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The Effects of a Division I Men's Ice Hockey Season on Strength and Power

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**The Effects of a Division I Men's
Ice Hockey Season on
Strength and Power**

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The Effects of a Division I Men's Ice Hockey Season on Strength and Power

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Abstract

Measures of strength and power were taken during a pre-season training segment in Division I men's ice hockey as well as two weeks post-season in order to determine the changes that occurred in a twenty-one week season of play. All subjects performed a concurrent resistance training protocol that aimed to develop power, strength, and minimize the risk for potential injury that led to missed game-playing time. The men's ice hockey athletes were practicing an average of four days a week with the sport coaches in addition to the resistance training sessions with the primary strength and conditioning coach. The mean values for front squat maximum, bench press maximum, maximum vertical jump, and maximum broad jump all decreased significantly over the course of the season, as evidenced by the post-season performance testing measures. The mean body mass measure for the team did not decrease as anticipated over the course of the twenty-one week in-season, and a small increase was seen in the subjects. The decrease in measures of strength and power despite resistance training efforts may be due to the physically grueling nature of men's ice hockey and the increase in volume of hockey-related activity during the in-season segment. Body mass maintenance was due to diligent efforts by sports performance staff to see to it that each individual player had a sound nutritional plan.

Chapter I

INTRODUCTION

NCAA Division I men's ice hockey can be described as an explosive, physical sport that demands extremely high-intensity work for short bursts. The strategy of the game and the violent nature create one of the fastest and most brutal games played on two feet. The needs of an elite collegiate ice hockey player include the ability to produce maximal force, explosive power, extreme quickness, and the ability to change direction efficiently. (15, 26, 32) These attributes allow student-athletes to not only withstand the physicality of the game but to deliver checks, maneuver around opponents, and create goal-scoring opportunities. In-season training comprises the majority of the annual training in collegiate ice hockey, due to a regular season that spans 5-6 months of the 9 month academic year. The primary goals in-season are centered around the health and the weekly physical and mental preparation of the team.

Given the length and the brutality of a collegiate men's ice hockey season, the comprehensive in-season training program and the strength and conditioning professional must be mindful of factors such as mass loss, fatigue, and an increased risk of injury. With the higher volume of practice and game play, it is essential that training challenges the student-athletes in a manner that allows for maintenance and development of strength, power, quickness, etc. without reaching a point of overtraining. Overtraining in its purest form is demonstrated by performance decrements as well as manifestations of mental and physical fatigue (10, 12, 19). The need to perform at a high level and the need to recover must be balanced in order to optimize in-season potential. The terminal goal of a strength and conditioning professional is to better prepare athletes for competition and a continual effort exists to better serve them.

The most successful in-season collegiate ice hockey training program will be non-periodized or undulating in nature (8). Due to the demands of each weekend and the varying demands placed on individual athletes, performance tracking can provide valuable insight regarding recovery status and game readiness. Especially as muscle damage and fatigue effects accumulate over the course of the season, a measure of performance can ensure that the in-season training is both effective and proactive (7, 21). If performance is not tracked or quantified in some way and a standard plan is implemented, the possibility of inducing excessive fatigue, losing strength/power gains, or overtraining athletes exists (19). There are many avenues by which athletic performance and recovery state can be qualified and it is the role of the strength and conditioning professional to take appropriate measures.

Post-season measures can implicate the success or shortcomings of the in-season weight training plan, as well as demonstrate the rigors of Division I men's ice hockey. A resistance training protocol that focuses solely on the maintenance and/or development of strength and power gains made in the off-season misses a large component of the training needs of a male ice hockey athlete. It is important to note that maintaining levels of force and power production are imperative but maintaining lean muscle mass is a concern that is too often not addressed in-season. Without a specific effort to maintain the cross-sectional area of muscle, and therefore the ability of the ice hockey athlete to withstand and deliver meaningful contact on-ice, a major component of the training plan is lost.

