injury when the training program is closely supervised and appropriately prescribed so that the program is matched to the initial capacity of the child (Faigenbaum et al., 1996). Therefore, physical fitness is not just important for future skill development, but also for the long-term development of healthy lifestyle behaviours across the lifespan. Importantly, the key to effective implementation of physical fitness testing and intervention programs is the use of qualified exercise personnel.

Using testing protocols (off-ice and on-ice) may provide a more sophisticated approach to player assessment in the early years of development. It may not only provide a more informed foundation for player selection, but it may also provide important training information for player development across skill levels.

2.3 The Canadian Long Term Athlete Development Model

The Canadian Long Term Athlete Development (LTAD) model is a framework that is proposed for the development of an optimal training, competition, and recovery schedule at each stage of athletic development (Balyi, Way, Higgs, Norris & Cardinal, 2014). The Canadian Sport for Life LTAD is made up of seven stages, from active start (ages 0 – 6) to active for life. The need for the LTAD came about from the declining international performances of Canadian athletes in some sports; including difficulties in identifying and developing the next generation of internationally successful athletes (Balyi et al., 2014). As such, the purpose of the LTAD model was to address various shortcomings within the Canadian sport system (e.g., an emphasis on chronological age rather than developmental age, a lack of a developed talent identification (TID) system).

At the age of nine, Atom-level ice hockey players are going through their first selection process to make a 'winter' team. According to the LTAD model, this is a critical time for physical development in youth athletes. At this age, athletes are considered to be in the '*Learning to Train Stage'*, wherein it is suggested that games and exercises are used to further develop strength, endurance, and flexibility. Moreover, this approach suggests that athletes should design training based on a 70:30 ratio (i.e., 70% training and 30% competition and competition specific training).

The next level in the LTAD is the "*Training to Train Stage'*, where the emphasis for males between the ages of 12 – 16 is on building an aerobic base, developing speed and strength, as well as the further development and consolidation of sport specific skills. It is postulated that this stage is peak height velocity (PHV) dependent, which means that it is dependent on the major growth spurt that occurs during the childhood years. Once PHV is established, it is suggested that there is a window of approximately 12 to 18 months where aerobic training should become a priority.

The Learning to Train and Training to Train stages are the most important foundational stages of athletic preparation (Balyi et al., 2014). During these stages, the athlete will experience success or failure. Undertraining at these stages results in a lack of basic skills and fitness, which can constrain an athlete's capability to succeed and improve in the later years. If an athlete is able to understand where they are physically during these two stages, they can be better prepared for development since they will realize what level they need to get to in order to succeed in a particular sport. Having a set of physical testing protocols for minor hockey athletes, which encompasses both off-ice and on-ice measures, will be able to provide a clearer pathway for progression, as well as facilitate the attainment of higher and more sustained levels of success (Balyi et al., 2014).

2.4 Physical Growth and Maturation

Maturation is a major confounding variable in youth and adolescent sport. As an athlete physically grows and matures, a number of hormonal changes occur throughout the body. These changes can result in physical characteristics that are valuable to sporting performance (Pearson, Naughton, & Torode, 2006). Philippaerts et al. (2006) report that males who are advanced in biological maturity demonstrate temporarily better performance (because of early maturation) when compared to their later maturing peers and therefore, have increased selection opportunity. There is no set timing to when an athlete reaches puberty (Beunen & Malina, 1988). Biological indicators of maturity, include assessment of skeletal age, age at appearance of secondary sex characteristics, and age at peak height velocity (PHV), which is the maximal rate of growth during the adolescent growth spurt. Inter-individual differences in motor performance are related to corresponding variations in growth and development, especially in boys (Yague & De La Fuente, 1998). The impact of these differences may be particularly salient in ice hockey because early maturing individuals may experience better opportunities to play the sport due to the fact that they are taller and stronger than their counterparts who have yet to fully mature.

Some of the most comprehensive work to date has been done by Pearson et al. (2006), who have reviewed both maturation and performance parameters used in talent identification. Variables such as height and weight may be a direct advantage in some youth sports. Early maturing males may be taller than average compared to their later maturing counterparts. For males, the average typical growth curve begins around the age of 12 and reaches a peak velocity of 12 cm/year at the age of 14 (Roemmich & Rogol, 1995). Early maturing males also experience Peak Weight Velocity (PWV) earlier, which is the maximum growth in body weight during adolescence (Beunen & Malina, 1998). During puberty, males will reach a peak weight velocity of 8.5 kg/year at age 12.5 and 9.5 kg/year at age 14 (Roemmich & Rogol, 1995). Therefore, early maturing athletes experience the advantage of being taller and weighing more compared to those athletes who have yet to mature. This is beneficial in the sport of ice hockey as early maturing males will be heavier and have greater leverage making it tougher to compete against.

The physical growth and maturation of a young athlete is associated with increases in aerobic power, anaerobic power, and strength (Roemmich & Rogol, 1995). Increases in muscle mass account for a large proportion of growth during adolescence in males (Pearson et al., 2006); therefore, early maturing males demonstrate significantly greater muscle mass than their late maturing peers. Gains in muscle mass occur, on average, after peak height velocity and peak weight velocity (Roemmich & Rogol, 1995). These athletes, whom experience early maturation, will gain a competitive edge in that they will be able to produce more strength and power; attractive qualities for player selection.

Aerobic capacity increases in a linear fashion between the ages of 8 – 16 years (Roemmich & Rogol, 1995), with the greatest improvements emerging between the ages of 11 – 15 years (Pearson et al, 2006). This is largely due to the influence of muscle mass and haemoglobin concentrations on aerobic capacity (Roemmich & Rogol, 1995). These values overlap with peak height velocity and peak weight velocity. Similarly, anaerobic power increases once a child reaches puberty. Sprinting speed and jumping capabilities are shown to improve during puberty, most notably between the ages of 14 and 15 (Pearson et al., 2006). While these tests are indicative of skating performance (Burr et al., 2007), possessing a high aerobic capacity and a high anaerobic capacity allows an athlete to produce more force and recover more quickly, which is highly desirable in the sport of ice hockey.

In summary, sports performance in youth is greatly influenced by the level of maturation that an athlete possesses (Rommich & Rogol, 1995). However, this does not mean that maturity equates to skill. Unfortunately, ice hockey is a sport that has a long tradition of favouring athletes who are taller and heavier. Therefore, maturational differences can lead to greater opportunities for the athlete. The heavier the player is, the tougher it is for an opponent to move him out of the way; the stronger the player is, the more power he will be able to generate to skate faster and shoot harder. The more advanced the aerobic and anaerobic systems are, the harder the player can push himself, or the more quickly the player can recover. All of these qualities can be linked back to the maturation level of an athlete. In youth ice hockey, those who mature early have an increased prevalence for team selection.

2.5 Relative Age Effect

In ice hockey, there is a substantial body of literature that supports the existence of a relative age effect. This effect refers to an unequal representation of players according to birth date in the calendar year, wherein there is a selection bias towards players who are born earlier in the calendar year (Musch & Grondin, 2001). A relative age effect occurs as a result of physical growth and maturation differences that naturally emerge between those born earlier in the calendar versus their counterparts born later in the year. Minor hockey uses December 31 as a cut-off. Therefore, the oldest children within a 1-year cohort are those born in January, while the youngest in the cohort are those born in December. While, individual differences exist in growth and maturation rates, older calendar date children often have an 11-month advantage over young calendar date children (Delorme, Boiche & Raspaud, 2009). While differences of a few months may not make a large impact on performance in adults, a few months can have a significant difference in the growth and maturation in children. As such, while unintentional, discrimination often occurs against players born later in the calendar year (Delorme et al., 2009).

The earliest known work on the relative age effect was conducted by Barnsley, Thompson, and Barnsley (1985), who first established the relative age effect in ice hockey players in the NHL, Western Hockey League (WHL), and the Ontario Hockey League (OHL). Their initial work on the relative age effect has now been studied in a number of different sports such as baseball (Stebelsky & Barnsley, 1991) and soccer (Barnsley, Thompson & Legault, 1992). The relative age effect has also been shown in minor hockey players (Barnsley & Thompson, 1988).

One of the major influences of selecting players to a minor hockey team is the size of the athlete (e.g., height and weight). Older children are both taller and heavier compared to their younger counterparts. Therefore, a selection advantage occurs in favour of the bigger, older athletes, who are more frequently overrepresented on teams, while smaller, younger athletes are underrepresented (Hancock, Ste-Marie & Young, 2013). Relative age effects in ice hockey are shown at the earliest of age groups, including novice and initiation, and exists into the upper echelons of minor hockey and beyond (Hancock et al., 2013). A contributing factor to relative age effects is the role that coaches play in the selection process. However, in the early years, parents also contribute to the emergence of relative age effects. For example, Hancock et al. (2013) have shown that parents are less likely to enrol young calendar date children in ice hockey. Therefore, parents play a pivotal role in early sport participation in youth.

Recently, Gibbs, Jarvis and Darfur (2011) have shown a reversal of the relative age effect. For those children born late in the calendar year, who make it to the elite levels of hockey (e.g., NHL, Canadian Olympic ice hockey teams, and NHL All-star teams) the relative age effect fades, and there is a reversal effect amongst Canadian born hockey players. For example, Gibbs et al. (2011) have demonstrated that 40% of Canadian-born first round drafts into the NHL (2007-2009) were born in the first quarter; yet, only 28% of Canadian players born in the first quarter played in the NHL. Moreover, career duration was shown to be longer for players born later in the year. Termed the 'underdog hypothesis' this notion suggests that during one's development, younger players may reap the long-term benefits of playing with their older counterparts. To make it, those younger calendar date players may actually possess greater talent than their older counterparts. While there is a breadth of literature on the relative age effect in minor hockey, and the seemingly overrepresentation of players born in the first half of the year, having another set of evaluation techniques could pose for a more equal representation of players chances of making certain teams.

2.6 Testing Protocols

Success in ice hockey requires a combination of speed, strength, and endurance (Burr, Jamnik, Dogra & Gledhill, 2007). Identifying what is required 'physically' to play the game can provide important information for the development, implementation, and modification of training regimes that address the strengths and weaknesses of the player, all in an effort to increase the overall performance of the athlete (Bracko, 2001).

Off-ice testing is used to gather valuable information on an athlete's functional capacity, and skill level of an athlete (Peyer, Pivarnik, Eisenmann & Vorkapich, 2011). The tests that are administered vary widely across settings; including assessments done in a laboratory or on a field (Tarter et al., 2009; Peyer et al., 2011). In general, athletes are often evaluated using assessments of speed, strength, agility, aerobic and anaerobic energy systems, and body composition (Tarter et al., 2009).

On-ice testing is used to gather valuable information of the athlete's capability to propel themselves around the ice. This information is beneficial to coaches, scouts, management, and selection committees, as skating ability is a significant factor in team and individual success of the hockey player (Bracko, 2001). As such, it greatly influences the selection process. On-ice assessments often include tests that evaluate acceleration, speed, and agility (Bracko, 2001).

Using a combination of off-ice and on-ice protocols to evaluate an athlete's capability and skill level can lead to more accurate assessments of players. These tests may work best when used in combination with one another and no one factor should be relied upon exclusively. However, to date there is an absence of research examining on- and off-ice tests in youth ice hockey players. Knowing the relationship between off-ice tests to on-ice performance can facilitate team selection, training program design, as well as the long-term development of the athlete.

2.6.1 Physical Fitness

Physical fitness refers to a physiologic state of well-being that allows one to meet the demands of daily living or provides the basis for sport performance, or both (Warburton, Nicol & Bredin, 2006). Health-related physical fitness involves the components of physical fitness related to health status, including cardiovascular fitness, musculoskeletal fitness, body composition, and metabolism (Warburton et al., 2006). Health-related physical fitness tests include measures for assessing muscular strength, muscular endurance, flexibility, and aerobic capacity. In contrast, performance-related physical fitness tests correspond to those components that affect an individual's athletic performance. Performance-related physical fitness tests include such assessments as: standing long jump, vertical jump, one-legged squat, the Wingate 30-second anaerobic capacity test, the 30-meter sprint test, and various agility tests.

2.6.2 Body Composition

Body composition refers to the amount of fat and fat free mass on the body as indicated by a body composition test (Gledhill & Jamnik, 2007). Too much body fat can slow a player down and make them tire faster. Body composition of a player can be determined by a number of different techniques including, but not limited to: sum of skinfolds test, bio-electrical impedance, and densitometry procedures such as hydrostatic weighing and whole body air displacement plethysmography. The sum of skinfolds test is the most common assessment of body composition and is assessed by the thickness of six skinfolds. These measurements are then substituted into a calculation and the results are the percent body weight that is fat (Gledhill & Jamnik, 2007). This assessment requires the tester to be familiar with Harpenden callipers and body anatomy to assess the client. Bio-electrical impedance is based upon the conduction of an applied electrical current through the body (Lukaski, Johnson, Bolonchuk & Lykken, 1985). This technique is safe and non-invasive, and one of the major advantages is that it requires no special skills on behalf of the operator or client (Lukaski et al., 1985). Until recently, hydrostatic weighing has often been considered the 'gold standard' of measuring body composition. This method uses Archimedes principle to determine total body volume by measuring the difference of a participant's weight in water and his or her weight in air, thereby determining whole-body density. The limitations of this technique include time, labour, intensity, participant discomfort, and inaccessibility for many populations (Biaggi, 1999). Moreover, the weighing tank is non-mobile and this technique is unsuitable for children (Wells & Fewtrell, 2006) as the protocol requires the participant to hold their expired breath underwater for as long as possible. In contrast, whole body air displacement plethysmography is based on the concept of body volume, much like hydrostatic weighing, however, it is potentially a more advantageous alternative to hydrostatic weighing (Dewit et al., 2000). Using an air filled chamber, the less invasive test measures the volume of air a persons body displaces rather than water compared to hydrostatic weighing. While all these tests can assess body composition it is up to the tester and the participant population being tested to determine the best method of assessment. When one common formula is utilized, the percent body fat of a number of players can be compared meaningfully (Gledhill & Jamnik, 2007).

