Using Anthropometric Variables and Performance Statistics to Assess the Effects of Rule Changes in the National Hockey League

by

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Abstract

Purpose: This study set out to determine whether or not rule changes imparted by the NHL in 2003 and 2005, have had an effect on the anthropometric profile of drafted NHL players. Primarily, this research aims to determine if there has been a change in the number of draftees who sign a Standard Player's Contract (SPC) from the time of their draft, secondly, to determine if rule changes have affected how much player anthropometrics and performance variables correlate with TOI/GP, and lastly to compare correlations of draft height and weight versus the year drafted to the NHL. The first objective of this research, using a Chi-square analysis, is to determine if there is a statistically significant difference in the number of draftees who reach the 10+ game threshold in each of their first 3 seasons post draft at two time periods (2005 draft cohort and 2015 draft cohort), which indicates the signing of a Standard Player's Contract. A Chi-square analysis was also used to determine if there was a statistically significant difference in the number of draftees who played any games in each of their first 3 season post draft at two time periods (2005 draft cohort and 2015 draft cohort). Lastly, an Independent Samples T-test was used to determine if there was a statistically significant difference between two draft cohorts (2005 and 2015) in the average number of games played by draftees in each of their first 3 NHL seasons post draft. The second objective utilizes in-season, anthropometric data and performance statistics to correlate time on ice/games played (TOI/GP) for the entire league for two different seasons (2003-2004 & 2015-2016). The correlations for each time period were compared for significant variables. The final objective used correlations between reported draft height and weight, and year drafted to the NHL between the 2003-2017 seasons. **Methods:** All secondary data was gathered from NHL.com. NHL regular season and draft data was used to determine the number of draftees that played any games in the NHL, the number of draftees that reached 10+

games played in the NHL, and the average number of games that draftees played from each cohort. NHL regular season data was used to determine how anthropometric measurements and performance statistics correlated to TOI/GP, and the effects that rule changes had on the anthropometrics of the league. **Results:** Chi-square analysis determined that there was no statistically significant difference in the number of players who played any NHL games, or who played 10+ NHL games in each of their first three seasons post draft for the 2005 and 2015 draft cohorts. An independent samples T-test determined that there was no statistically significant difference between the average number of games played for the 2005 and 2015 draft cohorts in each of their first three NHL seasons post draft. Pearson correlations revealed that in the 2003/2004 NHL season GP ($r = .542$), G ($r = .355$), A ($r = .591$), P ($r = .522$) all correlated to TOI/GP as significant independent variables at the .01 level, and PIM ($r = -.094$) was significant at the .05 level. Height ($r = .038$) and weight ($r = -.011$) were not significant. Pearson correlations for the 2015/2016 NHL season revealed that height (.096), GP ($r = .472$), G ($r = .322$), A ($r = .609$), P ($r = .528$) and PIM ($r = .166$) were significant independent variables at the .01 level. Weight ($r = .048$) was the only non-significant independent variable in the correlation. In the final objective, Pearson correlation results indicate that from 2003-2017, NHL draft classes have shown a significant negative correlation between the year drafted to the NHL and a player's height ($r = -.806$) and weight ($r = -.810$). **Conclusions:** Using height and weight as indicators, it appears that rule changes made by the NHL beginning in 2003 have been a contributing factor to decreasing the average size of drafted NHL players.

Keywords: NHL, anthropometric, draft, height, weight

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Chapter 1 - Introduction

1.1 Introduction

A common question with which people are faced when growing up is “what do you want to be when you are older?” Your parents may nag you about it, you may be asked in school or it might come up in conversation, but the age-old question ironically never gets old. When you ask this question to a child the answers can be completely unexpected, but you can always expect to hear “an NHL player” more than a handful of times, from boys and girls alike. Our country’s national sport has long been a vocational dream for many people, hoping to make it to the big league and get paid to do what they love, and like most things in life, this does not come easy. Hockey is an international sport with many amateur participants, and only the fastest, strongest and most skilled players are drafted to the National Hockey League (NHL) (5). Due to the multifaceted nature of hockey, the game’s most elite players are required to possess high levels of multiple aspects of fitness (8, 16), as well as high mental efficiency and character, too (5, 7). Nowadays in order to increase a team’s chances of success, all teams hire an extensive staff of personnel such as coaches, scouts, strength and conditioning specialists and psychologists. All of these people are part of an organization to aid in capturing the full spectrum of an athlete, with the singular focus to help that team win a championship.

This research aims to assess the effects that rule changes made by the NHL have had on NHL players and NHL draftees between the years 2003-2017. To the knowledge of the author, this is the only research to assess the effects that rule changes in the NHL have had on the style of game play, and on the anthropometric patterns of NHL players. The year 2003 saw significant rule changes implemented by the league with the goal of increasing the speed of the game, increasing goal scoring and moderating malicious violence [38, 40 41]. Concomitantly, it is hypothesized that this increased the utility of faster, more agile players, and lessened the effectiveness of comparatively heavy-set, enforcer-type players. Twelve years later, in a 2015, article written by Mike G. Morreale, published on NHL.com, this quote from Washington Capitals Assistant General Manager Ross Mahoney: "I think when there is less hooking and holding in the neutral zone, it allows players of smaller stature to be more successful in the NHL" [38].

In 2003, the NHL set a maximum length of goaltender pads at 38 inches, (previous length of goaltender pads could not be found), and limited calf-protectors to a maximum of 1.5 inches. Additionally, the league enforced that any goaltender knee protection must be worn under their thigh guard, and underneath their pants [39]. These changes were predicted to increase scoring opportunities. The second set of rule changes that the league implemented in 2003, to increase game speed and curb unwarranted obstruction and time-wasting, was the “hurry-up” faceoff rules (nhl.com). The “hurry-up” faceoff rule states that from when the whistle is blown for stoppage of play the league allots 18 seconds until the puck is dropped for a faceoff to resume play. In those 18 seconds, the visiting team has 5 seconds to choose which line they want on the ice, and then the home team has an additional 8 seconds to make their line selection. The remaining 5 seconds is for the players to position themselves for the faceoff. Additionally, the visiting team centreman must have their stick down on the ice first for the faceoff, and then the home team centreman can put their stick down, which gives the home team a positional advantage. If a player does not have their stick on the ice when the referee is ready to drop the puck, that player is removed from the faceoff and must be replaced by one of their teammates who is on the ice. Removal from the faceoff draw is a disadvantage, as faceoff-taking ability is a skill in-and-of-itself which is consistently practiced and, traditionally, non-centreman are not as skilled as the centreman in taking the faceoff draw.

The "hurry-up" faceoff rule change has a two-pronged effect. The minimal time between stoppage and resumption of play helps to minimize the between-play interactions amongst players (ie. posturing and combat), and concurrently, forces players to get to the bench as quickly as possible. In another article written by Bob Foltman in 2002 for the Chicago Tribune, NHL Commissioner Gary Bettman spoke on the new rule changes that were being implemented into the league "There has been more skating and less standing around, which is a good thing, and players have been allowed to skate without players clutching, hooking and holding.", Bettman said. Lastly, in 2003 the league made a point to decrease their tolerance for obstruction and interference, assigning a supervisor to monitor each game to ensure obstruction calls were being made properly. To aid in the consistency of obstruction calls, each official has a laptop computer where they can download clips from any game instantaneously, and this would be done each night to review any gray-areas with such calls [41].

There were also several rule changes in 2005, which contributed to the trend of increased game speed and goal scoring. The goal line was moved to 11 feet from the end boards, increasing the amount of space that players had to maneuver behind the net. The offensive zones (blue line) were increased from 73 feet from the end boards to 75 feet, allowing for more space and maneuverability in the offensive zone to generate scoring opportunities. Restrictions on goaltenders playing the puck outside of the designated area (trapezoid behind the net) were also introduced. Another impactful rule implemented in 2005, was that if a team ices the puck, that team is not permitted to make any player substitutions for the following faceoff. This has a multifaceted effect on goal scoring opportunities whereby the team that iced the puck is penalized by having a face-off in their defensive zone and thus, not having the opportunity to substitute players who may be fatigued. The team who did not ice the puck is granted an offensive zone face-off, as well as a chance to get rested players on the ice. Lastly, because of the consequences attached to icing the puck, players are less willing to ice the puck when under offensive pressure in their own end. The restricted ability to dump the puck and relieve the offensive pressure may lead to defensive-zone turnovers and consequently, goal-scoring opportunities by the opposition.

Another rule instated in 2005, which significantly affected the speed and strategy of NHL hockey, was eliminating the red-line (center-line) for the purpose of 2-line passes. The 2-line pass rule prevented any player from sending a stretch pass where the puck crossed 2 lines (blue line and the red line). This affected any player's ability to send long passes down the ice with the intent of sending a player on a breakaway, or to create an odd-man rush, whereby more offensive players are on a rush than the number of opposing defensive players. With the elimination of that rule, players are able to send passes down the length of the ice (as long as the offside rule is not broken). The ability to move the puck further distances increases the speed of the game and also makes it more feasible to send long, breakaway passes, which should increase the chance of quick, agile skaters to score**.** Lastly, in 2005 a rule was put in place stating that any player who instigated a fight in the last 5 minutes of the game or in overtime would be subject to a minor penalty, a major penalty, a misconduct penalty and an automatic one game suspension. It is logical to think that the severity of these consequences would make the traditional role of "an enforcer" a little bit outdated. In the present study, the effects of rule changes were focused on a specific point in time where the NHL had a specific intent of increasing goal scoring while moderating unwanted violence. Although rule changes are made yearly in the NHL and have been, and will continue to be ongoing, the rule changes made in 2003-2005 were specifically targeted on because they represent rule changes that had a direct impact on how the game of hockey in the NHL is played. The elimination of the two-line pass was monumental in that it had always been a part of hockey and limited teams' abilities to send long breakaway passes, this in turn caused teams to have to skate with the puck in the neutral zone more so than pass, and this caused a cluttered neutral zone which usually lead to tumultuous physicality just to gain the opposing team's offensive zone. The introduction of the trapezoid allowed the goaltender to be protected while they played the puck behind their own net where in the past the goaltender was essentially treated like skating player who was playing the puck. The rule preventing player substitutions after an icing infraction was also a substantial rule change as icing the puck was a tactical play used by coaches and teams to get an easy whistle and substitution so rested player could get on the ice. Rule changes such as those changed how hockey was played as we know it. NHL.com lists a historical record of rule changes beginning in 1910 (the NHL's inaugural year was 1917) through to 2015/2016. After the 2005/2006 season the website lists no rule changes until the 2011/2012 season where a slight modification is made to rules governing hits to the head. The following rule change listed is for the 2015/2016 season and deals with overtime consisting of 3 on 3 (opposed to the previous rule of 4 on 4), and video review challenges of off-sides and goaltender interference. Though after the 2005/2006 season the NHL did make additional rule changes, most of those changes are amendments to previous rules or involve the addition of more information to clarify any gray areas (such examples include new allowances for sizes of goaltender equipment which is proportionate to the goaltender's size, rather than using discrete measurements for all goaltenders). The rule changes in question that the NHL made between 2003-2005 were introduced with the intention of changing how the game was played, as a means to increase goal scoring and interest in the sport. The main goal of this research was to determine whether the anthropometrics of the average NHL player or draftee has significantly changed between when these rules were implemented, and the 2016-2017 season.

Chapter 2 - Literature Review

2.1 The NHL Combine and Entry Draft

The sporting industry is a lucrative market in today's economy, and the four major North American sports are all multi-billion-dollar industries themselves. As a result, organizations are placing more importance than ever on attaining successful players. A study by Gee et al. (2010) on NHL players found that talent identification is a crucial ingredient for a team's long-term success [29]. Today, the process of scouting a player is much more diverse and includes a variety of tests and measurements such as anthropometric measurements (height, weight, composition, BMI), physiological tests (aerobic, anaerobic, power tests), and psychological assessments [5-8, 29]. Teams use the information gathered from the battery of tests to make predictions of how successful a player will be in the NHL [1, 5, 8, 29]. To build a foundation for success, teams identify the players in the league who are talented, and the players coming into the league who *will* be talented, and this is why the draft is becoming ever more important [29]. Another reason the draft has become integral for team success is due to the salary cap levied by the NHL [29], which has caused teams to rely more heavily now on the entry draft to acquire desirable players.

Each year, the NHL holds its' annual entry draft where amateur players have an opportunity to be chosen by a professional team and work their way to having a professional career [5-8]. Teams select players in a purposeful order that is determined by perceived talent as judged by coaches, scouts, strength and conditioning specialists and psychologists [1, 5, 8]. Specifically, physical fitness is tested prior to the draft every year in June at the NHLED (National Hockey League Entry Draft) combine [5-8]. This pivotal event invites the top 110-120 players worldwide to undergo a battery of physical tests and measurements to provide potential employers with an idea of their fitness levels [5-8]. Hockey is a diverse game that requires aerobic and anaerobic components, and success at the elite level requires strong development of anaerobic sprint ability, aerobic endurance, as well as muscular strength, power and endurance [5, 7, 8]. The objective of the combine tests, which have historically been considered possible predictor variables, are set out to evaluate speed, strength, agility, aerobic and anaerobic energy systems and body composition [5,6]. The ability of fitness tests to predict hockey playing potential has been studied but have yielded inconsistent results [6, 8]. Tarter et al. (2009) state that one reason for the inconsistencies is the covariation between tests, and although one single test may not be a sufficiently robust predictor of future performance, combining correlated scores from multiple tests may have a stronger predictive ability [6]. Nightingale et al. (2013) suggest that testing a hockey player on-ice in their equipment should be considered in order to improve the utility of hockey testing protocols [8].

Although measurements of fitness are used to estimate a player's potential to perform in many team sports, few consistent findings have been found to support that these fitness measures can confidently predict performance in ice hockey [6, 8]. The study conducted by Tarter et al. (2009) showed some predictive capacity for performance results at the NHL combine, yet also goes on to state that physical fitness is one of many components required for success at the highest level [6]. Other NHLED factors are necessarily taken into consideration such as scouting reports, game statistics, mental efficiency and character [5, 7]. Although physical fitness is an important factor in assessing the performance or future performance of a NHL player [5, 6, 7, 10], the multifactorial nature of the sport requires other aspects of the player's abilities players to be taken into consideration when choosing a draft pick [6].In a 2014 article on NHL.com, Buffalo Sabers

Assistant General Manager Kevin Devine told reporter Mike Morreale: "by the time the combine rolls around we've done our checking, but what I look for in an interview is the maturity level and how far along they are in that area. That usually determines how far away they are from playing in the NHL" [24]. A study by Burr et al. (2008) found that prior to the combine, scouts already have a general idea of where players rank on the basis of gameplay, and that if two equally ranked players exhibit a difference in certain tests, scouts may actually choose the player with a deficit on a given test. The theory behind this is that given the players were initially ranked equally in playing ability, if a player has room for improvement on a physical attribute, then he can be coached to be physically equal or superior to his rival, and consequently become the better player [5].

Another study, conducted by Vescovi et al. (2006) looked at the combine results from three NHL draft years (2001-2003) which revealed that performance at the combine yielded no significant correlation with draft order. Subsequent univariate tests also revealed that that no single combine test could predict draft order either [7]. Tarter et al., however, addressed some shortcomings of Vescovi's study. Tarter stated that all three draft years were analyzed separately which diminished the sample size and limited the predictive capacity of the tests measured. Furthermore, all positions were examined together (skating players; forwards and defensemen and non-skating players; goaltenders) suggesting that all positions are expected to have the same physical and physiological qualities. Since there are inherent differences in the requirements of each position it should be noted that differences in physical and physiological profiles are expected and should not be treated as one and the same [5]. A study by Burr et al. (2008) used combine data over an eight-year period (1998-2006), whereby goaltenders were removed from the analysis. The exclusion of goaltenders increased the predictive ability of the study, suggesting that talent identification using the combine tests may be more appropriate for skating players. The advantage of this study was the large sample size of 853 players (493 forwards, 277 defensemen, and 83 goalies who were subsequently removed for separate analysis). The study included four models, which analyzed forwards, defense and goaltenders in conjunction, forwards and defense together, and forwards and defense separately. Results indicated that for defense, the strongest combination of predictor variables was peak anaerobic power, anaerobic fatigue and body index (which is a composite score of height, lean mass and muscular development). Quite similarly, the strongest combination of predictors for forwards was anaerobic power and body index.

