# Seasonal Changes in

# Whole Body, and Regional Body Composition Profiles

# of Elite Collegiate Hockey Players

By:

Neal Prokop

Department of Kinesiology and Physical Education

McGill University, Montreal, Quebec, Canada

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# Table of Contents

## List of Figures



## List of Tables

## List of Common Terms and Abbreviations

CIS – Canadian Interuniversity Sport (Collegiate Hockey League in Canada)

DXA – Dual Energy X-Ray Absorptiometry (Body Composition Methodology)

ES – End of Season time-point [February | March]

FHOS – First half of the regular season, the time period between pre-season and mid-season assessments

In-Season – The competitive regular season.

MS – Mid-Season time-point [November | December]

NCAA – National Collegiate Athletics Association (Collegiate Hockey League in USA)

NHL | AHL – National Hockey League, American Hockey League (Professional)

Off-Season – The time period between end of season and pre-season assessments.

OHL | QMJHL | WHL – Ontario, Quebec, Western Hockey League (Major Junior)

PS – Pre-Season time-point [August | September]

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# Abstract


## Abstract in English

The monitoring of a collegiate hockey player's body composition can reflect fitness characteristics, and may help players, coaches or strength & conditioning professionals optimize physiologic gains during an off-season, while simultaneously preventing performance decrements in-season. Two separate studies took place in this investigation. The first study's purpose was to examine changes in the whole-body, and regional-body composition profiles of elite collegiate hockey players in regards to fat and lean tissue mass during an off-season and the first half of a competitive season. The purpose of the second study was to evaluate if collegiate players could accurately perceive their fluctuations in body composition.

In the first study, the body composition profiles of nineteen elite Canadian collegiate hockey players were assessed using dual energy x-ray absorptiometry at three different time-points (i.e. end of season, pre-season and mid-season). A repeated measures anova was used to compare the player's changes in body composition at the different time-points. Statistically significant changes in body composition profiles were observed as players showed various tissue gains/losses depending on the region assessed. Overall, players gained (1.38kg, $p \leq .01$) and lost (.79kg, $p \leq .01$) fat tissue during the off-season and in-season, respectively. Players also showed a significant gain of leg lean tissue (.29 kg, $p = .02$) and loss of arm tissue mass (-.25 kg, $p = .02$) during the first-half of the competitive season. Several correlations emerged that may provide insight into potential trends that could be more pronounced during longer and more demanding schedules.

In the second study, a total of 24 players completed pre-season and mid-season assessments. Immediately before each scan, players answered questionnaires regarding their off-season and in-season training, and perceived change in their body composition and strength of particular regions during the 3-month time period. Two thirds of players and one-half of players accurately detected changes in arm-lean and arm-fat tissue respectively. Approximately two-thirds of players did not accurately perceive gains or losses of lean or fat tissue within their leg and overall body region.

The findings from each study can have important implications for the performance and development of collegiate athletes. The accuracy of a player's perceived change in body composition may affect their acceptance and adherence to a dietary or training intervention. Overall, the understanding of body composition profiles, body composition fluctuations, and potential variables that may influence the composition of collegiate hockey players can help coaches and athletic programs tailor their team's training, nutrition, lifestyle and informative resources to further support their athletes.

## Abstract in French

Le suivi de la composition corporelle des joueurs de hockey universitaires peut faire ressortir certaines de leurs caractéristiques physiques et peut aider les joueurs, comme les entraîneurs en préparation physique à optimiser les gains physiologiques durant l'entre-saison tout en évitant une diminution des performances durant la saison. Deux études distinctes ont pris place lors de cette grande recherche. La première étude avait pour but d'observer les changements de la composition corporelle du corps en entier, puis par région spécifique du joueur de hockey élite universitaire prenant en considération les tissus adipeux et maigres durant l'entre-saison et la première moitié de saison. Le but de la deuxième étude était de voir si les athlètes universitaires pouvaient précisément déterminer les changements de leur composition corporelle.

Dans la première étude, le profil de la composition corporelle de dix-neuf joueurs élites de hockey universitaire canadien a été évalué utilisant l'absorption de l'énergie double des rayons-x à trois différents moments (fin de la saison, pré-saison et mi-saison). La répétition de mesures d'anova a été utilisée pour comparer le changement de composition corporelle des joueurs à différents moments. Des changements signifiants de la composition corporelle ont été observés, alors que les joueurs ont montré différent gains/pertes de tissus tout dépendant de la région évaluer. Globalement, les joueurs ont gagné (1.38kg, $p \leq .01$) de tissus adipeux durant l'entre-saison et perdu (.79kg, $p \leq .01$) durant la saison. Les joueurs ont aussi montré des gains signifiant au niveau des tissus maigres des jambes (.29 kg, $p = .02$) et des pertes au niveau de la masse des tissus des bras (-.25 kg, $p = .02$) durant la première moitié de la saison régulière. Plusieurs corrélations émergent ce qui donnent un aperçu des tendances potentielles qui pourraient être davantage prononcées durant une plus longue et plus demandant cédule.

Dans la deuxième étude, un total de 24 joueurs a complété les évaluations de pré-saison et de mi-saison. Immédiatement avant le scan, les joueurs ont répondu à un questionnaire sur leurs entraînements durant la saison ainsi qu'hors-saison sur comment ils évaluaient l'évolution de leur composition corporelle et de leur force par rapport aux régions spécifiques désignées. Le deux tiers des joueurs on précisément perçue les changements dans leurs tissus maigres des bras et la moitié pour leurs tissus adipeux. Les deux tiers des joueurs n'ont pas précisément perçue les gains ou les pertes de leurs tissus maigres ou adipeux de leurs jambes et de leur corps en entier.

Les résultats de chacune des études peuvent avoir d'importantes implications pour la performance et le développement des athlètes universitaires. La précision des joueurs à percevoir les changements de leur composition corporelle peut affecter leur acceptation et leur adhésion à une diète ou à un programme d'entraînement. Globalement, la compréhension d'un profile de la composition corporelle, des variations et des autres variables potentiels qui peuvent influencer la composition corporelle des joueurs de hockey universitaires peut aider les entraîneurs et les programmes sportifs à adapter les entraînement d'équipe, la nutrition, le mode de vie et les sources d'informations de leurs joueurs de manière à mieux supporter leurs athlètes.

# Chapter 1 – Introduction

## *1.1 Scope of the Problem*

Collegiate-athletes often have ambitious athletic, and academic goals requiring hours of extra-curricular time commitments per week that could potentially be detrimental to a student's athletic performance, general health, and well-being. Over 460,000 collegiate-athletes participate in the United States' National Collegiate Athletic Association (NCAA) and 11,000 in Canada's Interuniversity Sport (CIS) leagues (Canadian Interuniversity Sport; National Collegiate Athletics Association, 2015). Across Canada, approximately 900 players will participate in CIS men's hockey each year. As Canadian collegiate-hockey players leave their respected junior teams to join university institutions, they are often faced with balancing greater academic and athletic priorities, and may experience new lifestyle changes that can be influential in their sport performance and health. Long practice days, substantial travel, demanding schedules, and game preparations might all influence a collegiate-athlete's sleep, nutrition, training, and activity levels outside of their sport of choice, and combine to have an impact on their overall body composition (Bailey et al., 2014; Kraemer et al., 1999; Reynolds et al., 2012; Volek et al., 2002). In the long-term, gains in adiposity and negative behavior patterns can increase or develop during colligate years (Cluskey & Grobe, 2009; Racette, Deusinger, Strube, Highstein, & Deusinger, 2008), and it is important to identify potential trends that could have an impact on an athlete's level of performance.

Although body composition can be reflective of many factors unrelated to elite sport, many recognize that this trait alone, can have a strong influence on the performance of elite athletes in competition (Ackland et al., 2012). Changes in body composition (e.g. lean mass, fat mass), and the overall composition profiles of student-athletes (i.e. hockey players) may also be indicative of short-term, and long-term health outcomes (Hanauer, 2005; Montague & O'Rahilly, 2000). Furthermore, the longitudinal tracking of a team's body composition can reflect fitness characteristics (Mattila, Tallroth, Marttinen, & Pihlajamäki, 2007; Miller et al., 2007; Miller, White, Kinley, Congleton, & Clark, 2002), which may influence the individual's athletic performance or success of a university athletics program.

Information regarding the body composition profiles of hockey players, especially collegiate-players in Canada is lacking, and the understanding of potential fluctuations in body composition profiles can help coaches, trainers, or strength & conditioning specialists improve the strength and conditioning programs of their athletes. Several physiologic mechanisms allow for body composition to be modified by training, nutrition, and overall lifestyle; however to create programs or make tailored recommendations for a subset of student athletes, a further understanding of the common changes in body composition profiles associated with collegiate-hockey players must first be understood. Maintaining an ideal body composition throughout the year may help ensure performance decrements in their sport do not occur, but can also benefit the health, and overall well-being of this student population.

### *1.2 Purpose*

The purpose of this investigation was to explore fluctuations in body composition measures among collegiate-athletes belonging to an elite university hockey team in Canada. The primary purpose of the first study was to assess body composition profiles (i.e. fat mass, lean (fat free | muscle) mass) of each player, and how each of these tissue volumes changed during an off-season and the first half of a competitive in-season. A second objective of this study was to evaluate the regional changes in body composition (e.g. leg vs. arm). Proper use of dual energy x-ray absorptiometry (DXA) allows for precise and accurate segmental body composition measures (Ackland et al., 2012; Bilsborough et al., 2014; Nana, Slater, Stewart, & Burke, 2014), and was used to evaluate the hockey player's distribution of tissue type. The main purpose within the second study was to gain further insight into the player's ability to accurately perceive their individual body composition fluctuation after the first half of a regular season.

### *1.3 Rationale*

Hockey is arguably one of the most demanding sports at the collegiate level in Canada. The sport has the longest regular season within the CIS, and requires some of the most demanding travel schedules of CIS teams. Compared to other collegiate sports, the demands of ice hockey are also unique. Since a hockey shift typically last 30-45 seconds, and players have multiple shifts per period, athletes should be trained both aerobically and anaerobically to optimize performance during a game, and ensure recovery between shifts. Performance enhancing programs include exercises that attempt to improve strength, power, stamina, balance, and coordination, because these characteristics are accepted as being generally advantageous for athletes, and hockey players (Baechle & Earle, 2008; M. Clark, Lucett, & Kirkendall, 2010). Although some fat mass may be advantageous for additional inertia during on-ice collisions, muscle mass is what stabilizes joints, and helps propel the player or puck across the ice (Burr et al., 2008). After a summer of off-season training, hockey players are usually expected to arrive at training camp in excellent shape since team roster positioning can be determined during the pre-season. However, little information is available on how the body composition attributes of collegiate-athletes change during the off-season, and during the competitive season, once athletic and academic obligations begin to accumulate. Because athletes participate in elite sport and partake in regular physical activity multiple times per week, it may be wrongfully assumed that varsity athletes have healthy and stable body compositions that allow for optimal performance.

The use of dual energy x-ray absorptiometry (DXA) to evaluate the body composition profiles and fluctuations amongst elite athletes has been gaining popularity, with studies now including soccer, rugby, field hockey, volleyball, swimming, track and basketball athletes (Beck & Doecke, 2005; Bilsborough et al., 2014; Harley, Hind, & O'Hara, 2011; Silvestre et al., 2006; Stanforth, Crim, Stanforth, & Stults-Kolehmainen, 2014). The use of DXA technology to evaluate body composition is considered to be a gold standard (Bray & Bouchard, 2014), and although body composition has previously been assessed in elite hockey players

(Agre et al., 1988; Peyer, Pivarnik, Eisenmann, & Vorkapich, 2011; Potteiger, Smith, Maier, & Foster, 2010; Quinney et al., 2008; Vescovi, Murray, Fiala, & VanHeest, 2006), to our knowledge, there is no study that has evaluated the body composition of elite collegiate hockey players in Canada using DXA technology, or reported a hockey player's change in body composition at multiple time-points. The project provides insight that may help to improve the general performance of collegiate-athletes, while providing intriguing sport-specific knowledge to hockey players and sport teams at the collegiate level. Furthermore, the study and team analysis serves as an example of what DXA body composition scans might accomplish for a competitive sport franchise.

Body composition can be reflective of fitness and athletic performance characteristics (M. Clark et al., 2010; Miller et al., 2007; Miller et al., 2002; Potteiger et al., 2010), and multiple body composition assessments can track the athlete's development, help predict an individual's athletic potential (e.g. talent, size), or assist in evaluating the effectiveness of an exercise or dietary intervention (Ackland et al., 2012; Nana et al., 2014). The understanding of body composition profiles, body composition fluctuations, the player's perception of body composition changes, and potential variables that affect body composition changes may help coaches and athletic programs optimize their team's training, nutrition, lifestyle and informative resources, to further educate and support their athletes.

## *1.4 Hypothesis*

### *Objective #1 (Study 1-A): Body Composition Profiles of Collegiate Hockey Players*

The demands required of elite collegiate hockey players vary between the off-season (e.g. off-ice training, employment) and in-season (e.g. on-ice training, hockey competition, school commitments); and therefore it was hypothesized that a player's composition measures were also likely to fluctuate between the time-points. During the season, it was assumed that less time is spent on maintaining fitness attributes (e.g. composition, strength, endurance, flexibility), because of school, travel, on-ice commitments, and sport-specific game preparations. *It was hypothesized that observable body composition attributes of collegiate hockey players would differ between the off-season and in-season. Overall, this sample of collegiate hockey players was expected to have an overall leaner body composition at pre-season (due to off-season fitness training), compared to their mid-season and their end-of-previous season measures.* Dual x-ray absorptiometry was used to evaluate the changes in each player's body composition, and questionnaires were used to help gain insight into the off-season and in-season lifestyles, training habits and demands placed on each athlete.

### *Objective #2 (Study 1-B): Regional Fat and Lean Tissue Change*

It's been previously suggested that off-ice strength training does not occur as frequently during the competitive in-season, as compared to the off-season (Montgomery, 1988), and it was *hypothesized that ice-hockey players may be susceptible to different levels of relative lean (muscle) mass fluctuations in particular* *regions of their body (e.g. upper vs. lower) during the competitive first-half of a regular season.* A DXA scan provides insight into regional muscle mass fluctuations because the lean tissue can be separated from fat and bone mass. Since there is an approximate relationship between muscle cross-sectional area and force/power generation, changes in muscle size that are relative to the athlete's body mass may be indicative of strength and performance changes (Ackland et al., 2012). *During the season, it was hypothesized that players would be more susceptible to a decrease in upper body lean muscle tissue, but likely would maintain or gain lower body lean tissue muscle tissue due to 4-5 weekly ice-times involving high-intensity bursts of skating. It was also predicted that significant differences in visceral fat mass would be observed at the end of the off-season, and at the end of the first half of their season.*

### *Objective #3 (Study 2): Perceptions of Body Composition Changes*

If collegiate athletes do not work with strength & conditioning coaches or dietitians, it may be necessary for the athlete to monitor their own body composition and make adjustments to their training/nutrition programs to achieve a desired composition (e.g. weight gain, weight loss, muscle gain). Since changes in body composition can often take place gradually, *it was hypothesized that collegiate-athletes would have inaccurate perceptions of how their body composition had changed during the competitive semester.*

### *1.5 Delimitations*

There are many potential factors that can impact student-athlete performance. The proposed project is intended to focus on analyzing the body composition profiles and regional fluctuations among this subgroup of student-athletes. Although attributes such as training volume or nutrition may affect body composition, these attributes were not controlled since it was beyond the scope of this investigation. However, the questionnaires regarding the player's training habits could potentially be used to help explain some of the observed body composition changes within this investigation.