2.6.3 Cardiovascular Fitness

Cardiovascular (or aerobic) fitness refers to the body's ability to transport oxygen during prolonged strenuous work or exercise (Warburton et al. 2006) and is indicative of the endurance capability of the player's heart, lungs, and muscles (Gledhill & Jamnik, 2007). The most commonly used measure to assess aerobic fitness is maximal aerobic power (VO_{2max}), which is the maximum amount of oxygen that can be transported throughout the body and used by working muscles (Warburton et al., 2006). While ice hockey is often known as a highly anaerobic sport requiring intermittent periods of high speed, aerobic endurance is also a critical factor for success (Leone, Leger, Lariviere, & Comtois, 2006). For example, good aerobic fitness is needed for offsetting fatigue over the course of a game or practice (Gledhill & Jamnik, 2007).

The best way for comparing players aerobic capacity is relative VO_{2max}, which is a player's VO_{2max} expressed in relation to his body mass (ml x kg^{-1} x min^{-1}). High scores can be attributed to training, genetic endowment, and/or a combination of the two. Another useful measure when assessing VO_{2max} is maximum heart rate, which refers to the maximal amount of times an individual's heart beats in one minute. This measurement is useful for setting up an optimal training program for the player (Gledhill & Jamnik, 2007). A direct VO_{2max} assessment is conducted in a laboratory setting where a participant performs work on a treadmill or bike ergometer until exhaustion and is connected to a metabolic cart and gas analyzers. This method of obtaining a direct VO_{2max} measurement is expensive, requires highly trained staff, and can only measure one athlete at a time (Warburton et al., 2006).

Valid and reliable indirect measurements have also been developed to assess aerobic fitness (Warburton et al., 2006), including submaximal tests (e.g., Rockport One-Mile Test), and intermittent maximal multistage tests (e.g., Leger Test) (Warburton et al., 2006, Leone et al., 2006). These protocols use heart rate and stage of completion to assess accurately VO_{2max}. Many fitness and health professionals prefer to use these indirect measurements to estimate aerobic fitness as they can test a number of participants at once, as well as participants varying in fitness level. Additionally, it is often recommended to assess children using running activities instead of cycling because of their less developed muscular strength (Warburton et al., 2006). For aerobic performance, a lower heart rate for a given workload is thought to represent a higher level of aerobic fitness (Warburton et al., 2006).

2.6.4 Musculoskeletal Fitness

Musculoskeletal fitness refers to the muscular strength, endurance, power, and flexibility of key areas of the body (Gledhill & Jamnik, 2007). An enhanced musculoskeletal system has been associated with an increased functional capacity (Warburton, Gledhill & Quinney, 2001), which is the ability to perform predominantly aerobic work (the integrative work of the heart, lungs, and circulatory system to deliver oxygen to the metabolically active muscle mass) (Fleg et al., 2000). In general, musculoskeletal fitness can be assessed with relative ease in a variety of environments (Warburton et al., 2006). While there are a number of tests that can assess musculoskeletal fitness, some of the more common tests include: grip strength (muscular strength), push-ups (muscular endurance), curl-ups (muscular endurance), and sit-and-reach (flexibility) (Warburton et al., 2006). More sport specific tests include: the bench press, standing long jump, 3-hop jump, and vertical jump (Burr et al., 2008). High scores in these measurements reflect the capacity to skate powerfully, shoot hard, push people out of the way, and be less prone to injury (Gledhill & Jamnik, 2007).

2.6.4.1 Muscular Strength, Muscular Endurance, and Muscular Power

While strength and power are often used interchangeably, they are actually two different concepts. Maximal strength refers to the ability of the nervous and muscular systems to produce enough internal force in the connective tissues and muscles to move an external force, such as a weight or the body. That is, the heaviest load that can be lifted for one repetition (Cronin & Henderson, 2004). In contrast, muscular power is a combination of force and speed (Gledhill & Jamnik, 2007). Having a high amount of muscular power means that a heavy load can be lifted or moved quickly, such as the explosive movement of pushing off and starting the skating motion quickly. Strength and power are important in hockey for shooting, controlling opponents, accelerating and skating speed (Gledhill & Jamnik, 2007). In addition, muscular endurance is the ability of the muscles to exert force repeatedly, which is important in the sport of ice hockey because of the repetitive use of key muscles (Gledhill & Jamnik, 2007) and the ability to continuously perform work without the onset of fatigue, such as skating.

2.6.4.2 Flexibility

Flexibility is defined as the maximum ability to move a joint through a range of motion and is believed to be an important aspect of sports specific activity (Hahn, Foldspang, Vestergaard, & Ingemann-Hansen, 1999). Optimal range of motion is recognized as an important component of overall fitness (Pelham & Hoyle, 1992). Flexibility is limited by both internal factors and external factors. Internal factors include bone structure, muscle volume and elasticity of muscles, tendons, joint capsules, and ligaments; while external factors include air temperature, warm up, and physical exercise (Hahn et al., 1999). Both imbalances in muscular strength and flexibility are associated with the prevalence of injuries in various sports. These imbalances may occur between different sides of the body or between agonist and antagonist muscle groups (Tyler, Nicholas, Campbell, & McHugh, 2001). The maintenance of adequate range of motion is important for the prevention of imbalance injuries (Pelham & Hoyle, 1992). Ice hockey players who have a greater range of motion can exert more power in their skating stride and their shots can be more forceful. The goaltender, specifically, needs to have a high degree of range of motion due to the low shots he faces and the need to make saves in the splits position (Pelham & Hoyle, 1992). In the NHL Combine, players are assessed on their trunk flexion (sit and reach) flexibility (Gledhill & Jamnik, 2007). This test is designed to measure flexibility in the lower region of the back and the back of the thigh (hamstrings), the area where the musculature propulsion in skating are located (Pelham & Hoyle, 1992).

2.6.5 Anaerobic Fitness

Anaerobic fitness refers to the body's ability to produce work without the use of oxygen (Warburton et al., 2006), wherein the work occurs at very high intensity levels for short (5 to 30 s) periods of time (Gledhill & Jamnik, 2007). Maximum anaerobic power is generally taken as the standard measure of anaerobic fitness (Warburton et al., 2006). Anaerobic fitness is important to hockey players because of the many rapid spurts of energy that are involved (Gledhill & Jamnik, 2007).

A number of different protocols are available to directly and indirectly assess one's maximum anaerobic power including all out efforts in cycling and running (e.g., the Wingate 30 second test) (Burr et al., 2008). During a maximal anaerobic test a participant will perform a maximum amount of work against a resistance calculated from their body weight. During the test a number of different measurements are recorded including: peak power output, average power output, and a fatigue index. Peak power output is the maximal amount of power output attained during the 30-second time period of the test (Bell & Cobner, 2011). This measurement in relation to hockey performance can reflect a player's capacity for spurts of speed or to clear opponents from in front of the net (Gledhill & Jamnik, 2007). Average power output refers to the average amount of power that a participant can produce during the entire 30-seconds of the test. This measurement reflects a player's capability to maintain a relatively high level of work throughout a 30 second shift (Gledhill & Jamnik, 2007). Lastly, fatigue index is measured which is the amount of power that is lost during the 30-second test as a result of the participant becoming fatigued. This measurement reflects the power drop-off that can be lost during a 30 second shift on the ice. During this measurement, the lower the percent drop-off, the better the score (Gledhill & Jamnik, 2007).

2.7 Chapter Summary

Minor hockey athletes are being evaluated for selection to representative, house, and spring hockey teams at very young ages, and the selection process continues for the duration of their careers. The vast majority of evaluation protocols are being performed on-ice at a young age with skating ability, a non-standardized measure, being a top criterion of selection procedures. This leads to the use of subjective measurements for evaluation purposes.

Off-ice testing is used to gather valuable information on an athlete's functional capacity and skill level (Peyer et al., 2011). In general, athletes are often evaluated using assessments of speed, strength, agility, aerobic and anaerobic energy systems, and body composition (Tarter et al., 2009). To be able to combine off-ice and on-ice evaluations would allow a more informed foundation for player selection, as well as provide important training information for player development across skill levels. Therefore, the goal of the proposed research is to begin collecting normative physical fitness information on young ice hockey players, and to examine the transferability of off-ice measurements to on-ice performance.

CHAPTER THREE: WHAT DO WE KNOW ABOUT ICE HOCKEY PLAYERS?

The purpose of this chapter will be to present a summary review of the literature that identifies and discusses factors with the highest capability for predicting hockey success in elite ice hockey players.

3.1 Introduction

Ice hockey is played in 104 countries around the world. Canada and The United States of America (USA) have over 4,400 rinks and 1.13 million registered players alone. These two countries play host to the National Hockey League (NHL), which is considered by many to be the highest level of competition in the world, and is one of the major professional leagues played in the two countries. With eight teams in Canada and 22 teams based in the USA, the season long competition for the Stanley Cup is an intense and gruelling endeavour that favours the top performing team with the greatest chance to win the championship.

The beginning of the NHL regular season starts in mid-October, in which 82 games are played by each of the 30 teams and concludes at the end of April. Each team has 23 active roster players and each athlete on these teams faces a unique set of demands, as the sport entails short bouts of high intensity on-ice play, followed by periods of intermittent rest between shifts (Burr, Jamnik, Baker, Macpherson, Gledhill & McGuire, 2008). An athlete's ability to meet these demands, by generating a great amount of force and recovering at a rapid rate, will greatly influence their sport-related success.

Vescovi, Murray, Fiala & VanHeest (2006) state that "the ability to successfully identify elite versus non-elite players or starters versus non-starters could influence a team's success; therefore, effectively classifying players based on physical characteristics and performance parameters requires a critical analysis of the qualities deemed important for the particular sport and the subsequent selection and implementation of appropriate tests to assess those attributes" (p. 207 -208). Within the sport of ice hockey, the ability to identify young athletes with the potential for future success could lead to advancement for the player, team, and sport.

Athletes must be able to develop a high fitness level, both anaerobically and aerobically, and maintain strength and power in order to meet the mixed demands of the sport (Roczniok et al., 2013). Due to the inherent constraints of equipment and playing surface, a number of performance tests are used to evaluate physical measures and skill level in an attempt to identify exceptional performers.

There is a belief that the earlier an athlete is identified in their career, the more likely they will be to receive advanced coaching, training, and continued success (Sherar, Baxter-Jones, Faulkner, & Russell, 2007). According to Sherar et al., (2007) the major characteristics that lead to selection of young athletes for youth hockey teams is based on speed, size, strength, and skill. Given that ice hockey is a sport of prominence and importance in Canada, even at the youngest of ages, parents invest significant time, money, and resources into the sport in hopes that their children reach their playing dreams.

3.2. Knowledge Synthesis Approach

The summary information presented in this chapter was generated through a rigorous, systematic, and evidence-based approach to examine critically the literature to identify physical factors that are associated with hockey success. The knowledge synthesis was restricted to research on male ice hockey players in high performance settings, wherein high performance referred to ice hockey players at an elite level of play (e.g., NHL, Canadian Hockey League (CHL), American Hockey League (AHL), National Collegiate Athletic Association (NCAA), University, and National Teams). The focus of the knowledge synthesis was on examining on-ice assessments, as well as off-ice assessment as it relates to hockey performance. Using an electronic search strategy (keywords: *ice hockey*, *National Hockey League, talent, expert, elite, high performance,* and *physiology),* three bibliographic databases (PubMed, EmBase (OvidSP), and SPORTDiscus) were searched. The articles generated were screened by two reviewers according to title, abstract, and full text, which yielded a total of 41 articles for review. From these articles, data was extracted, which included information regarding study design, population, participant characteristics, objectives of the study, testing protocol, outcome measures, equipment used, order of testing, major outcomes, and the comments and conclusions made based on the finding of the study. While this systematic review is currently under manuscript preparation, a summary of 'what the literature reports' is presented here.

3.2.1. What Measurements are Being Collected?

The most consistently reported measurements in the literature are anthropometric measures of elite hockey players (37% of articles), including: height (93%), weight (100%), and body fat percentage (67%). Measurements of lower body strength were reported in 20% of articles. The major testing protocols utilised were vertical jump (75%), broad jump (50%), and the squat (25%). With similar consistency, measurements of upper body strength were collected in 17% of articles and reported performance on: combined grip strength (43%), bench press (58%), push ups (57%), sit ups (57%), and isometric push and pull (29%). In all research measuring aerobic performance, VO_{2max} testing was conducted. Anaerobic capacity was examined in 24% of articles, including collection of relative anaerobic power (50%), Wingate peak power (40%), lactate threshold (40%), the 40 yard dash (10%) and the 30 metre dash (20%). Only 5% of the research examined on-ice performance measures. On-ice performance measurements included: the agility skate (100%), an acceleration skate of 6.1 m (50%), skating speed over 47.9 m (50%), 15.2 m full speed skating (50%), and a 35 m sprint skate (50%). The findings of these results are presented in Tables 3.1 to 3.6.

Table 3.1. Anthropometric Values

Publication		n	Age	Height (cm)	Weight (kg)	% BF	HR
Burr et al 2008		853	18.0	186.2	87.6	9.7	
Burr et al 2007		107	17.0	186.0	87.5	9.9	
Durocher et al 2010		12	21.4	181.8	87.3		
Gilenstam et al 2011		10	23.0	181.0	85.0		
Green et al 1979	Junior	9	17.7		82.4	10.0	188.0
	Pro	12	21.5		83.4	10.5	195.0
	University	19	21.5		77.6	10.7	198.0
Green et al 2006		29		182.0	84.9	12.0	
Hoff et al 2005	Elite	18	24.2	179.9	84.1	16.9	191.1
	Junior	21	17.6	179.0	72.3	15.7	203.0
Houston et al 1976		48	17.8	178.1	79.5	9.5	
Kochanska-Dziurowics et al 2013		19	17.1	183.0	80.0		
Peyer et al 2011		24	20.5	180.3	84.5	12.0	197.2
Potteiger et al 2010		21	20.7	181.9	88.8	11.9	
Quinney et al 2008		552	24.0	185.9	91.8		
Roczniok et al 2013		22		177.5	73.8	10.1	
Smith et al 1981		43	23.6	181.1	83.3		
Vescovi et al 2006		252	18.0	185.6	87.8	9.9	

All values are except sample size are expressed as means. %BF – Percent Body Fat. Max HR – Maximum Heart Rate. *Studies that only published one data point were excluded from table.