The findings of the study by Burr et al. differed from the study by Vescovi et al. in that predictive ability was found with the use of combine tests as predictor variables. However, even the best model (model 4 which includes defensemen only) in the study only explained 10% of the variance, providing further support for the fact that a player's physiological profile is only a fragment of what can predict a proficient hockey player, and that other characteristics of a player are considered during the draft.

2.2 Using Physical Fitness Tests to Predict NHL Performance

Hockey is a physically and physiologically demanding sport [8, 16, 42] that incorporates multiple aspects of fitness and athleticism by means of utilizing anaerobic power, aerobic endurance, agility, balance and muscular strength, power and endurance [5, 7, 8, 10, 16, 42]. Although hockey is a worldwide sport with many amateur participants, only the fastest, strongest and most skilled players are drafted to the NHL [5]. NHL teams regularly administer pre-season testing, and continue to test during the regular season, since elite levels of physical fitness are critical to succeed in the league [8]. The results of fitness tests are not only limited to ranking players, tracking progress or monitoring injury recovery [6, 8, 10], but can also influence a coach's decision on factors including playing time, and act as a gauge of game success and future career success as well [8].

Many studies have been conducted to measure whether fitness tests can predict NHL success. Individual player success in the NHL has been measured in different forms including draft status, games played, career point totals, time on ice, special teams opportunities, number of scoring opportunities, plus/minus and hockey specific physical proficiency [1, 5 - 12]. Such studies have compared off-ice tests to on-ice performance and on-ice tests to on-ice performance. Studies comparing off-ice tests to on-ice performance are logical because all tests performed at the NHL combine are off-ice tests and also have the potential to affect a player's draft status [5, 7]. Research studying the relationship between on-ice tests and on-ice performance is equally lucid as the entire game is played on ice. Some researchers argue that tests that have implications for predicting future performance would show a higher degree of prediction if they were sport-specific [7, 8, 42]. Moreover, the majority of studies conducted that compare off-ice fitness test performance to on-ice success have showed very little predictability [5, 7, 8, 11, 13]. This directly impacts how the combine and draft status should be viewed by team management and players. A study by Vescovi et al. (2006) correlated NHL combine tests against draft entry and found no significant correlation. Additionally, no single combine test predicted draft order either [7]. More details about the results and parameters of this study are discussed later. Bracko et al. (1998) used Pearson correlations calculated for on-ice acceleration, speed and agility using off-ice tests as predictors including body fat percentage, vertical jump, and a 40-yard sprint [8]. The significant positive correlation between an off-ice sprint and on-ice skating speed was reinforced by Farlinger er al. (2007) and, Behm et al. (2005) who also confirmed this to be true for female players [8, 9].

In a study comparing on-ice sport specific skating tests and off-ice cycle-ergometry, graded exercise testing in NCAA hockey players, Durocher et al. (2010) found that off-ice measures of VO2 max and lactate threshold were not accurate predictors of the same variables during the on-ice test. The off-ice VO2 max and lactate threshold values significantly under predicted on-ice measurements [14]. Comtois et al. (2011) found non-significant relationships between an on-ice 40m sprint and off-ice measures of power using broad jump and vertical jump procedures [21]. Likewise, Gilenstam et al. (2011) found no correlations between an on-ice sprint and off-ice measures of peak torque of the quadriceps and relative VO2 max for males and females [22] lending to the notion that sport-specific tests might be necessary to attain accurate values of physical fitness for ice hockey players. Conversely, Potteiger er al. (2010) found that the time of a 54 m on-ice sprint could be predicted using peak power attained from a cycle ergometer (23). Farlinger et al. took a different approach to studying skating ability. Rather than only testing skating speed in a linear sprint, a second test was included - the Cornering S Test, to capture a full range of skating techniques that better relate to in-game skating demands (9). The Cornering S Test was also chosen because it was reported to measure on-ice agility rather than speed (9). Consequently, Farlinger et al. hypothesized that horizontal leg power would be more closely related to on-ice sprint performance than vertical leg power was. Results in the Farlinger study for the 35m on-ice sprint test showed strong positive correlations with an off-ice 30m-sprint, the 3-hop jump and the broad jump. Those three tests were used to measure horizontal leg power, and as postulated by the researchers, correlated the strongest with the 35m on-ice sprint. With regard to the Cornering S Test, similar results occurred. The highest correlations were seen with the broad jump, the off-ice 30m-sprint and the Edgren side-shuffle. Vertical jump height and Wingate absolute mean power showed high predictability as well but were not as strong of predictors as the measures of horizontal leg power (9).

Tarter et al. (2009) believed that off-ice tests showed little predictability for on-ice performance because of the covariation between the off-ice tests, which were predictor variables. In order to compensate for covariation between physical tests, Tarter et al. pooled the combine tests into four categories; upper body strength, lower body power, body composition and energy systems. The authors termed this grouping the Composite Physical Fitness Index (CPFI). The results of the study showed a predictive capacity for fitness tests aggregated into a composite index that differed for defensemen and forwards alike. When scoring in the 80th percentile on the CPFI, defensemen and forwards had a respective 70% and 50% chance of playing 5 games in the NHL within 4 years of being drafted. When scoring in the 90th percentile, defense and forwards had a 72% and 61% chance of playing 5 games in the NHL within 4 years of being drafted respectively. Therefore, this study suggests that the higher that a player scores against their cohorts, the more likely they will be to be playing 5 games in 4 years. The current literature suggests that the NHL combine lacks the necessary specificity to yield reliable physiological measurements that mimic on-ice game scenarios (7, 8). Due to lack of predictability, researchers have found between off-ice tests and on-ice performance, the need to change the combine tests, and to include on-ice tests, is justified. These results may provide more reliable player data for teams to utilize in making player and investment decisions (5, 7, 8, 11, 13).

2.3 Do Physiological Measures Predict Season Performance?

A review of the current literature surrounding the predictive capacity of physiological measures of on-ice performance has yielded inconsistent findings (6, 8). Current practices of measuring a player's physiological profile occur off-ice, which may be one reason for the varying results (5, 7, 8, 11, 13, 16). However, different results can be found if different vectors for success are used as a means of assessing hockey performance. Peyer et al. examined the relationship between various on-ice and off-ice physiological test results of 24 NCAA Division I male hockey players and related them to a season-long measure of plus/minus (the difference in goals for and goals against a team while a particular player is on the ice – plus/minus is assigned to each skating player on a team). With the use of Pearson and Spearman correlations, the results indicated that leg press, chin-ups, bench press and repeat sprint performance were significantly positively correlated with the plus/minus score (12). This study was the only literature known to compare physiological performance measures and measures of ice hockey performance using plus/minus as a performance indicator.

Another study of 29 NCAA Division I male hockey players conducted by Green et al. (2006) compared a player's aerobic fitness (VO2 max), blood lactate levels and percent body fat to his time on ice, measured in minutes during the season, and his net scoring opportunities. Results attained from a stepwise regression indicated that lactate levels at the fourth stage of the treadmill test ($r = .41$) and percent body fat ($r = .39$) were significantly related to time on ice, but VO2 max was not ($r = .20$). With regard to scoring opportunities, both VO2 max ($r = .41$) and lactate threshold ($r = .33$) were significantly correlated but percent body fat was not ($r = .11$) [11]. Although many physical attributes are required in hockey, peak oxygen uptake is the only measure shown to correlate to a player's net scoring [16].

Buchheit et al. (2011) used an on-ice test to measure cardiorespiratory fitness. The test, termed the 30-15 Intermittent Ice Test, is a derivation of the 30-15 Intermittent Fitness Test, which is performed on land. Results showed good reliability for monitoring aerobic capacity [16]. An improvement of at least 2 skating stages (> 1.1km/h) or a decrease of at least 8 bpm at stage 8 indicated an "almost certain" improvement in a young elite hockey player's performance [16]. This test is relevant because it was an on-ice test, and also because hockey players rarely skate continuously for more than 30 seconds [16]. Although this study may not give direct insight to a correlation between physiological measures and quantifiable hockey performance measures, a link can be made to the aforementioned study by Green et al. that suggests an increased aerobic capacity can be linked to more total scoring opportunities over the course of a season.

Nightingale et al. (2013) also suggest that the results of physical fitness tests can be a gauge of game success and career success [8]. A comparison of on-ice and off-ice graded exercise testing protocols conducted by Durocher et al. (2010) conversely revealed that no correlation existed between off-ice VO2 max or lactate threshold values to the on-ice test. In fact, the authors went on to advise that cycle ergometry testing should not be used at the NHL combine for measuring VO2 max and lactate threshold because of the lack of sport specificity [14]. A review of Durocher's study indicates that VO2 max and lactate threshold cannot be accurately predicted from off-ice tests and therefore have very little predictive ability of on-ice aerobic capacity, and consequently, cannot correlate to net scoring opportunities. Although some studies have shown a predictive ability of off-ice tests relating to on-ice performance, most of the current literature in this subject area has showed little predictability to exist [5, 7, 8, 11, 13] and a review of the current literature on the prediction of hockey success using physiological profiles has revealed that a minimal amount of comprehensive studies have been performed on NHL hockey players.

A 26-year comprehensive study conducted by Quinney et al. (1979-2005, N=703) of the physiological profiles of one NHL team revealed that few differences existed between the seasons deemed successful and unsuccessful. Quinney et al. used a combination of points (team season total) acquired during the season (win percentage greater than 52%), reaching the postseason playoffs, and winning the championship (Stanley Cup) as their measures of team success for a season. The study found that the players who were part of the successful seasons exhibited lower body fat content and greater combined grip strength, whereas the players who were part of the unsuccessful seasons showed greater cardio-respiratory fitness and abdominal endurance. In conclusion, the study postulated that many of the preseason physiological results were not related to the success of the team, or at least were not markedly different between the successful and non-successful seasons. These findings support the idea that success in the NHL requires the inclusion of a myriad of other factors aside from physiological measures. Leadership, coaching, injuries, league schedule, psychological profile, player development, management, budget and individual player attributes and skills are some of the factors that must necessarily be taken into consideration when determining what contributes to overall team success.

2.4 NHL Rule Changes Impact Play Style

From a fan's perspective, the game of hockey is characterized by two main factors; scoring and violence, in the form of body checking and fighting specifically (17). Although fighting attracts fans in large numbers in Canada and The United States, the NHL has attempted to curb fighting with the intention to increase scoring and prevent unnecessary injury to players (17). Another motivating factor for such rule changes is that since the 1990's goal output in the NHL had fallen drastically primarily due to improved defensive systems and the dispersal of talent amongst the addition of expansion teams in the league (17). Details of rule changes were described in the introduction but generally, are designed to increase scoring by providing the players with more space behind the net, increasing the number of obstruction calls from the referees and enforcing limits on goal tender equipment size.

In the past decade, the NHL has made attempts to decrease unnecessary violence in the game, and even considered removing fighting completely. With respect to controlling violence, the NHL has put rules in place that subject players to suspensions and fines for malicious acts and repeat offenses. The NHL archives player statistics every year, which includes penalties and suspensions. Players who accumulate instigator penalties over a season can face a fine or suspension [(17)]. Some violent acts even necessitate litigation such as the slashing incident with Marty McSorley in 1999-2000, and more recently, the Todd Bertuzzi incident in 2004. These two incidents are now infamous in NHL history, and show that violence is not just an intrinsic part of the game. A 2003 economical and sociological study conducted by Rodney J. Paul regarding the factors determining NHL attendance found that increases in team scoring was found to have a negative correlation with attendance while increases in fighting was highly positively correlated with increases in attendance [(17)]. This 2003 study also noted that “enforcer” players have benefited from violence in the game, and have seen a positive impact on their salaries [(17)].

2.5 Trends in Player Size

Carter (1970) analyzed and compared the somatotypes (body physique) of different athletes: from elite and Olympic level, to physical education majors and non-athlete university students in an attempt to find similarities or differences in their physique based on sport. When observing the data of swimmers, San Diego State swimmers (avg. height 179.3 cm, avg. weight 74.9 kg) and Cureton’s Champion Swimmers (average height 183.4 cm, avg. weight 79.6 kg), it can be seen that the two groups are within a similar range of each other. The same observations can be made between football players and gymnasts too; San Diego State football players (avg. height 184.4 cm, avg. weight 94.4 kg), University of Iowa football players (avg. height 182.1 cm, avg. weight 86.1 kg) and Oregon football players (avg. height 181.6 cm, avg. weight 84.9 kg). Danish gymnasts (avg. height 172.7 cm, avg. weight 74.9 kg), University of Iowa gymnasts (avg. height 176.5 cm, avg. weight 71.8 kg), U.S.S.R. gymnasts (avg. height 172.7 cm, avg. weight 72.2 kg).

Although ice-hockey players were not present in Carter's study, the study demonstrated that athletes in the same sport and at similar levels of performance exhibit homogeneity in physique, and this phenomenon is more pronounced as the level of competition increases. The study by Carter demonstrates that when analyzing the physique of athletes of the same sport, and when the level of competition increases, it is likely that homogeneity among athletes will be present. The current study postulates that rule changes made by the NHL intended to increase scoring and curb unwanted violence have contributed to a temporal change in the physique of an NHL player, resulting in the average player weight of the NHL continuing to decrease since the 2003/2004 season.

A 26-year physiological study of NHL players conducted by Quinney et al. (1979-2005, N=703) showed that ice-hockey players have been increasing in stature, with body mass, height and BMI showing a consistent increasing trend over the time period of that study [6, 42]. Another study, published in 2006 by Montgomery showed the same trend. Montgomery analysed the anthropometrics of the Montreal Canadiens team from 1917-2003 (N=2291), and found that players in 2003 were an average of 37.5 pounds heavier than players from the 1920's and 1930's, and 10cm taller. When comparing the anthropometric values from the Quinney study, and from the more recent years of the Montgomery study to the current study, the height values do not drastically change, but the weight values are substantially different. Montgomery illustrated that the NHL league average weight in 2003 was 202.8 pounds, and the average player weight in Quinney's study was 202.4 pounds throughout the entirety of the study. Both Quinney and Montgomery analysed BMI. It is worth noting that the BMI increased throughout the Montgomery study (1917-2003), but the players percent body fat was unchanged during the 22-

year timespan in which percent body fat was measured, therefore the weight gain is likely muscle mass, and not fat gain [35].

In the Montgomery study, the average player height in the 1920s was 1.75m (approximately 5’9”) and increased in 2003 to 1.85m (approximately 6’1”). This trend appeared to be linear throughout the entire study, and was predicted to continue to increase in the future. The average body weight of the Montreal Canadiens in the 1920s was approximately 165.3 pounds. This increased by 37.5 pounds to 202.8 pounds in 2003, which represents a 23% increase, presumably in the form of muscle tissue [31]. Although in the early years of Montgomery’s study, the sample sizes were relatively small, like the Quinney study, the results showed an increasing linear trend throughout the study too.