Given the multi-faceted nature of the performance demands of a Division I ice hockey team, the resistance training protocol should be formatted in a way that meets the in-season needs of the sport and its athletes. The literature has indicated in certain studies that a non-linear

periodization model can serve to produce more significant maximal strength gains than the traditional linear model (2,35). The variability of volume and intensity that a non-linear or undulating model features will allow the strength and conditioning professional to address concerns with maintenance of lean muscle mass in-season. Rather than a linear increase in intensity coupled with a decrease in volume as seen in a linear periodized program, the in-season resistance training protocol can be specified to the week of play and the strength of opponent as necessary. (1 p 515) The in-season weight training needs of a team sport such as Division I men's ice hockey demand more specific programming than the traditional linear program allows. The ultimate goals of the in-season protocol are to allow for athlete recovery where it is necessary and attempt to maintain and develop strength and power production.

Avoiding overtraining effects and preparing student-athletes both mentally and physically is essential to the success of an in-season weight training program and ultimately, an NCAA season of play. The most significant measure of the success season is going to be team performance, but the most significant measures of the effectiveness an in-season training protocol are the performance gains or the losses that were made or suffered during game play. Pre-season and post-season measures can be taken to demonstrate the effectiveness of the in-season training program as well as the effects of a Division I ice hockey season on strength and power in the athletes.

Purpose

Therefore, the purpose of this study was to examine the changes in measures of strength and power over the course of a twenty-one week Division I collegiate men's ice hockey season.

Chapter II

REVIEW OF LITERATURE

This review will examine the sport of men's ice hockey; including the physiology of the sport, the effectiveness and execution of in-season strength and power development and recovery efforts, and methods of monitoring and tracking the physical state of an ice hockey athlete in-season. There are differing findings concerning athlete recovery and regeneration across exercise and sport but there is a wealth of literature that indicates non-linear periodization programs can result in gains in maximal strength/power in athletes.

Ice Hockey Physiology

Ice hockey is a high speed, hard-hitting sport that requires substantial strength, power, and agility. Pollitt notes that ice hockey players "must be able to display speed, agility, strength, balance, stability, and flexibility all while balancing on two 3-mm-wide by 28-cm long steel blades"(33). In addition, the violent nature of the game often results in significant amounts of acute muscle breakdown, which may require days to resolve (11). Further, at the collegiate level, the competitive schedule can be grueling, with games played on successive nights over the course of a four to six month season. Collectively, these demands make recovery a priority for the strength and conditioning coach. To that end, if acute and chronic recovery status is not prioritized while in-season, diminished power, force, speed, or quickness may result, and the risk of injury may increase correspondingly (14,43).

A physiological analysis of men's ice hockey would reveal that the sport taxes the body in a way that demands a sustained energy supply for the duration of a shift (30-45 seconds) as well as sustained execution of skill despite constant physical blows to the body (45). A given player may be expected to spend 15-35 minutes of the 60-minute total on-ice (30). The anaerobic energy system is most heavily

utilized during on-ice play, with the aerobic system serving a secondary but crucial role in efficient recovery from shift to shift. In 2011, Peyer et al. reported that the 2007 national champion NCAA Division I men's ice hockey team had a higher VO_2 max than those previously reported in similar studies and that this value (59 ml/kg/min) was significantly correlated to a repeated sprint test that was also performed in which recovery between work bouts is extremely important (32). Force and power production are essential in this fast-paced, brutal sport and the ability to change direction quickly can give a player a physical and/or tactical advantage on any given play. Accordingly, Burr et al. found that NHL draft selection could be predicted by performance on the standing long jump test, a measure of lower body power (7). Therefore, the development of muscular power in an annual format is of great importance to an elite-level ice hockey athlete's performance.

In-Season Training Considerations

A strength and conditioning professional must be concerned with the maintenance of a certain level of play throughout a collegiate season. This not only speaks to the maintenance and development of the physical parameters that lead to on-ice success but also the management and the minimization of negative effects such as fatigue, soreness, and losses in overall fitness. (14) Men's ice hockey is a game in which decisions are made quickly and even small decrements in performance can significantly affect a player's ability to execute their assignments and responsibilities. Also, the pace of the game is such that missed assignments can lead to turnovers, goals, or bodily harm/injury. Thus, as the season progresses, it becomes ever more important to minimize negative physical factors that could affect on-ice performance.