### *1.6 Limitations*

The sample was recruited from one elite varsity team (i.e. men's hockey). These findings may not reflect the body composition, health and lifestyles of *all* collegiate-athletes across different sports and universities. The members of the team come from different programs of study and may have had different motives for playing collegiate sport, which could influence their work ethic and the variability of our data if comparing our findings to other sports, levels or universities. The majority of scans were scheduled mid to late afternoon, however players were asked to refrain from eating immediately before the scans to minimize potential meal inconsistencies in the trunk, android, and gynoid regions. The mid-afternoon scheduling allowed a full 12-24 hour break from exercise (i.e. the previous practice day) and was scheduled to reflect the athlete's composition profile prior to their participation in their respected sport (i.e. practice or game). Although DXA is independent of hydration status (Ackland et al., 2012), the goal was still to complete each player's DXA scans under consistent and standardized conditions (i.e. hydration, meal timing, exercise). Some responsibility was placed on the players to abide to the recommendations, and maintain a similar routine prior to each of their scans. It was believed that since athletes are competitive and interested in potentially improving their performance, they followed the study's recommendations, however these potential variables were not monitored. Furthermore, while the findings of this study may provide insight into potential health and performance changes of elite ice hockey players, their physiological change in performance variables were not monitored during the study's duration.

### *1.7 Strengths*

Despite having only one team, the team was elite and from a top-ranked institution, which suggests strong athletic and academic ambitions. The team was national semi-finalists at the beginning of the study, and sat atop their respected conference at the end of the study. Although only one team was used, 78.9% of the roster had major junior hockey experience signifying a strong hockey background, with previous fitness, nutrition and training knowledge. It was theorized that the caliber of roster players should make the study's findings of interest to elite hockey teams of different ages and levels. Furthermore, the study is also strengthened by the use of precise DXA technology that minimizes experimenter error during the scans, and which took place over a 10-month period. To our knowledge, DXA has not been repeatedly applied to ice hockey athletes in previous literature.

# Chapter 2 – Review of Literature

There are a variety of determinants that can affect a collegiate-athlete's health, lifestyle and athletic performance. This literature review encompasses the study's primary variable (i.e. body composition) as it relates to hockey, and how body composition has important implications for both the athlete's health and athletic performance. Athletic performance has a physiologic and mental component, and although many variables are outside of the athlete's control, body composition is one physiologic variable that is partially controllable by the athlete since it can be modified with appropriate activity (i.e. training), meal planning and lifestyle interventions. The literature review also encompasses a section that provides an overview of collegiate hockey in Canada, which is important to understand if the study's findings are to be applied to other athletic populations of interest. **Figure 2.1** illustrates the variety of factors that can potentially impact the on-ice performance of hockey players.

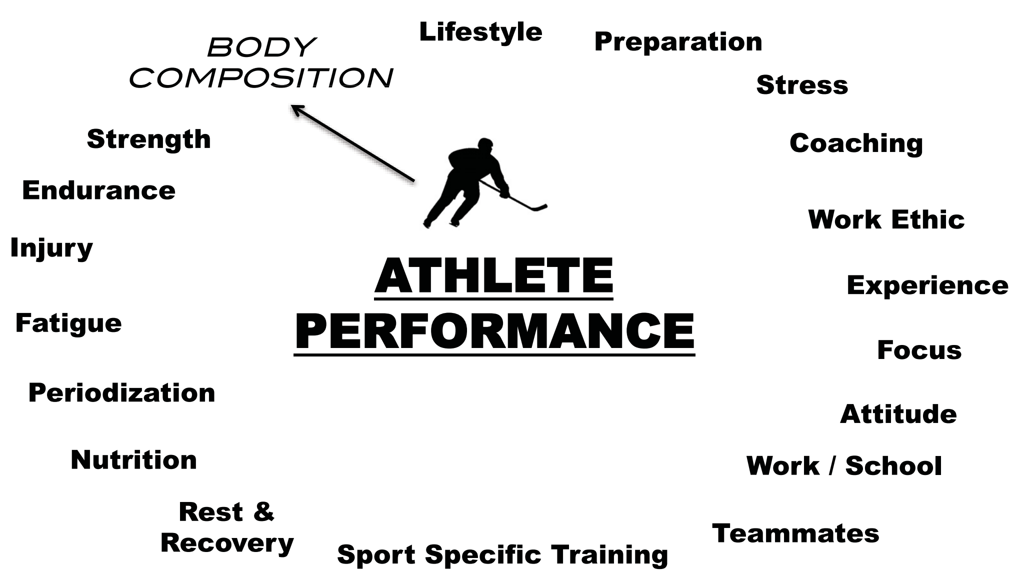


**Fig 2.1** Potential variables affecting athletic performance.

## *2.1 Body Composition for Health*

Assessments of body composition involve quantifying various compartments of the body such as fat mass, lean (muscle) mass, and often bone density, which can all be estimated using dual-energy x-ray absorptiometry (Ackland et al., 2012; Bilsborough et al., 2014; Nana et al., 2014). An individual's body composition is useful for evaluating a variety of health attributes, which can help identify the risk of diseases with increasing age (e.g. cardiovascular disease, sarcopenia, osteoporosis). Fat percentages, and fat distributions, are often body composition characteristics of interest, since they can have a direct effect on the individual's physiologic systems. For example, a high body fat percent will decrease the body's insulin sensitivity, increase fasting insulin levels and the likelihood of developing diabetes (Montague & O'Rahilly, 2000; Ohlson et al., 1985). Adipose tissue releases additional adrenocortical hormones, and can affect the breakdown and metabolism of macronutrients (i.e. lipids) (Durst, Moore, Painter, & Roberts, 2009) by the brain, liver and muscles (Hanauer, 2005). In addition, android fat distribution, centered around the abdominal and waist region, is correlated with an increase risk of coronary artery disease, hypertension, hyperlipidemia, diabetes and hormone dysfunction (Cassano, Segal, Vokonas, & Weiss, 1990; Durst et al., 2009). Researchers are no longer considering fat mass as a passive fat-storage unit, but rather as an endocrine organ, that can significantly affect other organ systems in the body (Hanauer, 2005).

From an athlete health perspective, excess adiposity may also be an under-recognized risk factor for tendinopathy (i.e. inflammation, pain, tearing, tendonitis) with mechanical and systemic mechanisms (Del Buono, Battery, Denaro, Maccauro, & Maffulli, 2011; Gaida, Ashe, Bass, & Cook, 2009). Higher body weights, upwards of what the musculoskeletal system can handle, increases the weight bearing loads on tendons. Secondly, similar tendon characteristics between upper and lower-body tendons of overweight individuals suggests that bioactive peptides released by adipose tissue, may also influence the structure of tendons in the body (Gaida et al., 2009). There has been strong associations between tendon abnormality and abdominal adiposity in male volleyball players (Malliaras, Cook, & Kent, 2007) and it's been suggested that an individual's body composition could have an impact in regards to predicting injuries among athletes (Bilsborough et al., 2014). However, a general consensus regarding the relationship between excess body fat and the risk of sustaining an injury has yet to be established.

The American College of Sports Medicine categorizes body fat percentages to help health care professionals make informed decisions regarding exercise prescription and an individual's health status (American College of Sports Medicine, 2013). These norms are presented on the next page in **Table 2.1**. Body fat percentage tends to rise with increasing age (Dugdale, A.D.A.M. Health Solutions, & Ebix Inc, 2012), and should students find themselves with unhealthy body fat percentages during their collegiate years, the risks for chronic disease and pre-mature mortality will likely become more concerning in the future. It is imperative

**Table 2.1.** ACSM Body Fat Percentiles for Males aged 20-29
*(American College of Sports Medicine, 2013)*

| % Percentile | Category | % Body Fat |
|---|---|---|
| 99 | Very Lean | 4.2 |
| 95 | | 6.4 |
| 90 | Excellent | 7.9 |
| 85 | | 9.1 |
| 80 | | 10.5 |
| 75 | Good | 11.5 |
| 70 | | 12.6 |
| 65 | | 13.8 |
| 60 | | 14.8 |
| 55 | Fair | 15.8 |
| 50 | | 16.6 |
| 45 | | 17.5 |
| 40 | | 18.6 |
| 35 | Poor | 19.7 |
| 30 | | 20.7 |
| 25 | | 22 |
| 20 | | 23.3 |
| 15 | Very Poor | 24.9 |
| 10 | | 26.6 |
| 5 | | 29.2 |
| 1 | | 33.4 |

that students develop healthy lifestyles during collegiate years, since changes in body composition can accumulate into adulthood, and have negative health implications that become more noticeable with increasing age. Males have approximately 5% of essential fat, 5-13% is desirable for good performance, 10-25% is desirable for health, and anything greater than 25% is considered as obese (Jackson, 2004). By comparison, the ACSM categorizes a body fat percentage of higher than 18.6% as poor, and a percentage greater than 23.3% as very poor.

Decreases in an individual's muscle mass, muscle strength, and bone densities are also reflective of body composition changes with increasing age. Dynapenia is a condition that indicates a loss of muscle strength, sarcopenia indicates a loss of muscle mass, and a decrease in bone density will increase the fragility of bones and risk of osteoporosis (B. C. Clark & Manini, 2008). The accumulation of body fat, combined with decreases in muscle and bone mass can affect an individual's long-term ability to maintain independence and functional capacity. It can be assumed that the average athlete, as a university student or young adult, would be expected to have a healthy body composition, however body composition assessments may help identify athletes that could later be at greater risk for health problems and complications in the future.

Participating in repetitive weight-bearing movements at a moderate to vigorous intensity places loading on an athlete's body, and can benefit the individual's short-term, and long-term health by improving body composition characteristics (i.e. enhanced bone, muscle). Ice hockey players participate in short, explosive, frequent and intense, lower-body weight-baring activities while they skate. Since weight training and athletic movements also require athletes to produce high, or repetitive, amounts of force in relatively short periods of time, they help themselves maintain, or enhance, muscle mass and strength. From a short-term health perspective, a collegiate-athlete's muscle mass and strength should also be well above the values representative of poor health, low functional capacity and immobility. However from an athletic performance perspective, an individual's body mass and body composition can affect speed, endurance, power, strength, and agility (M. Clark et al., 2010), and thus impact their ability to athletically perform optimally.

### *2.2 Body Composition for Performance*

Although the body will eventually adapt to gradual changes in body composition, it is important to consider whether these changes improve or inhibit the player's performance. A study intended to replicate adipose tissue weight gain suggested that an external load of only 2% applied to an athlete's body weight decreases anaerobic exercise performance by an average of 3-4% (Inacio, Dipietro, Visek, & Miller, 2011). Coaches, athletes, and scientists recognize the importance of lean tissue in determining sports performance, since an approximate relationship between muscle cross-sectional area and force/power generation is well known (Ackland et al., 2012). Changes in muscle size, relative to the athlete's body mass can be used alongside a variety of other fitness measures to help prepare and monitor athletes for high-level competition. In sports requiring participants to meet a particular weight class, the type of tissue gained or lost (i.e. body fat, lean muscle), the reason for the composition fluctuation (e.g. dehydration, diet, training) and the athlete's physiologic response to these changes in body composition will especially be of concern to athletes and coaches (Pineau, Filliard, & Bocquet, 2009). Since most sports' competitive seasons last multiple months, and finish with a league championship, monitoring an athlete's body composition during multiple time-points could help ensure that optimal performance attributes are maintained throughout a season. Body composition assessments can help track long-term development or training effects, but might also be used to help predict an individual's athletic potential (e.g. talent, size), or the effectiveness of an exercise or dietary intervention (Ackland et al., 2012; Nana et al., 2014).

An athlete's overall performance is determined by many variables as displayed previously in Fig 2.1, and body composition alone will not determine if an athlete becomes an elite player. However, overall body composition can be a critical component of an athlete's overall fitness, which could influence or mediate a variety of performance attributes such as speed, agility, strength, endurance, and mobility (M. Clark et al., 2010). Body fat was negatively correlated with 20 and 40 yard sprints in collegiate football players (Miller et al., 2002), and body fat was inversely related to $VO_2$ max in collegiate women soccer players during a competitive season (Miller et al., 2007). Among hockey players, body fat percentage was also inversely related to skating speeds (Potteiger et al., 2010). In competitive sport, the difference between winning and losing is typically small, and since there are many uncontrollable variables affecting an athlete's performance, or game outcome (e.g. officials, playing conditions, luck, opponents), athletes and coaches will focus on variables they have partial control over (e.g., their own training, preparation, sleep/fatigue, fitness, body composition).

### *2.3 Monitoring Seasonal Changes in Body Composition and Performance*

Several studies have tried to described off-season and in-season training, detraining, and changes in physical fitness (Koutedakis, 1995), however these characteristics could be dependent on several variables (e.g., the sport, level of athlete, training intensity/volume). Further research is needed to make stronger interpretations of seasonal changes in body composition and athletic performance. In ice hockey, an elite collegiate player's $VO_2$ max was found to decrease over the course of the competitive season (i.e. pre-season to post-season) (Durocher, Leetun, & Carter, 2008). Significant decreases in upper and lower body strength have been observed among division 3 field hockey collegiate-athlete during a regular season (Astorino, Tam, Rietschel, Johnson, & Freedman, 2004). During a NCAA division 1 four-month season, soccer players' had significant changes in total mass and lean mass, but no change in fat mass using DXA, and no change in vertical jump height or sprint speed, but saw improvements for total body and lower body power (Silvestre et al., 2006). Collegiate basketball players in the NCAA showed significant decreases in lower body strength, sprint time and vertical jump during the competitive season (Hoffman, Fry, Howard, Maresh, & Kraemer, 1991), however professional basketball players by comparison, enhanced lower body power and jump ability (Gonzalez et al., 2013). Professional volleyball players saw improvements in upper and lower body strength through additional in-season training programs (Marques, van den Tillaar, Vescovi, & González-Badillo, 2008). Elite rugby league players lost lean mass (-1.54% ; 1.19kg) and gained fat mass (4.09%; 0.57kg) during the second half of a competitive season (i.e. 3-4 months period) (Harley et al., 2011).

Among collegiate athletes, a recent three-year longitudinal study was conducted, which used dual energy x-ray absorptiometry to assess NCAA Division 1 female athletes of different sports (i.e. basketball, soccer, swim, track, volleyball). Members of the basketball team were the only female athletes that showed a significant change in overall fat mass of +9% (1.8kg, $p$ <.05) after the three-year study, which likely is functionally insignificant, but could be problematic if their gains in body fat continue to accumulate in the future. Interestingly, the volleyball players showed gains of 5% in lean mass (+1.8 kg, $p$ <.05), but no significant changes in fat mass (Stanforth et al., 2014).

Past research has clearly shown that the body composition, fitness and performance of athletes can change during an off-season and competitive in-season, however more insight is necessary to analyze individual sports, and identify the potential contributors for fluctuations in composition and performance. This current thesis focuses only on body composition fluctuations, which is an aspect of sport-specific fitness that as previously stated, could potentially impact an athlete's performance. Likely the sport, gender, level of play, training, facility and resource accessibility can influence an athlete's change in body composition, and although some research exists regarding an athlete's seasonal change in body composition, little information is available regarding the changes of collegiate hockey players. As mentioned, hockey is arguably the most demanding collegiate sport in Canada, however no published study to our knowledge has tracked or identified the body composition profiles and changes of CIS collegiate hockey players using DXA.