Unlike the Montgomery study, Quinney et al. analyzed forwards, defensemen and goaltenders separately. Quinney found the average weight and height of defenseman to be 206.8 +/- 11.9 pounds and approximately 6 foot 2 inches+/- 2.12 inches). Forwards were an average weight of 198 pounds (+/- 15.87 pounds) and were an average height of 6’05” (+/- 1.96 inches). While goaltenders being the smallest were an average weight of 185.2 pounds (+/- 15.65 pounds), and an average height of 5’11” (+/- 2.2 inches). When averaging height and weight of the forwards and defensemen together, the resulting average weight of an NHL skating player in the Quinney study was 202.4 pounds, while the average height was approximately 6’1”. Since those studies were published, there have been no further published investigations into height and weight, nor their trends over time. The Montgomery study that analyzed the Montreal Canadiens team from 1917-2003 indicated that NHL players were increasing in height and body mass throughout the entirety of the study. It could be said that concomitantly, the general population was also increasing in height and weight during the earlier years of the study and so it is difficult to determine if these phenomena were unrelated or if those findings were a result of a secular trend that was occurring across a larger population of people. Observing trends in player size in other sports may give some insight into whether increasing player size was only occurring in NHL hockey, or if this was the case in other sports too. Perhaps opposite to the current anecdotal perception of NHL players, public perception is that current NFL players are heavier than before [36], but this may not be true for all positions. A historical study by Kraemer et al. observed NFL players from the Indianapolis Colts prior to the commencement of the 2003 season. Players were divided into groups by position for comparative purposes with previous studies on NFL player size, and to create a historical time line for NFL player body composition. Kraemer et al. compared their results to three previous studies; Willmore and Haskell (1972), Willmore and Haskell (1976) and Snow et al. (1998). Kraemer et al. found that the biggest increase in mass compared to the 1970's was observed in offensive and defensive linemen, however height remained essentially unchanged, similar to findings in the NHL by the current study. Kraemer et al. noted that although height and body mass profiles for football players have increased dramatically over the past 30 years at the college Division I level, it must be considered that only the best college players are drafted to the NFL and so basic body structure as related to height remains unchanged due to homogeneity amongst athletes at the most elite level especially when considering a player's position [36]. In contrast to college football comparisons, body size of various NFL players has remained similar since the 1970's with the exception of offensive and defensive linemen, which is possibly attributed to rule changes, changes in positional demands, as well as significant improvements in training programs and nutritional interventions [36].

Similar to the NHL, factors related to rule changes and position skills could have effects on player size, and with regard to the NFL may be mediating factors for high body mass in linemen [36]. – Rule changes that have permitted chop blocks, scramble blocks, spearing tackles, setting picks, extending the arms and hands for pass blocking, and offensive line play moving to an above the waist push-blocking style rather than tackling at the legs were put in place for the purpose of player safety. Like the NHL, these rule changes may have an effect on the physique of players in these positions.

2.6 Gaps in The Literature

While there may be league officials who are tracking how these rule changes have altered how the game is played, there is no existing research aimed to understand how rule changes may impact players and draftees to the league. With the combined effect of increased obstruction penalties and more scoring opportunities, it is reasonable to assume that smaller, more agile players have more room and freedom to skate and evade opponents. "When the rules changed, it opened up the game more as far as the speed of the game and it has allowed smaller players to succeed more in the NHL," Washington Capitals assistant general manager Ross Mahoney said. "You still have to have strength. But the smaller players that do play in the League have that (strength), and by small, I mean height-wise" [38]. If these rule changes have started to change the nature of the game and how it is played, then these players should be considered more valuable on draft day, as evidenced by a higher draft status. It is unknown whether there has been any change in the anthropometric qualities of the top drafted players in recent years, but the current study attempts to shed some light on this topic.

Additional evidence that the league is becoming more interested in a game that is predominated by talent rather than violence is that the NHLED has made changes to the battery of combine tests. Where previously the combine consisted of mainly aerobic, anaerobic and anthropometric measurements, the NHLED has very recently (2014) introduced tests that measure speed and agility [(25)]. In the 23-year history of the combine, 2014 was the first year in which speed and agility were measured, by means of the pro-agility test and the hex-test. Placing additional value on agility may also favour the late-maturing athletes who present at the draft. However, those players may also need additional time to finish their growth and maturation cycles, and as such, may not become a contributing member of the team as immediately as an early-maturing, well-developed (ie. muscular strength) player might. In order to evaluate this, a measurement beyond simply draft status is required, and this work proposes the use of a standard player contract as a measure of achieving some form of success in hockey players.

The goal of this research was to determine the effect of rule changes and emerging trends on the anthropometric trends of drafted and successful NHL athletes between 2003 and 2015. This was accomplished by gathering all relevant physical attributes and performance indicators of NHL players and NHL draftees from two time periods, separated by 10 years, and performing descriptive and inferential statistics on this population.

Primary Objectives:

Objective 1: To determine if there is a statistically significant difference in the number of draftees who reach the 10+ game threshold in each of their first 3 seasons post draft at two time periods (2005 draft cohort and 2015 draft cohort) using a Chi-square analysis.

Objective 1: To determine if there was a statistically significant difference in the number of draftees who played any games in each of their first 3 season post draft at two time periods (2005 draft cohort and 2015 draft cohort) using a Chi-square analysis.

Objective 1: To determine if there was a statistically significant difference between two draft cohorts (2005 and 2015) in the average number of games played by draftees in each of their first 3 NHL seasons post draft using an Independent Samples T-test.

Objective 2: To determine whether anthropometric measures and performance statistics have shown a stronger ability to correlate with NHL success as measured by time on ice, in recent NHL players (2015/16 season) compared to NHL players in 2003. To determine whether anthropometric measures have shown a stronger ability to correlate with NHL success as measured by time on ice, in recent NHL draftees (2015/16 season) compared to NHL draftees in 2003.

Objective 3: To assess anthropometric trends of NHL draftees from 2003-2017.

Hypotheses:

Hypothesis 1: A greater number of draftees from the 2015 draft cohort will have played any NHL games, and will have reached the 10+ game threshold in each of their first three seasons following their draft compared to the 2005 draft cohort. Draftees from the 2015 draft cohort will have a greater average number of games played in the NHL in each of their first three seasons following their draft compared to the 2005 draft cohort.

<u>Hypothesis 2 (league):</u> Player's anthropometrics in the 2015/2016 NHL season would correlate less with their TOI/GP than compared with player's anthropometrics in the 2003/2004 NHL season.

<u>Hypothesis 2 (draftees):</u> The anthropometric measures of NHL draftees who reached the 10-game threshold in the 2003 cohort would correlate less with their TOI/GP than compared with draftee's anthropometrics measures in the 2015/2016 NHL season.

<u>Hypothesis 3:</u> The average size (height and weight) of NHL draftees from 2003-2017 will follow a linear, decreasing trend.

Chapter 3 – Methodology

3.1 Data Extraction

Data was gathered from the internet from NHL.com and hockeydb.com to build comprehensive player profiles that included all players' draft information (round and overall selection, team drafted to), their nationality, anthropometric information (draft and season height and weight), the name of their amateur team and league they played for prior to the NHL draft, and their season statistics information (games played, goals, assists, points, plus-minus, penalty minutes and time on ice). NHL.com was the primary and preferred source of information as it is updated and regulated by employees of the NHL and therefore it was determined to be the most accurate and complete. Hockeydb.com was an ancillary source used to verify any omitted data from NHL.com, and to ensure correctness. On occasion, there was precarious data or missing data from NHL.com for a particular player. As such, the information was double-checked and verified using hockeydb.com. For instance, one player found on hockeydb.com (Miroslav Zalesac) played 2 games in the NHL for the San Jose Sharks during the 2003-2004 season recording zero points or penalty minutes, and a minus 1 rating. This player was not found on NHL.com when attempting to verify the correctness of the information, nor did he meet the 10-game minimum threshold criteria, so he was removed from the data set aside with any other player who played less than 10 games in an NHL season of interest.

Two different methods were used to extract the data from NHL.com and hockeydb.com. Data mining software (Outwit Hub, Produced by Outwit Technologies – Version 5) was used to extract the information provided online. The software was used to take all of the data from the desired website, and organize it into a Microsoft Excel spreadsheet so the data could be manipulated and reformatted as necessary. The other method used to obtain the online data was using copy and paste functions. The information was copied directly from the website, and then pasted directly into an excel spreadsheet. NHL.com only offered this information for 50 players at a time per page (ex. Page 1: 1-50, Page 2: 51-100 etc). In order for this procedure to work properly, copy and paste functions had to be repeated several times until the information for every player in the league was obtained. For this reason, it was determined that the data-mining software was more appropriate and efficient to use whenever possible. It is important to note that all goaltenders were removed from the entirety of this study. Previous research [5, 6, 42] has documented that when goaltenders are treated the same as skating players, the predictive capacity of statistical analyses is lessened due to the inherent physiological, physical and positional differences of being a goaltender.

3.2 Data Manipulation

<u>Comparison groups</u>

Players who had exceeded the 10+ game criteria were determined with custom Excel code. The number and percentage of draftees from the 2005 and 2015 draft year who had attained this status in the first 3 years following their draft was calculated and recorded. Initially this research intended to compare the 2003 and 2013 draft cohorts, however the 2004/2005 NHL season was a total lockout and this would have caused complications with analyzing the data concerned with games played in the three years following each respective draft. Due to this circumstance, 2005 was chosen as the starting point to compare draft cohorts. For the purpose of this study, the first group of draftees analyzed were players drafted in 2005, and were termed “Group 1 draftees”. The second group of draftees analyzed were players drafted in 2015, termed “Group 2 draftees”. Previous studies have suggested that performing analyses on NHL players where skating players and goaltenders are treated as the same, takes away from the predictive capacity of such analyses due to inherent physiological, physical, and positional differences [5, 6, 42]. Goaltenders were removed from every calculation in the entirety of this study. The number of goaltenders drafted in each year was subtracted from the draft class total for each year, and the goaltenders were removed from the total number of players in the league. This was performed so that an accurate representation of the percentage of skating player draftees could be represented when analyzing what percent of draftees of the draft class met the 10-game threshold.

Comparison variables

Player's draft height and weight were collected for every player in the NHL Entry Draft between the years 2003-2017. Subsequently the average height and weight of each entire draft class was calculated for each draft year, and was assessed for patterns or changes that occurred over the previous 14 years. This same procedure was completed for the first-round draft picks only, between the years 2003-2017. First-round selections were chosen to analyze separately because first-round players are generally considered the most the most derisible players of the draft class and are expected to be the most impactful, therefore it would be noteworthy to evaluate if the pattern was any different for these players, and to see if there was an averaging-out effect caused by the rest of the draftees. Draft status was defined by the draft round selection (1-7 rounds in 2005 and 2015), and overall draft selection (1st overall – last overall selection). Variables that were of interest for correlation analyses were; Height, Weight, Games Played, Goals, Assists, Points, Plus/Minus and Penalty Minutes.

3.3 Statistical Analysis

An Independent Samples T-test was used to compare the average number of NHL games played by the Group 1 and Group 2 draft cohorts in each of their first three seasons following their respective drafts. However, given that the data at our disposal did not meet many of the assumptions for a T-test, namely normal distribution of data, and comparing two independent populations rather than random samples from the same population, it was determined that a more appropriate analysis would be a Chi-Square. Chi-square analysis was used to compare the number and percentage of draftees from the 2005 draft cohort and 2015 draft cohort that played any NHL games, and that exceeded the 10+ games threshold in the first three years following their respective drafts. A 10-game minimum threshold criteria was used for part of the analysis to give a true representation of NHL-caliber players and to ensure that players who had not met this criteria did not skew the data. The 10-game minimum threshold was chosen in accordance with the NHL's most recent collective bargaining agreement which states that when an NHL player aged 18 or 19, or who turns 20 years old between September 16 and December 31 of the year in which he signs his first Standard Player's Contract (SPC) gains a year of professional experience when they have played 10 or more NHL games.

Descriptive statistics were used to discern trends in the data between 2003 and 2017. Particularly, histograms and normality curves were used to assess the distribution of height, weight and BMI of all NHL draftees in the 2003 draft and the 2017 draft. Pearson correlations were used to assess the strength and direction of relationships between anthropometric measures and performance statistics against TOI/GP for the 2003/2004 and 2015/2016 season. These correlations were performed for the entire league, and for the draftees in those years who reached the 10+ game threshold. Pearson correlations were also used to evaluate the temporal relationships between draft height and weight characteristics of the top draft picks, and the entire league as a function of time from 2003-2017.

Chapter 4 – Results

NHL Success: Time to 10 games played post-draft

The first objective of this work was to compare the average number of NHL games played by draftees from the 2005 draft cohort and the 2015 draft cohort in each of their first three seasons following their respective drafts using an Independent Samples T-test. Additionally, a Chi-Square analysis was also used to compare the number and percentage of draftees from the 2005 draft cohort and 2015 draft cohort that played any NHL games, and that exceeded the 10+ games threshold in the first three years following their respective drafts. These analyses were performed on two separate draft classes a decade apart. The average number of games played by the Group 1 and Group 2 draftees was calculated for three subsequent years beyond each respective draft (Table 4.1). The number and percentage of Group 1 and Group 2 draftees who played any NHL games, and who met the 10-game threshold criteria was calculated for the three subsequent years beyond each respective draft (Table 4.2, Figure 4.3). An Independent Samples T-test determined that there was no statistically significant difference in the average number of games played by draftees from the Group 1 and Group 2 draft cohort. This information is available in greater detail in table 4.1. Chi-square analysis revealed that there was no statistically significant difference in any of the three seasons compared with respect to the number and percentage of draftees that played any games in the NHL. Chi-square analysis also revealed that there was no statistically significant difference in the number and percentage of draftees that met the 10+ games played criteria in any of the three respective seasons compared. This information is available in greater detail in table 4.2 and figure 4.3.

TOI/GP Correlation: 2003/2004 and 2015/2016 entire league analysis

The correlation model for the 2003/2004 NHL season included GP (r = .542), G (r = .355), A (r = .591), P (r = .522) as significant independent variables at the .01 level, and PIM (r = -.094) which was significant at the .05 level. Height (r = .038) and weight (r = -.011) were not significant in the correlation. The correlation model for the 2015/2016 NHL season included height (.096), GP (r = .472), G (r = .322), A (r = .609), P (r = .528) and PIM (r = .166) as significant independent variables at the .01 level. Weight (r = .048) was the only non-significant independent variable in the correlation. This information is available in more detail in table 4.3 and 4.4.

TOI/GP Correlation: 2003/2004 and 2015/2016 draftee analysis

The correlation model for the 2003/2004 NHL season (draftees meeting 10+ game threshold only) included GP (r = .538), A (r = .622), P (r = .543) as significant independent variables at the .01 level. Height (r = .230), weight (r = -.054), G (r = .346), and PIM (r = .318) were not significant in the correlation. The correlation model for the 2015/2016 NHL season (draftees meeting 10+ game threshold only) included A (.850) and P (r = .828) as significant independent variables at the .01 level. GP (r = .711) and G (r = .731) were significant at the .05 level. Height (r = .386), weight (r = -.075), and PIM (r = .523) were non-significant independent variable in the correlation. In both the 2003 (-.054) and the 2015 (-.075) correlations weight was the only variable that had a negative coefficient. This information is available in more detail in table 4.5 and 4.6.

Draft selection 2003-2017: Anthropometric analysis of entire draft class

The decreasing trend for average height and weight of each entire draft class from the years 2003-2017 is depicted in Figure 4.1. The difference in the average weight of the entire draft class from the 2003 draftees to the 2017 draftees was 11.03 pounds. The difference in height from 2003-2017 was 0.15 feet (1.81 inches). The range of this data for weight was 13.05 pounds (SD: 4.10 pounds), and for height was 0.16 feet (1.97 inches) (SD: 0.04 feet).