Table 3.2. Upper Body Strength Measures

Publication		CGS (kg)	Bench Press (reps)	Push-up (reps)	Chin-up (reps)	Sit-up (reps)	Iso Push (kg)	Iso Pull (kg)
Burr et al 2008		117.5	9.0	25.0		24.0	127.9	118.4
Farlinger et al 2007				22.0				
Hoff et al 2005	Elite		1RM = 100.8					
	Junior		1RM = 75.3					
Peyer et al 2011			20.0	65.3	14.3			
Quinney et al 2008		135.6				58.7		
Smith et al 1981								
Vescovi et al 2006		113.6	7.7	26.2		28.6	119.4	119.0

All values are expressed as means. CGS – Combined Grip Strength. Iso Push – Isometric Push Test. Iso Pull – Isometric Pull Test. *Studies that published only one data point were excluded from table.

Table 3.3. Lower Body Strength Measures

Publication		Vertical Jump (inches)	Vertical Jump (Watts)	Broad Jump (cm)	3 Hop Jump (m)	Squat
Burr et al 2008		24.4	5673	254.0		
Burr et al 2007	Jump Mat CMJ		5213			
	Jump Mat SJ		5149			
	Vertec CMJ		5631			
	Vertec SJ		5511			
Farlinger et al 2007		20.2		210.0	6.53	
Hoff et al 2005	Elite	22.0				1RM = 200.0 kg
	Junior	19.8				1RM = 140.3 kg
Kea et al 2001				157.0 Nm		
Peyer et al 2011	Forward					reps at 182 kg = 33.3
	Defense					reps at 182 kg = 24.8
Smith et al 1981						
Vescovi et al 2006		24.7		252.7		

All values are expressed as means. CMJ – Counter Movement Jump. SJ – Squat Jump *Studies that published only one data point were excluded from table.

Table 3.4. Aerobic Measures

Publication			Absolute VO2 max (L/min)	Relative VO2 max (ml/kg/min)
Burr et al 2008			5.0	57.4
Durocher et al 2010	On ice			46.9
	Off ice			43.6
Gilenstam et al 2011				56.0
Green et al 1979	Junior			55.0
	Pro			55.3
	University			58.9
Green et al 2006				59.0
Hoff et al 2005	Elite		4.8	57.4
	Junior		4.2	58.5
Houston et al 1976	Junior	Forward	4.3	56.3
		Defense	4.5	55.6
	University	Forward	4.4	54.6
		Defense	4.5	53.6
Kochanska-Dziurowics et al 2013				53.9
Peyer et al 2011	Forward			59.2
	Defense			56.2
Quinney et al 2008	Forward		4.8	54.0
	Defense		4.9	52.5
Roczniok et al 2013				58.5
Vescovi et al 2006				57.1

All values are expressed as means.

Table 3.5. Anaerobic Measures

Publication			Relative Anaerobic Power (W/kg)	Wingate Peak Power (W)	Lactate Threshold (mmol/L)	40 yard dash (sec)	30 meter dash (sec)
Burr et al 2008				975.0			
Durocher et al 2010	On-ice				90.1% HR max		
	Off-ice				79.4% HR max		
Farlinger et al 2007			13.4	950.0			4.67
Hoff et al 2005	Elite					5.50	
	Junior					5.69	
Houston et al 1976	Junior	Forward			12.2		
		Defense			13.0		
	University	Forward			12.3		
		Defense			13.3		
Peyer et al 2011	Forward				16.6		
	Defense				14.8		
Potteiger et al 2010			14.7	1305.5			
Quinney et al 2008			13.0				
Roczniok et al 2013			10.9				4.71
Vescovi et al 2006			11.5	1006.4			

All values are expressed as means.

Table 3.6. On-Ice Measures

Publication	Agility Skate (sec)	Acceleration Skate (sec) 6.1m	Skating Speed (sec) 47.85m	15.2 m Full Speed (sec)	35m Sprint (sec)
Farlinger et al 2007 (12)	9.20				5.14
Gilenstam et al 2011 (14)	8.30	1.06	5.92	1.51	

All values are expressed as means.

3.3. Discussion

The literature to date shows that the sport of ice hockey requires a number of different physical characteristics that are necessary to perform at an elite level. Certain physical traits allow an athlete to be effective in skating and puck handling, managing the physicality of the game, and the intense game and practice schedules that ice hockey players' experience (Quinney, Dewart, Game, Snydmiller, Warburton & Bell, 2008). Research has found that ice hockey favours a bigger, stronger, and leaner athlete compared to the average male population who are between the ages of 25 – 44 (Shields, Connor Gorber & Tremblay, 2009).

Due to the physical demands of ice hockey, the ability of an athlete to succeed at an elite level requires a highly developed musculoskeletal system. Players with high levels of muscular strength, power, and endurance have a competitive advantage over their counterparts (Burr et al., 2008). Compared to the average population, elite ice hockey players are considered on par or slightly above average with their ability to perform push-ups and bench press exercises. Elite ice hockey players are above average and score a rating of good to excellent on sit-up performance. The one test in which elite ice hockey players perform vastly better than the average population is on combined handgrip strength. Normative data from male university students showed that elite hockey players have a combined grip strength score 41.5 – 63.5 kg (36.5 – 46.9%) more than the students (Quinney et al., 2008; Vescovi et al., 2006; Vanderburgh, Mahar, & Chou, 1995).

The fast paced nature of ice hockey requires athletes to stop, start, accelerate, and change direction quickly and forcefully. Those athletes who are able to adjust their momentum rapidly and under control excel in the sport and often exhibit greater explosive force and power (Burr, Jamnik, Dogra & Gledhill, 2007). Since the most powerful and explosive movements in skating come from the lower body there have been three major testing protocols used to examine leg power. The vertical jump, which is often considered the gold standard for evaluating leg power, has been associated with predicting on-ice skating performance in elite athletes (Farlinger, Kruisselbrink & Fowles, 2007.) Elite ice hockey players are also considered well above average and are categorized into an excellent category in the vertical jump, broad jump, and squat exercises.

In addition to anthropometric measures and strength measurements, aerobic and anaerobic capacities are important factors among elite ice hockey players. Development of these systems has improved with the advancement of research, technology, and training methods; and has evolved to meet the demands of a sport where athletes are getting bigger, faster, and stronger (Hoff, Kemi & Helgerud, 2005.) The most common and accepted value for assessing aerobic capacity is VO_{2max} testing, which measures maximal oxygen consumption over a period of time during exercise. This value is reported in two different ways: an absolute measurement, which is reported in Liters per minute (L/min) and a relative measurement, which is based on the weight of a person and expressed as ml/kg/min. Due to the increased mass of elite hockey players, their relative VO_{2max} values may be slightly lower than someone who has the same absolute value as mass is divided into the absolute measurement. The relative VO_{2max} values of elite ice hockey players are considered good to excellent, while their absolute VO_{2max} values are considered excellent.

The ability to produce a great amount of force over a short distance is ideal for facilitating a top skating speed. By generating short, powerful bursts in ice hockey, the body is using the anaerobic system. A well-trained anaerobic system can help contribute to a successful elite ice hockey player.

The most basic and fundamental skill of an ice hockey player is the ability to skate. The skating motion requires quick, repetitive, powerful strides to propel an athlete (Farlinger et al., 2007). Due to limitations from ice hockey equipment and playing surface, a number of performance tests for ice-hockey athletes are performed off-ice. These tests are used to evaluate physical measures and skill level in an attempt to identify exceptional performers. However, three studies (Durocher, Guisfredi, Leetun & Carter, 2010; Farlinger et al., 2007; Gilenstam, Thorsen & Henriksson-Larsen, 2011) tested athletes in full equipment and on the ice. Durocher et al., (2010) found that the lactate threshold was obtained at a heart rate max of 11.3% higher on-ice compared to an equivalent testing protocol, which was performed off-ice. Farlinger et al., (2007) and Gilenstam et al., (2011), reported values of skating agility, skating speed, and skating acceleration. While no comparison can be made with the other on-ice tests due to the limited amount of literature available, it is important to understand that true values of performance measures should be considered in a setting comparable to that in which an athlete competes.

In the sport of ice hockey, being stronger, taller and having more lean body mass can help facilitate an athlete's success. Therefore, relatively older players possess advantages compared to younger players in the same age group. These advantages at an early age can lead to selection on better teams, which leads to improved coaching, training and competition, and in the end continued success (Hancock, Ste-Marie & Young, 2013.) Thus, having a birthdate earlier in the chronological year can be a distinct advantage to certain athletes. It has been shown in research that there is evidence of a relative age effect in the sport of ice hockey (Boucher & Mutimer, 1994; Bruner, Macdonald, Pickett & Cote, 2011; Deaner, Lowen & Cobley, 2013; Hancock et al., 2013; Lemez, Baker, Horton, Wattie & Weir P, 2013; Sherar, et al., 2007; Sherar, Bruner, Munroe-Chandler & Baxter-Jones, 2007; Weir, Smith, Paterson & Horton, 2010). For example, research has shown that there is an overrepresentation of players born in the first quarter (January – March) and second quarters (April – June) of the year, compared to the last two quarters of the year, when examining the relative age effect in youth ice hockey players (Hancock et al., 2013; Lemez et al., 2013; Weir et al., 2010). Additionally, Sherer et al. (2007) stated that 78.9% of players who were able to fast track their way into elite hockey had a birthdate in the first half of the year.

Not only being born at the right time can influence an athlete's path to success, but according to both Cote, Macdonald, Baker & Abernethy (2006) and Curtis & Birch (1987), where you are born can also play a factor in determining sporting advancement. These studies found that players born in cities with a population over 500,000 are consistently under-represented in terms of producing professional athletes, while cities with a population under 500,000 are of expected proportions or over-represented. Cities with populations between 50,000 - 100,000 are overrepresented among elite ice hockey athletes and present the best odds of producing elite athletes (Cote et al., 2006; Curtis & Birch, 1987).

It is quite evident that there exists a relative age effect in the sport of ice hockey. However, Gibbs, Jarvis & Dufur, (2011) have also found that a strong relative age effect fades and then reverses across levels of hockey play amongst Canadian-born players and the career duration of all Canadian born NHL hockey players born in the first quarter of the year was one season shorter than those players born in the last quarter of the year.

What defines success at a young age is still a topic of debate. Research has shown that the earlier a young athlete matures, the more likely they are to be selected to a better team due to size and strength components they possess over chronologically younger or less-developed young athletes. However, other physical indicators of athletic success have not been documented.

Examining the literature in ice hockey is limited by the heterogeneity of the population investigated (e.g., elite level of performers). Moreover, success in ice hockey is also position-dependent, as each position requires certain characteristics and success is determined differently for each position and player. Quinney et al. (2008), have shown that defensemen were generally larger and had greater musculoskeletal fitness compared with other positions; whereas, forwards demonstrated greater relative aerobic fitness and lower body fat scores. Therefore, these findings may undermine the positional demands of ice hockey athletes and testing should be reported by positions and not limited to group reporting which may not represent all cohorts that play ice hockey. Furthermore, there is an absence of a standardized physical fitness protocol that can be utilized across all levels of development, which are sport-specific. While several investigations evaluate off-ice testing and its correlation to hockey performance, most involve elite players and highly specialized equipment. Further research is required to evaluate ice hockey players in a sport-specific setting on an ice surface, in a way that is not resource-intensive and easily reproducible. In addition, research investigating the characteristics of children and youth is also required and is needed to develop ice hockey training programs in youth sport.

3.4. Conclusion

Elite ice hockey players display anthropometric and physical properties that are above average compared with the general population; with a vast difference in hand grip strength and vertical jump. With above average qualities, these measures have been correlated with elite hockey players and the level of competition at which they compete. Further research is required to effectively and accurately evaluate the performance of off-ice testing in relation to on-ice performance; especially in youth ice hockey players.

CHAPTER FOUR: THE RELATIONSHIP BETWEEN OFF-ICE TESTING AND ON-ICE PERFORMANCE IN MALE YOUTH ICE HOCKEY PLAYERS

The purpose of this chapter is to present the research investigation, the goal of which was to investigate the relationship between off-ice physical fitness performance and sport-related performance on on-ice assessments in male, minor ice hockey players.

4.1 Introduction

The fast-paced and physically demanding sport of ice hockey requires players to develop a well rounded physical fitness platform, including anaerobic sprint ability, a strong aerobic endurance base, and high levels of muscular strength, power, and endurance (Burr et al., 2008). Games consist of three 20-minute periods at an elite level, and the average length of a shift in professional men's ice hockey is approximately 61 seconds (Ransdell & Murray, 2011) with varying recovery time depending on power plays, penalty kills, and the amount of double shifting. In minor hockey, the duration of each period is less, often 12 to 15 minutes long, and each shift is around 60 seconds. Despite the shorter periods of play, the young hockey players still need a high level of fitness to compete at a high level.

Part of the player selection process in the upper regimes of ice hockey involves rigorous testing in an attempt to identify those with the capability to play hockey and succeed at a high level. While there are numerous factors that can make one player more skilled than another, there are specific quantifiable characteristics that may be used to indicate a player's physical capacity (Burr et al., 2008). A number of different laboratory and field tests have been used to evaluate the physical capabilities of athletes to determine their strengths and weaknesses (Gilenstam et al., 2011). However, at the minor hockey level, team selection is based solely on the on-ice evaluation of players by coaches, volunteer observers, and parents. This subjective assessment of skill by the evaluating committee takes into account the observers' own experience and training (Nadeau et al., 2008). Implementing another evaluation protocol in minor hockey, such as off-ice testing, could help identify those players who are more physically fit, stronger, powerful or combination of all three, which might be otherwise hidden when using on-ice evaluation in isolation.