### *2.4 Body Composition for Ice Hockey*

Athletes of different sports (e.g. aerobic vs. anaerobic) have different body compositions (Baechle & Earle, 2008; Jeukendrup & Gleeson, 2010) because of their various sport-specific demands. Despite body composition being one of the most common fitness attributes tested among *professional* hockey teams in North America (Ebben, Carroll, & Simenz, 2004), the norms and datasets of these players have not been reported in recent literature. The most recent reported findings of National Hockey League (NHL) players date back to the 2002 and 2003 seasons in which the average body fat percentage of a NHL team was 10.35% ± 1.5% (n=92) using a 6 site-skinfold protocol (Montgomery, 2006). Another investigation, reported a body fat percentage for NHL players in 1988 using underwater weighing. This particular study reported that the mean fat percentage for players was 9.2 ± 0.9% (n=27) (Agre et al., 1988). Four common skinfold sights among NHL players taken over 26 years of data collection was reported in 2008, however since there is no valid prediction formula for body composition using four sites, fat percentage was not computed (Quinney et al., 2008). The top NHL prospects from the NHL entry draft, consisting of 17-18 year olds had a mean estimated body fat percentage of 9.5% ± 1.6 (n=92) in 2003, 10.0 ± 1.5% in 2002, and 10.2 ± 1.6 in 2001, also while using a 6-site skinfold methodology (Vescovi et al., 2006).

The most recent studies that include collegiate-hockey players are from 2010 and 2011. Both studies used the 'Bod Pod' air displacement system to assess composition, and reported body fat percentages of 11.9 ± 4.6% (Potteiger et al.,

2010) and 12.0 ± 3.6% (Peyer et al., 2011) respectively. Among Canadian Interuniversity Sport (CIS) men's hockey players, no recent study to our knowledge has reported or tracked a player or team's overall body composition. The only study ever measuring body fat percentage in CIS hockey players took place almost 40 years ago at the University of Waterloo, with players showing an average body fat percentage of 8.6% (SD not reported, n = 8) using skin fold estimates (Green et al., 1976). However, body composition was not the primary attribute studied, nor did the researchers have access to modern body composition assessing technologies. Ice hockey has evolved substantially in recent years (e.g. rule changes, equipment, improved player fitness, increased physical and psychological demands (Montgomery, 2006; Quinney et al., 2008)), and therefore continued evaluations of a hockey player's body composition could be insightful for goal-setting, and future or past player comparisons.

### *2.5 Body Composition Methodologies*

Body composition and body fat percentages in ice-hockey players have historically been estimated by skinfold measurements (Burr et al., 2008; Montgomery, 2006; Quinney et al., 2008; Vescovi et al., 2006), which is arguably the most popular technique due to their low cost. However, there are several assumptions to be cautious of when using skinfold sums and ratios (Ackland et al., 2012). A skinfold assessment assumes a constant skin to adipose fraction, constant skinfold compressibility, and consistent fat patterning. This method measures only subcutaneous fat, and it may be difficult to achieve an accurate body fat measure at specific sites. Skin fold measures need to follow standards and be collected by experienced professionals (Ackland et al., 2012) to provide reliable and consistent estimates of adiposity. Compared to other methods (i.e. DXA, Bod Pod), skinfold measurements may overestimate lean muscle mass, underestimate body fat percentage or fat mass, and not be precise enough to detect training induced changes in body composition to as high a standard (Sillanpää, Häkkinen, & Häkkinen, 2013).

The Bod Pod is a relatively portable, but more expensive piece of equipment that uses air displacement plethysmography (ADP) to estimate body fat and muscle mass percentages (Ackland et al., 2012). The athlete sits in the chamber with minimum clothing for only a few minutes allowing a fast and convenient method of evaluating body composition. The Bod Pod has previously been used to evaluate the body composition of collegiate ice hockey players in the United States (Peyer et al., 2011; Potteiger et al., 2010), however it is unable to provide the regional estimates of adiposity. Furthermore, the results from ADP can be affected by facial hair and improper use of a swimcap worn in the capsule (Higgins, Fields, Hunter, & Gower, 2001).

Dual energy x-ray absorptiometry (DXA) is considered to be one of the most accurate methods for evaluation body composition, and is becoming a more common method for measuring elite athletic populations (Buehring et al., 2014; Dengel et al., 2014; Nana et al., 2014; Stanforth et al., 2014). The DXA technique uses a three-compartment model to distinguish fat, bone mineral and lean (fat-free) mass since each type of tissue (i.e. bone, fat, lean muscle) has different characteristics (e.g. density) that will affect the attenuation of the x-ray beams. The total mass of each tissue region can be calculated to obtain the individual's full body-composition. DXA machines also have excellent precision and can be a reliable measure of body composition profiles among athletes (Stewart & Hannan, 2000). Body composition evaluations of Australian soccer players used DXA and provided the coefficient of variation intervals regarding the precision of repeated scans. Fat-free soft tissue, fat mass, and bone mass represented CV% of 0.5-0.6%, 17.2-17.9% and 2.2-.2.3% respectively (Bilsborough et al., 2014). A methodological review of studies using DXA with athletes or active populations reported that 50% of the collected studies found CV% ranging from 0.5-2.5% and 0.8-5.0% for lean mass and fat mass (Nana et al., 2014). It was also suggested that a sample of approximately 20 players is adequate to detect a 5% change in fat mass, compared to a recommended >400 players to detect changes using bioelectrical impedance analysis (Bilsborough et al., 2014).

One of the most unique characteristics of the DXA technique is it can estimate the regional body composition profile of different parts of the body using customizable or default anatomical boundaries on the participant. Athletes, in particular, can benefit from these regional analyses since various sports may have specific demands that require additional training and monitoring of distinct regions of their body. These features may also be used to gain insight and interpret potential tissue mass differences between dominant and non-dominant limbs (e.g. asymmetries). Furthermore, the DXA technique can be used to help evaluate the athlete's metabolic health measures such as their visceral, android (i.e. waist) and gynoid (i.e. hip) fat mass. A high volume of abdominal fat mass, especially visceral fat, which as opposed to subcutaneous fat, is located deep inside the abdominal between organs, and has been linked to type 2 diabetes (Montague & O'Rahilly, 2000), cardiovascular disease (Després, 2007), and inflammatory diseases (Hanauer, 2005).

Although costly, a DXA machine is time efficient and relatively easy to use, however these machines are primarily used in a medical or research settings to diagnose conditions such as osteoporosis. Compared to other types of equipment and methodologies used for body composition evaluations, DXA machines may not be as commonly accessible to an athletic population. Different DXA machine manufactures and the type of beam (pencil vs. beam) may affect the accuracy of multiple scans (Ackland et al., 2012), however these limitations are partially avoidable with consistent procedures, calibrations and settings (Nana et al., 2014).

### *2.6 Muscle Mass, Muscular Strength and Power*

Despite the demands of ice-hockey, elite players display a muscle fiber composition similar to untrained individuals and may be susceptible to strength decrements due to a lack of specifically designed strength maintenance programs (Montgomery, 1988). However today, it seems that all professional hockey teams recognize the importance of strength and conditioning and have hired specialists within their organization (Ebben et al., 2004).

Two of the most important characteristics of a hockey player are muscular strength and muscular power (Montgomery, 1988). *Muscular strength* is defined as the maximal amount of force that can be generated at a specific moment in time, whereas *muscular power* is the amount of force generated during a specific time interval (Power = force / time). Increases in strength and power are often a result of increased muscle hypertrophy, or could be a result of improved neuromuscular efficiency, defined as 'the central nervous system's ability to allow agonists, antagonists, synergists and stabilizers to work interdependently during dynamic athletic activities' (M. Clark et al., 2010). Conversely, a loss of muscle mass should theoretically be associated with a decrease in muscle strength. Since the DXA machine can evaluate regional lean tissue and body fat, it may be predictive of muscle strength, power and endurance attributes of athletes. A study involving 140 Finnish conscripts (i.e. armed service men) used DXA technology to evaluate body composition and found associations between DXA scores and fitness performance scores (Mattila et al., 2007). Lower limb muscle mass was associated with standing long jump, and body fat percentage was associated with endurance and strength measures. Off-season testing with our thesis population also showed a significant Pearson r correlation ($r = .461$, $p < .05$) with single-leg triple jump and leg lean tissue (Prokop, Reid, & Andersen, 2015). Body composition may provide some insight regarding individual fitness parameters, and in regards to the athlete's unique development, however it should not be used independently to make generalizations regarding an athlete's overall strength, power, or anaerobic capabilities.

Though many hockey specific skills (i.e. shooting, passing, checking) can be affected by several variables (i.e. vision, skill, equipment), skating speed is essentially determined by two measures, stride length and stride frequency, where increasing either component should improve the individual's relative speed. Since muscular strength and power directly influence stride attributes, the relative muscle to fat ratio, and absolute muscle mass, in the lower body, could provide insight into the player's overall skating speed.

The monitoring of athletes during a competitive season is essential to ensuring performance maintenance throughout the season. During an off-season, athletes commonly work to improve their fitness and weaknesses in their game. However once the competitive season starts, less time is spent on maintaining fitness attributes and more time is spent on sport specific practice and game preparations. A loss of strength, power and endurance over the course of a competitive season could be a result of fitness specific de-training that may be more prominent at a collegiate level since student-athletes must dedicate a sizable amount of time to their academic pursuits.

### *2.7 Brief Overview of Collegiate Hockey in North America*

There are two main leagues of collegiate-hockey in North America; the Canadian Interuniversity Sport (CIS) is the national governing body for premiere competitive sport across Canadian universities, whereas the National Collegiate Athletics Association (NCAA) is the governing body for competitive collegiate-sport in the United States. For ice hockey, the CIS is the top level for hockey players wanting to complete a post-secondary education full time in Canada.

For some players, the leagues are also a stepping-stone to future professional hockey opportunities in North America and Europe. Compared to other semi-professional, collegiate (ex. NCAA) and junior leagues (ex., Canadian Hockey League) in North America, the CIS has many disadvantages. Collegiate sports in Canada have much smaller attendance, operating budgets and revenue streams compared to collegiate sports in the USA (Geiger, 2013). Major junior, NCAA and professional teams are able to generate significantly more gate and sponsorship revenue than CIS teams that allows their players and coaches to be better compensated with tangible (e.g. scholarships, salaries) and intangible (e.g. premiere facilities) incentives. As such, CIS athletes may not have access to the same resources that other collegiate athletes have in the USA.

A collegiate-hockey team in Canada will usually be on the ice 5-6 times per week (i.e. 2 games, 3-4 practices). The pre-season begins in early September of each year, and teams commonly play between 4-6 exhibition games during this period.

The regular season begins early to mid October, with the first half concluding at the end of November to allow the athletes time to prepare for their first semester exams. The second half will begin during first week of January and continue until the middle of February. Playoffs start the next week and conclude with the national tournament approximately one month later (i.e. approximately the second or third weekend of March). Off-ice training sessions are common among CIS teams, however their frequency, and intensity can be dependent on the coaching staff and team preferences.

In CIS and NCAA hockey, the regular season consist of only 20-28 games, whereas professional and major junior leagues will play upwards of 70 games. Professional teams will regularly play 3-4 games per week, compared to only 2 games per weekend at the collegiate level. Differences in regular season games across leagues are displayed on the next page in **Figure 2.2**.

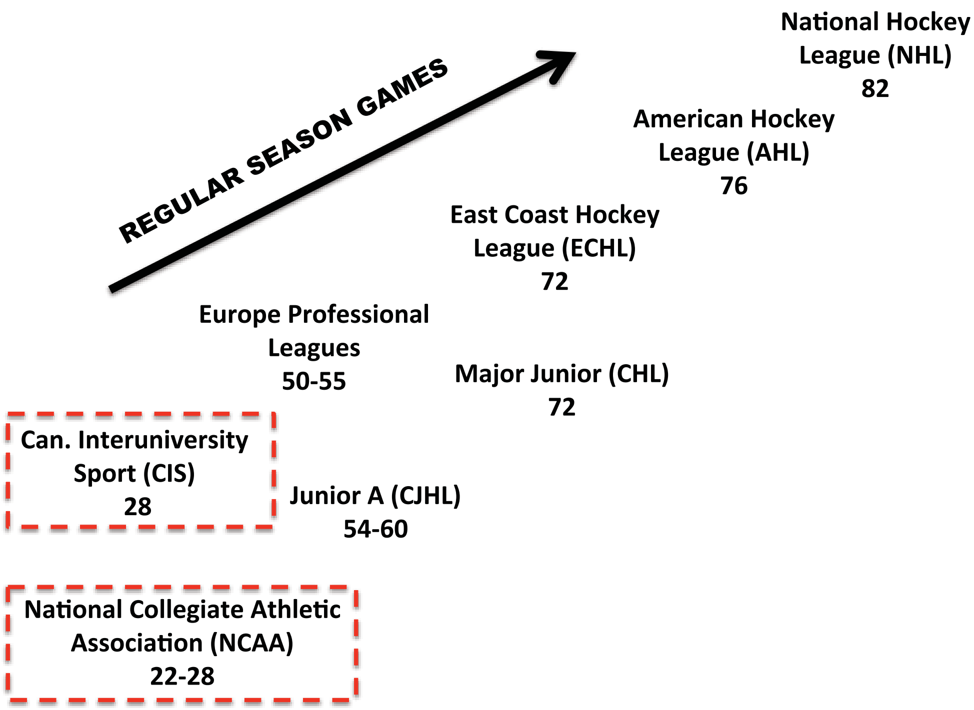


**Fig 2.2** Number of regular season games in North American hockey leagues.

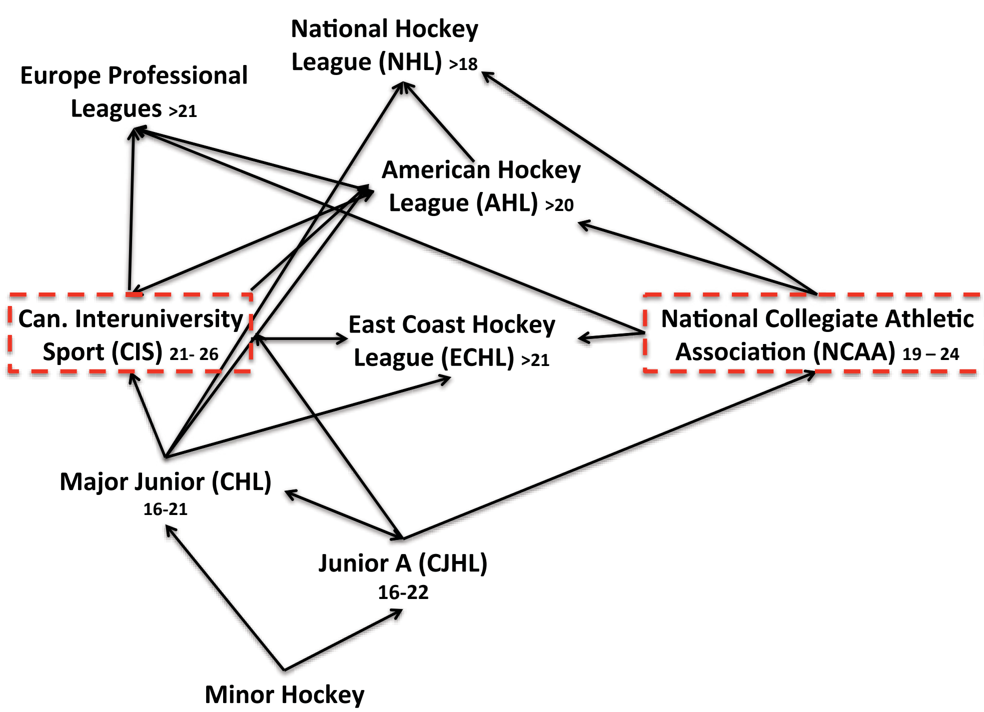


**Fig 2.3** Common development path for Canadian hockey players with age.

It is also important to understand the development pathway of university hockey players to apply the findings of this study to other athletes of interest. **Figure 2.3** illustrates the common pathways for player development in various leagues. Players in Canada must choose between the Canadian hockey league (CHL) and NCAA at a young age (i.e. 15-16 years old), since a player loses their NCAA eligibility as soon as they play one game of major junior hockey in Canada (CHL). Many players join the CIS following their major junior or junior A (CJHL) careers, whereas collegiate players in the United States join NCAA programs from high school, American junior, or Canadian junior *A* programs (CJHL) (See Fig 2.3). Although the quality of CIS hockey is excellent, and players often have semi-professional or major junior experience, the CIS is not often viewed as a development league for the 'National Hockey League', with few players going on to play professionally at the top level. Players however can play in other North American or European professional leagues. Although the CIS does differ from other elite hockey leagues, current body composition profiles of collegiate-hockey players in Canada have not been reported, yet may help improve the general health of collegiate-athletes, while providing intriguing sport-specific knowledge to other hockey players and teams of interest.