In men's ice hockey, high rates of muscle damage can be explained by a number of factors, including long seasons with high game play volume. As an example, during the 2013-2014 season at the University of Connecticut, thirty-three games were played over the course of five months, excluding the conference and national playoff contests that followed. Given these considerable demands, it is reasonable to suggest that team success is at least partially determined by the ability of the strength and

conditioning coach to ensure that players possess the physical resilience and preparation needed to maintain performance through the last post-season game. In order for this to occur, evidence-based weight training and recovery programs should be in place throughout the season. Such programs will act to combat the overuse injuries that can plague athletes as a season of play progresses. The most susceptible system to overuse effects in adults in sport is the musculotendinous unit and the strength and conditioning professional must make a diligent effort to negate these effects (23).

As evidenced in other team sports with varying positional demands, individual hockey players will experience unique physical and psychological effects over the course of a season. These varying physiological profiles will demand specific recovery and regeneration programs (28, 45). In addition to the unique positional demands faced by forwards, defensemen, and goalkeepers, muscle damage and injury risk may incorporate factors such as the team's style of play, shift time and number, line placement, and total distance covered on the ice. These variables must be considered in an attempt to optimize each player's performance in every game. In-game and longitudinal performance can and will be affected if a pro-active resistance training and recovery plan is not implemented in-season (22). A pro-active plan will focus on post-play recovery utilizing active recovery strategies, which have been shown in the literature to be superior to passive recovery and complete rest. A 2006 paper explored the effect of recovery techniques post-match on creatine kinase levels in elite male rugby players by comparing contrast water therapy, a compression garment, low-intensity active exercise, and passive recovery. The authors concluded that the contrast water therapy, compression garment, and low-intensity active exercise were superior regeneration methods to passive recovery or rest in this sport that taxes the body in a similar manner to ice hockey (12). With the resources of collegiate strength and conditioning coaches in mind, active recovery techniques would be the most easily and effectively employed in a team weight room setting.

In-Season Training Principles

The literature regarding in-season ice hockey largely speaks to the epidemiology and occurrence of injuries, due to the high level of contact that occurs on-ice and creates anatomical trauma (17). In-season programming and resistance training principles for ice hockey specifically are not as well explored as injuries during a season of play, but the underlying goals of training a team sport during their in-season segment apply. Due to an increased volume of ice hockey-related activities (practice, game play, meetings, video analysis), the frequency of resistance training and the volume will decrease accordingly. This is initially as a result of the strict number of hours that an NCAA Division I ice hockey team has to devote to all ice hockey activities in one week, but also in a concerted effort to manage the total volume of activity that the student-athletes are participating in in-season (4). Intensity of resistance training when speaking to load or percentage of one-repetition maximum must be managed effectively as well in a team sport, due to the multiple weekly contests in which the athletes are expected to be at their peak physical performance. The management of volume of training as well as intensity of work is essential to avoiding overtraining effects that can negatively affect an athlete's performance in scheduled games (19).

Along with the management of volume of total training, minimizing the risk of ice hockey-specific injuries becomes important when the time spent playing ice hockey and performing ice hockey-specific movement increases in-season. It has been indicated in the literature that these specific injuries can be prevented in part by a pre-season exercise program that focuses on the specific anatomical systems most susceptible to overuse or contact ice hockey injuries. Specifically, Tyler et al. found that a pre-season exercise program that focused on strengthening the adductor muscles prevented strains in comparison to the previous years when no exercise intervention was present (44). A sound pre-season program with the goal of minimizing injury in ice hockey can be carried into the collegiate season. The low intensity and low volume of the preventative exercises is conducive to the in-season training format. The smaller musculature of the hip, knee, ankle, and shoulder are the major points of focus, due to the

role that these systems play in force production, power production, and absorbing the forces of opponents' repeated blows. (17)

The in-season training segment in men's ice hockey presents a unique challenge to strength and conditioning professionals working with the program due to the importance of each weekend of play. In Olympic sports such as track and field or swimming, a much more linear resistance training plan can be utilized in which volume decreases as intensity increases, because there are very specific races or contests in which athletes and coaches are looking to peak performance (2). In an effort to maintain strength and power developed during the off-season and pre-season training segments, lower-volume, higher-intensity programs can be utilized in the team sport setting. Sets of 2-4 and repetitions each set of 1-6 are utilized in this traditional in-season training scheme. As mentioned by Allerheligen in a 2003 article, the ultimate challenge to the strength coach then becomes maintaining muscle mass, as lower-volume programs are not conducive to hypertrophy (1). Fatigue effects associated with the increased volume of ice hockey and training for ice hockey will negate lean mass gains as well. With the high number of physical contacts and the major role that body-checking plays in the game strategy in men's ice hockey, the maintenance of lean muscle mass is of great significance as a season progresses (35, 16, 14). With a necessity to balance so many performance factors, a resistance training plan that is periodized but non-linear in nature can benefit an ice hockey team during a season of play.