Importantly, this approach may provide a model for counteracting the prevalence of relative age effects, wherein there is an unequal representation of players born earlier in the calendar year (Musch & Grondin, 2001). Relative age effects already emerge in ice hockey at the earliest of age divisions and intensify as players are organized into tiers. In ice hockey, relative age effects emerge around the cut-off date of December 31st meaning that the oldest children in the age cohort are born in the first months of the calendar year and the youngest are those born in the last months of the calendar year. As a result of the extra months afforded by an early calendar birthdate for growth and maturation, selection decisions made by coaches are often in favour of the older child. Using alternative evaluation protocols in minor hockey, such as off-ice testing, may give insight into a younger athlete's potential and give them a better chance at being selected for a team, rather than using size and strength alone, provided normative data can be generated. As such, generating normative data taking into account both birth year and calendar quarter may facilitate better informed decisions around physical capacity and potential relative to age, with the goal of enhancing long-term development and retention of the individual.

In the fast-paced sport of ice hockey, a number of different attributes have been associated with elite players and their performance on the ice. In previous literature, much of the research in off-ice testing has been performed on elite hockey players. Burr et al. (2008) reported that peak watts achieved during a 30-second Wingate test, body index, fatigue index, and standing long jump were significant predictors of draft selection in draft eligible athletes. In addition, Potteiger et al. (2010) found that NCAA Division one hockey players on-ice skating times were significantly correlated with Wingate anaerobic power and capacity measures. Mascaro et al. (1992) found that skating speed of East Coast Conference players was significantly correlated with vertical jump and anaerobic power. In a 26-yr longitudinal study on a NHL team, Quinney et al. (2008) has also shown that grip strength was higher on successful teams versus less successful years. Finally, Bracko & George (2001) found that 40-yard dash and vertical jump had the strongest off-ice predictability of skating speed over 44.8 meters in Women's ice hockey players. While this information is useful in an elite setting, little is known about the relationship between on-ice and off-ice performance in minor hockey-age youth and the subsequent selection and tiering of players.

The primary purpose of this investigation was to examine the relationship between off-ice physical fitness performance and sport-related performance on on-ice assessments in male, minor ice hockey players. We hypothesize that players who exhibit higher scores on off-ice measures will also demonstrate better scores on on-ice measures. In addition, it is also postulated that off-ice measures requiring high power output from the legs such as vertical jump, standing long jump, Wingate cycle ergometer test, and the 30-meter sprint will be particularly salient in predicting on-ice performance.

4.2 Methodology

4.2.1 Participants

Eleven male minor hockey players were recruited across three birth years (2004, 2005, and 2006). The sample ranged in age from 9 to 11 years. All participants were pre-screened for physical activity by completing the 2014 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (Appendix B). No individual was excluded from participating based on pre-screening (i.e., all participants responded 'no' to each question on page 1 of the PAR-Q+). The investigation received approval from, and was executed in exact accordance with the ethical guidelines set forth by the University of British Columbia's Behavioural Research Ethics Board for research involving human participants. All participants' legal parent and/or guardian provided informed written consent (Appendix D) and all players provided informed written assent (Appendix E).

4.2.2 Assessments

All players performed a battery of 14 off-ice tests and 4 on-ice tests. Off-ice assessments included measurements of: anthropometrics, body composition, muscular strength, muscular endurance, muscular power, flexibility, anaerobic fitness, aerobic fitness and agility. On-ice assessments included measurements of: skating speed, skating acceleration, skating agility, and shot velocity

4.2.2.1 Off-Ice Assessment: Anthropometry and Body Composition

Anthropometry and body composition were evaluated noninvasively using standing height, wingspan, and body weight. Standing height was measured with a Seca free-standing stadiometer (Birmingham, United Kingdom), wherein participants stood without footwear, with their heels together and the backs of their feet touching the stadiometer. Standing height was measured to the nearest 0.5 cm from the highest point on the top of the head. Wingspan was measured to the nearest centimetre, from the tip of one middle finger, to the tip of the other middle finger. The participants stood with their back touching the wall, extending their arms out to the sides at shoulder height. The middle finger of their right hand was placed on a block that indicated the starting point of the measurement, and measurement was taken to the tip of the other middle finger. Body weight was measured to the nearest 0.1 kg using a Tanita digital scale (Arlington Heights, Illinois, USA). The participants were without footwear and were dressed in shorts and t-shirts.

4.2.2.2 Off-Ice Assessment: Muscular Strength, Endurance, and Power

Muscular strength. Muscular strength was examined using grip strength. Grip strength was performed on both hands and measured to the nearest kilogram using an Almedic Hand Grip Dynamometer (Saint-Laurent, Quebec, Canada). The dynamometer was adjusted to fit the participant's hand, and with their arm outstretched at a 45-degree angle from the body, the participant squeezed the dynamometer as forcefully as possible keeping the arm extended at all times. Two trials were performed for each hand with the maximum force obtained being recorded.

Muscular Endurance. Muscular endurance was examined via curl-ups and push ups. Curl-ups were performed on a mat and done in time with a metronome. The participant started in a supine position, knees bent at an angle of 90^{o}, heels in contact with the ground, and arms crossed over the chest with each hand on the opposite shoulder. The metronome was set at a rate of 25 curl ups per minute. One curl up was completed when the scapulae were in contact with the floor, elbows then contacted the thighs with the heels still on the floor, and then returned to have the scapulae back on the floor. The test administrator placed one hand under the player's scapulae to ensure a return to the floor. The participant performed a maximum number of curl ups, without pausing, up to 100. The test was terminated if the participant appeared to be experiencing unusual discomfort, was unable to maintain required cadence, was unable to maintain the proper curl up technique (e.g., heels come up off the floor) over two consecutive repetitions despite corrections by the appraiser, and/or 100 repetitions were performed (4 minutes had elapsed).

Push-ups were performed at a rate of 25 per minute in time with a metronome. The participant started on their stomach with their legs together. The hands were positioned under the shoulder with the fingers pointing forward. The starting position required that the participant fully straightened the elbows using the toes as the pivot point. The upper body needed to be kept in a straight line. The participant then lowered the body to the point where the elbow reached a 90^{o} angle then returned to the starting position. A push up was not counted if the stomach or thighs came in contact with the mat.

Muscular Power. Standing long jump, vertical jump and the single leg squat were administered to assess muscular power. Standing long jump was measured to the nearest 0.5 cm, from the starting line to the back of the participant's heels upon landing. The participant stood with his feet slightly apart behind the starting line. Using an arm swing to assist the jump, the participant was asked to jump as far as possible making sure that he controlled the landing. This meant that the player could not take a step after the landing, put his hands down to balance, or fall over. If the player did not land appropriately, another attempt was given. Participants were given two attempts and the highest score was recorded.

Vertical jump was measured to the nearest 0.5 inch. The participants were asked to reach as high as possible with his fingers outstretched with their dominant arm, keeping both shoulders at the same height. The Vertec apparatus (Vertec Power Systems, Knoxville, Tennessee, USA) was set to the participant's outstretched finger. The participant took a comfortable position below the Vertec apparatus, approximately an elbows length away from the apparatus. Without a pre-step, and the fingers outstretched on their dominant arm, the participant would descend to a squat position. The tester would then count to three and the participant would jump as high as they can, hitting the highest number of markers possible. Participants were given two attempts and the highest score was recorded.

Single leg squat was recorded on a point system of 15 points per squat on one leg (Appendix F). Five consecutive repetitions were performed on each leg giving a grand total of 150 points to be scored for the entire test. The participant started with one foot on the ground (the scoring leg) and one leg hanging freely beside the other. To start the movement the participant would descend slowly until the top of their thigh was parallel with the ground. As the participant was descending the hanging leg and arms would rise forward and upward so that the arms and leg were straight out in front of them and parallel with the ground. On the down phase the participants gluteal muscles could not come in contact with the heel. There should be a one-second pause at both the bottom and top of the movement. During the entire movement, the participant's spine should be extended so that it is upright.

4.2.2.3. Off-Ice Assessment: Agility

The pro agility test was administered to test off-ice agility. The off-ice pro agility test was measured to the nearest 0.01 s using Brower TC timing gates (Brower Timing Systems, Draper, Utah, USA). Participants started 10 cm behind the start line in a ready position. The participants always faced the same way to start the test, and depending on what direction they started the test, that was the direction that was recorded (i.e. if the first movement was to the right, the recording score was to the right). From the start position, the participant would sprint 15 feet to the right, touch the line with their right hand, change direction as quickly as possible, and sprint 30 feet to the left and touch the line with their left hand, change direction, and sprint 15 feet back to the start/finish line. The participant must touch the right line with their right hand, and the left line with their left hand. The timing started when the participant passed through the timing gates set up on the start/finish line, and stopped when they passed through the same timing gates for the second time. Participants performed the test twice in each direction with the fastest time being recorded as their score. If the participant were to stumble, fall or slip, they were given another attempt.

4.2.2.4 Off-Ice Assessment: Flexibility

The trunk flexion (sit and reach test) was measured to the nearest 0.5 cm using a flexometer. The participants were without shoes and sat with their legs fully extended with the soles of their feet placed on either side of the measuring surface. The balls of their feet were placed two centimeters away from the measuring surface. Keeping their legs fully extended and placing the middle fingers on top of one another, the participants were to bend and reach forward sliding a marker along the measuring tape as far as possible. The participants were to hold the final position for two seconds and no jerking of the body was allowed. To avoid negative measurements, the bottom of the foot was set at the 25.5 cm mark of the measuring scale. This meant that reaching short of the bottom of the foot would result in a score of less than 25.5 cm, and reaching further than the foot would result in scores greater than 25.5 cm.

4.2.2.5 Off-Ice Assessment: Anaerobic Fitness

The 30-second Wingate cycle ergometer test and the 30-meter sprint were assessed to measure anaerobic fitness. A Racermate Velotron cycle system (Racermate Velotron, Seattle, Washington, USA) was modified with a youth bike frame so that it would fit the younger and smaller participants of the study (Figure 4.1). The participants were fitted for the bike so that when the pedals were in the down position the leg was slightly flexed. Participants were given a two-minute warm up on the bike. The resistance that the participants pedalled against was calculated by 7.5% of the participant's body weight (Child Health and Exercise Medicine Program). To start the test the participant would begin to pedal and progressively get faster. A countdown would appear on the computer screen starting at 10. The participant was instructed to be pedaling as fast as they possible could by the time the countdown reached 1. Once the participant was pedaling as fast as possible a load was placed against the wheel of the bike and the test begun. The participant would pedal at a maximum capacity for 30 seconds against the designated resistance. Once the test was finished, the participant was encouraged to pedal at a slow rate for one minute to initiate a cool down. Calculations from the recording included power output (expressed in watts/kilogram), peak power output, mean power output, minimum power output and fatigue index.

Figure 4.1. Electronic bike used for 30 second Wingate cycle ergometer test as modified for youth participants.

The 30-meter sprint was also used to measure anaerobic sprinting ability. The 30-meter sprint was measured to the nearest 0.01 s including a 6.1-meter split time measured to the nearest 0.01 s using Brower TC timing gates. Participants started 10 cm behind the starting line in a ready position. The tester would countdown from three before saying, “go”. On the word “go”, the participant would sprint as fast as they could for 30 m. The timing would start when the participant passed through the first timing gate and stop when they passed through the last timing gate 30 m away. There was another timing gate

6.1 m from the start line to measure the participant's acceleration time. Participants performed the test twice with the fastest time being recorded as their score. If the participants were to stumble, fall or slip, they were given another attempt.

4.2.2.6 Off-Ice Assessment: Aerobic Fitness

Aerobic fitness was assessed using the 20-meter multi stage shuttle run test (Leger & Lambert, 1982). Participants ran in between two lines that were placed 20 meters apart in time to recorded beeps. The participants stood behind one of the lines and faced the other line. An audio recording sounded with a "beep" and the participants began to run to the other line that is 20 meters away. The speed starts off quite slow, however, the beeps get closer together decreasing the time allowed to run between lines. The participants continuously ran between the two lines and turned around from one line to the other when signalled by the beep sound. If a line was reached before the beep sound, the participant would wait until the beep to continue running. If the beep sounded before the participant got to the line a warning was given. After two warnings and not being able to keep up to the beeps the test is over and the level reached is recorded. The athlete's score was the level they reached as well as the number of shuttle runs in that level. The level reached was then calculated into a VO_{2max} score using the equation (Leger et al., 1987):

VO_{2max} (ml x min^{-1} x kg^{-1}) = 31.025 + (3.238 x Velocity) – (3.248 x Age) + 0.1536 x Velocity x Age).

4.2.2.7 On-Ice Assessments

On-ice testing was comprised of four tests. The 15.2-meter maximum speed test, a 6.1-meter acceleration test with a continuation into a 47.9-meter top speed test (for a total of 54 meters), an agility cornering S turn test (Bracko, 2001), as well as a shot velocity test.

The on-ice maximal speed test was measured to the nearest 0.01 s using Brower TC timing gates. Participants would start from the opposite blue line and begin skating toward the defensive end of the ice. The participant would then circle around the defensive zone face-off dots picking up speed as they headed toward the defensive zone blue line. The first set of timing gates were set up on the defensive zone blue line at which time, the participant should be a full speed when the break the plane of the first timing gate. The participant then skated as fast as the could for 15.2 m to the offensive zone blue line where another set of timing gates were set up to measure the total amount of time. Participants performed the test twice with the fastest time being recorded as their score. If the participant were to stumble, fall or slip, they were given another attempt.

The on-ice 54-meter test was measured to the nearest 0.01 s including a 6.1-meter split time measured to the nearest 0.01 s using Brower TC timing gates. Participants started 10 cm behind the starting line in a ready position. The tester would countdown from three before saying, “go”. On the word “go”, the participant would skate as fast as they could for 54 m. The timing would start when the participant passed through the first timing gate and stop when they passed through the last timing gate 54 m away. There was another timing gate 6.1 m from the start line to measure the participant’s acceleration time. Participants performed the test twice with the fastest time being recorded as their score. If the participant were to stumble, fall, or slip, they were given another attempt.