# Chapter 3 – Methods

The purpose of the study was to identify full and regional body composition measures of a collegiate men's hockey team, and to identify if their body composition profiles changed after an off-season and the first half of a competitive in-season. Secondly, we wanted to gain insight into whether players could accurately perceive how their body changed during the competitive season.

### *3.1 Participants*

In all, nineteen players [n=19] were eligible to participate in both off-season and in-season monitoring of body composition profiles. Since new recruits joined the team at the beginning of the season, we were able to obtain the perceptions of body composition fluctuations (perceptual change (PC)) among twenty-four players [n=24], and compare their perceptions to their true change (actual change (AC)) using DXA. All participants were members of the McGill Redmen men's varsity hockey team and were excluded from the off-season vs. in-season analysis if they suffered an injury that prevented them from participating in over 75% of the team's practices, training sessions or games. The team was national semi-finalists at the beginning of the study, and a top their conference at the completion of the study. Players had an average pre-season age of 23.1 ± 1.3 years, height of 181.7 ± 5.7 cm and weight of 87.1 ± 8.0 kg. Recruitment for the study was done in person, following a McGill Varsity Hockey team practice.

The McGill University Faculty of Medicine Institutional Review Board approved this investigation. The aims of the study, methodology and importance of research was explained to eligible players, and all players provided written informed consent for their participation while having the opportunity to ask for clarification, or further details privately with the investigator.

### *3.2 Timeline*

Three assessments, at three different time-points (i.e. End Season (ES), Pre-Season (PS), and Mid-Season (MS)) evaluated the players' body composition over an off-season and the first half of a competitive regular season. Players completed the body composition assessment and questionnaires during a 30-minute session, at a time convenient to the participant during the designated data-collection time period. During this particular study, the first half of the in-season took place between the pre-season and mid-season assessments, when players participated in 24 competitive games (e.g. 8 pre-season, 16 regular season) often taking place on Friday and Saturday nights. The common week schedule was as follows; Monday (60-90 minute on-ice practice | 20-40 minute weights), Tuesday (Day off, 75 minute practice, or optional ice-time), Wednesday (50-70 minute practice), Thursday (50-70 minute practice), Friday (Game), Saturday (Game), Sunday (Day Off). Some players completed additional weight sessions depending on their course workload, fatigue and the time of season.

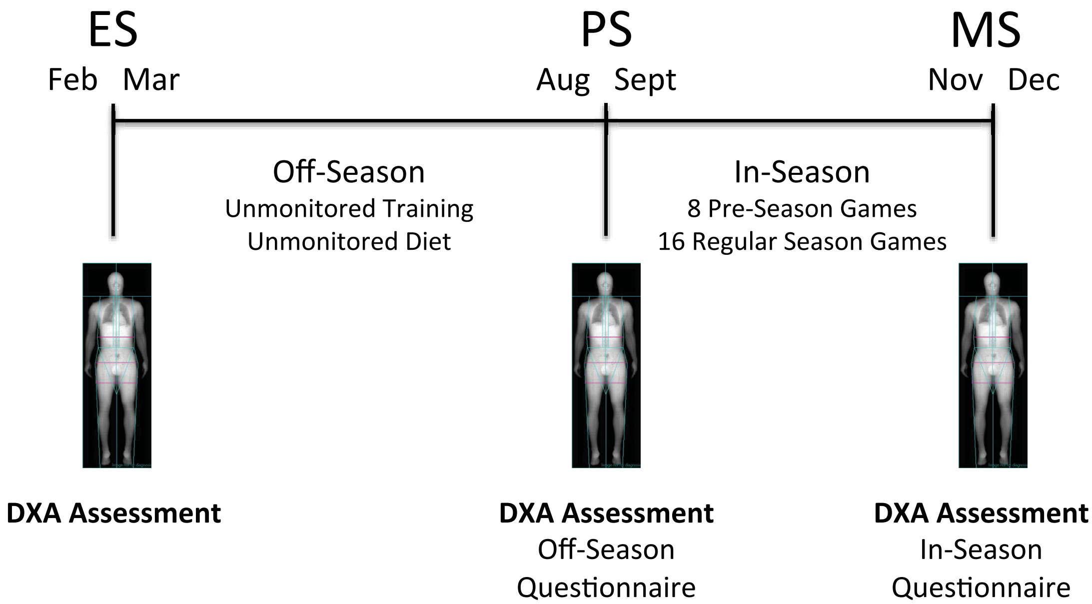


**Fig 3.1** Timeline diagram of longitudinal body composition evaluations.

### *3.3 Body Composition DXA*

Body composition was assessed using a Lunar DXA™ machine (Dual Energy X-Ray Absorptiometry, GE Healthcare™, USA) and corresponding software (Lunar enCORE™) was used to provide estimates of whole body and regional body composition (i.e. fat mass, lean (muscle) mass, fat percentage (%) and visceral fat). Dual energy x-ray absorptiometry (DXA) is considered to be a gold standard, and one of the most accurate methods for evaluating body composition measures (Bray & Bouchard, 2014). The use of DXA is quickly becoming a popular method for measuring the composition of elite athletic populations (Buehring et al., 2014; Dengel et al., 2014; Nana et al., 2014; Stanforth et al., 2014), since it offers a safe and reliable procedure. The dose of radiation from a single DXA scan is only .0042 mSv/scan, compared to the worldwide average dose from natural background radiation at 2.4mSv/year (Damilakis, Adams, Guglielmi, & Link, 2010). Scan time took approximately 5-10 minutes per person and to ensure precision of the DXA machine, calibration was checked and passed using the GE Lunar calibration phantom on a daily basis before each of the player's scanning session (Carver, Christou, & Andersen, 2013)

**Fig 3.2** DXA Table and positioning

### *3.3.1 Participant Positioning on DXA*

Participant positioning followed manufacturer's recommendations and guidelines (Center for Disease Control and Prevention, 2011). Players were asked to wear gym attire to their assessment, if not, shorts and t-shirts were provided. Participants were not allowed to wear metal (i.e. rings, watches, necklaces), and all objects were removed from their pockets. They were instructed to sit on the side of the DXA bed before swinging their legs over to align themselves with the scanning bed's longitudinal midline. Once the participants were centered, they were asked to slowly lower their upper body to maintain positioning and keep their spine aligned with the midline. Players laid in the supine position, with their arms along their side, palms pronated to lie flat (Bilsborough et al., 2014; Center for Disease Control and Prevention, 2011) or slightly rotated to face thigh to ensure the limb was fully in the scan area. A slight gap was maintained between their arms and legs to ensure there was no crossover when it came time to analyzing different regions of the body. The subject's feet were pointed inwards slightly, secured by a Velcro strap.

### *3.3.2 Participant Evaluation*

The statistics obtained from each individual player's scan included fat percentage, total tissue mass (i.e. fat tissue + lean (fat-free/muscle)), fat tissue mass (FM) and lean (fat-free/muscle) tissue mass, and visceral fat mass. A further breakdown looked at these tissue statistics as full (whole) body, and in the arm, leg, android and gynoid regions. The statistic for each region was computed by taking the average mass of the right and left sides of the player's body, however on the rare occasion that part of the player's limb (i.e. arm or leg) moved and exceeded the boundary lines, the DXA program multiplied the opposite limb's value by two when calculating their body composition for that region. The default boundaries (Lunar enCORE™) can be observed in **Figure 3.3**. The arm and midsection (trunk) boundary cross through the glenohumeral joint, whereas the boundary of the leg crosses through the head of the femur and extends to the top of the pelvic girdle.

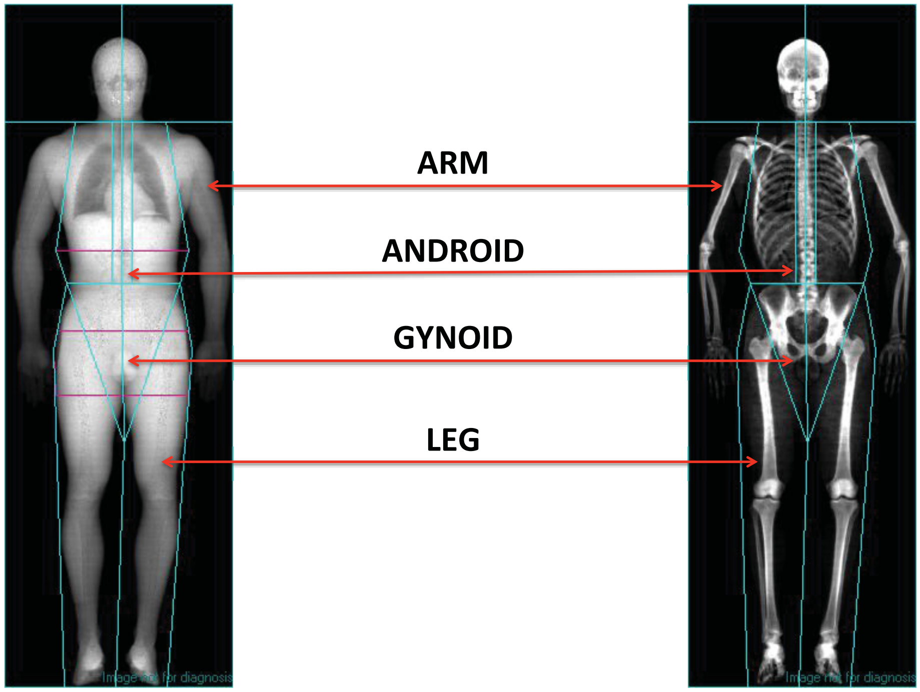


**Fig 3.3** Regional boundary lines of DXA composition scans

### *3.4 Player Evaluation and Questionnaires*

Off-season and in-season training perceptions, including perceived demands and lifestyle attributes, and the accuracy of each player's perceptions regarding their body composition change was evaluated by questionnaire, which can be viewed in the appendices of this thesis. The objective of the questionnaires were to 1) determine if players have accurate perceptions regarding their physiologic change [i.e. overall and regional body composition] during the first half of a competitive season, and 2) gain a brief insight into the off-season and in-season lifestyles of collegiate-hockey players. The off-season and in-season training questionnaire included re-call questions about the player's access to training facilities, training program, and their volume/frequency of off-ice and on-ice training sessions. The questionnaires were intended to help identify potential variables that may influence the body composition of collegiate-athletes.

The player's perceived changes in body composition were measured on a 7-point scale. The participants indicated if they perceive that tissue volume had; 1 = Decreased Considerably (+6.5%) = the equivalent to <13 on a 200 lbs person, 2 = Decreased Noticeably (+4 to 6.5%) = Between -8-13 lbs on a 200 lbs person, 3 = Decreased Slightly (+1.5 to 4%) = Between -3-8 lbs on a 200 lbs person, 4 = Stayed the Same (+/- 1.5%) = Between 0-3 lbs on a 200 lbs person, 5 = Increased Slightly (+1.5 to 4%) = Between +3-8 lbs on a 200 lbs person, 6 = Increased Noticeably (+4 to 6.5%) = Between +8-13 lbs on a 200 lbs person, 7 = Increased Considerably (+6.5 %) = >13 on a 200 lbs person. Players used this scale to indicate their perceived changes in 1) total body fat mass, 2) total body lean muscle mass, 3) lower body [legs] fat mass, 4) upper-body [arms] fat mass, 5) lower-body [legs] lean muscle mass, 6) upper-body [arms] lean muscle mass.

### *3.5 Analysis*

Data was collected and interpreted through company software (Dual Energy X-Ray Absorptiometry, Lunar enCORE™, GE Healthcare™, USA) and then analyzed using the statistical software SPSS (IBM Corporation). Repeated measures ANOVAS for each region and tissue variable were used to compare the player's composition attributes over the three different time-points (e.g., ES vs. PS, PS vs. MS). The player's relative change was calculated using the difference between two time-points (e.g. time-point 1 vs. time-point 2), as a percentage of their time-point 1 values.  Example as follows;

$$Relative\ Off\ Season\ Change\ (\%) = \frac{Pre\ Season\ Tissue\ Mass - End\ of\ Season\ Tissue\ Mass}{End\ of\ Season\ Tissue\ Mass} \times 100$$

Pearson-r correlations were used to explore the relationships among the questionnaires, regional body composition profiles, the fluctuations in body composition and the perceptions of composition changes in different areas of the body.

# Chapter 4 – Seasonal Changes in Whole Body and Regional Body Composition Profiles of Collegiate Ice-Hockey Players

Prokop, NW., Reid, RER., Andersen, RE.
*McGill University, Health and Fitness Promotion Laboratory, Montreal, Quebec, Canada.*

## *Abstract*

**Background:** The monitoring of a collegiate hockey player's body composition can reflect fitness characteristics, and may help players, coaches or strength & conditioning specialists optimize physiologic gains during an off-season, while simultaneously preventing performance decrements in-season. The purpose of the study was to investigate changes in whole-body and regional-body composition of fat and lean tissue.

**Methods:** The body composition profiles of nineteen elite Canadian collegiate hockey players were assessed using dual energy x-ray absorptiometry. Players completed end of season, pre-season and mid-season assessments with questionnaires relating to their off-season and in-season training.

**Results:** Statistically significant changes in body composition profiles were observed between the different time-points as players showed various tissue gains and losses depending on the region assessed. Overall, players gained (1.38kg, $p \leq .01$) and lost (.79kg, $p \leq .01$) of fat tissue during the off-season and in-season, respectively. Players also showed a significant gain of leg lean tissue (.29 kg, $p = .02$) and loss of arm tissue mass (-.25 kg, $p = .02$) during the first-half of the competitive season. Several correlations emerged that may provide insight into potential trends that could be more pronounced during longer and more demanding schedules.

**Conclusion:** Collegiate hockey players show changes in body composition during the off-season and in-season. The understanding of body composition profiles, body composition fluctuations, and potential variables that may influence the composition of collegiate hockey players, can help coaches and athletic programs tailor their team's training, nutrition, lifestyle and informative resources to further support their athletes.

### *Introduction*

Over 450,000 collegiate-athletes participate in the United States' National Collegiate Athletic Association (NCAA) or Canada's Interuniversity Sport (CIS) leagues. Long practice days, substantial travel, demanding schedules, and game preparations all influence a collegiate-athlete's sleep, nutrition, training, and activity levels outside of their sport of choice, and can have an impact on their overall body composition (Bailey et al., 2014; Kraemer et al., 1999; Reynolds et al., 2012; Volek et al., 2002). Although body composition can be reflective of many factors unrelated to elite sport, many recognize that this trait alone, can be influential on the performance of elite athletes in competition (Ackland et al., 2012). Information regarding the composition profiles of hockey players, especially collegiate-players in Canada is lacking, and the understanding of body composition profiles help coaches, trainers, and strength & conditioning specialists improve the development programs of their athletes since longitudinal tracking of fluctuations within an athlete's body composition can be reflective of fitness characteristics (Mattila et al., 2007; Miller et al., 2007; Miller et al., 2002). Maintaining an ideal body composition throughout the year can help ensure performance decrements in their sport do not occur, but can also benefit the health, and overall well-being of an athlete population.