Non-linear Periodization

As mentioned previously, the traditional resistance training program is linear in nature, with a specific goal that serves as an "endpoint" to that phase of the program. The mesocycles in such a plan gradually and progressively increase in intensity over time (2). Demonstrated by the length of the season and the volume of games that are played in a collegiate schedule, men's collegiate ice hockey is not a team sport in which performance can peak in a completely linear fashion. It stands true that athletes must

be physically and mentally prepared for post-season play at the conclusion of the season, but the results of the regular season schedule affect both the opponents faced in the post-season as well as the existence of post-season play.

The benefits of a non-linear or undulating periodized resistance training program in regards to strength and power increases have been documented in numerous training studies (37, 27, 38, 42) as well as in rugby and football seasons (3). This type of training is characterized by large fluctuations in the load and volume assignments for the core or major exercises on a daily or weekly basis. According to Baechle et al., “An underlying factor that appears to support the undulating model is the absence of accumulated neural fatigue caused by the extended, ever-increasing training intensities common to the linear model (2, 21). This model of programming for weight training is conducive to an in-season segment due to the variability that it offers. If the difficulty of a game is higher (based on level of opposition, training days between games, or game location) undulating periodization enables the strength coach to manipulate volume and load accordingly in that specific week or pre-game training session (18). A lower-volume, higher-intensity session would be favorable prior to a game with a high level of difficulty, whereas a higher-volume, lower-intensity session could be implemented prior to a game with a lower level of difficulty. The higher volume option allows the strength and conditioning coach to address in-season challenges regarding maintaining lean muscle mass. Recovery weeks or recovery sessions can also be factored into this non-linear model of periodization, with respect to the ice hockey schedule and the physical state of the athletes.

Athlete Recovery

The ultimate goal of any strength and conditioning professional is the attainment of peak competitive performance. By definition, physical training programs are designed to accomplish this task through the development of physical abilities that improve performance and the ability to recover (24, 32). A complete program will include a recovery plan, where rest, repair, nutrition, and active recovery

work are prescribed to maximize the likelihood of maintaining a competitive physical condition.

Combatting the effects of muscle damage as a result of physical trauma and physical exertion on-ice becomes paramount to the long-term success of the ice hockey student-athlete. Muscle damage can occur in an acute or long-term situation and collegiate ice hockey will subject student-athletes to both of these issues over the course of the regular season (36). With repeated bouts of exercise either in a traditional weight room setting or on ice, there are two major types of damage or breakdown that a strength and conditioning coach must consider. These are the depletion of energy substrates and physical deformation of the muscle (2 p.114). The high eccentric loads that are experienced by ice hockey players during decelerating and changing direction on the ice can result in microtrauma to the muscle that can induce soreness, swelling, and reduced range of motion in the days following a game (29). Ensuring proper replenishment of substrates (carbohydrates, protein) is the responsibility of the strength and conditioning professional, but their most active role will be in regaining the quality of movement and power production temporarily compromised by acute muscle damage.

In men's ice hockey, there are specific concerns when attempting to optimize athlete recovery and performance. Due to the physical nature of the game, muscle tissue quality must be of primary importance to the strength and conditioning professional. Following repeated blows to the body and damage/deformation to muscle itself, restoration of the quality must be obtained in order to maximize utilization of the entire system. A common and effective way to restore the quality of tissue is through myofascial release techniques, most notably self-myofascial (SMR) release via the use of foam rollers or similar pieces of equipment. Currently, the support for SMR via foam rolling as a tool for recovery and/or physical preparation is essentially split. Healey et al. found that foam rolling prior to performance tests (vertical jump height and power, isometric force, and agility) had no significant effect on the result. Foam rolling was compared to a series of isometric planks and post-exercise fatigue measures were lower in the foam rolling group than the planking group. (15) Although there is research that indicates there are no performance benefits related to foam rolling prior to specific tests of performance, the literature

supports the notion that range of motion can be increased after a two-minute bout as well as a ten-minute bout of SMR (25). Thus, foam rolling exercises can be included as a part of a program that is focused on the quality and the function of soft tissue.