The on-ice agility test was measured to the nearest 0.01 s using Brower TC timing gates. Participants would start from a ready position in the center of the goal crease in one zone of the rink 10 cm behind the starting timing gate. The participants always faced the same way to start the test, and depending on what direction they started the test, that was the direction that was recorded (i.e. If the first movement was to the right, the recorded score was to the right). The participant would then skate in one direction around the big faceoff circle and continue on to the other big face off circle making a big "S" shape. Once around the second faceoff circle, the participant will skate as fast as they can to the blue line (18.9 m away from the icing line) and break the plane of the second timing gate. Participants performed the test twice in each direction with the fastest time being recorded as their score. If the participant were to stumble, fall or slip, they were given another attempt.

Shot velocity was measured to the nearest mile per hour using a Bushnell Radar Gun (Bushnell, Vaughan, Ontario, Canada). From a distance of 30 feet, the participants would shoot the puck as hard as they could towards the net. The participants were given the choice to use whichever shot they felt had more velocity. The participants were allowed to skate into the shot, however, the puck had to remain 30 feet from the net when contacted. Participants were allowed two attempts to record the fastest score. If the participant missed the net, breaks their stick, stumble or fall, or the radar gun does not register the shot, the participant was given another attempt.

4.2.3. Procedures

All participants were asked to volunteer for two days of testing with a total time of commitment of 3 hours (90 minutes per day). All on-ice assessments were conducted at a local ice hockey arena, and all off-ice assessments were administered at the Cognitive and Functional Learning Laboratory, Physical Activity Promotion and Chronic Disease Prevention Unit at the University of British Columbia.

Day 1: Questionnaires and Off-Ice Assessments

Each participant completed the PAR-Q+ and a demographic questionnaire, which included playing experience. Written informed consent was received from a parent/guardian, as well as player informed assent. All participants were then tested in the same order for each test including: height, weight, sit and reach flexibility, Wingate anaerobic test, wingspan, grip strength, 30-meter sprint, push-ups, curl-ups, one-legged squat, standing long jump, vertical jump, pro-agility test, and the Leger 20-meter shuttle run test (Figure 4.2). The order of tests was also conducted in the same way for each participant ensuring adequate rest time between intense tests to allow for appropriate recovery.

Day 2: On-Ice Assessments

The on-ice assessments required the participants to be dressed in their complete hockey apparel, including helmet and all protective gear. The participants were then led through a standardized warm-up that was the same for each player. The warm up included two laps around the ice at a minimal pace, two laps around the ice at a 60% pace and two laps around the ice at an 80% pace. The participants were then tested in the same order for each test including: 15.2-meter maximal speed test, 6.1-meter acceleration to 47.9-meter full speed test, shot velocity, and agility test.

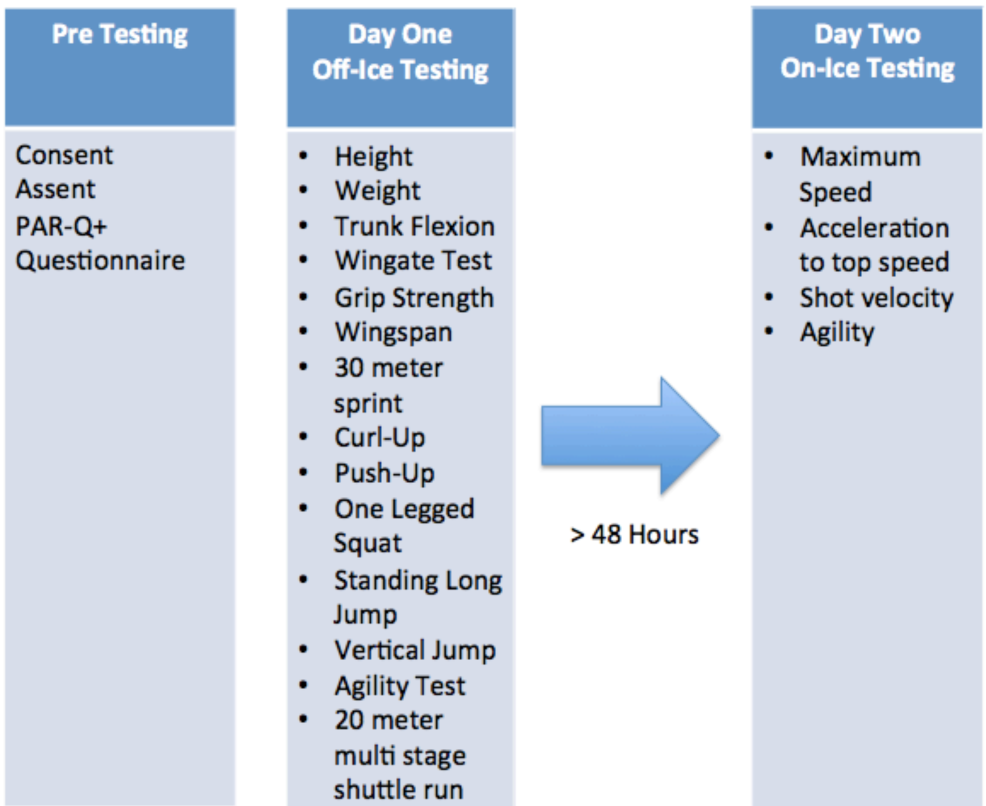

Figure 4.2. Schematic Representation of the Investigation Procedure

4.3 Statistical Analysis

Statistical analyses were performed using SPSS Version 20.0 software (SPSS Inc., Chicago, Illinois). Statistical analysis included stepwise multiple linear regression between all on-ice and off-ice variables. Pearson product moment correlations were performed between individual on-ice and off-ice variables. Descriptive data including means and standard deviations were calculated for all variables. For all statistical tests, a level of significance was set a priori at $p < 0.05$.

4.4 Results

4.4.1 Participant Characteristics

A total of 14 participants began the investigation. However, two participants were unable to complete the off-ice testing protocols, and a single participant was unable to complete the on-ice testing protocols. Therefore, a total of 11 elite male youth ice-hockey players (mean age = 10.5 ± 0.6 yr) completed the investigation and were included in the statistical analysis. Participant characteristics are presented in Table 4.1. Of the 11 participants, 9 were forwards (mean age = 10.3 ± 0.6 yr) and 2 were defensemen (mean age = 10.9 ± 0.4 yr). Of the 11 participants, 5 were born in the first quartile of the year (Jan – Mar), 3 were born in each of the second and third quartiles (Apr – June and July – Sep), and no participants were born the last quartile (Oct – Dec) (Figure 4.3). Descriptive statistics (mean and SD) for all off-ice variables measured are displayed in Table 4.2, while descriptive statistics for all on-ice tests are presented in Table 4.3.

Table 4.1. Participant Characteristics

Variable	Mean (± SD)
Age (years)	10.5 ± 0.6
Height (cm)	141.5 ± 6.3
Weight (kg)	35.9 ± 6.3
Wingspan (cm)	139.8 ± 7.4
Years Played Hockey (yr)	4.9 ± 1.1
Times per week hockey is played in the winter	4.5 ± 0.6
Hours per week hockey is played in the winter	5.6 ± 1.2
Times per week hockey is played in the summer	3.7 ± 1.8
Hours per week hockey is played in the summer	4.5 ± 2.2

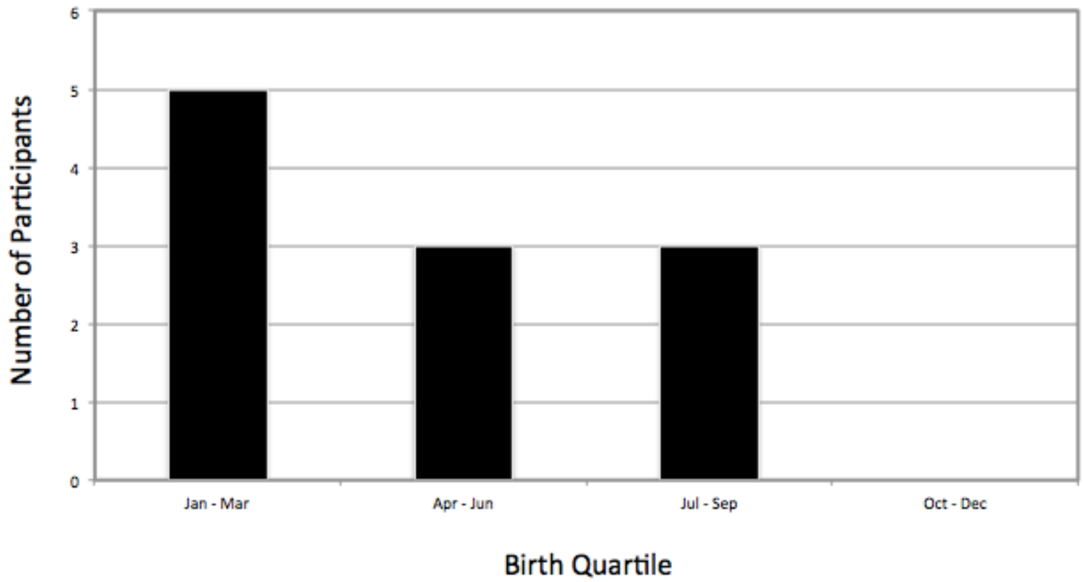

Figure 4.3. Participant Distribution by Birth Quartile

Table 4.2. Off-Ice Measures

Variable	Mean (± SD)
Grip Strength Right Hand (kg)	21.2 ± 3.8
Grip Strength Left Hand (kg)	21.2 ± 3.9
Grip Strength Combined (kg)	42.4 ± 6.9
Trunk Flexion (cm)	29.0 ± 7.3
Push Ups	10.1 ± 3.6
Curl Ups	19.3 ± 15.6
Vertical Jump (inches)	14.9 ± 2.9
Standing Long Jump (cm)	161.9 ± 17.9
One Leg Squat Right Leg	52.7 ± 10.4
One Leg Squat Left Leg	55.5 ± 14.5
One Leg Squat Combined	108.2 ± 23.7
Agility Split – Right (s)	3.1 ± 0.2
Agility Total – Right (s)	5.8 ± 0.3
Agility Split – Left (s)	3.0 ± 0.2
Agility Total – Left (s)	5.8 ± 0.3
6.1 m Acceleration Sprint (s)	1.5 ± 0.1
30 m Total Sprint (s)	5.5 ± 0.4
Mean Watts (W)	231.7 ± 28.7
Peak Watts (W)	320.5 ± 56.5
Minimum Watts (W)	176.2 ± 24.9
Anaerobic Capacity (W/kg)	6.6 ± 0.8
Anaerobic Power (W/kg)	8.9 ± 0.8
Fatigue Index (W/s)	5.0 ± 1.6
Leger Stage Completed	7.2 ± 1.8
Estimated VO_{2max} ($ml \bullet kg^{-1} \bullet min^{-1}$)	54.1 ± 4.4

Table 4.3. On-Ice Measures

Variable	Mean (± SD)
Maximal Speed Test (s)	2.0 ± 0.1
6.1 m Acceleration Sprint (s)	1.5 ± 0.2
54 m Total Sprint (s)	8.7 ± 0.5
Agility to the Right (s)	10.4 ± 0.4
Agility to the Left (s)	10.7 ± 0.5
Shot Velocity (mph)	38.2 ± 4.0

Results revealed significant correlations for maximal speed test, on-ice agility to the right, on-ice agility to the left, and shot velocity with body weight ($r = 0.682$, $r = 0.702$, $r = 0.679$ and $r = 0.644$ respectively, $p < 0.05$) (Figures 4.4 to 4.6). Wingspan was also significantly correlated to shot velocity ($r = 0.734$, $p < 0.05$) (Figure 4.7).

Standing long jump demonstrated significant correlations to all skating tests including: maximal speed ($r = -0.664$, $p < 0.05$), on-ice agility to the left ($r = -0.670$, $p < 0.05$), on-ice agility to the right ($r = -0.777$, $p < 0.05$), on-ice acceleration time ($r = -0.839$, $p < 0.05$), and the 54 m on-ice full speed time ($r = -0.939$, $p < 0.05$) (Figures 4.8-4.10).

Findings also revealed a significant correlation between push-ups and on-ice acceleration time ($r = -0.752$, $p < 0.05$) and 54 m on-ice full speed time test ($r = -0.667$, $p < 0.05$) (Figure 4.11-4.12).