First-Round Draft selection 2003-2017: Anthropometric analysis

The difference in the average weight of the first-round draft picks from 2003-2017 was 21.41 lbs. The difference in height was 0.03 feet (0.38 inches). The range of this data for weight was 24.13 lbs (SD: 7.44 lbs), and the range for height was 0.48 feet (5.77 inches) (SD: 0.10 feet).

Draft year and Anthropometrics Correlation: Entire draft class draftee analysis

The final objective evaluated the correlation between anthropometric features, namely height and weight, and draft year between 2003-2017. The height correlation for the entire draft class showed a very strong, significant, negative correlation between the year drafted to the NHL and the average height of the draft class, $r = -.806$, sig (2-tailed) $p = .0001$ (Figure 4.1). There was also a very strong, significant, negative correlation between the year drafted to the NHL and the average weight of the draft entire class, $r = -.810$, sig (2-tailed) $p = .001$.

Draft year and Anthropometrics Correlation: First Round draftee analysis

Repeating the correlations with the first round of the draft class only, revealed the weight correlation showed a very strong, significant, negative correlation between the year drafted to the NHL and the average weight of the draft class, r = -.829, sig (2-tailed), p = .0001 (Figure 4.2). The height correlation for the first-round draft picks of each draft class between 2003 and 2017 showed a moderate to strong, significant, negative correlation between the year drafted to the NHL and the average height of the draft class, r = -.632, sig (2-tailed) p = .011.

Table 4.1: Independent Samples T-test analysis results

		05 Draft Cohort	15 Draft Cohort	t	P
N		207	187		
Mean GP 1st Year post draft	**Mean**	2.26	1.27	.952	.342
	Standard Deviation	12.12	8.96		
Mean GP 2nd Year post draft	**Mean**	4.97	6.47	-.839	.402
	Standard Deviation	17.62	20.07		
Mean GP 3rd Year post draft	**Mean**	8.92	10.94	-.915	.360
	Standard Deviation	22.01	24.55		

Table 4.2: Chi-square analysis results

		05 Draft Cohort	15 Draft Cohort	Chi-Square X(1)	P-Value
% played 1st year post draft	N	15	8	.446	.504
	%	7.25%	4.28%		
% played 10+ 1st year post draft	N	10	4	.989	.320
	%	4.83%	2.14%		
% played 2nd year post draft	N	36	35	2.49	.115
	%	17.39%	18.72%		
% played 10+ 2nd year post draft	N	21	18	.387	.534
	%	10.14%	9.63%		
% played 3rd year post draft	N	57	50	1.53	.217
	%	27.54%	26.74%		
% played 10+ 3rd year post draft	N	43	41	1.90	.186
	%	20.77%	21.93%		

Table 4.3: 2003/2004 TOI/GP Correlation (entire league)

Correlations

		TOIGP03	Height03	Weight03	GP03	G03	A03	P03	PIM03
TOIGP03	Pearson Correlation	1	.038	-.011	.452**	.355**	.591**	.522**	-.094*
	Sig. (2-tailed)		.297	.760	.000	.000	.000	.000	.010
Height03	Pearson Correlation	.038	1	.767**	-.001	-.133**	-.119**	-.131**	.234**
	Sig. (2-tailed)	.297		.000	.984	.000	.001	.000	.000
Weight03	Pearson Correlation	-.011	.767**	1	.021	-.124**	-.142**	-.142**	.397**
	Sig. (2-tailed)	.760	.000		.568	.001	.000	.000	.000
GP03	Pearson Correlation	.452**	-.001	.021	1	.571**	.634**	.642**	.364**
	Sig. (2-tailed)	.000	.984	.568		.000	.000	.000	.000
G03	Pearson Correlation	.355**	-.133**	-.124**	.571**	1	.788**	.923**	.049
	Sig. (2-tailed)	.000	.000	.001	.000		.000	.000	.181
A03	Pearson Correlation	.591**	-.119**	-.142**	.634**	.788**	1	.964**	.026
	Sig. (2-tailed)	.000	.001	.000	.000	.000		.000	.480
P03	Pearson Correlation	.522**	-.131**	-.142**	.642**	.923**	.964**	1	.037
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.309
PIM03	Pearson Correlation	-.094*	.234**	.397**	.364**	.049	.026	.037	1
	Sig. (2-tailed)	.010	.000	.000	.000	.181	.480	.309	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Listwise N=747

Table 4.4: 2015/2016 TOI/GP Correlation (entire league)

Correlations

		TOIGP15	Height15	Weight15	GP15	G15	A15	P15	PIM15
TOIGP15	Pearson Correlation	1	.096**	.048	.472**	.322**	.609**	.528**	.166**
	Sig. (2-tailed)		.010	.192	.000	.000	.000	.000	.000
Height15	Pearson Correlation	.096**	1	.723**	-.038	-.103**	-.059	-.083*	.124**
	Sig. (2-tailed)	.010		.000	.308	.005	.111	.025	.001
Weight15	Pearson Correlation	.048	.723**	1	-.023	-.074*	-.073*	-.079*	.232**
	Sig. (2-tailed)	.192	.000		.539	.046	.049	.033	.000
GP15	Pearson Correlation	.472**	-.038	-.023	1	.588**	.672**	.686**	.446**
	Sig. (2-tailed)	.000	.308	.539		.000	.000	.000	.000
G15	Pearson Correlation	.322**	-.103**	-.074*	.588**	1	.720**	.899**	.214**
	Sig. (2-tailed)	.000	.005	.046	.000		.000	.000	.000
A15	Pearson Correlation	.609**	-.059	-.073*	.672**	.720**	1	.951**	.229**
	Sig. (2-tailed)	.000	.111	.049	.000	.000		.000	.000
P15	Pearson Correlation	.528**	-.083*	-.079*	.686**	.899**	.951**	1	.240**
	Sig. (2-tailed)	.000	.025	.033	.000	.000	.000		.000
PIM15	Pearson Correlation	.166**	.124**	.232**	.446**	.214**	.229**	.240**	1
	Sig. (2-tailed)	.000	.001	.000	.000	.000	.000	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Listwise N=736

Table 4.5: 2003/2004 TOI/GP Correlation (draftees meeting 10+ games played criteria)

Correlations

		TOIGP03D	Height03D	Weight03D	GP03D	G03D	A03D	P03D	PIM03D
TOIGP03D	Pearson Correlation	1	.230	-.054	.538**	.346	.622**	.543**	.318
	Sig. (2-tailed)		.303	.810	.010	.114	.002	.009	.149
Height03D	Pearson Correlation	.230	1	.672**	-.044	-.292	-.111	-.186	.079
	Sig. (2-tailed)	.303		.001	.844	.187	.622	.407	.727
Weight03D	Pearson Correlation	-.054	.672**	1	-.115	-.391	-.242	-.310	.208
	Sig. (2-tailed)	.810	.001		.611	.072	.278	.160	.352
GP03D	Pearson Correlation	.538**	-.044	-.115	1	.688**	.876**	.842**	.538**
	Sig. (2-tailed)	.010	.844	.611		.000	.000	.000	.010
G03D	Pearson Correlation	.346	-.292	-.391	.688**	1	.820**	.926**	.295
	Sig. (2-tailed)	.114	.187	.072	.000		.000	.000	.183
A03D	Pearson Correlation	.622**	-.111	-.242	.876**	.820**	1	.975**	.442*
	Sig. (2-tailed)	.002	.622	.278	.000	.000		.000	.039
P03D	Pearson Correlation	.543**	-.186	-.310	.842**	.926**	.975**	1	.405
	Sig. (2-tailed)	.009	.407	.160	.000	.000	.000		.061

PIM03D	Pearson Correlation	.318	.079	.208	.538**	.295	.442*	.405	1
	Sig. (2-tailed)	.149	.727	.352	.010	.183	.039	.061	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Listwise N=22

Table 4.6: 2015/2016 TOI/GP Correlation (draftees meeting 10+ games played criteria)

Correlations

		TOIGP15D	Height15D	Weight15D	GP15D	G15D	A15D	P15D	PIM15D
TOIGP15D	Pearson Correlation	1	.386	-.075	.711*	.731*	.850**	.828**	.523
	Sig. (2-tailed)		.271	.836	.021	.016	.002	.003	.121
Height15D	Pearson Correlation	.386	1	.613	.331	.188	.254	.234	.316
	Sig. (2-tailed)	.271		.059	.350	.602	.479	.515	.373
Weight15D	Pearson Correlation	-.075	.613	1	.000	.052	-.166	-.076	.360
	Sig. (2-tailed)	.836	.059		1.000	.887	.647	.835	.307
GP15D	Pearson Correlation	.711*	.331	.000	1	.813**	.884**	.884**	.620
	Sig. (2-tailed)	.021	.350	1.000		.004	.001	.001	.056
G15D	Pearson Correlation	.731*	.188	.052	.813**	1	.861**	.953**	.805**
	Sig. (2-tailed)	.016	.602	.887	.004		.001	.000	.005
A15D	Pearson Correlation	.850**	.254	-.166	.884**	.861**	1	.975**	.601
	Sig. (2-tailed)	.002	.479	.647	.001	.001		.000	.066
P15D	Pearson Correlation	.828**	.234	-.076	.884**	.953**	.975**	1	.712*
	Sig. (2-tailed)	.003	.515	.835	.001	.000	.000		.021

PIM15D	Pearson Correlation	.523	.316	.360	.620	.805**	.601	.712*	1
	Sig. (2-tailed)	.121	.373	.307	.056	.005	.066	.021	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Listwise N=10

Figure 4.1: Draft Height and Weight Correlation – All Skating Players, Entire Draft Class