Dual energy x-ray absorptiometry (DXA) technology has been used to evaluate body composition in active men, and strong associations between DXA scores and fitness performance scores have been reported (Mattila et al., 2007).

Lower limb muscle mass was related to standing long jump, and body fat percentage was associated with measures of endurance and strength. Although some fat mass may be advantageous for additional inertia during on-ice collisions, muscle mass is required to stabilize joints, and helps propel the player or puck across the ice (Burr et al., 2008). Coaches, athletes, and scientists have recognized the importance of lean tissue in determining sports performance, since an approximate relationship between muscle cross-sectional area and force/power generation is well known (Ackland et al., 2012). Changes in muscle and lean tissue, relative to the athlete's body mass, can be used alongside a variety of other fitness measures to help assess and monitor athletes for high-level competition.

The purpose of this investigation was to examine fluctuations in body composition measures among collegiate-athletes during the off-season, and the first half of a competitive regular season. It was hypothesized that players would gain lean tissue during the off-season since a greater emphasis would be placed on strength and conditioning during off-season training, and that players would gain fat mass during the regular season since a greater emphasis is placed on technical sport-specific training (i.e. on ice practices) and academic obligations. Increased lower body, and upper body muscle mass and strength should be advantageous for hockey specific skills, such as skating speed or puck protection, and thus a second objective of the study was to evaluate the regional changes in body composition. The use of DXA allows for precise and accurate whole-body, and regional (i.e. arms, legs, android, gynoid,) body composition measures (Ackland et al., 2012; Bilsborough et al., 2014; Bray & Bouchard, 2014; Nana et al., 2014) which we believed would be reflective of various sport specific demands, and provide further insight into the current composition profiles of elite hockey players across multiple time-points.

Currently little information is available on how the body composition attributes of collegiate-athletes change during the off-season and competitive season once athletic and academic obligations begin to accumulate. Furthermore to our knowledge, there is no current study that has evaluated the body composition profiles of elite Canadian collegiate hockey players using DXA across multiple time-points. The information would provide insight that may help improve the general performance of collegiate-athletes, while providing important sport-specific knowledge to hockey players and sport teams at the collegiate level. The understanding of body composition profiles, body composition fluctuations, and potential variables that may influence the composition of student-athletes, can help coaches and athletic programs optimize their team's training, nutrition, lifestyle and informative resources to further support their athletes.

***Methods***

Body composition assessments took place at 3 different time-points (i.e. End of Regular Season (ES) (i.e. February | March), Pre-Season (PS) (i.e. August | September), and Mid-Season (MS) (i.e. November | December)). The off-season occurred between the ES and PS, and players partook in unmonitored training to help elicit the natural off-season training regimens and lifestyles of collegiate hockey players in Canada. The assessments were completed mid-afternoon before the team's on-ice practices, as this was often the best time that accommodated the player's athletic and academic schedules. The timing allowed for the players to avoid food consumption in the previous two-three hours before the scan, and provided approximately a full day recovery from the previous on-ice practice. Questionnaires were used to gain insight into the player's off-season and in-season training habits (e.g. frequency of resistance training and conditioning (i.e. cardio) sessions, the average number of ice times), access to fitness facilities, future goals, previous hockey experience, summer employment, and where they obtained their training program (e.g. strength coaches, independently designed). The first half of the in-season took place between the PS and MS assessments, when players participated in 24 competitive games (e.g. 8 pre-season, 16 regular season) often taking place on Friday and Saturday nights. The common week schedule was as follows; Monday (60-90 minute on-ice practice | 20-40 minute weights), Tuesday (Day off, 75 minute practice, or optional ice-time), Wednesday (50-70 minute practice), Thursday (50-70 minute practice), Friday (Game), Saturday (Game), Sunday (Day Off). Some players completed additional weight sessions depending on their course workload, fatigue and the upcoming schedule.

***Participants***

All eligible returning players (n=19) from the McGill Varsity Hockey team participated in the 10-month study. The McGill Faculty of Medicine Institution

Review Board approved the protocol, and written consent from players was obtained for their participation in the project. Players were excluded from our analyses if they suffered an injury that prevented them from participating in over 75% of the team's practices, training sessions or games. Twenty players originally completed baseline ES assessments, however one player was excluded from our analysis after suffering an off-season concussion that necessitated a long recovery. The players were members of a national semi-finalist team at the end of the previous season, and a top their conference at the completion of the study. Players had an average pre-season age of 23.1 ± 1.3 years, height of 181.7 ± 5.7 cm and weight of 87.1 ± 8.0 kg.

***Procedures | Statistical Analysis***

A Dual Energy X-ray Absorptiometry (DXA) machine (General Electric Encore™ 11.20) and corresponding software was used to provide estimates of whole body and regional body composition (i.e. fat mass (kg), lean mass (kg) and fat percentage (%)). Subject positioning followed common recommendations and positioning guidelines from the center of disease control and prevention (Center for Disease Control and Prevention, 2011) and the software's default boundaries were used to divide the body into arms, legs, trunk, android, gynoid and full body regions. A repeated measures ANOVA was used to evaluate body composition changes across the three time-points. Pearson correlations were used to explore relationships between variables of interest and changes in body composition.

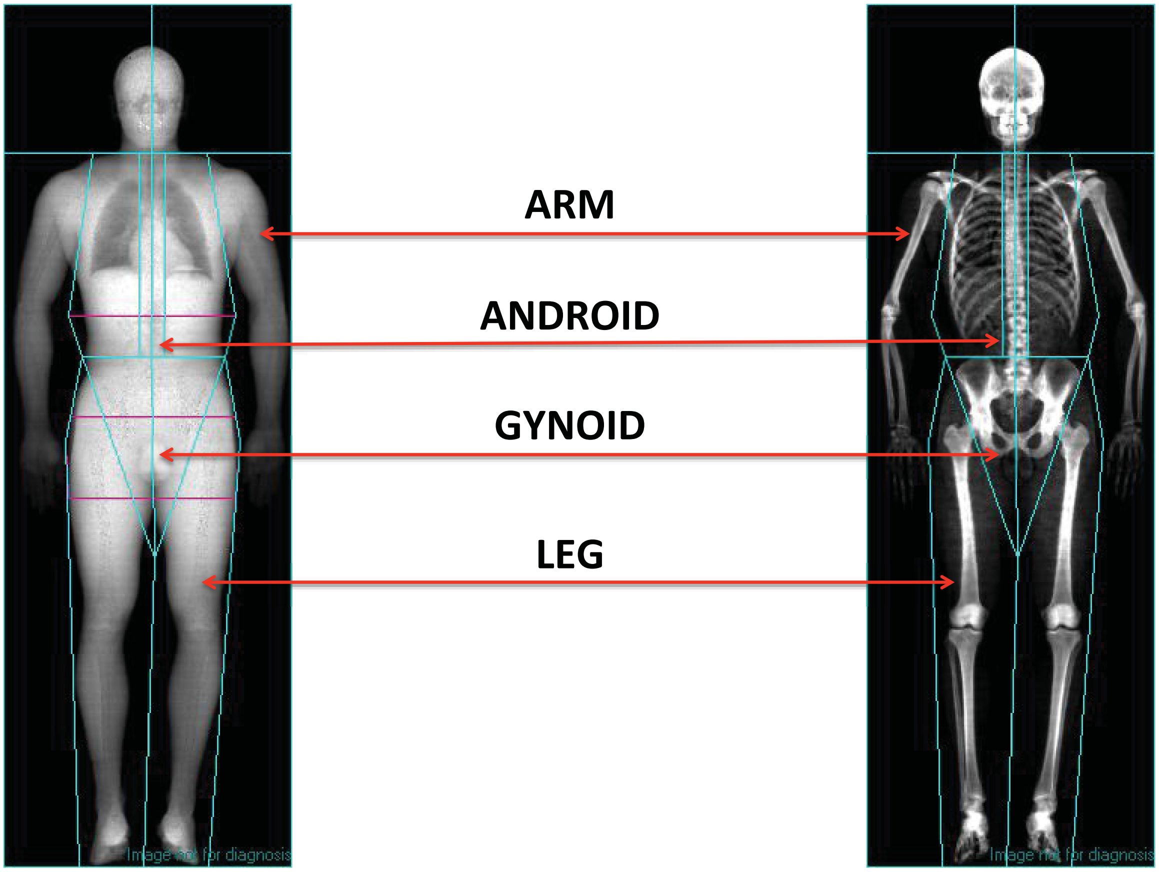


**Figure 4.1** Regional boundary lines of DXA composition scans

## *Results*

The sample's general characteristics of interest are presented in **Table 4.1**, and are important to consider when applying these findings to other athletes and hockey teams of interest. Of the 19 players in the study, 78.9% had experience at the highest level of major junior hockey in Canada (i.e. OHL, QMJHL, WHL) indicating an elite sample size with a strong hockey background. All players had access to a gym or fitness facility, however there were obvious differences in their frequency of resistance training (3.6 ± 1.3 vs. 1.8 ± .59, $p \leq .01$) and cardio sessions (2.7 ± 1.4 vs. 4.5 ± 1.0, $p \leq .01$) between the off-season and in-season, respectively.

Eleven players (57.9%) chose to follow an off-season training program designed by a strength coach or fitness professional, and 6-of-19 players have professional hockey ambitions (i.e. AHL, ECHL, Europe) after obtaining their collegiate degree, compared to 13-of-19 players who plan to begin working full time and only participate in recreational or competitive hockey on the side. The majority of players felt they slept better, ate healthier, lifted weights more frequently and had a greater amount of free time during the off-season, despite the average player working 11.4 ± 4.6 weeks for 35 ± 15.2 hours per week.

**Table 4.1** Characteristics and Tendencies of Players

| | | X | | SD |
|---|---|---|---|---|
| **Off-Season** (May - Aug) **Statistics of Interest** | Weight Sessions Per Week (Days/week) | 3.6 | ± | 1.3 |
| | Cardio Sessions of 20min+ (Days/week) | 2.7 | ± | 1.4 |
| | Average Ice Times per week (Days/week) | 2 | ± | 0.8 |
| | Summer Job (weeks per summer) | 11.4 | ± | 4.6 |
| | Summer Job (hours per week) | 35.0 | ± | 15.2 |
| | | **N (yes)** | | **% (of 19 players)** |
| | Access to a Gym/Fitness Facility | 19 | | 100% |
| | Program Designed by Strength Coach | 11 | | 57.9% |
| | | **X** | | **SD** |
| **Pre -Season** (Aug I Sept) **Statistics of Interest** | Age | 23.1 | ± | 1.3 |
| | Height (cm) | 181.7 | ± | 5.7 |
| | Weight (kg) | 87.1 | ± | 8.0 |
| | | **N (yes)** | | **% (of 19 players)** |
| | Major Junior Experience (OHL,WHL,QMJHL | 15 | | 78.9% |
| | | **X** | | **SD** |
| **In-Season** (Sept - Dec) **Statistics of Interest** | Weight Sessions Per Week (Days/week) | 1.8 | ± | .59 |
| | Cardio Sessions of 20min+ (Days/week) | 4.5 | ± | 1.0 |
| | | **N (yes)** | | **% (of 19 players)** |
| | Pro Hockey Ambitions after University | 6 | | 31.6% |
| | | **Off-Season** | **In-Season** | **No Difference** |
| **Off Season Vs In-Season** | I have better sleep during the … | 11 (57.9%) | 3 (15.8%) | 5 (26.3%) |
| | I eat healthier during the . . . | 10 (52.6%) | 7 (36.8%) | 2 (10.5%) |
| | I have more down/free time during the … | 16 (84.2%) | 3 (15.8%) | 0 (0%) |
| | I lift weights more during the … | 15 (78.9%) | 4 (21.1%) | 1 (5.3%) |
| | I participate in cardio more during the … | 5 (26.3%) | 13 (68.4%) | 1 (5.3%) |

***Body Composition Profiles***

The DEXA machine was able to detect statistically significant changes between the team's off-season and in-season body composition profiles. The total body and segmental body composition profiles of players at each time-point are presented in **Table 4.2**. Regional changes in body composition with significance values are presented in **Table 4.3.** The average player's fat mass increased 11.5% ± 17.0 during the off-season, but decreased 4.5% ± 11.1 during the first half of their season (FHOS). During the off-season, the average player's lean mass decreased 0.2% ± 2.8 and increased 0.3% ± 2.0 during the FHOS. During the off-season, the player's average fat tissue in their arm region increased by 15.7% ± 19.8 but decreased 7.5% ± 9.4 during the FHOS. In the leg region, the player's average fat mass increased by 9.2% ± 13.8 during the off-season, and decreased 4.0% ± 9.2 during the FHOS.

**Table 4.2** Changes in Whole Body and Regional Body Composition Values

| | Body Region \| Tissue | End of Season (Feb\|Mar) | Pre-Season (Aug\|Sept) | Mid-Season (Nov\|Dec) |
|---|---|---|---|---|
| | | X ± SD | X ± SD | X ± SD |
| **Arm Region** | Tissue Fat Percentage (%) | 13.0 ± 3.3 | 14.4 ± 4.1 ** | 13.5 ± 3.7 ^^ |
| | Total Tissue (kg) | 10.8 ± 1.1 | 11.2 ± 1.4 ** | 11.0 ± 1.3 ^ |
| | Fat Tissue (kg) | 1.4 ± 0.4 | 1.6 ± 0.6 ** | 1.5 ± 0.5 ^^ |
| | Lean Tissue (kg) | 9.4 ± 1.0 | 9.6 ± 1.2 | 9.5 ± 1.1 |
| **Leg Region** | Tissue Fat Percentage (%) | 16.3 ± 4.4 | 17.5 ± 4.5 ** | 16.7 ± 4.1 ^ |
| | Total Tissue (kg) | 28.5 ± 3.0 | 28.6 ± 3.1 | 28.6 ± 2.9 |
| | Fat Tissue (kg) | 4.7 ± 1.6 | 5.1 ± 1.7 * | 4.8 ± 1.5 |
| | Lean Tissue (kg) | 23.8 ± 2.2 | 23.5 ± 2.0 | 23.8 ± 2.0 ^ |
| **Trunk Region** | Tissue Fat Percentage (%) | 15.8 ± 5.0 | 17.3 ± 5.2 * | 16.5 ± 4.9 |
| | Total Tissue (kg) | 38.3 ± 3.4 | 38.9 ± 3.9 * | 38.5 ± 3.4 |
| | Fat Tissue (kg) | 6.1 ± 2.2 | 6.8 ± 2.6 * | 6.4 ± 2.4 |
| | Lean Tissue (kg) | 32.2 ± 2.8 | 32.1 ± 2.7 | 32.1 ± 2.6 |
| **Android Region** | Tissue Fat Percentage (%) | 15.1 ± 6.0 | 16.9 ± 6.2 * | 16.1 ± 6.0 |
| | Total Tissue (kg) | 5.4 ± 0.6 | 5.5 ± 0.6 | 5.5 ± 0.5 |
| | Fat Tissue (kg) | 0.8 ± 0.4 | 1.0 ± 0.5 * | 0.9 ± 0.4 |
| | Lean Tissue (kg) | 4.6 ± 0.4 | 4.5 ± 0.4 | 4.6 ± 0.3 |
| **Gynoid Region** | Tissue Fat Percentage (%) | 16.0 ± 5.2 | 17.5 ± 5.3 ** | 16.4 ± 4.5 ^ |
| | Total Tissue (kg) | 13.4 ± 1.3 | 13.4 ± 1.3 | 13.4 ± 1.2 |
| | Fat Tissue (kg) | 2.2 ± 0.8 | 2.4 ± 0.9 * | 2.2 ± 0.7 ^ |
| | Lean Tissue (kg) | 11.2 ± 1.0 | 11.1 ± 0.9 | 11.2 ± 1.0 |
| **Full Body Region** | Tissue Fat Percentage (%) | 15.9 ± 4.1 | 17.2 ± 4.3 ** | 16.4 ± 4.0 |
| | Total Tissue (kg) | 82.2 ± 6.9 | 83.4 ± 7.8 | 82.8 ± 7.1 |
| | Fat Tissue (kg) | 13.1 ± 3.9 | 14.5 ± 4.6 ** | 13.7 ± 4.1 ^ |
| | Lean Tissue (kg) | 69.0 ± 5.7 | 68.9 ± 5.6 | 69.1 ± 5.4 |
| **Visceral Adipose Tissue** | Volume ($cm^3$) | 402.5 ± 149.7 | 445.3 ± 203.7 | 469.4 ± 175.1 |
| | Mass (g) | 379.8 ± 141.0 | 420.1 ± 192.1 | 442.8 ± 165.3 |