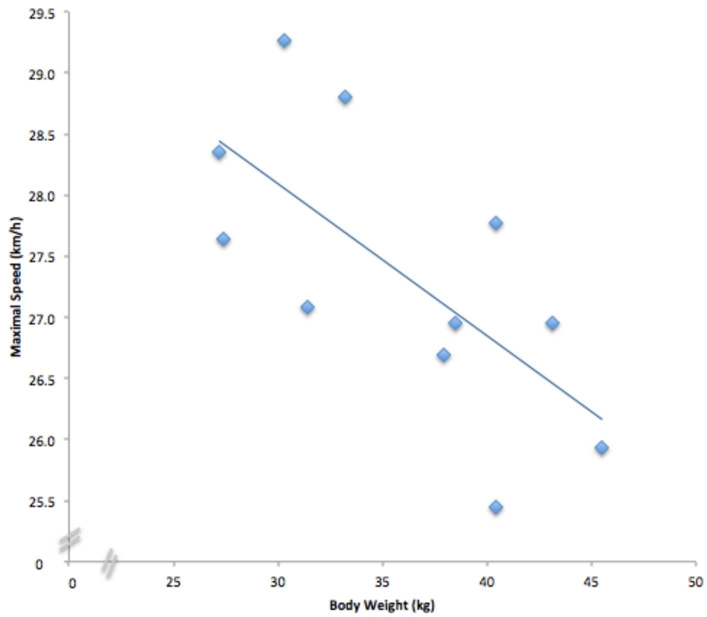

Figure 4.4. Correlation between Body Weight and Maximal Speed, r = -0.682; $p < 0.05$

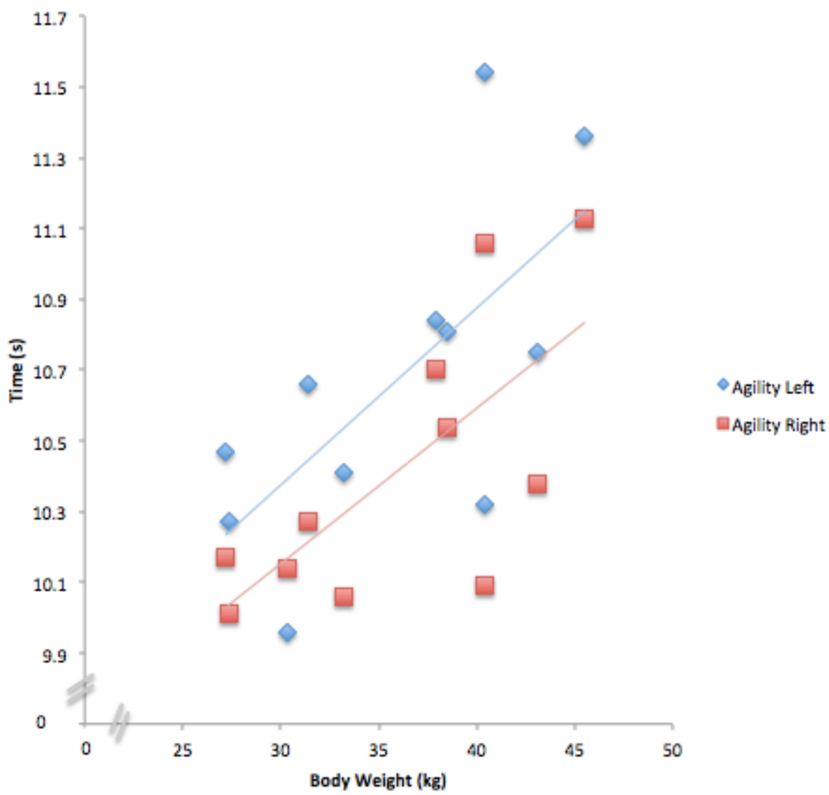

Figure 4.5. Correlation between Body Weight and Agility Time.
Agility to the left, $r = 0.679$; $p < 0.05$.
Agility to the right, $r = 0.702$; $p < 0.05$.

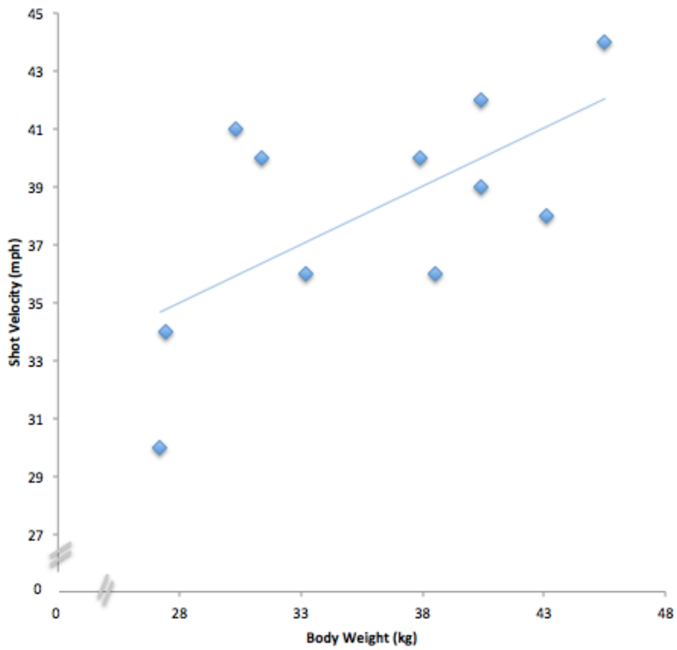

Figure 4.6. Correlation between Body Weight and Shot Velocity, r = 0.644; $p < 0.05$

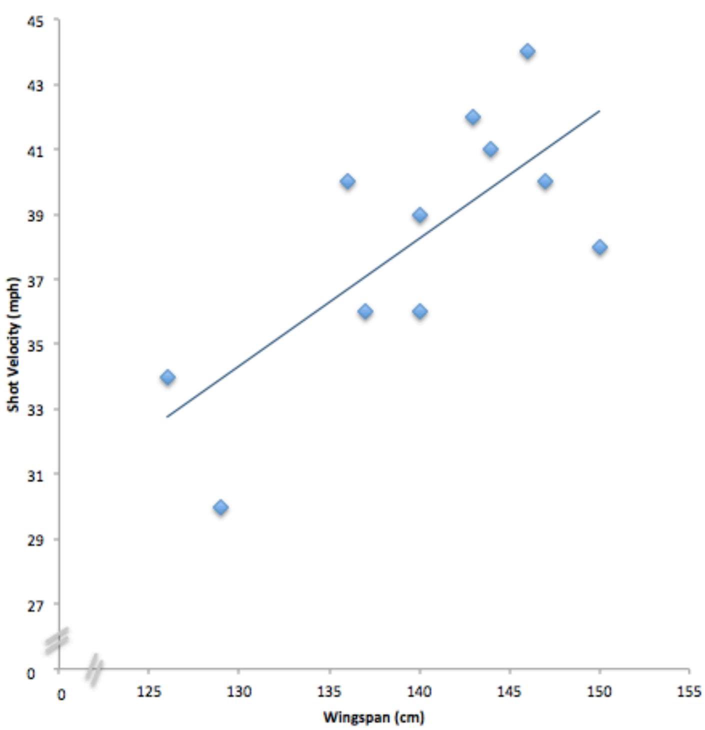

Figure 4.7. Correlation between Wingspan and Shot Velocity, r = 0.734; $p < 0.05$

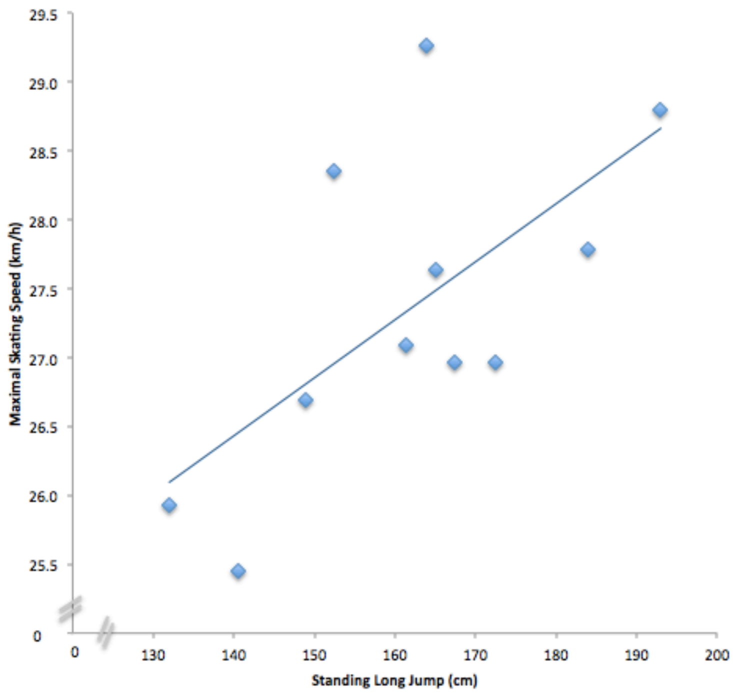

Figure 4.8. Correlation between Standing Long Jump and Maximal Skating Speed, $r = 0.644$; $p < 0.05$.

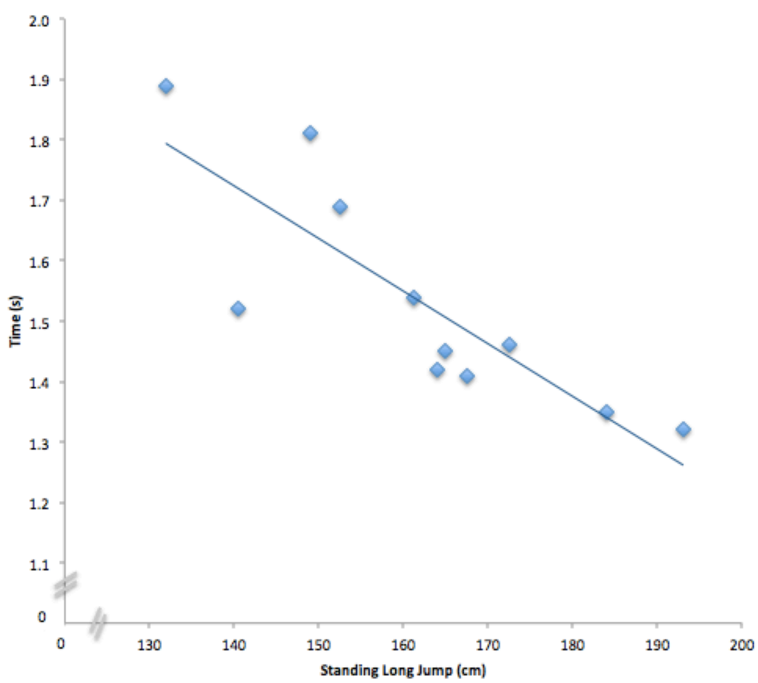

Figure 4.9. Correlation between Standing Long Jump and On-Ice Acceleration Time, $r = -0.839$; $p < 0.05$.

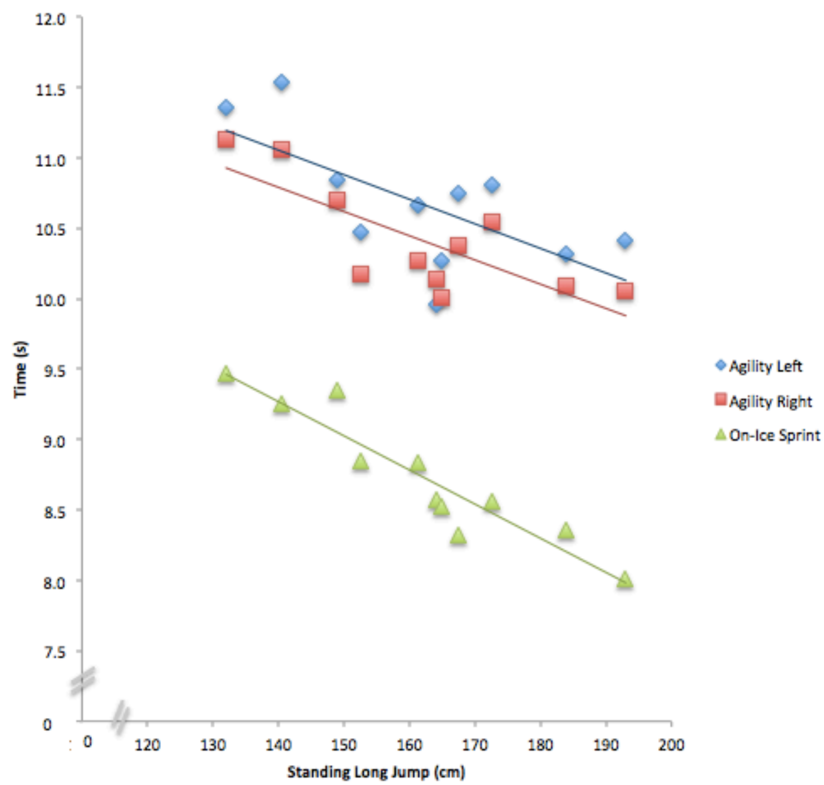

Figure 4.10. Correlations between Standing Long Jump and Agility and On-Ice Sprint Time. Agility to the left, $r = -0.670$; $p < 0.05$. Agility to the right, $r = -0.777$; $p < 0.05$. On-Ice sprint time, $r = -0.939$; $p < 0.05$.

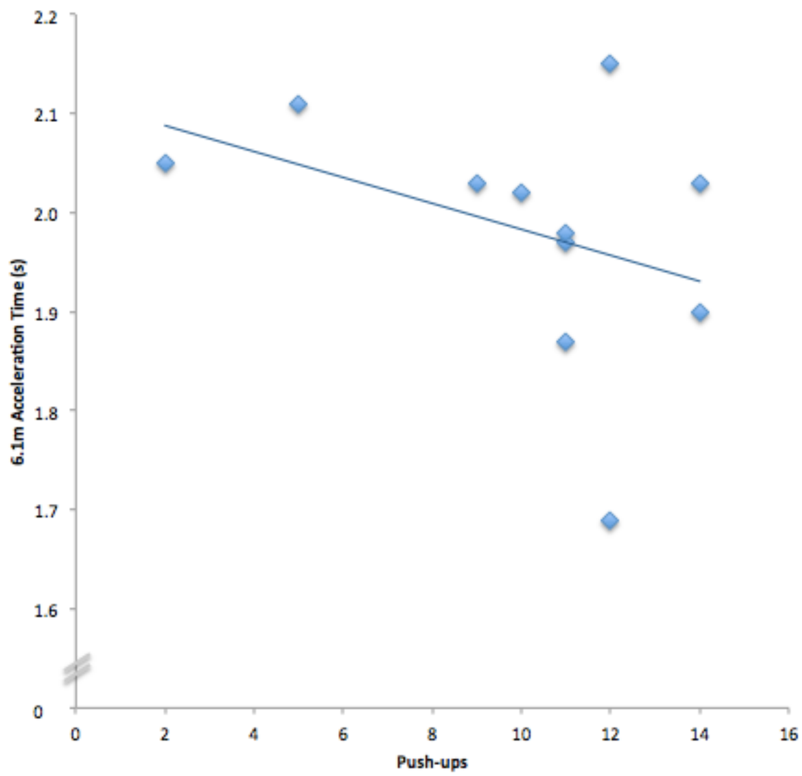

Figure 4.11. Correlation between Push-ups and On-Ice Acceleration Time, $r = -0.752$; $p < 0.05$.