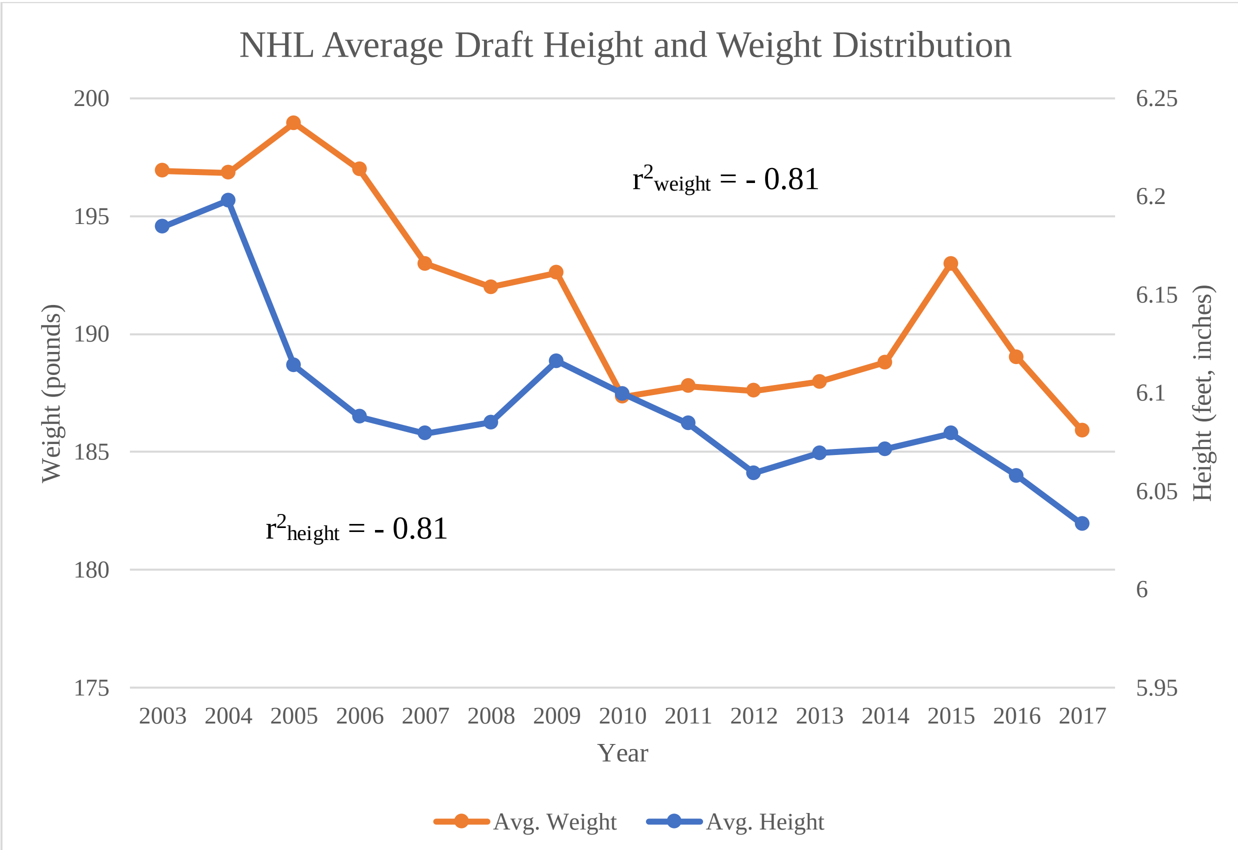


Figure 4.2: Draft Height and Weight Correlation – First Round Selections Only

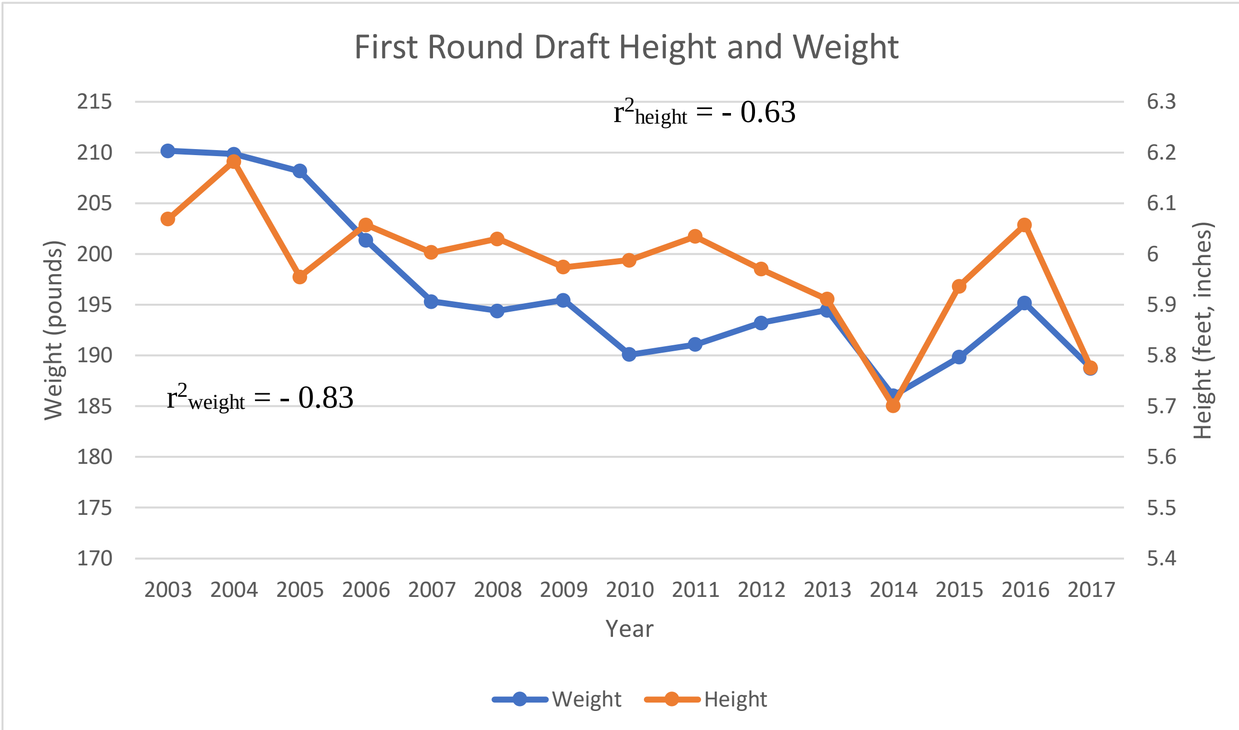
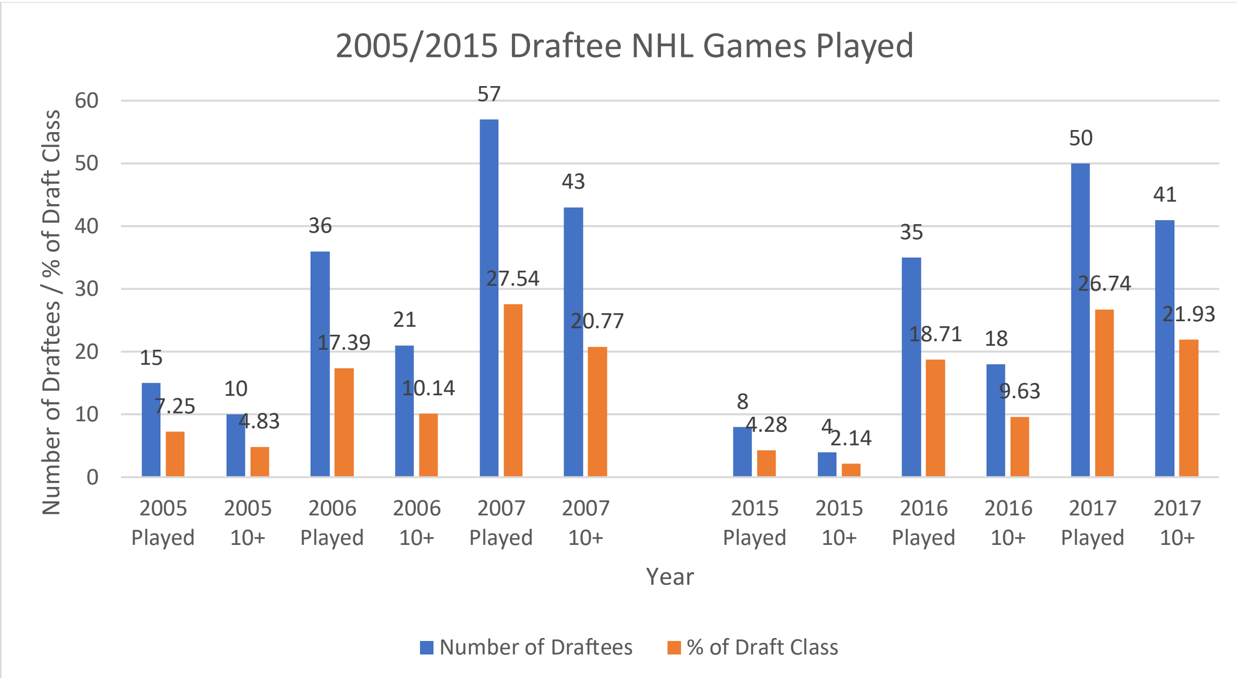


Figure 4.3: % of Draftees that have played in the NHL, and that have met the 10+ game threshold.



Chapter 5 - Discussion

This research investigation was driven in large part by the evidence over the past 10-15 years wherein the NHL has adopted a different style of play. Rule changes, intended to speed up the pace of the game, increase goal scoring and decrease violence, that began in 2003, may have caused a league-wide cascading effect that has not yet been thoroughly researched or documented. In that same timeframe, Hockey Canada started to roll out their long-term athlete development model, in which an emphasis on the value of late-developing players is promoted to coaches. We theorized that in this climate, bigger, enforcer-type-players would begin to be a less desirable draft pick, which would open the door for smaller, more skilled players to be ranked, and chosen higher in the draft. Montgomery (2006), who studied the Montreal Canadiens, collected data from 1917-2003 found that NHL players in 2003 were an average of 37.5 pounds heavier than players from the 1920's and 1930's, and 10cm taller. Montgomery also measured BMI, and found that BMI increased throughout the study and percent body fat remained unchanged, therefore attributing the weight gain to increases in height and muscle mass [35]. Montgomery found there to be a 23% increase in player weight from the 1920's and 1930's compared to players in 2003, and along with player height, these values were predicted to continue to increase in the future. Quinney et al. found that over a 26-year period (N = 703, one NHL team from 1979-2005), ice-hockey players had increased in stature, become progressively faster, stronger, and more aerobically fit to meet increasing demands of their sport [31]. This research intended to determine the effect that rule changes had on the NHL in a three-pronged analysis; first, comparing the average number of games played by draftees, and the number and percentage of draftees that were playing in the NHL, and who had exceeded the 10-game threshold, at two time periods (2005-2007 and 2015-2017), second, if any change existed in the strength of which anthropometric measures and performance statistics correlated to TOI/GP at two time periods (2003/2004 and 2015/2016), and lastly, to examine any temporal change in the average anthropometrics of draft classes between 2003 and 2017.

NHL Draftees 10+ Game Threshold: 2005 and 2015 Draft

While players that are late-developing may be seeing increased success at the draft level (as evidenced by draft status), they may represent delayed utility to the team that drafts them, as they may still be growing and maturing. Observing trends in the ability of draftees to meet the 10+ games played criteria support the concept that the path to becoming an elite hockey player is undergoing a shift. Hence, an objective of this research was to determine and compare the number and percentage of draftees from the 2005 and 2015 draft cohorts that play any games in the NHL, that meet the 10+ games played criteria, and the total number of NHL games played from each cohort within three years of their respective drafts. The 10+ game threshold was chosen to establish a true representation of an NHL caliber player and is in accordance with the most recent NHL Collective Bargaining Agreement's (September 16, 2012 to September 15, 2022) description of how a young player enters into a Standard Player's Contract (SPC). The draft cohort from Group 1 (2005) saw a higher number of draftees playing any games in the NHL in each of their first three seasons following their draft (Group 1 [Group 2]: 1st year: 15 [8], 2nd year: 36 [35], 3rd year: 57 [50]). The draft cohort from Group 1 (2005) also saw a higher number of draftees reaching the 10+ game threshold in the NHL in each of their first three seasons following their draft (Group 1 [Group 2]: 1st year: 10 [4], 2nd year: 21 [18], 3rd year: 43 [41]). When only observing the number of draftees that played any NHL games or that met the 10+ games played criteria it appears as though more of the Group 1 draftees are entering the

NHL more readily. However, when comparing the percentage of draftees using the same outcome measures, the 2005 and 2015 cohort are nearly identical, with the 2015 cohort showing a higher percentage of draftees playing any NHL games in their 2^{nd} year post draft (2005 cohort: 17.39%, 2015 cohort: 18.72%), and a higher percentage of draftees meeting the 10+ games played criteria in their 3^{rd} year post draft (2005 cohort: 20.77%, 2015 cohort: 21.93%). Furthermore, even though there are differences in the numbers and percentages of draftees that played any NHL games or that met the 10+ game criteria, Chi-square analysis revealed that there was no statistically significant difference in either of the outcome measures. The mean number of games played by each draft cohort in their first, second and third season following their draft was also calculated and compared. It was revealed that average number of games played by the Group 2 cohort was greater than that of the Group 1 cohort in the second- and third-year post draft (Group 1 [Group 2]: 1^{st} year: 2.26 [1.27], 2^{nd} year: 4.97 [6.47], 3^{rd} year: 8.92 [10.94]), however an Independent Samples T-test also revealed that no statistically significant difference existed in the average number of games played for each cohort in each of the first three seasons after their respective drafts.

The current draft data seems to suggest that a lesser number of the 2015 draftees are meeting the 10+ game criteria and entering the NHL, and we have already postulated that those players seem to fit a late-maturing profile (shorter, less muscular mass). Hence, these late-developing athletes may require more time to finish their growth and development prior to being deemed NHL-ready. On the other hand, through anecdotal evidence, there are numerous hockey reporters, coaches and trainers stating that players are now more "NHL ready" than they have ever been in the past. So, it seems counterintuitive that players from the Group 1 draft class were entering the league more readily compared to players from the Group 2 draft class. There may be several explanations for why a greater number of the Group 1 draftees entered the league than the Group 2 draftees. For instance, improved training modalities, improvements in medical and other professional health care, and the reduction of malicious violence may have allowed for greater longevity in the careers of older veteran players, who in turn would stay in the league longer, creating less opportunity for new rookies to move in and take their place. The current work puts forward the idea that draftees have started to represent more of a late-maturing athlete profile, which requires more time in the "farm league" system to reach full maturation prior to advancing to the NHL ranks. Additionally, when observing the results of the Independent Samples T-test and Chi-square analysis there appears to be no statistically significant difference in how many draftees are playing any games in the NHL, how many draftees are playing 10+ games in the or in the total number of NHL games played within three years of each draft respectively.

TOI/GP Correlations

As stated earlier, hockey is a multifaceted sport that requires various tangible and intangible factors to achieve individual or team success [5-8, 10, 16, 42]. Although many dynamics are taken into consideration when choosing a draft pick, researchers and hockey organizations have sought to find ways to better predict when to draft a player as a means of talent identification. The intention behind these selective processes is achieving team success as measured by wins, winning a division or conference championship, playoffs appearances, and winning the National Hockey League championship - the Stanley Cup. This study set out to determine whether a player's TOI/GP would correlate to their anthropometric measurements or NHL game statistics. Pearson correlations were performed to predict TOI/GP from in-season anthropometric variables (height and weight) and game statistics (points (P), goals (G), assists (A), games played (GP), penalty minutes (PIM), plus/minus (+/-)). Analysis was performed separately for the 2003/2004 and 2015/2016 NHL regular seasons.

03/15 TOI League Correlation

The TOI/GP correlation results for the entire league in 2003 and 2015 do not completely support the hypothesis that the importance of anthropometric variables would be more impactful over time, especially since height and weight were not strong predictors in either time period. Weight did exhibit a change from being a negative independent variable in 2003 ($r = -.011$) to a positive independent variable in 2015 ($r = .048$), but nonetheless was not significant and showed a very weak correlation. The correlation between TOI/GP and height was small when referencing Cohen's effect size (0-0.2 = small) but was statistically significant at the 0.01 level (.096). This is likely attributed to the large sample size (N=736). Furthermore, as height was shown to remain relatively unchanged throughout the years of this study, and when considering that at the highest levels of competition homogeneity amongst athletes is expected, it is determined that player height has little effect on their time on ice. The data shows that height and weight do not closely correlate to time on ice, and it appears that performance measures are better suited for determining time on ice, or at the very least, a combination of performance measures and anthropometric measures. This data also suggests that the characteristics of the ideal draft player may have shifted to a late-developing athlete profile, although the actual make-up of the NHL league continues to be dominated by larger, stronger players who can contribute to gameplay in a variety of ways (i.e. goals, assists, TOI, penalty-killing). A future step of this research should be to repeat the Quinney et al. (2008) analysis using the entire NHL cohort between the years of

2003-2015. This would also lend support to our theory that the draft cohort (or at least, a large majority of it) is late-maturing players not yet ready to enter the NHL ranks while the NHL league is made up of fully matured athletes of increasing stature and weight. Perhaps, over a longer period of time, if teams continue to draft more of these late-maturing players and less of the heavy-set players, a temporal change in the size of players actually playing in the NHL will show a change, as more of the smaller players enter the league and stay there, and more of the bigger players are phased out.

Another relationship to consider was that penalty minutes correlated negatively (-.094) with time on ice in 2003/2004. This is logical because the more penalty minutes that a player accumulates, the more time that player spends in the penalty box, and consequently, the less time that player is afforded to be on the ice. It seems counterintuitive that PIM would be a positive independent variable in the 2015 analysis as anecdotal evidence suggests that penalties are less warranted with the style of play in today's NHL. Moreover, with the NHL making deliberate changes to aid in the reduction of intentional, malicious violence in the game of hockey, and the NHL moving away from between-play skirmishes, it is unexpected that PIM would be a positive, significant variable in the 2015 analysis, irrespective of the fact that it exhibited a very weak correlation. In the recent NHL, it would be expected that players who accumulate a lot of penalty minutes (especially penalties unwarranted by the coach and team) would see a negative correlation with their TOI/GP, as was observed in 2003/2004. In the 2003/2004 NHL regular season the league total PIM was 36, 677 minutes (nhl.com) with 27/30 teams accumulating over 1000 PIM. In the 2015/2016 NHL regular season the league total PIM was only 23, 925 minutes (nhl.com) with only 2/30 teams accumulating over 1000 PIM. This represents a 65.23% decrease in the league total penalty minutes, and an 83.33% decrease in the number of teams accumulating over 1000 PIM from the 2003/2004 season to the 2015/2016 season. Although there may be more to the story behind those numbers, the staggering reduction in penalty minutes over that 12-year time span gives some indication into the change in the style of play that has been adopted in the NHL. Special teams have always been a big part of hockey, but with the increased speed of the game, and the increased skill level of players (puck moving and handling ability, faster more accurate shooting, drastic improvements in player equipment – namely the sticks, improved training and edge work on skates), this research posits that there is a low tolerance in the NHL for players who take unwarranted penalties consistently, and therefore would expect PIM to show a stronger negative correlation in 2015, than in 2003.

03/15 TOI Draftee Correlation

In both the 2003 ($r = -.054$) and the 2015 ($r = -.075$) correlations weight was the only variable that had a negative coefficient. In both instances the correlation was very weak, and not statistically significant. Height was positive in both the 2003 ($r = .230$) and the 2015 ($r = .386$) correlations but showed a weak correlation and neither were statistically significant. It is evident that when correlating anthropometric qualities and performance statistics of NHL draftees to TOI/GP in 2003 and 2015, anthropometric qualities alone are not robust enough to strongly correlate to a player's time on ice. Although there may be some relationship between a player's physique and their time on ice, it appears that the same conclusions can be drawn for NHL draftees as well as NHL players playing in the league; it is more appropriate to use a player's performance statistics, or a combination of performance statistics and anthropometric qualities when attempting to determine a player's time on ice.

In the absence of strong predictors of hockey performance, this study hypothesized that time on ice should be a valid proxy of a player's success. The more time on ice a player is granted, it is logical to posit that they earned this time on ice due to various factors recognized by the coaching staff. This might include such things as point production, plus/minus, success on special teams play (power play and penalty kill), and leadership qualities. In a 26-year physiological study of NHL players, Quinney et al. state that many premier NHL players exceed 20 minutes of total ice time during a game [(31)]. Generally speaking, defensemen almost always accrue more time on ice than forwards. This is primarily due to the fact that NHL teams utilize less defensemen than forwards (6 starting defensemen vs. 12 starting forwards – these numbers may vary slightly but the NHL teams always utilize more forwards than defensemen). Top ranked forwards in the league also regularly exceed 20 minutes of ice time per game too. Although there are inherent positional differences between defensemen and forwards alike, the primary goal of this analysis was to determine to what extent anthropometric variables and NHL-game statistics correlated to TOI/GP in the NHL.

Time on ice has not previously been used as a vector for NHL success. The only other study that could be found that used time on ice as a success proxy was a 2006 study conducted by Green et al. (2006) that compared NCAA player's aerobic fitness (VO2 max), blood lactate levels and their percent body fat to their time on ice, and consequently, their net scoring opportunities. Green et al. found that lactate levels at the fourth stage of an incremental treadmill test (Lac 4) and percent body fat, but not VO2 max were significantly correlated to time on ice. In addition, a stepwise regression showed that both Lac 4 and percent body fat were significant predictors of time on ice. With regard to scoring opportunities, Green et al. also found that both VO2 max and Lac 4 were significantly related but, percent body fat was not. Although the study by Green et al. and the current study both use time on ice as dependent variables, Green's study uses physiological independent variables to predict time on ice, and the current study uses anthropometric and performance variables to predict time on ice. Green's study also uses hockey players from the NCAA where the current study focusses on professional hockey (NHL) players. For these reasons, it is difficult to make direct comparisons between Green's study and the current study. But in both cases, it is demonstrated that time on ice can be significantly predicted using physiological data, or a combination of anthropometric and performance data. However, there was still a lack of strong predictor variables that could provide coaching staff with strong evidence about the "type" of player to draft to ensure team success.