** $p \leq .01$, * $p < .05$ Significantly different from End of Season
^^ $p \leq .01$, ^ $p < .05$ Significantly different from Pre-Season

**Table 4.3** Mean Off-Season vs. In-Season Changes in Body Composition Values

| Body Region | Type of Tissue | End of Season to Pre Season (Off-Season) | | Pre-Season to Mid Season (In-Season) | |
|---|---|---|---|---|---|
| | | X ± SD | p-value | X ± SD | p-value |
| **Arm Region** | Total Tissue | .42 ± 0.53 | ≤ .01** | - .25 ± 0.42 | .02* |
| | Fat Tissue | .22 ± 0.27 | ≤ .01** | - .13 ± 0.14 | ≤ .01** |
| | Lean Tissue | .19 ± 0.48 | .09 | - .11 ± 0.38 | .20 |
| **Leg Region** | Total Tissue | .13 ± 1.02 | .56 | .05 ± 0.65 | .75 |
| | Fat Tissue | .40 ± 0.64 | .01* | - .25 ± 0.54 | .06 |
| | Lean Tissue | -.26 ± 0.74 | .14 | .29 ± 0.51 | .02* |
| **Trunk Region** | Total Tissue | .68 ± 1.30 | .04* | - .45 ± 0.95 | .06 |
| | Fat Tissue | .76 ± 1.18 | .01* | - .41 ± 0.99 | .09 |
| | Lean Tissue | - .09 ± 1.09 | .72 | - .04 ± 0.81 | .83 |
| **Android Region** | Total Tissue | .10 ± 0.27 | .13 | - .05 ± 0.21 | .35 |
| | Fat Tissue | .12 ± 0.20 | .03* | - .05 ± 0.17 | .20 |
| | Lean Tissue | - .02 ± 0.21 | .65 | .00 ± 0.13 | .81 |
| **Gynoid Region** | Total Tissue | .04 ± 0.45 | .08 | - .08 ± 0.39 | .04 |
| | Fat Tissue | .22 ± 0.35 | .01* | - .18 ± 0.34 | .03* |
| | Lean Tissue | - .17 ± 0.37 | .05 | .10 ± 0.31 | .18 |
| **Full Body Region** | Total Tissue | 1.22 ± 1.64 | .27 | - .62 ± 1.64 | .27 |
| | Fat Tissue | 1.38 ± 1.54 | ≤ .01** | - .79 ± 1.54 | ≤ .01** |
| | Lean Tissue | - .16 ± 0.03 | .59 | .17 ± 0.03 | .58 |
| **Visceral Adipose Tissue** | Volume ($cm^3$) | 42.8 ± 122.8 | .15 | 24.0 ± 105.1 | .31 |
| | Mass (g) | 40.3 ± 115.8 | .31 | 22.7 ± 99.2 | .31 |

All tissue changes are presented in kg

Players who were on the ice more often through the off-season gained less fat (*r* = .582, p = .02) and gained greater lean tissue (*r* = .473, p = .04). As expected, the number of resistance training sessions the player participated in during the off-season seemed directly related to changes in lean body mass (*r* = .606, p ≤ .01). In addition, a greater frequency of resistance training sessions during the off-season was also correlated with higher fat gain (r = .497, p = .03) and muscle loss (*r* = -.529, p = .02) during the FHOS suggesting that players with the greatest off-season adaptations may not necessary be able to maintain them once the competitive season and academic semester begins. A greater self-reported perceived fatigue level (i.e. a score from 1-10) in November was also related to a higher fat gain over the FHOS (*r* = .612, p ≤ .01), which stresses the importance that athletes and coaches manage their fatigue levels as athletic and academic priorities begin to conflict over the course of a semester. To better interpret potential associations between overall changes in fat and lean tissue during the different seasons, Pearson-r correlations are presented in **Table 4.4** as a correlation matrix. The table also provides insight into which type of tissue (i.e. fat, lean) is responsible for the changes in overall tissue mass.

**Table 4.4** Correlations between Fat and Lean Tissue Mass between Off- and 1st Half

| | | Off Season | | | 1st Half | | |
|---|---|---|---|---|---|---|---|
| | | Full Body Tissue | Full Body Fat Tissue | Full Body Lean Tissue | Full Body Tissue | Full Body Fat Tissue | Full Body Lean Tissue |
| Off Season | Full Body Tissue | - | | | | | |
| | Full Body Fat Tissue | .703** | - | | | | |
| | Full Body Lean Tissue | .638** | -.098 | - | | | |
| 1st Half | Full Body Tissue | -.632** | -.636** | -.195 | - | | |
| | Full Body Fat Tissue | -.314 | -.737** | .359 | .669** | - | |
| | Full Body Lean Tissue | -.422 | .077 | -.673** | .465* | -.347 | - |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

## *Discussion*

This study addressed several gaps in the literature, including 1) the use of DXA among collegiate hockey players, 2) the assessing of body composition attributes among Canadian collegiate hockey players, and 3) the understanding of common off-season and in-season body composition fluctuations among hockey players.

### *Body Composition for Ice Hockey*

This was the first study, to our knowledge, that tracked the whole, and regional body composition profiles of elite Canadian collegiate hockey players at different time points throughout an off-season and the first half of a competitive regular season. The players in our study had an overall fat percentage of 15.9% and 16.4% at the end of the regular season and first half of season respectively. Recent studies that include the body composition profiles of collegiate-hockey players are from the 2010 and 2011 NCAA seasons. Both studies used the 'Bod Pod' air displacement system to assess composition, and reported body fat percentages of 11.9% ± 4.6 (Potteiger et al., 2010) and 12.0% ± 3.6 (Peyer et al., 2011) respectively, however the BOD POD has reported lower estimates of body fat composition compared to DXA in male collegiate athletes (Collins et al., 1999). The only study found reporting the body fat percentage of CIS players took place almost forty years ago at the University of Waterloo. Players showed an average fat percentage of 8.6% (SD not reported, n = 8) using skin fold estimates (Green et al., 1976). However, body composition was not the primary attribute studied.

Body composition and percent body fat in elite ice-hockey players have historically been estimated by skinfold measurements (Burr et al., 2008; Montgomery, 2006; Quinney et al., 2008; Vescovi et al., 2006), which is arguably the most popular technique due to their low cost. However skin folds measure only subcutaneous fat, and it may be difficult to achieve correct measurements at specific sites since the skin folds need to follow reliable standards, and be collected by experienced professionals (Ackland et al., 2012) to provide accurate and consistent insight. The most recent reported findings of body composition profiles among National Hockey League (NHL) players date back to 2002 and 2003 seasons in which the average body fat percentage of a NHL team was estimated to be 10.35% ± 1.5% (n=92) using a 6 site-skinfold protocol (Montgomery, 2006). The top NHL prospects from the NHL entry draft, consisting of 17-18 year olds had a mean body fat percentage of 9.5% ± 1.6 (n=92) in 2003, 10.0 ± 1.5% in 2002, and 10.2 ± 1.6 in 2001, also using a 6-site skinfold prediction equation (Vescovi et al., 2006). Although the ideal body composition varies between individuals, an understanding of the norms at different levels of hockey would help coaches and players set objectives, and allow for player-to-player comparisons across time.

***Monitoring Seasonal Changes in Body Composition and Performance***

Secondly, we monitored the body composition profiles of collegiate hockey players at three time-points (i.e. end of season, pre-season, mid-season) and showed interesting trends that were statistically significant, and likely of interest to coaches and strength & conditioning specialists in the field. To our knowledge, this is also the first study that has involved repeated regional body composition assessments of elite hockey players following the off-season and partial in-season.

Players in our study gained approximately 1.38kg ± 1.64 ($p \leq .01$) of fat tissue during the off-season, however lost -.79 kg ± 1.54, ($p \leq .01$) of their fat tissue during the first half of their season (FHOS). Although the monitoring of body composition and performance attributes in collegiate hockey players has not been reported in the literature, several other studies can help put our findings into context. For example, professional soccer players also had higher preseason fat percentages compared to the end of their previous season, but had no significant changes in lean or fat-free mass (Ostojic, 2003). Twenty-five NCAA male soccer players underwent DXA assessments and performance tests to evaluate body composition and physical fitness changes during the season (Silvestre et al., 2006). It was found that for the entire team, body mass significantly increased 1.5kg ± 0.4 during the season; predominantly resulting from significant increases in total lean tissue (0.9 kg ± 0.2), with total fat mass being unchanged. Similarly to our study, the players also showed statistically significant gains in leg lean tissue during the season. Finally, in rugby players, increases in maximal aerobic power and muscular power, and reductions in skinfold thickness were observed during the early phases of the season when training loads were highest. Like rugby, hockey often has higher training loads at the start of the season partially to focus on sport-specific tactics before the season and intensity of competition progresses. In ice hockey, an elite collegiate player's $VO_2$ max was found to decrease over the course of the competitive season (i.e. pre-season to post-season) (Durocher et al., 2008), just like muscular power and maximal aerobic power declined among the amateur rugby players. Interestingly, skinfold thickness was increasing alongside the rugby players' performance decrements (Harley et al., 2011). The authors concluded that high playing intensities and match loads in end-of-season matches could contribute to increases in injury rates and residual fatigue, which can compromise the physical development of rugby league players. While no study has looked at hockey players in-depth, the similarities (i.e. physical contact, intense games) between rugby and hockey may provide insight into the composition fluctuations of these types of athletes. In our sample of ice hockey players, we saw trends suggesting that on average, collegiate players gained fat tissue during the off-season, while losing or maintaining muscle mass. However during the competitive season, it appeared players lost fat tissue, and gained or maintained muscle tissue. When looking at the player's composition by region during the competitive first half of their season, players lost upper body mass (i.e. fat and lean tissue) in the arm region. In the leg region, players lost fat mass while gaining lean tissue. Although the study showed statistically significant trends, some players showed even greater individual gains and losses that were larger than the team's means.

When examining our participants' average change in full body tissue during the off-season, a 1.2 kg gain was observed. A potential explanation for fat gain and lean tissue loss during the off-season are the demanding work and intern schedules that a collegiate athlete may face. Players worked or interned for considerable time during the off-season, potentially justified by a large number of players assuming they would be working full time after their university degree, rather than trying to make the jump to play professional hockey. Since summer employment seemed to be a significant part of a player's off-season, the type of job that athletes have during these months could be of interest of coaches and trainers in multiple sports. A sedentary job may have implications for the health and performance of athletes (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008; Owen, Healy, Matthews, & Dunstan, 2010) since it's been suggested that sedentary behavior in elite athletes is significantly correlated to higher trunk and total adiposity among eleven different sports (Júdice, Silva, Magalhães, Matias, & Sardinha, 2014), regardless of the athlete's vigorous or moderate physical activity levels.

***Future Directions***

Body composition can be an important component of an athlete's fitness, which could influence a variety of performance attributes such as speed, agility, strength, endurance, and mobility (M. Clark et al., 2010). For example, body fat was negatively correlated with 20 and 40 yard sprints in collegiate football players (Miller et al., 2002), and an increase in body fat coincided with a decrease of relative $VO_2$ max in collegiate women soccer players during a competitive season (Miller et al., 2007). Among hockey players, greater body fat percentage was moderately correlated with slower skating speeds (Potteiger et al., 2010). Several studies have described off-season and in-season training, detraining, and changes in physical fitness among athletes (Astorino et al., 2004; Gonzalez et al., 2013; Harley et al., 2011; Koutedakis, 1995; Stanforth et al., 2014), although none provide an in-depth analysis into whole body and regional body composition of elite ice-hockey players. Within this study design, we did not obtain physiologic and performance measures simultaneously with the changes in body composition, and future studies can determine if changes in body composition have associations with sport-specific fitness attributes related to ice hockey. It is important to consider that a particular body composition may be desired depending on the player's style of play or position (e.g. quick, agile scorer vs. big, powerful defenseman) but despite body composition being one of the most common fitness attributes tested among professional hockey teams in North America (Ebben et al., 2004), the detailed norms and data sets of these players are scarce in the current literature.

When interpreting the results of this study, it is important to consider that the study length and regular season of collegiate players is substantially shorter and less demanding than professional (i.e. NHL, AHL, ECHL) and junior hockey leagues (i.e. OHL, QMJHL, WHL, USHL) (24-28 vs. 64-82 games). Future research can further investigate if the trends observed in our study are predictive of more pronounced differences in body composition fluctuations during a longer, and more demanding schedule. These trends will likely depend on the athlete, sport, and sport specific demands (e.g. more frequent games, longer seasons).

### *Strengths and Limitations*

The study is strengthened by the use of dual energy x-ray absorptiometry, multiple time-points and the full-cooperation of a nationally ranked top-10 collegiate hockey team. Although only one team was used, almost 80% of the roster had major junior hockey experience signifying a strong hockey background, with previous fitness, nutrition and training knowledge. Our findings are still limited, and should not be generalized to all collegiate hockey-teams or levels of hockey, however they can provide insight into the body composition profiles and sport-specific fluctuations that may occur. Although several questionnaires were intended to gain insight into potential variables that could lead to body composition fluctuations, the player's training, nutrition and lifestyle went unmonitored. These behaviors were unmonitored intentionally to best reflect the collegiate athletes' current behaviors and training habits. Furthermore, we understand that a decrement in optimal body composition does not fully indicate a change in performance. An aspect of strength, for example, indicates the body's neural-muscular ability to recruit muscles, which would not be reflected in a body composition analysis. As such, body composition assessments alone should not be used to make assumptions regarding fitness attributes of an athlete.

### *Practical Applications*

Body composition assessments can help monitor a team's overall fitness that coaches can use to tailor their athlete development and training programs. The individual analysis of players may also be beneficial by providing insight to help optimize sport-performance improvements. Collegiate-hockey players could be at a greater risk for gaining fat mass, and losing lean tissue in their legs during the off-season, which suggests an increased emphasis on balancing cardiovascular exercise with lower body resistance training during this time period. Off-season dietary counseling may also be helpful to assist athletes in optimizing off-season body composition improvements. Furthermore, players may be at risk for losing upper body mass and strength during the competitive season suggesting a need for a greater emphasis on upper-body resistance training. In competitive sport, the difference between winning and losing can be small, and since there are many uncontrollable variables affecting a team's performance or game outcome, athletes and coaches should focus on the individual variables that they have partial control over (e.g., training, preparation, sleep/fatigue, fitness, body composition). While the findings provides preliminary insight into the seasonal changes of collegiate hockey players, there are several different variables that can influence an athlete's body composition and caution should be used when applying the findings to other collegiate sports and levels of hockey.