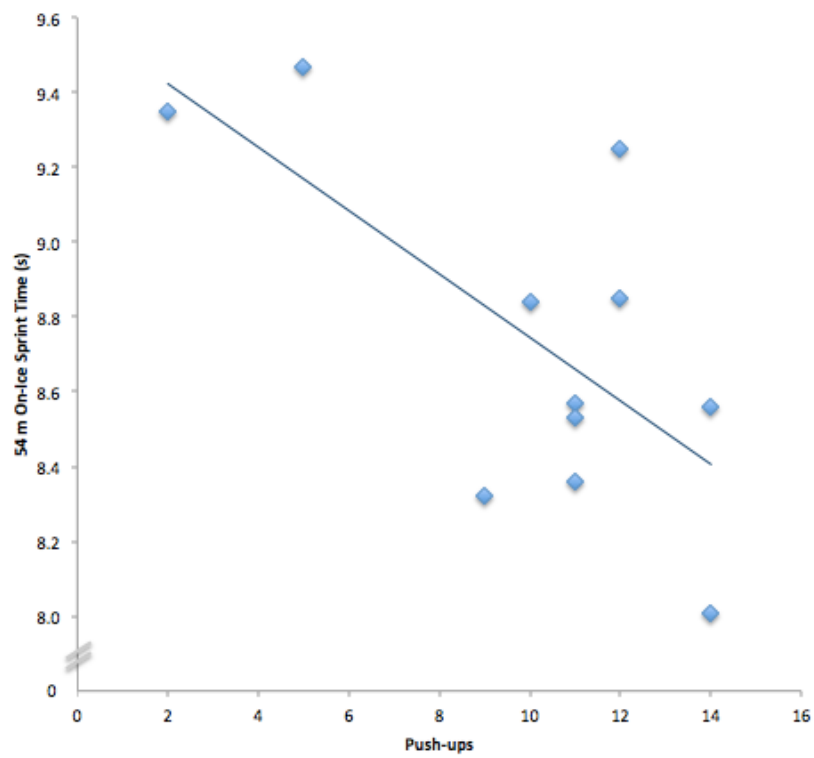

Figure 4.12. Correlation between Push-ups and On-Ice 54-meter Sprint Time, $r = -0.667$; $p < 0.05$.

4.5 Discussion

The primary purpose of this study was to investigate the relationship between off-ice physical fitness performance and sport-related performance on on-ice assessments in male, minor ice hockey players. One trend of the investigation was that the youth athletes exhibited similar correlations to on-ice and off-ice measures when compared to older elite ice-hockey players. Additionally, the anthropometric differences between positions (forwards and defensemen) were similar to current literature involving older elite athletes (Quinney et al., 2008).

To our knowledge, this is the first study to investigate male youth ice-hockey players with respect to on-ice and off-ice performance measures. The laboratory tests were chosen for inclusion on the premise that they are the evaluation measures for the NHL combine entry draft players (Gledhill and Jamnik, 2014). These tests included measures of anthropometrics, body composition, muscular strength, muscular endurance, muscular power, flexibility, anaerobic fitness, and aerobic fitness. The on-ice assessments included skating speed, skating acceleration, skating agility, and shot velocity (Bracko, 2001).

The findings showed that standing long jump is a significant off-ice variable correlated to on-ice skating ability. The standing long jump is a skilful test that measures the explosive power of the legs, in addition to coordination of the whole body when taking off, in mid air flight, and when landing. When jumping, there is a multi-dimensional component involved, where the participants explosively push themselves in both an upward and forward direction. This is much different than the vertical jump where the participant travels in only one plane. The results of this investigation are similar to those found by Farlinger et al., (2007) who demonstrated that the standing long jump was moderately correlated to sprint performance and cornering ability in Bantam, Midget, and Major Midget players. The results from this off-ice test indicate that there is a high component of muscular power and coordination needed to propel the athlete in two different directions, which is similar to the skating stride. Pushing the body vertically and forward mimics the skating movement where the athletes push themselves forward while extending their legs forcefully out and behind them.

Farlinger et al. (2007) suggested that sprinting performance off-ice and on-ice was important because of the similarities in stride length and rate. Our results indicate that this is also a trend in youth ice hockey players; however, the data was not statistically significant. Farlinger et al. (2007) also noted that the Wingate results of mean watt output and peak watt output were significantly correlated to on-ice sprint speed in elite Bantam, Midget; and Major Midget athletes; however, our results were inconclusive. Other trends that emerged from the investigation were that vertical jump was related to on-ice sprinting speed. This trend could be attributed to the fact that the hockey stride is a very powerful lower body movement and is similar to the jumping motion in that the same muscles that produce the power for both are being stressed for the movement. The youth participants in this study did show a correlation between push-ups and on-ice skating speed. Due to the fact that push-ups are an upper body movement and skating is a lower body movement, push-ups could potentially be an indicator of overall body strength. It has also been suggested that on-ice sprint time is related to anaerobic power (Mascaro et al., 1992); however, in the present study anaerobic power had very low correlation to on-ice sprint time.

Having a high level of agility as a hockey player is a necessary attribute to succeed at an elite level. It allows the player to move quickly from side to side, in addition to the ability to change direction in a very brief amount of time. This motion requires quick powerful movements from the legs and coordination of the whole body, as the body must twist and turn, as well as perform certain skating motions such as cross-overs. As described previously, the standing long jump was significantly correlated to the agility test, which may be indicative of the complex movements of the task. The weight of the athlete was also correlated to the agility test. This indicates that the lighter the participant, the more agile they were and they were able to complete the test in less time compared to those athletes who weighed more. This is important to note, as this has not been documented in a youth population. Having a high amount of muscle mass would help the athlete make powerful strides, but having too much fat mass could be detrimental in the performance of an athlete, even at a young age.

Maximum skating speed displayed a trend when compared to off-ice sprint time, which supports the findings of other investigations (Behm et al., 2005) and further supports the literature in that the skating stride and running stride are similar when examining the motion of the movement. In addition to off-ice sprint time, off-ice agility also displayed trends with maximum skating speed.

The present study also found that the distance measured during the standing long jump was significantly correlated to maximal skating speed, which supports the findings of Burr et al. (2008). In addition, body weight was also significantly correlated to maximal skating speed; however, body weight was shown to be a limiting factor to skating speed. That is, the heavier the participant, the slower the speed at which they were able to skate.

Novel trends that were observed in the investigation include the relationship of aerobic fitness scores across all skating measures. The Leger level achieved during the investigation emerged as an influencing factor on the on-ice maximal speed test, on-ice acceleration test, on-ice agility test, and on-ice sprint test. The findings of our investigation suggest that aerobic fitness is a contributing factor to intense, short duration exercises and plays a role in anaerobic performance.

This investigation also indicated that a trend emerged between anaerobic capacity, as well as fatigue index, and on-ice maximal speed. Due to the very short time duration to complete the maximal skating speed test, the evidence suggests that having a high fatigue index could indicate a slower time as the player would tire faster during the short all out bursts and not be able to produce as much power in the stride from the beginning of the test to the end. This is indicative of the energy systems needed for ice hockey as a high anaerobic system is required to produce power for all out sprints during a shift with a combination of a high aerobic base to recover while resting.

Shot velocity, while not an explosive skating movement, does require muscular power in addition to technique. Although the latter may be difficult to quantify, we can measure certain attributes that relate to how hard someone can shoot the puck. In this investigation, two off-ice tests were significantly correlated to shot velocity: weight and wingspan. The technique of shooting the puck requires the player to put muscle and weight behind their shot, which could explain the correlation of the two parameters. Having a longer wingspan could potentially allow for longer levers to manipulate the stick and having more weight could add more flex to a longer shaft that will produce the snap of the stick through the shot increasing the speed at which the puck is shot at. It is interesting to note, that handgrip strength revealed no significance to shot velocity which was thought to have more of an impact on the test.

Previous research (Quinney et al., 2008; Houston et al., 1976) has noted that anthropometric differences exist between playing positions in elite level adult ice hockey players, in that defensemen were taller and heavier compared to forwards. This positional characteristic was noted in the present investigation as well, as defensemen were the tallest of the participants, in addition to being in the top three for weight.

Due to the unique demands of ice hockey, as well as the playing surface and movement patterns, there were tests and protocols that were found in the investigation to have very little relationship to one another. The off-ice tests that were identified to be of minimal value to on-ice performance included: grip strength, sit and reach, curl-ups, and the single leg squat.

Grip strength, as reported by Quinney et al., (2008), was found to be higher in NHL teams that had more success. While our investigation did not include team measurements, but rather individual measurements, it was still of interest to note that grip strength had very low relationship to on-ice tests, including shot velocity. The participants of our investigation were also much younger than those reported by Quinney et al., (2008) which could be a determining factor. In addition, grip strength may be more influential once an athlete enters puberty and develops their muscular system.

The sit and reach test was also shown to have little relevance to on-ice performance. Our investigation included participants who played forward and defense, with no goalies being tested. Due to the demands of each position, and goalies exhibiting more flexibility (Quinney et al., 2008) than forwards and defensemen, it could be inferred that flexibility, while an important aspect of physical fitness to help prevent and reduce injury (Tyler et al., 2001), it is not a decisive factor in on-ice performance in youth ice hockey players.

Core stability is an important part of ice hockey physical fitness due to the fact that it plays a pivotal role in stability of an athlete (Quinney et al., 2008). Curl-ups in our investigation however, did not relate to any on-ice tests specifically. That being said, core stability is still a crucial component of ice hockey players as it may reduce the risk of injury, including lower back pain (Quinney et al., 2008).

The single leg squat is a test that evaluates unilateral leg strength, balance, and full body coordination (Gledhill & Jamnik, 2014). Due to the nature of the skating stride where both left and right sides of the body are equally important in the skating stride, it is understandable that measuring one side of the body did not reveal any significant findings to on-ice performance. It should be noted though that imbalances throughout the body could lead to injury and that a measure of unilateral strength may be important in the injury prevention of ice hockey players.

4.5.1. Study Limitations and Methodological Considerations

Using performance measures such as those undertaken in the present investigation are valuable and informative assessments that can be used to assess the physical attributes of athletes. However, while these tests have been prescribed for an adult elite level athlete, it is important to note that the athletes tested in the present investigation had never seen some or all of these tests before. For example, the 30 seconds Wingate cycle ergometer test was difficult for the participants due to the unfamiliarity of the test. Increased familiarization to the equipment and test protocol is needed, and the players should be provided the opportunity to perform the test more than once. In those players with previous test exposure, results were yielded that were more reflective of their capabilities. One of the biggest limiting factors of the investigation is the low sample size and a much larger sample size is needed across birth years.

4.6. Conclusion

This investigation was the first to report the relationships between off-ice assessments and on-ice performance in male, youth ice hockey players. This information provides insight into physical fitness tests that are potentially associated with on-ice performance. Furthermore, our data indicate that the standing long jump is highly correlated to all skating tests measured in the investigation. In addition, weight was a limiting factor to maximum speed and agility, however, it was an influencing factor to shot velocity.

These observations provide information into what physical fitness parameters can be indicative of on-ice performance. This information is important to athletes, parents, and coaches alike as the underlying principles of these movements can facilitate the development of appropriate programming for young players.

CHAPTER FIVE: GENERAL DISCUSSION AND FUTURE DIRECTIONS

The purpose of this chapter is to summarize each chapter of the thesis. Also, we provide suggestions for future areas of research and concluding remarks.

5.1 General Discussion

To play in the NHL is a dream that most youth have when starting out in minor hockey. The chances of making it are low, however, many athletes will train and perform for a chance to play with the best players in the world.

Recent investigations have studied off-ice parameters that could potentially lead to increased on-ice performance. Moreover, these investigations have demonstrated that certain off-ice performance tests can be precursors for skating performance in elite ice hockey players (Potteiger et al., 2010; Mascaro et al., 1992; Bracko and George, 2001), as well as, draft status of draft eligible players (Burr et al., 2008). Despite the number of investigations on the transferability of certain laboratory tests to sport specific tests, the literature to date is actually limited, especially in a younger population. Therefor, this thesis investigation highlights the important findings of off-ice testing protocols to on-ice performance in elite male youth ice hockey players.

As outlined in Chapter Two, the selection process for youth minor hockey league teams begins at the age of 9, when they play in the Atom age division. This selection process is based on the subjective qualities that coaches and other volunteer evaluators feel are important for success in hockey, and often takes into account the level of experience and knowledge that they possess. Due to the subjectivity of the evaluations, size, height and strength are often influencing factors when determining a team. This often has very little to do with the skill of the player, but rather the physical maturity of the individual. This unintentional bias often skews the selection committees and can equate to lesser skilled athletes being chosen for higher ranked teams due to their size.

Chapter Three provides a comprehensive summary of the traits that elite hockey players exhibit, both on-ice and off-ice. These traits of elite athletes have propelled them to the top echelons of hockey and serve as a benchmark for developing players to aim for. Finally, Chapter Four provides evidence that certain off-ice tests, such as standing long jump and sprinting speed, are influential in the performance of on-ice skating performance even in youth ice hockey players. More specifically, those tests that involved movements that required high power output from the legs, such as standing long jump, were better correlated to on-ice tests than those tests which do not require a lot of power from the lower extremities.

5.2. Strengths and Limitations:

The current investigation did present with several limitations. The small sample size makes it difficult to determine if non-statistical significant findings were due to a lack power. However, even with small numbers, statistically significant findings were revealed in a number of areas, which provide important information for the advancement of the literature. In addition, given the novelty of the testing environment to many of the young participants, individual performance scores may not have reached maximal levels due to the lack of test familiarization or test wiseness. It is important to note that all tests, except the Wingate test, were given two trials to obtain a top score; however, it is postulated that performance scores would likely have increased as a function of test exposure across both on-ice and off-ice measures for all participants.