In sum, this work provides some evidence that players with smaller physiques are being preferentially drafted to the NHL, but they may not be making the NHL roster as quickly as before. The hockey system may be moving towards a system in which smaller, less physically mature players still have a chance to be considered at the NHL draft but must have more experience (in the form of time in the league) before moving into the NHL as a contracted player. While player height and weight do not seem to be strong predictors of time on ice, evidence from this research demonstrates that player size in the NHL has been decreasing since 2003, and NHL draftees have also been following the same pattern too. A reasonable conclusion can be drawn that these anthropometric variables are not mitigating factors for smaller players in the NHL with respect to their time on ice, and utilization by a team.

Draft Year and Height/Weight Correlations

The current work sought to determine whether a relationship also existed in the NHL draft between the years 2003-2017 where NHL draftees' height, weight and BMI were increasing. Unlike the NHL data from 1979-2005 (Quinney et al.), the results of the current study showed a strong negative correlation between draft year, and both the average draft height, and weight of drafted players. The present investigation demonstrated a linear, negative (or rather decreasing) trend with respect to height and weight, especially when considering the first-round draft picks between 2003 and 2017, skating players weights dropped from 210.17 lbs to 188.75, a difference of 21.41 lbs. The average height of the first-round draft picks in 2003 was 6'2/3", and in 2017 the average height of first-round draft picks was 6'1/2", an absolute difference of 0.16 inches. The data demonstrated a slight increase in average height and weight in the 2008, 2009 season but that was quickly followed by a steep decline in weight and a fairly steep decline in height too. In the 2015 draft class there was an increase in both average height and weight compared to the previous 3 years, however, the trend is considerably decreasing for both average draft height and weight over the entire timespan (2003-2017). The observed data suggests that in recent years, coaches and general managers have been preferentially selecting draft picks that are smaller-statured and lighter than they have been in the past. Whether or not all of these players make the next step to the NHL quickly, or whether they make an immediate impact is not as straightforward. Nonetheless, it does show that the NHL as a whole is making more room for smaller players, and these players are becoming more prominent in the draft and the league when compared to 2003 and by inference, the years previous to that. The observed differences in the anthropometric draft measurements is even more pronounced when observing the first-round draft picks *only*, who are considered the most sought-after players by the league. Generally, these players are chosen strategically so that an organization drafts the type of player who best fits a team's system, or a player who fills some type of void that the team is in need of replacing (i.e. a goal scorer, an offensive defenseman, a 2-way forward). It is not that uncommon to find homogeneity in the physical attributes of some types of players, especially players who play a particular role for teams.

During the latter years of the Quinney study, NHL players are still taller and heavier. Quinney reports the 2005 average NHL player height to be 6'2"and average weight to be 211.64 lbs making them heavier than every average draft class weight from 2003-2017, and taller than every average draft class height from 2005-2017. The reversal of the trend of increasing player height and weight can begin to be observed in about 2006, where a steady decline of draft height and weight can be seen. The current study posits that this might be attributed to rule changes in the NHL that began in 2003. Additionally, it corresponded with a time when the NHL set guidelines for the dimensions of goaltender equipment, established time limits for players to get into proper position for face-offs and introduced coaching principles around long-term athlete development. We have been unable to conclude how the draft data from 2003-2017 ties into the NHL player profile in the years beyond the Quinney et al. study. Though that was not an objective of this study, it does however point to the need for more longitudinal studies in future research to evaluate the effects that rule changes, expansions, improved training modalities, and improved hockey development have had on the current population of people who have played or entered the NHL fairly recently.

Chapter 6 - Limitations and Future Research

Limitations in this study relate, firstly, to the reliability, consistency and accuracy of the secondary data utilized. In this study, data was gathered from two online sources. Primarily, all data was gathered from NHL.com, and then from Hockeydb.com as an ancillary source to verify any omitted data or precarious data from NHL.com. NHL.com was the preferred primary source as it is updated and regulated by NHL employees, and was therefore determined to be the most correct. However, assumptions were made regarding the collected data. It was assumed that the height and weight data collected was accurately reported, and not back-adjusted to inflate the values. If the anthropometric data was not collected independently by the NHL, but rather, collected by each individual team and sent to the NHL to be reported, there is a possibility that the teams back-adjusted their data to make their players seem bigger or smaller than they were actually measured to be. Additionally, it was assumed that all data could be retrieved from nhl.com at any time, however periodically the website format was updated causing issues with the ability to retrieve data properly. Initially data could be copy and pasted into Microsoft Excel with no issues, however after the NHL updated its website format, issues arose with accessing data.

It was also assumed that the anthropometric data collected had high inter-rater reliability. In the 14-year span of the data collected for the current study, it was assumed that the methods of collecting height and weight measurements remained the same, and retained the same threshold for reliability and accuracy, so even if different practitioners collected the data from year to year, the standard for the correctness of the measurements should have been the same. It was assumed that NHL collected the height and weight data at a standardized date for every team, and not at staggered or random dates. All draft height and weight data was assumed to be collected at the same time for all draftees, and the collection of this information was assumed to be independent of any height and weight measurements previously gathered from the league each draftee previously played in. It was assumed that the height and weight data reported by the NHL was collected prior to the commencement of an NHL season each year, and the data reported was not the most recent measurement collected from a previous season.

Time on ice data was assumed to be reported accurately for each player in the current study. The current study looked at time on ice as a whole, and did not make any adjustment for players who receive more time on ice per game because of special teams' opportunities (power play and penalty kills). Generally, when a player is on the ice for a penalty kill their game-play adjusts to more of a defensive style of play to prevent a goal being scored on their team. While these players may accrue more time on ice, their ability to score any points is decreased because they are one player short on the ice, this may affect the strength of performance statistics (goals and assists) to be able to correlate to time on ice.

Another limitation of this study relating to accessibility of data, in particular, was the performance statistics of potential draftees. Initially, a goal of this research was to predict NHL draft status and time on ice using anthropometric data, as well as performance statistics from each draftee's final season in their respective league previous to being drafted to the NHL. It would have been useful and beneficial to be able to predict NHL draft status and time on ice with the use of anthropometric information *combined* with each player's performance statistics from the league they played in the year they were drafted to the NHL. However, with players coming from many different junior leagues around the world it is difficult to find performance statistics for every player in each draft class, and so the analysis for predicting draft status could only use anthropometric information, and no analysis could be performed to predict the time on ice of rookie players. For this reason, it was decided that it would not be feasible to run a regression to predict draft status or time on ice for draftees. A database or website that has every drafted player's statistics amalgamated into one location would be extremely efficient for conducting further research on how a player's performance in the final year in their respective league affects their draft status, time on ice, and performance in the NHL. On this note, some form of ranking of the prerequisite leagues would also give useful insight into the quality of these leagues, so fairer comparisons can be made amongst player's success in different leagues. Although the quality of each league may vary year-to-year with new incoming and exiting talent, generally some leagues are stronger than others and see a much higher percentage of their players being drafted to the NHL and having NHL careers.

The current study removed all goaltenders from all analyses performed. Previous research stated that treating goaltenders and skating players as the same decreased the predictive ability of their findings, and that it was not appropriate to treat them as the same, as there are inherent physical, physiological and positional requirements for being a goaltender that differed from that of skating players. It was assumed that the removal of goaltenders from all analyses was appropriate, and that the inclusion of goaltenders in the analyses could diminish the accuracy of the results. The current study analyzed forwards and defensemen together for all analyses which may have consequently limited the predictive power of the analysis conducted. Analyzing forwards and defensemen separately could give more insight into the factors that correlate to draft status or time on ice specific to each position. Defensemen generally accumulate more time on ice than forwards, and due to positional differences, are at a disadvantage when it comes to scoring opportunities, so it is likely that studying the two positions separately would give a better insight into how anthropometrics and performance variables affect each position individually.

Expanding the analysis of this study to include, other factors such as position, injuries, special-teams' opportunities, as well as an objective ranking system of the quality of players of a specific position for a team could have been used to increase predictive power, but they were not available thereby limiting analysis. For instance, if one were to attempt to predict how readily the top 10 defensemen from each draft class were securing a roster spot on a team, it would be worth noting how successful the defensive pairings for each team are. Two defensemen may be ranked 1 and 6, but the lower ranked player may secure a roster spot sooner than the higher ranked player because the lower ranked player is drafted to a team that is currently in need of a defenseman, or their defense has been dismal. On the same note, a lower ranked player may acquire a roster spot sooner than a higher ranked player due to an injury on a team. Consideration of these factors may decrease the potential of having confounding variables which can affect the accuracy of the outcomes.

Further research can be explored on the NHLED combine too. Previous studies have either yielded inconsistent results using the combine to predict future NHL performance or have found that combine tests are not good predictors of NHL performance. However, in 2014 new tests were added to the combine (overhand pull-ups, single-leg squats and the pro-agility test), which replaced push-ups, the push-pull station, and the seated medicine-ball throw. With the replacement of three tests, and the first inclusion of an agility test in the combine's history, it would be worth analyzing if these new tests have increased the strength of the prediction of combine tests, and if the new addition of an agility test has any benefits for predicting skating ability.

Analytics appears to be a rapidly growing trend in studying sport performance, especially in the field of hockey where in recent years, new statistics, like Corsi and Fenwick, have been used to represent other aspects of the game in greater detail. NHL.com is now featuring this new information under their website's "stats" tab. "For the first time, enhanced statistics are now available on NHL.com. *Enhanced statistics* are statistics derived from the NHL's real-time scoring feed with clearly defined formulas. Shot attempts (SAT), also known as Corsi, and unblocked shot attempts (USAT), also known as Fenwick, are two enhanced stats that are commonly used as a proxy for puck possession. The variations of these enhanced statistics give insights into analysis of time on ice, relative performance and in-game context. Also displayed for the first time are other enhanced stats such as primary and secondary assists (1st A, 2nd A), rate stats like goals/20 (G/20) and zone starts (ZS%)" (nhl.com). The enhanced statistics has only been available since the 2009/2010 season therefore it would be valuable to use these new statistics in future research endeavors to determine their usefulness.

In conclusion, the current study found that no difference existed in the average number of games played, or in the number and percentage of draftees playing any games in the NHL or meeting the 10+ games played criteria between the 2005 and 2015 draft cohorts. Furthermore, a combination of anthropometric information and performance statistics correlated to a player's time on ice, but anthropometric measurements on their own were not robust enough to have a strong correlation with TOI/GP. Finally, NHL players have been decreasing in size since 2003 as per anthropometric draft measurements, and this trend is even more pronounced when observing first-round draft picks only.

Chapter 7 – Conclusion

In conclusion, an Independent Samples T-test revealed that there was no statistically significant difference in the average number of games played in each of the three NHL seasons following the respective drafts of the 2005 and 2015 draft cohort. Chi-square analysis revealed there was no statistically significant difference between the number and percentage of draftees that played any NHL games or that met the 10+ games played criteria in each of the three seasons following the 2005 and 2015 drafts respectively. These results are different than the hypothesis which stated that draftees from the Group 2 cohort were expected to have played a greater average number of games, and to have had a greater number of draftees that played any NHL games or that met the 10+ games played criteria. The precise explanation(s) behind this phenomenon are unclear but it can be speculated that improvements in physical conditioning and training regimens, improvements in medical and other professional health care fields, and a reduction of malicious violence has allowed for greater longevity in the careers of veteran players, and thus reducing the amount of open roster spots in the league for up-and-coming players. More research can be done to determine if or why veteran players are seeing increased career longevity, and why current players are taking longer to enter the ranks of the NHL, as compared to the past. Another potential reason for current draftees taking longer to secure a spot on an NHL roster may lay within the fact that hockey organizations are growing, and have more intricate farm-systems than in the past. Draftees may have to have success in one or more farm systems before graduating to the NHL. Further research could be done to determine whether or not the NHL farm-system has changed in recent years, and what effect this has had on the development of players coming into the league.

This study also concluded that an overall strong negative correlation existed between draft height and draft weight, against the year drafted to the NHL (from 2003-2017). This trend was linear, and was the opposite of what was observed in two previous longitudinal studies on NHL players conducted by Montgomery and Quinney et al. (data collection ending in 2003 and 2005 respectively). Although the Montgomery study followed one NHL team throughout the study and involved players playing in the NHL, as opposed to the current study which used NHL draftees who have not yet entered the league, the height and weight differences observed were substantial, and even more pronounced when observing the first-round selections only. The present study found that the highest average draft height for an entire draft class of skating players between 2003-2017 was in 2004 at 6'2", while the lowest average draft height was in 2017 at 6'0". This trend was considerably more pronounced when observing first-round draft selections only (nearly 4" difference). The highest average draft weight for an entire draft class of skating players between 2003-2017 was in 2005 at 198.95 pounds, while the lowest average draft weight was in 2017 at 185.89 pounds. This trend was also considerably more pronounced when observing first-round draft selections only (difference of 22lbs).

Lastly, Pearson correlations were performed for two different NHL seasons (2003/2004 and 2015/2016) to determine if anthropometric information and performance statistics were related to a player's time on ice during an NHL regular season. In the 2003/2004 analysis of the entire league, GP, G, A, P and PIM all correlated significantly with TOI/GP. Assists was the strongest predictor with a correlation coefficient of .591. In the 2015/2016 analysis of the entire league, Height, GP, G, A, P and PIM all correlated significantly with TOI/GP, with assists being the strongest predictor again with a correlation coefficient of .609. In the 2003/2004 analysis of the draftees meeting the 10+ games played criteria, GP, A, and P all correlated significantly with TOI/GP. Assists was the strongest predictor with a correlation coefficient of .538. In the 2015/2016 analysis of the draftees meeting the 10+ games played criteria, GP, G, A P and PIM all correlated significantly with TOI/GP, with assists being the strongest predictor again with a correlation coefficient of .850.

In conclusion, the multifaceted nature of hockey makes it difficult to confidently predict if or when to draft a player with the likelihood that said player will be elite in the league. Coaches and hockey organizations should draft with the intent to select a player who will best fit the needs of their team, rather than simply selecting who they believe is the *most skilled* player available at the time of their selection. Having an early selection may put pressure on an organization to select the most talented player available, or a fan-favourite, rather than the player who would be best-suited for the team by filling a void. Furthermore, as hockey is a late-specialization sport, professional coaches should place more consideration on a player's skillset and hockey-IQ, and less consideration on their size criteria when selecting a draft pick. Come draft time many NHL-caliber players have not yet reached full maturation, and likely have room for physical growth where they can catch-up to their counterparts. The same notion should be considered by coaches of adolescent and youth players as well. Grassroots and competitive youth leagues often see an imbalance of physical maturity when it is selection time for a team. Youth players who are not selected to a competitive team should still receive the same quality of coaching and programming offered to those in the competitive programs. This will likely reduce early dropout and concomitantly allow for late-maturing athletes to reach their full potential in a sport.