### ***Chapter Comment***

The text of Chapter 4 (Study 1) compared the change in body composition of collegiate hockey players across the three various time-points.  This chapter is supplemented by Chapter 5 (Study 2), which compares the players' perceived change in body composition (i.e. as measured by questionnaire), with their true change in composition (i.e. as measured by DXA).

# Chapter 5 – Do Collegiate Hockey Players Accurately Perceive Body Composition Changes after Unmonitored Training and Diet

Prokop, NW., Duncan, LR., Andersen, RE.
*McGill University, Health and Fitness Promotion Laboratory, Montreal, Quebec, Canada.*

## *Abstract*

**Background:** Collegiate athletes often use nutritional programs and supplements to elicit body composition changes in muscle or fat. It is unknown if athletes can accurately perceive their fluctuations in body composition, yet their understanding may help them make more accurate interpretations regarding the success of potential nutrition or exercise regimens. The purpose of this study was to investigate if collegiate hockey players could accurately perceive fluctuations in their body composition during a competitive 3-month period within their regular season, in which no pre-determined nutritional or exercise program was provided.

**Methods:** Twenty-four male elite Canadian collegiate hockey players completed pre-season and mid-season body composition assessments using dual energy x-ray absorptiometry. Immediately before each scan, players answered questionnaires regarding their perceived fluctuations in the composition and strength of particular body regions.

**Results:** Two thirds of players and one-half of players accurately detected changes in arm-lean and arm-fat tissue respectively. Approximately two-thirds of players do not accurately perceive gains or losses of lean or fat tissue within their leg and overall body region. Although some collegiate athletes can partially detect changes in lean and fat tissue in particular regions, the vast majority of players cannot detect the type, or amount of tissue gained and lost across the overall body.

**Conclusion:** Body composition assessments, rather than an athlete's perceptions, should be used to help interpret the success of a sport nutrition or exercise program. Dietitians and trainers should ensure athletes are aware that physiologic adaptations in lean and fat tissue might take place unnoticed, which could affect the acceptance and adherence of a dietary intervention.

### *Introduction*

Body composition can influence the performance of elite athletes in competition (Ackland et al., 2012) and although several physiologic mechanisms allow for body composition to be modified by training, nutrition, and lifestyle; individualized diets, nutrition and exercise programs are popular interventions that can help elicit a desirable change in the athlete's composition. Maintaining an ideal body composition throughout the year can help prevent performance decrements in their respected sport, while benefiting the health and overall well-being of an athlete.

Although it can be debated whether the use of some supplements is worthwhile, necessary, or cost-efficient to the athlete, the use of ergogenic aids and nutrition or fitness supplements among collegiate athletes is common, and as high as 88% (Burns, Schiller, Merrick, & Wolf, 2004; Smith-Rockwell, Nickols-Richardson, & Thye, 2001). An athlete' perception of their change in body composition may influence their use of supplements and other ergogenic aids, as well as their acceptance and adherence to nutritional programs and interventions. Furthermore, for collegiate athletes who do not work with dietitians or strength and conditioning coaches, it may be necessary for the athlete to monitor their own body composition and make adjustments to their training and nutrition programs to achieve a desired composition (i.e. weight gain, weight loss, muscle, fat) for their respective sport.

In ice-hockey, although there are several variables that could determine if an athlete attains an elite status, body composition is among the variables that is commonly used as a predictor of future performance (Ebben et al., 2004). Greater body fat percentage is moderately correlated with slower skating speeds (Potteiger et al., 2010) and although fat mass may be advantageous for additional inertia during on-ice collisions, it is lean muscle mass that helps stabilizes joints, and helps propel the player or puck across the ice (Burr et al., 2008). Thus, accurately estimating body fat percentage may have important implications with respect to an athlete's performance, as the individual's mass and body composition can affect their speed, endurance, power, strength, and agility (M. Clark et al., 2010).

Dual energy x-ray absorptiometry (DXA) is often used to accurately assess body composition and has the unique ability to categorize an individual's fat-tissue mass, lean-tissue mass, and bone density within a particular region. DXA can be used, in part, to assess the physiologic adaptations in whole-body and regional fat or lean tissue (Ackland et al., 2012; Stewart & Hannan, 2000). Although a DXA scan can be used to help estimate the true change in body composition of particular regions, DXA machines are not always available to athletes since they are used primarily in a healthcare setting. Since the demands, lifestyle and periodization of an athlete's training demands can often change depending on the time of year (i.e. off-season vs. in-season), athletes will often have to gauge variation, and adjust their training and nutritional regimens accordingly. Currently, little is known about whether collegiate-athletes can accurately perceive a change in body composition across the various phases of a competitive season. Therefore, the purpose of this study was to compare if a subset of elite, collegiate hockey-players could detect the correct change in their body composition during a three-month period as they transition out of their off-season, and into their competitive season playing form. We hypothesized that the majority of players would be unable to accurately perceive whether they gained or lost fat and lean tissue during this time period.

## *Methods*

### *Subjects*

Twenty-four male elite Canadian collegiate hockey players took part in the study (mean age: 22.8 ± 1.4 years). Written consent from players was obtained for their participation in the project, and the McGill University Faculty of Medicine Institution Review Board approved the study. Players reported to the lab two times: once at the start of the fall semester [pre-season] and again at the end of the fall semester [mid-season]). During these assessments, players completed a whole body DXA scan and a questionnaire. The players were not monitored or required to follow any set nutritional and/or training program during the duration of the study; however all studied participants took part in over 75% percent of the team's on-ice and off-ice practices.

### *Body Composition Assessment*

Whole body and regional body composition measures (i.e. fat mass (kg), lean mass (kg)) were obtained using dual energy x-ray absorptiometry (General Electric

Encore™ 11.20) and corresponding software. Players were in an anatomical supine position with the forearms pronated so that the palms were on the table (Bilsborough et al., 2014; Center for Disease Control and Prevention, 2011). The default settings of the DXA machine's corresponding software (i.e. Lunar enCORE™) was used to distinguish the composition profiles of the arms, legs and total body.

### *Questionnaires*

Each player's perceived changes in body composition and strength were queried on a 7-point scale. The participants were asked to indicate if they perceive that they had: 1 = Decreased Considerably (+6.5%) = the equivalent to <13 on a 200 lbs person, 2 = Decreased Noticeably (+4 to 6.5%) = Between -8-13 lbs on a 200 lbs person, 3 = Decreased Slightly (+1.5 to 4%) = Between -3-8 lbs on a 200 lbs person, 4 = Stayed the Same (+/- 1.5%) = Between 0-3 lbs on a 200 lbs person, 5 = Increased Slightly (+1.5 to 4%) = Between +3-8 lbs on a 200 lbs person, 6 = Increased Noticeably (+4 to 6.5%) = Between +8-13 lbs on a 200 lbs person, 7 = Increased Considerably (+6.5 %) = >13 on a 200 lbs person. Players used this scale to indicate their perceived change in 1) total body fat mass, 2) total body lean muscle mass, lower body [legs] fat mass, 4) upper-body [arms] fat mass, 5) lower-body [legs] lean muscle mass, 6) upper-body [arms] lean muscle mass. Players were also asked to rank their overall fatigue level on a scale of 1 (not fatigue) to 10 (extremely fatigued) for each of the three months (i.e. September, October, November). Anthropometric measures (i.e. age, height, and weight) were also obtained at pre-season.

### *Statistical Analysis*

The player's relative change was calculated using the difference between their start of semester (i.e. pre-season) and end of semester (i.e. mid-season) body composition assessments, as a percentage of their pre-season values.

$$Relative\ Change\ (\%) = \frac{Mid\ Season\ Tissue\ Mass - Pre\ Season\ Tissue\ Mass}{Pre\ Season\ Tissue\ Mass} \times 100$$

Pearson-r correlations were used to explore the relationship between fluctuations in composition within a particular region of the body and the perceptions of composition changes in different areas of the body.

## *Results*

### *Persistent vs. Actual Change*

Each athlete's perceived change, as indicated by their questionnaire, was compared to their actual change, as measured by DXA. The frequency of perceived versus actual gains and losses for the six body regions are presented in **Table 5.1,** along with the number of accurately perceived responses. Overall, the majority of the players perceived decreases in lean muscle tissue, and increases in fat tissue during the first half of their regular (FHOS). The player's actual change was best reflected by their perceptions in the arm region, with players being able to accurately identify a gain, loss, or no change approximately 58% of the time (50% arm fat, 66.7% arm lean).

## Table 5.1 Perceived vs. Actual Change (Gain, Loss, Stay the Same)

| | Tissue | 1st Half Change | Perceived Change | Actual Change | # of Players with Accurate Perception | Percentage Correct | Accuracy Percentage for Region |
|---|---|---|---|---|---|---|---|
| Arm [Upper Body] | Arm Fat | | | | | | |
| | | Gained | 12 | 5 | 4 of 12 players | 33.3% | 50.0% |
| | | Stayed the Same | 5 | 4 | 1 of 5 players | 20.0% | |
| | | Lost | 7 | 15 | 7 of 7 players | 100.0% | |
| | Arm Lean | | | | | | |
| | | Gained | 5 | 10 | 5 of 5 players | 100.0% | 66.7% |
| | | Stayed the Same | 5 | 1 | 0 of 1 player | 0.0% | |
| | | Lost | 14 | 13 | 11 of 14 players | 78.6% | |
| Leg [Lower Body] | Leg Fat | | | | | | |
| | | Gained | 6 | 11 | 4 of 6 players | 66.7% | 41.7% |
| | | Stayed the Same | 9 | 1 | 0 of 9 players | 0.0% | |
| | | Lost | 9 | 12 | 6 of 9 players | 66.7% | |
| | Leg Lean | | | | | | |
| | | Gained | 3 | 10 | 1 of 3 players | 33.3% | 33.3% |
| | | Stayed the Same | 11 | 11 | 5 of 11 players | 45.5% | |
| | | Lost | 10 | 3 | 2 of 10 players | 20.0% | |
| Total [Full Body] | Total Fat | | | | | | |
| | | Gained | 12 | 10 | 7 of 12 players | 58.3% | 37.5% |
| | | Stayed the Same | 8 | 3 | 0 of 8 players | 0.0% | |
| | | Lost | 4 | 11 | 2 of 4 players | 50.0% | |
| | Total Lean | | | | | | |
| | | Gained | 3 | 6 | 2 of 3 players | 66.7% | 33.3% |
| | | Stayed the Same | 5 | 14 | 3 of 5 players | 60.0% | |
| | | Lost | 16 | 4 | 3 of 16 players | 18.8% | |

Displayed as '# of players' [n=24]
Gained = > 1.5% of PSM, Stayed the Same = +/- 1.5% of PSM, Lost < 1.5% of PSM
Abbreviatons: PSM = Pre-Season Mass

As hypothesized, the players had difficulty identifying the amount of fat and lean tissue, gained and lost. The player's perceived vs. actual changes, as categorized by their relative change (i.e. the difference in tissue from pre-season to mid-season; and expressed as a percentage of their pre-season value) are presented in **Table 5.2**. No player had an accurate perception of the amount of total whole-body fat mass gained or lost during the first semester (i.e. no player accurately identified their correct fluctuation category, which were categorized by tissue mass changes of 2.5% (i.e. the equivalent to 5lbs on a 200lb person)). Only one quarter of players perceived the accurate amount of total whole-body lean tissue change. Players best perceived composition changes in the arm region, with 20.8% and 37.5% of players identifying the correct amount of fat and lean tissue respectively.

## Table 5.2 Perceived vs. Actual Change (Relative Change Categories)

| Region of Interest | Tissue | **Gain or Lost** **Category** | Decreased<br>Considerably -6.5% | <br>Noticably -4.0 to -6.5% | <br>Slightly -1.5 to -4.0% | **Stayed The Same** | Increased<br>Slightly 1.5 to 4.0% | <br>Notticiably 4.0 to 6.5% | <br>Considerably 6.5% |
|---|---|---|---|---|---|---|---|---|---|
| **Arm [Upper Body]** | **Fat** | **Perceived** | 0 | 1 | 6 | 5 | **10** | 2 | 0 |
| | | **Actual** | **10** | 4 | 1 | 4 | 1 | 1 | 3 |
| | | Perceived Accurate Category | 0 of 0 players | 1 of 1 players | 1 of 6 players | 2 of 5 players | 1 of 10 players | 0 of 2 players | 0 of 0 players |
| | **Lean** | **Perceived** | 0 | 1 | **14** | 5 | 4 | 0 | 0 |
| | | **Actual** | 1 | 3 | **11** | 1 | 6 | 2 | 0 |
| | | Perceived Accurate Category | 0 of 0 players | 0 of 1 players | 7 of 14 players | 0 of 5 players | 2 of 4 players | 0 of 0 players | 0 of 0 players |
| **Leg [Lower Body]** | **Fat** | **Perceived** | 0 | 0 | **9** | **9** | 6 | 0 | 0 |
| | | **Actual** | **9** | 3 | 1 | 5 | 6 | 0 | 0 |
| | | Perceived Accurate Category | 0 of 0 players | 0 of 0 players | 0 of 9 players | 0 of 9 players | 1 of 6 players | 0 of 0 players | 0 of 0 players |
| | **Lean** | **Perceived** | 0 | 1 | 9 | **11** | 2 | 1 | 0 |
| | | **Actual** | 0 | 0 | 3 | **11** | 7 | 3 | 0 |
| | | Perceived Accurate Category | 0 of 0 players | 0 of 1 players | 2 of 9 players | 5 of 11 players | 0 of 2 players | 0 of 1 players | 0 of 0 players |
| **Total [Full Body]** | **Fat** | **Perceived** | 0 | 0 | 4 | 8 | **11** | 1 | 0 |
| | | **Actual** | **9** | 2 | 3 | 3 | 7 | 0 | 0 |
| | | Perceived Accurate Category | 0 of 0 players | 0 of 0 player | 0 of 4 players | 0 of 8 players | 0 of 11 players | 0 of 1 players | 0 of 0 players |
| | **Lean** | **Perceived** | 0 | 2 | **14** | 5 | 3 | 0 | 0 |
| | | **Actual** | 0 | 0 | 4 | **14** | 5 | 1 | 0 |
| | | Perceived Accurate Change | 0 of 0 players | 0 of 2 players | 2 of 14 players | 3 of 5 players | 1 of 11 players | 0 of 0 players | 0 of 0 players |

displayed as '# of players' [n=24]
**<bold>** indicates mode (i.e. most frequent range selected)

Multiple statistically significant correlations and trends emerged from the data. Players who perceived greater gains in lean tissue during the first semester started the season with a lower amount of lean tissue overall (*r* =.462, *p* = .023), in the arm (*r* = .442, *p* = .030), and trunk (*r* = 508, *p* = .01) regions. As expected, players who perceived an increase in lean tissue, also perceived increases in lower-body (*r* = .602, *p* ≤ .002) and upper-body (*r* - .561, *p* ≤ .004) strength. Those who perceived a greater amount of fatigue at the mid-point of the first semester (i.e. October) as assessed on a scale of 1-10, perceived a greater gain of fat tissue during the semester (*r* = .424, p = 039). Because the player's perceptions were assessed on a scale ranging from 1 to 7, Pearson-r correlations were also used to evaluate the accuracy of the player's perceptions, and to see potential trends with other regions of the body. Values of interest are presented in **Table 5.3**.