One of the major strengths of the investigation was the tests themselves and the fact that the tests replicated those that are used in the NHL draft entry combine. The participants were excited to understand what future NHL players were being subjected to, and to see where their results stood in comparison to those players who are considered the top in their sport.

5.3. Future Research:

From this investigation, future research should continue to investigate the role that off-ice physical fitness tests have on the performance of on-ice tests. Furthermore, increasing the sample size and collecting more data across the birth years is critical to our understanding of the relationship between on-ice and off-ice measurements, as well as for the development of normative data. In addition to sample size, research also needs to be collected to include a greater variety of participant cohorts (e.g., participants representing different skill levels: house, elite, super elite). This will allow for a greater distribution in data.

With the inclusion of more participants and greater variety in skill levels, current data could then be compared to other populations, such as other sporting teams to observe how the physical fitness of ice hockey players compare to that of other sports in the same age ranges. This would also allow the researchers to monitor and determine what the best testing protocols are for young athletes and how this relates to the development of training protocols for both sport-specific development and long term health and well being. Therefore, future research investigations should also focus on the design of developmentally appropriate training programmes to assist in the development of youth athletes. Ideally, collecting longitudinal data on this cohort would also allow for investigation into the long-term effects of ice hockey training and health related physical fitness of the individual.

5.4. Conclusion:

There are a number of different methods to assess the physical capabilities of an athlete. Choosing sport specific measures gives evaluators a better sense of the physical capacity of the athlete in their particular sport and can relate these measures to game simulating movements. These measures also allow evaluators to understand the overall health and fitness of the athlete, and can determine whether or not the athlete is chosen to a specific team.

Current literature supports the idea that laboratory testing is an important part of sport performance. However, whether or not certain tests are associated with the performance of an athlete is an area for further discussion. In ice hockey, a number of studies report that measures such as, the Wingate test, body index and standing long jump are predictive of draft order (Burr et al., 2008), anaerobic power, anaerobic capacity and vertical jump are indicative of maximal skating speed (Potteiger et al., 2010; Mascaro et al., 1992) and vertical jump and 40 yard dash predict on ice sprinting speed (Bracko & George, 2001). However, this work is limited to elite players and little is known about young hockey players.

The present investigation looked at the relationship of off-ice tests to the performance of on-ice measures in elite male youth ice hockey players, which included 14 off-ice tests and 4 on-ice tests. It was found that older players were taller and heavier than the younger players, and defensemen were taller and heavier when compared to forwards. Across participants, standing long jump was positively correlated to all skating tests (i.e., speed, agility, and acceleration). Players who jumped further demonstrated significantly greater on-ice skating performance. Significant correlations were also found between player weight and maximum speed, agility, and shot velocity. Lighter players were faster and more agile on the ice, while players with a greater mass demonstrated higher scores in shot velocity. A significant relationship was also found between push-ups and off-ice sprinting capability. Taken together, these findings were consistent with high performance research with adults revealing that physical measures (such as standing long jump) may have predictive value for on-ice performance even in young, pre-pubertal ice hockey players. While such measures may contribute to the successful identification and selection of players for high performance, utilizing such assessments also has important training implications for the long-term development and performance of all players.

Overall, the investigation provided important first step information in determining critical off-ice testing measures that relate to on-ice performance in male, youth ice-hockey players. Further research is warranted to investigate the transferability of results to different age and skill levels, as well as, to determine if similar results track longitudinally.

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APPENDIX A – Initial Contact Letter

UNIVERSITY OF BRITISH COLUMBIA

Cognitive & Functional LEARNing Laboratory

Title of Project:	Examining the Relationship Between Off-ice tests and On-ice tests in Youth Hockey Players
Principle Investigator:	Dr. Shannon SD Bredin, PhD
Co-Investigator:	Dr. Darren ER Warburton, PhD
	Mark Rice (MSc student)
Institutions:	School of Kinesiology, University of British Columbia
Contact Person:	Dr. Shannon Bredin, [redacted]
	Mark Rice, [redacted]

Dear ____________________,

You have been contacted to inform you of a research study being conducted by Dr. Shannon Bredin, Dr. Darren Warburton, and Mark Rice in the School of Kinesiology at the University of British Columbia.

The purpose of this study is to conduct a series of off-ice physical fitness measures and see how they relate to on-ice performance in youth ice hockey players.

The study will involve two (2) testing days. The first day will consist of off-ice tests that will measure physical characteristics such as height and weight, as well as physical fitness involving measures of muscular strength and endurance, power, flexibility, and aerobic fitness. These off-ice tests will then be compared to four (4) on-ice tests that will measure skating speed, skating agility and shot velocity. These on-ice tests will be conducted on the second day of testing.

We would like to contact you further to discuss your minor hockey association's interest in participating in this research. We would appreciate the opportunity to provide you additional information and discuss this research with you further. If appropriate, we can also provide a presentation to your Executive Board. If you are interested in knowing more about this research, Dr. Shannon Bredin is available for further discussion at [redacted] or Mark Rice at [redacted].

Thank you for consideration of this research.

Sincerely,

Dr. Shannon Bredin　　　　Mark Rice

Version 1: February, 2015　　　　1 of 1

APPENDIX B – 2014 PAR-Q+

2014 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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08-01-2014

2014 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

OSHF Ontario Society for Health and Fitness

2014 PAR-Q+

6. Do you have any Mental Health Problems or Learning Difficulties? *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you **ALSO** have back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

2014 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ______________________ DATE ______________________

SIGNATURE ______________________ WITNESS ______________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References
1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

APPENDIX C – Hockey History Questionnaire

UNIVERSITY OF BRITISH COLUMBIA

Title of Project:	Examining the Relationship Between Off-ice tests and On-ice tests in Youth Hockey Players
Principal Investigator:	Dr. Shannon SD Bredin, PhD
Co-Investigator:	Dr. Darren ER Warburton, PhD Mark Rice (MSc student)
Institutions:	School of Kinesiology, University of British Columbia
Contact Person:	Dr. Shannon Bredin, [redacted] Mark Rice, [redacted]

This questionnaire is being used to gain further information about your hockey history.

Name:____________________________________

Birthdate ____/_____/_____ (Month/Day/Year)

How many years have you been playing hockey? ______________

Please list the most recent winter hockey team that you played for:

____

Have you ever played spring hockey? If so, in what year(s) and for what team(s)?
____
____
____
____

During the winter season, how many times a week do you participate in hockey related activity (This includes games, practices, specialized coaching, etc.)?

____

During the winter season, how many hours a week do you participate in hockey related activity (This includes games, practices, specialized coaching, etc.)?

____

During the spring season (if applicable), how many times a week do you participate in hockey related activity (This includes games, practices, specialized coaching, etc.)?

____

During the spring season (if applicable), how many hours a week do you participate in hockey related activity (This includes games, practices, specialized coaching, etc.)?

____

Do you participate in any other sports or skill based programs (ie., Soccer, music lessons, etc) and if so which activities?

____
____
____
____

APPENDIX D – Informed Consent Form

THE UNIVERSITY OF BRITISH COLUMBIA

Study Information and Informed Consent

Title of Project:	Examining the Relationship Between Off-ice tests and On-ice tests in Youth Hockey Players
Principle Investigator:	Dr. Shannon SD Bredin, PhD
Co-Investigator:	Dr. Darren ER Warburton, PhD Mark Rice (MSc student)
Institutions:	School of Kinesiology University of British Columbia
Contact Person:	Dr. Shannon Bredin, [redacted] Mark Rice, [redacted]

What is the purpose of this study?
The purpose of this study is to examine the relationship of off-ice testing and on-ice testing in a battery of hockey related physical fitness tests in minor hockey league players.

What is involved?
If you decide to volunteer for this study, you will be asked to participate in off-ice physical measures on the first day and on-ice skating measures on the second day. The first day will consist of 14 off-ice assessments; while the second day will consist of four on-ice assessments.

What is the time commitment for this study?
Each assessment will take between 5 seconds and 20 minutes. Therefore, the total time commitment will be approximately three hours (two hours on the first day and one hour on the second day).

Who is conducting the test?
All testing is conducted by qualified professionals, who are trained on how to administer each test and overseen by experts in long-term athlete development and sport performance.

What type of physical fitness tests will be administered?

Five different groups of off-ice tests will be administered. These will be include:
1) Anthropometrics: standing height, wingspan, weight
2) Strength, Power, and Muscular Endurance: grip strength, curl-ups, push-ups, standing long jump, vertical jump, single leg squat

3) Flexibility: trunk flexion
4) Anaerobic Fitness: Wingate cycle ergometer test, 30 meter sprint test, agility test
5) Aerobic Fitness: 20-meter Leger test

Four different on-ice assessments will be administered. These will include:
1) Agility cornering S turn
2) 6.1-meter acceleration into 44.8 meter speed test
3) 15.2 meter full speed test
4) Shot speed

What are the benefits to participating?
All participants will receive a summary of their own results at the completion of the investigation. If desired, participants can also receive a summary of the entire investigation when the data has been analyzed and submitted for publication.

What are the risks of participating?
Participants will be asked to participate in physical fitness tests; therefore, as with any test of physical fitness individuals will be requested to physically exert themselves. After testing, participants may experience mild muscle soreness, but this is normal with any exercise. All testing will be performed under the supervision of trained and qualified personnel.

What are the rights and welfare of the Participant?
Individuals have the right to refuse participation in this study. It is also understood that a participant is free to withdraw from any or all parts of the study at any time without penalty or consequence. In addition, participants can ask questions at any time (before, during, and/or after the study).

Are participant results confidential?
The identity of the individual remains confidential at all times. All records and results are analyzed and referred to by number code only. All information is kept in a secured manner in the Cognitive and Functional Learning Laboratory at the University of British Columbia. Only those directly involved in the study will have access to the data. You will never be referred to by name in any study reports or research papers. In addition, individual results will never be released to a third party as all data remains confidential at all times.

Who can I contact about the study?
If you have any questions or concerns about what we are asking of you, please contact Mark Rice at [redacted] and/or Dr. Shannon Bredin at [redacted]

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, please contact the Research Participant Complaint Line in the UBC Office of Research Ethics at [redacted] or if long distance e-mail [redacted] or call toll free [redacted]

THE UNIVERSITY OF BRITISH COLUMBIA
Informed Consent Form

Title of Project:	Examining the Relationship Between Off-ice tests and On-ice tests in Youth Hockey Players
Principle Investigator:	Dr. Shannon SD Bredin, PhD
Co-Investigator:	Dr. Darren ER Warburton, PhD Mark Rice (MSc student)
Institutions:	School of Kinesiology, University of British Columbia
Contact Person:	Dr. Shannon Bredin, [redacted] Mark Rice, [redacted]

Your child's participation in this study is entirely up to you. You have the right to refuse to participate. If you decide to take part, you may choose to withdraw your child from the study at any time without giving a reason and your withdrawal will not affect you or your child in any way.

I, ________________________________, understand the purpose and procedures
(Please Print Name)
of the study.

I, _________________________________, consent to ____________________
(Please Print Name) (Please Print Child's Name)

participating in the study.

I understand the purpose and procedures of this study and I agree to participate voluntarily in this investigation. I am free to withdraw from the study at any time. I understand that I do not waive my legal rights by signing the consent form. I understand the contents of the consent form and the proposed procedures. I have had the opportunity to ask questions and have received satisfactory answers to all inquiries regarding this study. I have received a copy of the consent form.

________________________________ ________________
Signature of Parent/Guardian Date

________________________________ ________________
Signature of Researcher Date

APPENDIX E – Participant Informed Assent Form

UNIVERSITY OF BRITISH COLUMBIA

PARTICIPANT ASSENT FORM

Assent Form: Examining the Relationship Between Off-Ice Testing and On-Ice Performance in Youth Ice Hockey Players

Invitation
I am being invited to be a part of a research study. This research study is trying to find out how well off-ice fitness tests relate to on-ice performance in hockey. It is my decision if I want to be in this study. No one will make me be a part of the research study. Even if I decide to be a part of the research study now, I am allowed to change my mind later. No one will be mad at me if I decide not to be a part of this study.

Why Is This Study Being Done?
Researchers are collecting information about hockey players to see if there is a link between off-ice fitness tests and on-ice performance.

What Will Happen in This Study?
If I agree to be in this study, the researchers will be allowed to collect information about me. The researchers will be allowed to share information about me with the other researchers in the study, but no one else will ever see my information.

Who Is Doing This Study?
Dr. Shannon Bredin, **Mark Rice**, and other researchers from the University of British Columbia will be doing this study. I can call them at [redacted] if I have any questions about the study.

Who Will Know I Am in the Study?
Only the researchers who collect data and some of my teammates will know I am in the study. When the study is finished, the researchers will write a report about what was learned. This report will never say my name or that I was in the study. My parent/guardian and I do not have to tell anyone that I was part of the study. The researchers will follow strict rules from the British Columbia Freedom of Information and Protection of Privacy Act when they share my information.

When Do I Have To Decide?
I have as much time as I want to decide to be a part of the study. I have also been asked to talk about my decision with my parent/guardian.

Signatures:
If I put my name at the end of this form, it means that I agree to be in the study:

Signature: ____

Written Name: ____

Date: _____________________________________

APPENDIX F – Single Leg Squat Scoring Matrix

Single Leg Squat Scoring Sheet	LEFT LEG TRIAL NUMBER					RIGHT LEG TRIAL NUMBER				
	1	2	3	4	5	1	2	3	4	5
Depth										
Top of thigh parallel to ground or below with hang leg parallel to ground /3 Femur parallel to ground with hang leg not parallel to ground /1										
Heel										
In contact with the ground /3 Not in contact with the ground /1										
Spine										
Neutral Position of the spine with erect posture /3 Neutral position of the spine bent forward at the waist /2 T-spine flexed /1										
Knee										
Neutral Position /3 Vagus or Valgus /1										
Balance										
Moves under control with one second pause at top and bottom /3 Moves under control without pause at bottom /2 Cannot move under control or loses balance /1										
TOTAL SCORE										
GRAND TOTAL										