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Appendices

Appendix A: NHL.com Performance statistics table

Statistics

HOME LEADERS **PLAYERS** TEAMS GLOSSARY

SEASON BY SEASON 2017-2018 To 2017-2018 | GAME TYPE: Regular Season | REPORT: Skater Summary | Run Report | Refine Results | Legend | Print

GAME BY GAME 10/04/2017 To 11/29/2017

Sum Results

	Player	Season	Team	Pos	GP	G	A	P	+/-	PIM	P/GP	PPG	PPP	SHG	SHP	GWG	OTG	S	S%	TOI/GP	Shifts/GP	FOW%
1	Steven Stamkos	2017-18	TBL	C	24	10	26	36	10	10	1.50	7	16	0	0	1	0	73	13.7	19:04	22.38	46.9
2	Nikita Kucherov	2017-18	TBL	R	24	17	18	35	9	16	1.46	3	14	0	0	4	0	88	19.3	20:49	23.75	100.0
3	Johnny Gaudreau	2017-18	CGY	L	24	11	23	34	4	4	1.42	2	13	0	0	1	0	71	15.5	19:06	21.71	33.3
4	Jaden Schwartz	2017-18	STL	L	24	13	19	32	19	8	1.33	4	5	0	0	2	0	49	26.5	19:48	24.79	42.9
5	Phil Kessel	2017-18	PIT	R	26	11	21	32	2	24	1.23	3	17	0	0	2	2	99	11.1	18:08	21.92	30.0
6	Brayden Schenn	2017-18	STL	C	24	10	20	30	19	20	1.25	2	8	0	0	4	1	67	14.9	19:37	24.50	44.7
7	Connor McDavid	2017-18	EDM	C	25	10	20	30	1	8	1.20	3	7	0	1	2	1	69	14.5	21:37	24.84	37.2
8	Jakub Voracek	2017-18	PHI	R	25	7	23	30	4	26	1.20	1	9	0	0	1	0	89	7.9	19:23	23.80	66.7
9	John Tavares	2017-18	NYI	C	24	16	12	28	2	6	1.17	4	6	1	2	1	0	73	21.9	20:15	23.83	49.0
10	Mark Scheifele	2017-18	WPG	C	24	12	16	28	7	4	1.17	5	11	1	1	1	0	48	25.0	21:20	25.83	49.0
11	Anze Kopitar	2017-18	LAK	C	25	12	16	28	5	6	1.12	2	10	0	1	3	0	62	19.4	22:24	26.64	55.1
12	Vladimir Tarasenko	2017-18	STL	R	24	12	16	28	18	9	1.17	2	8	0	0	1	0	108	11.1	19:44	24.21	
13	Claude Giroux	2017-18	PHI	C	25	11	17	28	8	8	1.12	3	7	0	0	0	0	51	21.6	19:58	24.56	56.6
14	Blake Wheeler	2017-18	WPG	R	24	6	22	28	4	18	1.17	1	11	0	1	2	0	71	8.5	20:42	25.71	41.2

Appendix B: NHL.com Time on ice table

Statistics

HOME LEADERS **PLAYERS** TEAMS GLOSSARY

SEASON BY SEASON 2017-2018 To 2017-2018
GAME BY GAME 10/04/2017 To 11/29/2017
Sum Results

GAME TYPE Regular Seaso
REPORT Time On Ice (s
Run Report
Refine Results
Legend
Print

	Player	Season	Team	Pos	GP	EV TOI	EV TOI/GP	SH TOI	SH TOI/GP	PP TOI	PP TOI/GP	TOI↓	TOI/GP	Shifts	TOI/Shift	Shifts/GP
1	Oliver Ekman-Larsson	2017-18	ARI	D	27	528:11	19:33	47:56	01:46	104:28	03:52	680:35	25:12	834	00:48	30.89
2	Drew Doughty	2017-18	LAK	D	25	507:08	20:17	73:33	02:56	93:43	03:44	674:24	26:58	802	00:50	32.08
3	John Carlson	2017-18	WSH	D	25	483:09	19:19	84:43	03:23	98:32	03:56	666:24	26:39	728	00:54	29.12
4	Kris Letang	2017-18	PIT	D	26	489:42	18:50	74:43	02:52	100:13	03:51	664:38	25:33	775	00:51	29.81
5	Ryan Suter	2017-18	MIN	D	24	494:07	20:35	78:48	03:17	76:30	03:11	649:25	27:03	680	00:57	28.33
6	Ivan Provorov	2017-18	PHI	D	25	494:01	19:45	88:58	03:33	43:03	01:43	626:02	25:02	731	00:51	29.24
7	Alex Goligoski	2017-18	ARI	D	27	527:54	19:33	41:48	01:32	55:11	02:02	624:53	23:08	789	00:47	29.22
8	Alex Pietrangelo	2017-18	STL	D	24	466:30	19:26	60:11	02:30	94:39	03:56	621:20	25:53	683	00:54	28.46
9	Jason Demers	2017-18	ARI	D	27	498:38	18:28	59:29	02:12	57:05	02:06	615:12	22:47	837	00:44	31.00
10	Victor Hedman	2017-18	TBL	D	24	458:18	19:05	64:13	02:40	86:50	03:37	609:21	25:23	659	00:55	27.46
11	Seth Jones	2017-18	CBJ	D	25	500:43	20:01	51:01	02:02	54:33	02:10	606:17	24:15	726	00:50	29.04
12	Mattias Ekholm	2017-18	NSH	D	24	447:53	18:39	91:04	03:47	60:00	02:30	598:57	24:57	716	00:50	29.83
13	Nikita Zaitsev	2017-18	TOR	D	26	489:40	18:50	99:40	03:50	06:34	00:15	595:54	22:55	764	00:46	29.38
14	Duncan Keith	2017-18	CHI	D	24	429:11	17:52	72:59	03:02	92:48	03:52	594:58	24:47	744	00:47	31.00

Appendix C: NHL.com Player bio table

Statistics

HOME LEADERS **PLAYERS** TEAMS GLOSSARY

SEASON BY SEASON 2017-201ε To 2017-201ε — GAME TYPE: Regular Seaso — REPORT: Bio Info — Run Report — Refine Results — Legend — Print

GAME BY GAME 10/04/2017 To 11/29/2017

Sum Results

	Player	Season	Team	Pos	S/C	DOB↓	Birth City	S/P	Ctry	Ntnlty	Ht	Wt	GP	G	A	P	Draft Yr	Rnd#	Overall
1	Alex Formenton	2017-18	OTT	L	L	1999-09-13	Barrie	ON	CAN	CAN	74	165	1	0	0	0	2017	2	47
2	Filip Chytil	2017-18	NYR	C	L	1999-09-05	Kromeriz		CZE	CZE	74	202	2	0	0	0	2017	1	21
3	Owen Tippett	2017-18	FLA	R	R	1999-02-16	Peterborough	ON	CAN	CAN	73	200	7	1	0	1	2017	1	10
4	Martin Necas	2017-18	CAR	C	R	1999-01-15	Nove Mesto na Morave		CZE	CZE	73	167	1	0	0	0	2017	1	12
5	Nico Hischier	2017-18	NJD	C	L	1999-01-04	Brig		CHE	CHE	73	175	24	5	13	18	2017	1	1
6	Kailer Yamamoto	2017-18	EDM	R	R	1998-09-29	Spokane	WA	USA	USA	68	154	9	0	3	3	2017	1	22
7	Nolan Patrick	2017-18	PHI	C	R	1998-09-19	Winnipeg	MB	CAN	CAN	74	198	16	2	4	6	2017	1	2
8	Jesper Bratt	2017-18	NJD	L	L	1998-07-30	Stockholm		SWE	SWE	70	175	24	7	8	15	2016	6	162
9	Clayton Keller	2017-18	ARI	C	L	1998-07-29	Chesterfield	MO	USA	USA	70	168	27	11	10	21	2016	1	7
10	Mikhail Sergachev	2017-18	TBL	D	L	1998-06-25	Nizhnekamsk		RUS	RUS	75	215	24	6	10	16	2016	1	9
11	Pierre-Luc Dubois	2017-18	CBJ	C	L	1998-06-24	Ste-Agathe-Des-Monts	QC	CAN	CAN	75	207	25	4	3	7	2016	1	3
12	Victor Mete	2017-18	MTL	D	L	1998-06-07	Woodbridge	ON	CAN	CAN	69	184	24	0	3	3	2016	4	100
13	Janne Kuokkanen	2017-18	CAR	C	L	1998-05-25	Oulunsalo		FIN	FIN	73	188	4	0	0	0	2016	2	43

Appendix D: Hockeydb.com NHL draft table

2015 NHL Entry Draft

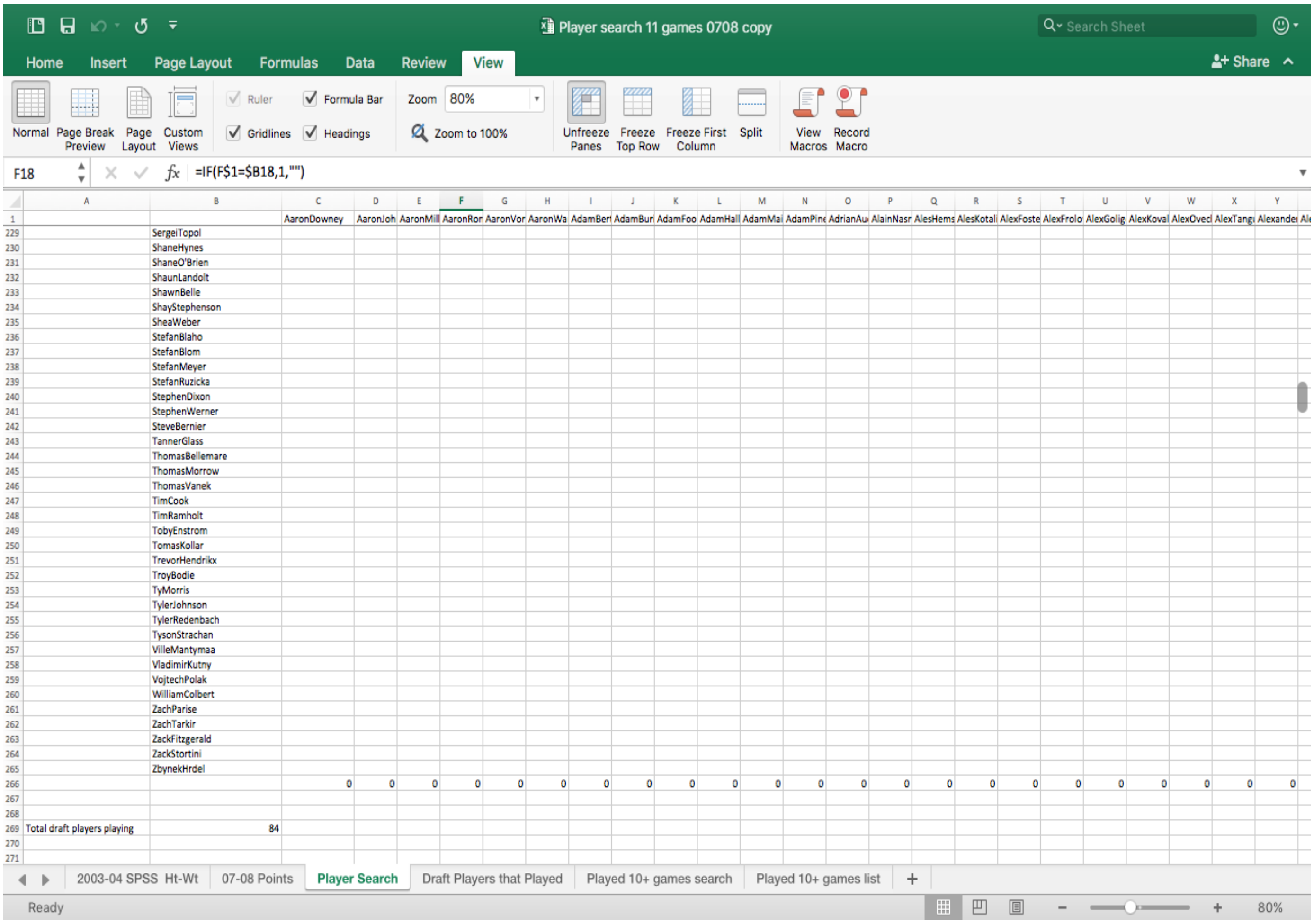
Drafts -> NHL -> Entry -> 2015

This is the list of players selected in the 2015 NHL Entry draft. There were 211 prospects selected across 7 rounds. Also included is each player's career NHL totals. If a player has no totals listed, this means that he has not played in a regular season game in the NHL. You can click on the headings of the tables to sort the information.

Round 1						NHL Totals					
Round	Num.	Drafted By	Player	Pos	Drafted From	GP	G	A	Pts	PIM	Last Season
1	1	Edmonton	Connor McDavid	C	Erie Otters [OHL]	152	56	122	178	52	2017-18
1	2	Buffalo	Jack Eichel	C	Boston University [H-East]	167	55	77	132	58	2017-18
1	3	Arizona	Dylan Strome	C	Erie Otters [OHL]	10	0	1	1	0	2017-18
1	4	Toronto	Mitch Marner	C	London Knights [OHL]	103	21	56	77	40	2017-18
1	5	Carolina	Noah Hanifin	D	Boston College [H-East]	183	12	52	64	52	2017-18
1	6	New Jersey	Pavel Zacha	C	Sarnia Sting [OHL]	91	10	22	32	33	2017-18
1	7	Philadelphia	Ivan Provorov	D	Brandon Wheat Kings [WHL]	107	10	32	42	42	2017-18
1	8	Columbus	Zach Werenski	D	U. of Michigan [Big-10]	103	18	43	61	18	2017-18
1	9	San Jose	Timo Meier	R	Halifax Mooseheads [QMJHL]	56	5	5	10	31	2017-18
1	10	Colorado	Mikko Rantanen	R	TPS Turku [SM-liiga]	106	27	31	58	36	2017-18
1	11	Florida	Lawson Crouse	L	Kingston Frontenacs [OHL]	79	5	7	12	53	2017-18
1	12	Dallas	Denis Gurianov	R	Tolyatti (Russia Jrs.)	1	0	0	0	0	2016-17
1	13	Boston	Jakub Zboril	D	Saint John Sea Dogs [QMJHL]						
1	14	Boston	Jake DeBrusk	L	Swift Current Broncos [WHL]	21	5	7	12	0	2017-18
1	15	Boston	Zachary Senyshyn	R	Sault Ste. Marie Greyhounds [OHL]						
1	16	NY Islanders	Mathew Barzal	C	Seattle Thunderbirds [WHL]	26	6	18	24	16	2017-18
1	17	Winnipeg	Kyle Connor	L	Youngstown Phantoms [USHL]	39	9	11	20	8	2017-18
1	18	Ottawa	Thomas Chabot	D	Saint John Sea Dogs [QMJHL]	6	0	3	3	0	2017-18
1	19	Detroit	Evgeny Svechnikov	R	Cape Breton Screaming Eagles [QMJHL]	2	0	0	0	0	2016-17
1	20	Minnesota	Joel Eriksson-Ek	C	Farjestads BK Karlstad [SweHL]	35	4	6	10	10	2017-18
1	21	Ottawa	Colin White	C	U.S. National Development Team [USHL]	2	0	0	0	0	2016-17
1	22	Washington	Ilya Samsonov	G	Magnitogorsk-2 (Russia Jrs.)						