**Table 5.3 Perceived vs. Actual Correlations by Region of Interest**

| Perceived | | Actual | | *r* | *p* |
|---|---|---|---|---|---|
| Increase | Arm lean tissue | Increase | Arm lean tissue | 0.449 | 0.03 |
| Increase | Arm lean tissue | Increase | Relative Arm lean tissue | 0.473 | 0.02 |
| Increase | Arm lean tissue | Increase | Total Body lean tissue | 0.477 | 0.02 |
| Increase | Leg fat tissue | Increase | Trunk fat tissue | 0.451 | 0.03 |
| Increase | Leg fat tissue | Increase | Relative Total Body fat tissue | 0.427 | 0.04 |
| Increase | Leg lean tissue | Decrease | Trunk fat tissue | 0.422 | 0.04 |
| Increase | Leg lean tissue | Increase | Trunk lean tissue | 0.427 | 0.04 |
| Increase | Leg lean tissue | Increase | Relative Trunk lean | 0.433 | 0.04 |
| Increase | Total Body fat tissue | Increase | Leg fat tissue | 0.431 | 0.04 |
| Increase | Total Body lean tissue | Increase | Trunk lean tissue | 0.434 | 0.03 |
| Increase | Total Body lean tissue | Increase | Relative Total Body lean tissue | 0.419 | 0.04 |

### *Discussion*

The results of our study suggest that although some collegiate athletes can partially detect changes in lean and fat tissue in particular regions, the majority of players cannot accurately detect the type, or amount of tissue gained and lost across the overall body. Players were particularly inaccurate in identifying changes in fat tissue, which partially supports previous observations that university students may have difficulty precisely estimating their amount of whole-body fat tissue (Tanaka, Itoh, & Hattori, 2002). Comparative studies between perceived and actual body composition fluctuations are scarce, especially in athletes, despite their potential to have meaningful implications for this unique population. Athletes have a more positive body image compared to non-athletes (Hausenblas & Downs, 2001); however, they also are at a greater risk for disordered eating patterns (Sundgot-Borgen & Torstveit, 2004), and often use supplements or ergogenic aids (Burns et al., 2004; Smith-Rockwell et al., 2001). In some cases, such as collegiate wrestlers, eating attitudes have been shown not to change despite a significant weight gain during the season (Enns, Drewnowski, & Grinker, 1987). When we attempted to categorize the groups into an accurate (i.e. answered $\geq$ 3 regions correct) or an inaccurate group, no significant differences were present between the groups that could identify whether a player would have more accurate perceptions.

Body composition and body mass can partially be controlled through diet, nutrition and exercise, and influence a variety of athletic attributes such as speed, agility, strength and endurance (Ackland et al., 2012; M. Clark et al., 2010; Miller et al., 2007; Miller et al., 2002). As previously mentioned, in ice hockey specifically, excess body fat suggests decreases in skating speeds (Potteiger et al., 2010). It would be beneficial for players, and athletes to monitor their body composition during short-term (e.g. a competitive game, practice, tournament week) and long term (e.g. an off-season, regular season) time periods. In the short term, encouraging players to measure body mass and composition changes might help elicit hydration and post-game recovery, as it was shown that elite junior players in Canada lost over 1% of their bodyweight during an on-ice practice (Palmer & Spriet, 2008). Dehydration and decreases in body mass can have devastating consequences on the ability to sustain optimal athletic performance, especially at a high-intensity (Jeukendrup & Gleeson, 2010). In the long term, it can also be beneficial for an athlete to self-monitor their body composition during parts of a competitive season, which as demonstrated in this study, may be difficult to achieve since the majority of collegiate hockey players did not accurately perceive changes in their body composition during the three-month period. Past studies involving athletic populations have shown fluctuations in body composition during the in-season and off-season (Harley et al., 2011; Ostojic, 2003; Silvestre et al., 2006), as well as varying changes in performance tasks in which body composition may have an effect on (Astorino et al., 2004; Durocher, Guisfredi, Leetun, & Carter, 2010; Gonzalez et al., 2013; Hoffman et al., 1991).

Most athletes do not have adequate knowledge in the sport nutrition field (Torres-McGehee et al., 2012) and need to turn to dietitians, or sport professionals to obtain nutritional, dietary and exercise information for their respective sport. It would be beneficial to develop, and share strategies that educate athletes (e.g. hockey players) to help them make informed decisions when monitoring their body composition. Implementing multiple fitness testing and body composition evaluations during the year, or ensuring that players have access to a weigh scale before and after competitions are simple tactics that might help provide more accurate feedback to the athlete.

Professionals should ensure athletes are aware that physiologic adaptations and changes in body composition, lean and fat tissue can take place without the athlete's observation, or contradict what the athlete perceives. Body composition assessments, rather than an athlete's perceptions, should be used to help interpret the success of a sport nutrition or exercise program, and professionals should consider the athlete's perceptions of body composition fluctuations given that they might influence the athlete's acceptance and adherence to a dietary intervention.

# Chapter 6 – Conclusion

## *6.1 Summary*

This project was designed to examine several unique attributes of collegiate hockey players that had not been previously studied or reported in the literature. Although DXA is gaining popularity as a precise tool for estimating an athlete's overall body composition, the use of this technique among collegiate hockey players has not been previously done. The first study estimated the whole and regional-body composition profiles of collegiate hockey players using DXA at various time-points during the off-season and in-season. Players had an overall body fat percentage of 15.9% ± 4.1, 17.2% ± 4.3, 16.4% ± 4.0 at the end of season, pre-season and mid-season, respectively. These values provide further insight into the dynamic body composition profiles of collegiate hockey players at various time-points during the year.

Secondly, this study is also one of the first to observe regional composition changes in an athlete's body composition during an off-season and in-season, and is especially unique because of its' inclusion of Canadian collegiate hockey players. The DXA has excellent precision and reliability when assessing body composition, and we have reported significant changes in fat tissue and lean tissue between the two time periods (i.e. off-season vs. in-season) and the regions evaluated (i.e. arms vs. legs). It was observed that players gained fat mass in their arm and leg regions during the off-season, but lost fat mass in these regions during the in-season.

Participants also showed a significant gain of lean mass in the leg region during the first-half of their season. The regional changes in fluctuations may be a result of the sport-specific demands of hockey, as well as the season-specific training, diet and lifestyle behaviors of collegiate players.

Thirdly, within the second study of this thesis was a unique assessment that compared the actual composition fluctuations of collegiate players, with their perceived change in composition. The findings suggested that collegiate athletes could partially detect changes in lean and fat tissue in particular regions, however the majority of players cannot detect the type, or amount of tissue gained and lost across the overall body. The majority of players perceived a slight increase in fat during the in-season, when in fact most players lost a considerable amount (9 of 19 players lost $\geq$ 6.5% of their pre-season fat value). The opposite held true for muscle, in which most of the players perceived a slight decrease in muscle, but then stayed the same or gained tissue during the first half of the season. These findings suggest that on-going body composition assessments may be important for both strength and conditioning coaches and the athletes themselves since an athlete's perceptions of their training progress may not accurately reflect actual changes in adiposity, lean mass and body composition over a given period of time

### *6.2 Future Directions*

Body composition profiles are an aspect of sport-specific fitness that coaches and athletes will continually try to manipulate to help elicit the optimal physical attributes for sport-specific performance. As previously discussed, body composition attributes have been associated with fitness attributes in a variety of sports (e.g., football, soccer), and future research can attempt to identify exactly how different measures of whole-body and regional body composition can affect the various hockey-specific skills and characteristics of players in a variety of domains (i.e., skating, shooting, agility, speed, biomechanics, fatigue, risk of injury). Limited studies compare different methodologies when estimating body composition in athletes (i.e. DXA vs. BOD POD vs. Skin Fold), and future research could also compare the body composition profiles of hockey players using these different approaches.

Secondly, although statistically significant changes in body composition were observed in this study, future research is needed to evaluate if these trends are present at other levels of hockey. It would be worthwhile to investigate the potential trends highlighted in this study to determine if these findings may be more pronounced during longer and more demanding schedules, or if the fluctuations in body composition are unique to the collegiate level. The understanding of body composition profiles, body composition fluctuations, and potential variables that may influence the composition of collegiate hockey players can help coaches and athletic programs tailor their team's training, nutrition, lifestyle and informative resources to further support their athletes.

### *6.3 Practical Applications*

Although body composition can be reflective of many factors such as training, nutrition and overall lifestyle, it is recognized that an athlete's body composition alone can be influential on their sport performance in competition. This study provided insight regarding the dynamic body composition profiles of elite collegiate hockey players, and the potential changes in composition that can commonly take place during an off-season and competitive in-season. Coaches, trainers and the players themselves, may consider these findings and make adjustments to their team or athlete's training, nutrition, lifestyle and informative resources in an attempt to further optimize their performance.

Collegiate-hockey players could be at a greater risk for gaining fat mass, and losing lean tissue in their legs during the off-season, which suggests an increased emphasis on balancing cardiovascular exercise with an increased emphasis on lower body resistance exercise during this time period. Off-season dietary counseling and the periodization of training around a collegiate-athletes potential summer employment or intern schedules, may be beneficial in helping athletes optimize off-season body composition improvements. During the season, players may be at risk for losing upper-body mass and strength during the competitive season, suggesting a greater emphasis on upper-body resistance training.

Dietitians should ensure athletes are aware that physiologic adaptations in lean and fat tissue might still take place without the athlete's observation, or contradict what the athlete perceives. Body composition assessments, rather than an athlete's perceptions should be used to only partially interpret the success of a sport nutrition or exercise program, however professionals should still consider the athlete's perceptions of their body composition change, since it might influence the athlete's acceptance and adherence to a dietary or training intervention.

It should not be assumed that all collegiate-athletes can maintain peak performance during an academic workload, and are healthy because of their participation in elite sport. Long practice days, substantial travel, demanding schedules, and game preparations can all influence a collegiate-athlete's sleep, nutrition, training volume, and activity levels outside of their sport of choice, and have an impact on their overall body composition. Maintaining an ideal body composition throughout the year can help enhance off-season development and ensure in-season performance decrements in their sport do not occur. The understanding of body composition profiles, body composition fluctuations, and the player's perception of body composition changes can help coaches, dietitians, collegiate-athletes and athletic programs optimize their team's training, nutrition, lifestyle and informative resources. Together, we can provide support to help optimize a collegiate-athlete's performance, health and well-being, as they continue to pursue their academic and athletic ambitions.

# Appendices A – Off-season and In-Season Training Questions

***The player provided the following information to the investigators;***

## Off-Season Training Questions

**All questions related to the off-season time period (April/May – August);**

**OST -** Did you have regular access or membership to a fitness facility (encompassing cardio and resistance training equipment?
□ No □ Yes

**OST -** Did you have a set training program?
□ No □ Yes

**OST -** Where was your training program obtained? ___________________
□ 'I created my program/ did everything on my own'

**OST -** During the **off-season**, on average, how many times weekly did you complete a weight lifting workout/**lift weights?** (Consisting of 3-4 exercises, 3-6 sets)

1 2 3 4 5 6 7

**OST -** During the **off-season**, on average, how many times weekly did you complete a **cardio** session? (Consisting of 20+ minutes of moderate to vigorous Intensity)

1 2 3 4 5 6 7

**OST -** During the off-season, did you perceive a gain or loss of strength?

**Lower Body Strength [LEGS]**
□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Upper Body Strength [ARMS]**
□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**OST -** During the off-season months [May/June/July/August], How many times (i.e. on average) did you partake in on-ice sessions/summer skates?

**May**

□ 1 = No ice times
□ 2 = 1-4 ice times (or once per week)
□ 3 = 5-8 ice times (between 1-2 times per week)
□ 4 = 8-12 ice times (between 2-3 times per week)
□ 5 = >12 ice times (more than 3 times per week)

**June**

□ 1 = No ice times
□ 2 = 1-4 ice times (or once per week)
□ 3 = 5-8 ice times (between 1-2 times per week)
□ 4 = 8-12 ice times (between 2-3 times per week)
□ 5 = >12 ice times (more than 3 times per week)

**July**

□ 1 = No ice times
□ 2 = 1-4 ice times (or once per week)
□ 3 = 5-8 ice times (between 1-2 times per week)
□ 4 = 8-12 ice times (between 2-3 times per week)
□ 5 = >12 ice times (more than 3 times per week)

**August**

□ 1 = No ice times
□ 2 = 1-4 ice times (or once per week)
□ 3 = 5-8 ice times (between 1-2 times per week)
□ 4 = 8-12 ice times (between 2-3 times per week)
□ 5 = >12 ice times (more than 3 times per week)

**OSDL -** Did you work (summer job) or intern this past summer?

□ No □ Yes

**OSDL -** If yes, How many **weeks** and hours **per week** did you work/intern on average this past summer?

_____weeks _____hours per week

## In-Season Training Questions

**All questions relate to the in-season time period (August|September –November|December);**

**FHT -** During the **1st half of season**, on average, how many times weekly did you complete a weight lifting workout/**lift weights?** (Consisting of 3-4 exercises, 3-6 sets)

≤1  2  3  4  5  6  7

**FHT -** During the **1st half of season**, on average, how many times weekly did you complete a **cardio** session (including on-ice practices)? (Consisting of 20+ minutes of moderate/vigorous Intensity)

1  2  3  4  5  6  7

**FHT -** During the **1st half of season**, did you perceive a gain or loss of strength?

**Lower Body Strength [LEGS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Upper Body Strength [ARMS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**FHT -** During the **1st half of season**, please rate your fatigue (tiredness) on a scale of 1 to 10.
1 (No Fatigue) ---------------------------------------------------------------------- (Extremely Fatigued) 10?

September: ______  October: ______  November: ______

**FHT -** During the **1st half of season**, How many games/practices did you miss due to injury?

None  <5  6-10  11-20  21-30  30 +

**FHT -** After you graduate, what do you plan to do the following year?

□ Continue playing **competitive hockey** (ex, American Hockey League, East Coast Hockey League)
□ Begin **Working (Full time)** and Play hockey ***recreationally***
□ Begin **Working (Full time)** and Play hockey ***competitively*** *(ie. senior)*
□ Other: (Please Specify): ____________________________________________

## Perceptive Tissue Mass Questions

During the | □ **Offseason** | □ **1st ½ of Season** |, do you believe you gained or lost tissue (mass)?

**Reference Points**

| | |
|---|---|
| 1 = Decreased Considerably (+6.5%) | → Ex (<13 on a 200 lbs person) |
| 2 = Decreased Noticeably (+4 to 6.5%) | → Ex (Between -8-13 lbs on a 200 lbs person) |
| 3 = Decreased Slightly (+1.5 to 4%) | → Ex (Between -3-8 lbs on a 200 lbs person) |
| 4 = Stayed the Same (+/- 1.5%) | → Ex [Between 0-3 lbs on a 200 lbs person) |
| 5 = Increased Slightly (+1.5 to 4%) | → Ex {Between +3-8 lbs on a 200 lbs person) |
| 6 = Increased Noticeably (+4 to 6.5%) | → Ex {Between +8-13 lbs on a 200 lbs person) |
| 7 = Increased Considerably (+6.5 %) | → Ex { >13 on a 200 lbs person) |

**Total Body Fat Tissue Mass**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Total Body Lean [Muscle] Tissue Mass**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Lower Body Fat Mass [LEGS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Upper Body Fat Tissue [ARMS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Lower Body Lean [Muscle] Tissue [LEGS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

**Upper Body Lean [Muscle] Tissue [ARMS]**

□ 1 = Decreased Considerably (+6.5%)
□ 2 = Decreased Noticeably (+4 to 6.5%)
□ 3 = Decreased Slightly (+1.5 to 4%)
□ 4 = Stayed the Same (+/- 1.5%)
□ 5 = Increased Slightly (+1.5 to 4%)
□ 6 = Increased Noticeably (+4 to 6.5%)
□ 7 = Increased Considerably (+6.5 %)

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