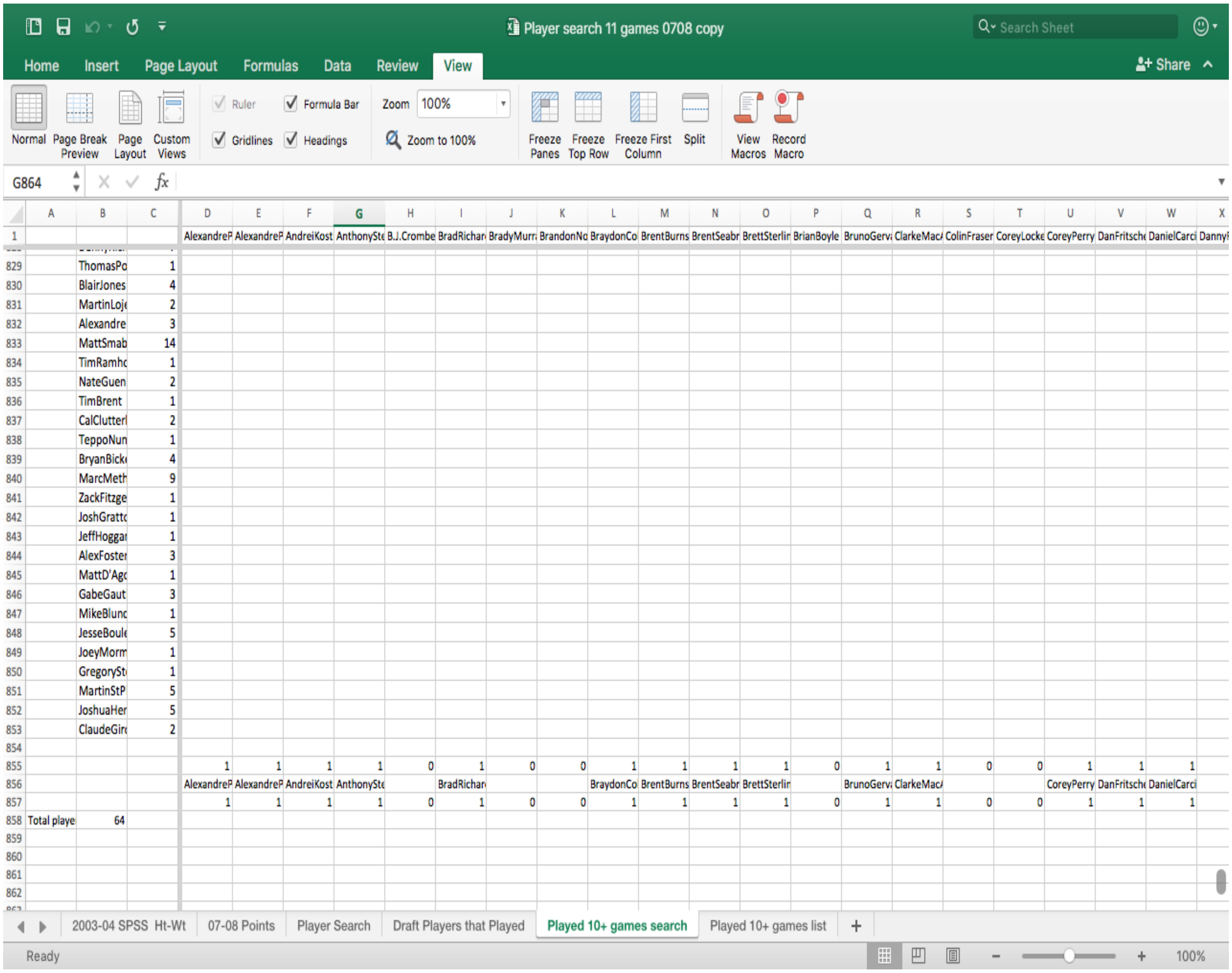
Appendix E: Example data table

Custom Microsoft Excel code to determine how many draftees played at least 1 game in the NHL in the subsequent season following their draft.



Appendix F: Example data table

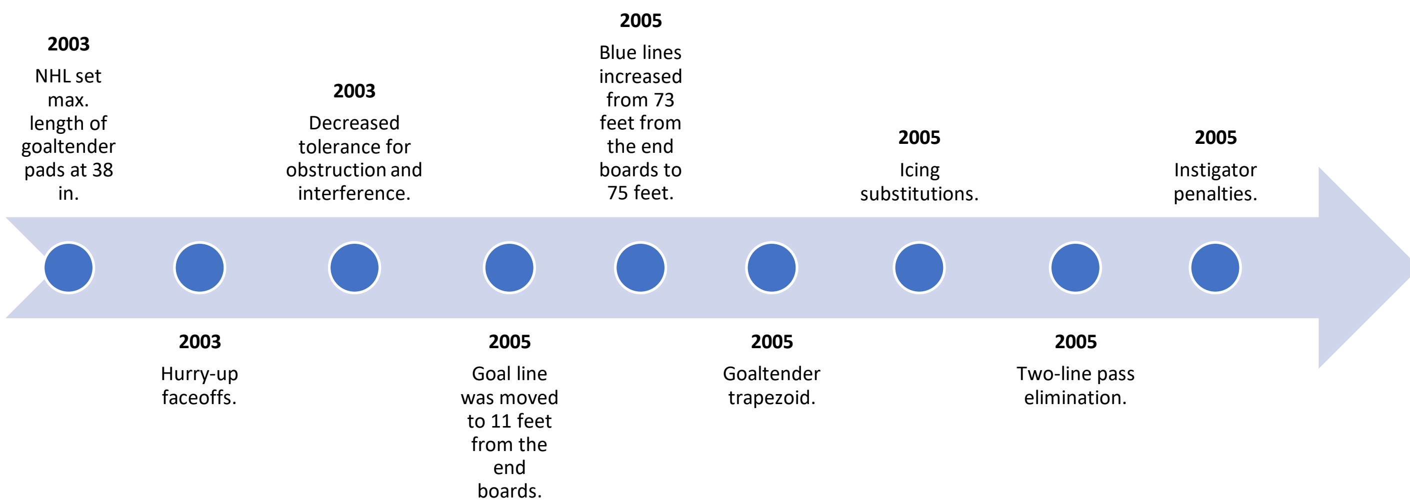
Custom Microsoft Excel code to determine how many draftees played at least 10 games in the NHL in the subsequent season following their draft.



	A	B	C
829		ThomasPo	1
830		BlairJones	4
831		MartinLoje	2
832		Alexandre	3
833		MattSmab	14
834		TimRamhc	1
835		NateGuen	2
836		TimBrent	1
837		CalClutterl	2
838		TeppoNun	1
839		BryanBicke	4
840		MarcMeth	9
841		ZackFitzge	1
842		JoshGrattc	1
843		JeffHoggar	1
844		AlexFoster	3
845		MattD'Agc	1
846		GabeGaut	3
847		MikeBlunc	1
848		JesseBoule	5
849		JoeyMorm	1
850		GregorySt	1
851		MartinStP	5
852		JoshuaHer	5
853		ClaudeGir	2
854			
858	Total playe	64	

	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	AlexandreP	AlexandreP	AndreiKost	AnthonySte	B.J.Crombe	BradRichar	BradyMurr	BrandonNo	BraydonCo	BrentBurns	BrentSeabr	BrettSterlin	BrianBoyle	BrunoGerva	ClarkeMacA	ColinFraser	CoreyLocke	CoreyPerry	DanFritsche	DanielCarci	DannyR
855	1	1	1	1	0	1	0	0	1	1	1	1	0	1	1	0	0	1	1	1	
856	AlexandreP	AlexandreP	AndreiKost	AnthonySte		BradRichar			BraydonCo	BrentBurns	BrentSeabr	BrettSterlin		BrunoGerva	ClarkeMacA			CoreyPerry	DanFritsche	DanielCarci	
857	1	1	1	1	0	1	0	0	1	1	1	1	0	1	1	0	0	1	1	1	

Appendix G: Timeline of NHL Rule Changes (To increase goal scoring and decrease violence)



Appendix H: Background information on the Relative Age Effect (RAE) and Long-Term Athlete Development (LTAD)

2.7 Relative Age Effect in Hockey

A concept known as the relative age effect (RAE) has been discussed widely in education [1, 4], and in sport since the 1980's [1]. The relative age effect occurs when individuals who are born earlier in the year in a given cohort experience advantages over those who are born later in that cohort, who are relatively younger [1]. With respect to sport, it is well understood that RAE puts those younger individuals at a disadvantage when compared to their older peers [1]. This is due to the early year players being bigger, stronger, faster, better coordinated, more skillful and more emotionally mature [1-4] than the relatively younger athletes or late year players. Elite sports teams have a limited number of available roster spots and select players based on perceived talent to create the best team possible [1]. Those who are relatively older, and exhibit the advantages of the RAE, have a greater chance of making such teams, resulting in a selection bias toward athletes born early in the year. Selection bias refers to relatively older athletes receiving inflated access to coaches, better training facilities and are awarded more opportunities during competition than their relatively younger counterparts [1, 4]. On the other hand, relatively younger individuals erroneously receive fewer opportunities (instruction, access to an elite team) than is warranted by their latent talent that may emerge at a later date [1].

In a recent study conducted by Deaner et al. (2013) regarding RAE and selection bias in the National Hockey League (NHL) (Canadian players only) draft, showed over a 27-year span (1980-2006) that relatively younger players significantly and consistently outperformed their older counterparts using games played and total points as proxies [1]. In fact, when the players in the study were divided by birth quarter, more players born in the 4th birth quarter (Oct 1 – Dec 31) reached career benchmarks of 200, 400 and 600 games played as well as 100 and 200 career points than players born in the first three birth quarters. Despite these statistics, relatively younger players are still underrepresented in the NHL draft especially in the higher rounds. Conversely, in a more recent article published by Gibbs et al. in 2011 found that RAE for Canadian-born NHL players was less prominent than in major junior leagues, and when looking at the most elite levels of play (all-star teams and Olympic teams) it was found that RAE actually reversed [(18)]. The authors examined the Canadian Olympic roster for the 2010, 2006, 2002 and 1998 teams and found values of 13%, 17%, 26% and 14% for players on the roster who were born in the first birth quarter, respectively. A normal distribution would spread the birth date distribution equally over each quarter. It is evident that the number of Canadian players born in the first birth quarter on Olympic teams is significantly less than those born in the first birth quarter that were only drafted to, and playing in the NHL. The authors support this reversal phenomenon with statistics comparing the number of Canadian NHL draft picks born in the first birth quarter (2007-2010) against the number of Canadian born draft picks born in the first birth quarter who were actually playing in the NHL, and who were a part of all-star and Olympic rosters. From 2007-2010 the amount of Canadian first round NHL draft picks born in the first birth quarter were 40%, 41%, 47% and 33% respectively. Those numbers are very high, but when compared to the number of Canadian players born in the first birth quarter who are actually playing in the NHL, the values decrease to a mere 28%. Furthermore, the combined average of all-star and Olympic rosters of first quarter-born Canadian players is only 17% [(18)].

While RAE may be strong in junior hockey, and may govern draft position, the effect does not appear to continue when trying to understand who will achieve hockey success in the NHL. Gibbs et al. found that how you define hockey success can drastically affect the outcome of your results if you are attempting to demonstrate how many hockey players achieve "hockey success". If hockey success is defined as playing Major Junior Hockey (Gladwell), then RAE is strong. If hockey success is defined as making the NHL (Howell and Nolan, 2010) the effect is diminished, and when performance and skill are considered (Baker and Logan 2007) the effect is further diminished. Finally, when Gibbs et al. use selection to an elite team as their proxy for success; the effect that RAE has on NHL players is significantly diminished and was actually shown to reverse [18].

The majority of previous studies surrounding RAE and NHL hockey have used an end goal of being drafted to the NHL, and because not all of the drafted players make an NHL roster or even play a single NHL game, the RAE seems inflated due to the high prevalence of RAE in major junior hockey. If people really want to know the true effect of RAE on NHL hockey players, it would appear that defining success in the NHL (ie.as games played, selection to elite teams, time on ice, point totals) would provide a different perspective as these players have actually played in the NHL and experienced success, rather than just being drafted by a team. These alternative measures of success (beyond draft status) may provide more meaningful ways to understand whether there is systematic underestimation of players' potential happening across the league. For instance, the statistic known as "games played" is an important measure of productivity. The logic behind this measure is that if a player continues to be utilized by a team, he must be viewed as more desirable than the alternative players that could be used in his place [1].

Regression analysis was performed to predict games played using points per game and draft slot as predictors. Both variables mutually predicted games played with the coefficient for draft slot being negative. When position, height, weight and plus/minus per game were added as predictors, the effect that draft slot had on playing opportunity remained considerable. The results of the analysis indicated that players who were drafted “later than they should have been” must produce more in order to receive equal playing opportunities. Deaner et al. did not state what “more” refers to, but in the context of the article it would be logical to interpret the author was referring to point totals. The authors’ other published works have measured success in the NHL in different forms including draft status, point totals, time on ice, special teams’ opportunities, number of scoring opportunities, plus/minus, and hockey specific physical proficiency [1, 5-12].

One example of an alternative measure of success is the 10+ game threshold. The value of 10 games is meaningful because it is in accordance with the most recent NHL Collective Bargaining Agreement’s (CBA) (September 16, 2012 – September 15, 2022) description of how a young player enters into a Standard Player’s Contract (SPC). Article 10.2 (a) (i) (A) of the SPC states that a player aged 18 or 19 earns a year of professional experience by playing ten (10) or more NHL games in a given NHL season, and a player aged 20 or older (or who turns 20 between September 16 and December 31 of the year in which he signs his first SPC) earns a year of professional experience by playing ten (10) or more Professional Games under an SPC in a given league year. An athlete who is maintained on a roster beyond the 10-game threshold can be deemed as being seen as worthwhile by the club’s management, coaches etc. Although not frequently cited, this measure of success may have potential in this field of study.

2.8 Long-Term Athlete Development

Compounding the RAE, is another phenomenon that may hinder early athletic performance and participation of younger individuals in sport, and that is whether they present with early or late maturing characteristics. Early maturation refers to an individual's biological development that is more advanced when compared to the average biological development of other children with the same chronological age. Late maturation refers to individuals whose biological maturation is less advanced when compared with their peers of the same chronological age. Biological maturity rates are different for boys and girls and so comparisons of biological maturity are made amongst children of the same sex. In these definitions, biological maturity is described as an evaluation of maturity using criteria including measures of morphological, skeletal, dental and sexual age [(33)]. From the long-term athlete development literature, early developers will experience advantages in strength, power, endurance and speed, especially in sports where mass is advantageous (i.e. hockey). These athletes typically outperform their peers simply due to body stature, as opposed to superiority in skill. The result of this is greater recognition and reinforcement from their coaches [(33)], ultimately leading to selection bias. Eventually the average and late maturers do catch up their growth and maturation, making them on average, the same size as early-maturing athletes. However, a skill discrepancy may exist between the two groups, based on how they were treated through their formative years in the sport. For instance, early maturing athletes can rely upon their physical dominance for early success due to their advanced developmental age, but as a result, some will not develop the necessary skills or fitness required to play at a high level [(34)]. Conversely, the late maturing athletes experience failure at an early age, and are often disregarded by their coaches and therefore experience little recognition. Late maturers are prone to early drop-out [(34)] for this reason. The late maturers who do remain in the sport program often exhibit greater levels of skill and technique since they had to evolve their game to play against the stronger, faster early-maturing athletes [34]. For these reasons, it is important as a coach or parent to ensure that all players, regardless of maturational status obtain skill development while maturing.

The concepts of RAE, selection bias and long-term athlete development (LTAD) are relatively new in the hockey world, with most Canadian sport LTAD models having only been developed since 2011. However, the concepts dovetail with the rule changes described earlier, in which smaller, more agile players have an advantage for play-making and goal-scoring. The opportunities for late-maturing athletes may be opening up at the draft level, but they may not be achieving success at the same rate that early-maturing athletes would. As discussed, measures of success likely need to extend beyond simply making the draft, to measures of quality during on ice time. The use of additional measures of success has not been thoroughly explored in the body of research and in particular, there is a lack of focus on how this impacts late vs early maturing athletes in the sport.