Another component of a pro-active in-season training segment would be a focus on on-ice mobility. Skating demands movement patterns that differ greatly from walking or running therefore mobility work specific to these skating strides will benefit the athlete most. Optimal range of motion and ease of range of motion through the hip, knee, and ankle musculature are most important considering the nature of ice hockey. The demands on the hip musculature in particular are going to be more intense than traditional "land" athletes due to the stresses that occur in all planes of motion in a skating stride (26).

Appropriate mobility at a joint can serve as an injury prevention strategy as well as a performance enhancement strategy. Using Gray Cook's Functional Movement Screen (FMS™), a 2007 paper found that NFL football players scoring less than fourteen out of a possible twenty-one were more likely to suffer an injury than those that scored higher. The FMS™ is a comprehensive test of muscle strength, range of motion, proprioception, flexibility, and coordination as determined by seven fundamental movement patterns. (20) Limited range of motion pre-season in itself can be a predictor of in-season muscle strain injuries, according to Bradley and Portas. They observed that "players who injured the knee or hip flexor muscles during the season had a preseason range of motion approximately three degrees less than that of the un-injured players" (6). In-season injury risk reduction strategies are essential when taking a pro-active approach to programming. In collegiate ice hockey, these are going to focus on the anatomy of the ankle, knee, hip, shoulder, and neck based on the systems most susceptible to injury (16). Objectives will be maintaining or improving range of motion at the joints, strengthening the muscles that stabilize, and mobilizing systems that provide for hockey and on-ice specific movements.

The importance of next-day recovery is extremely relevant in this sport because the athletes generally compete in two games in a forty-eight hour span. When speaking to acute regeneration, ice

hockey athletes cannot play one or two physically grueling hockey games and then remain in a state of total rest for a day or two. Post-play, the fascia surrounding the muscle and the muscles themselves are in a compromised state in comparison to pre-game (45). A study examining the timing of post-play recovery techniques in Australian rules football matches found that muscle soreness, flexibility, and power were not significantly enhanced by performing an immediate post-match recovery in comparison to next-day recovery training. (9) This speaks to the fact that one method is not more effective than another, but in the effort to accelerate athlete regeneration, a strength and conditioning coach must use all resources that are available to them. Combatting the extreme soreness that results from an ice hockey game and maintaining an appropriate range of motion through joint system mobility are essential to restoring effective movement patterns on-ice.

Monitoring Performance and Physical State

A typical training week in men's ice hockey at the University of Connecticut will look as follows: Friday/Saturday games, Sunday recovery/regeneration session, and one mandatory lift session that must be completed prior to Wednesday at noon. If a Sunday session does not occur due to coaching decisions, the athletes are mandated to complete two lift sessions prior to Wednesday at noon. This, of course, will vary if a mid-week game is on the schedule and training/recovery work will be dependent on that specific day of play. Pre- and post-game warm-up and cool down stretch sessions are an integral part of in-season play in addition to the traditional weight room sessions. On a typical Friday/Saturday game weekend, a full mobility, dynamic warm-up will be administered prior to getting on the ice. A slightly more static stretching session will take place immediately post-game in the locker room with the intent to counteract some of the soreness that will present itself in the following days (41). In a typical ice hockey weekend even the subjective level of recovery experienced by individual athletes headed into the second game can be crucial to performance. A session with a focus on acute regeneration takes place mid-morning on

Saturday with the ultimate goal of preparing the athletes physically and mentally via active recovery techniques.

One of the most important in-season questions is: "What has the quality of recovery been from week to week, and where are we in terms of recovery right now?" In order to answer this question, the coach must have some means of measuring and tracking recovery state. If performance and recovery from gameplay are not tracked in some longitudinal way, aside from game performance, it is difficult to determine whether players and the team are in optimal competitive conditions. As coaches, it is important to utilize accurate measures of performance, rather than information that can be subjective.

There are a number of methods that can be used to objectively track aspects of the physical state and overall performance. Measures of lower body power can be obtained in order to identify acute or chronic decreases in power output (11). Bodyweight vertical jumps or broad jumps provide free, expedient, non-invasive, and informative measures of lower body power, and can provide even more information when coupled with accelerometers or force transducers, which can often provide body position-specific information about velocity, power, and force. If decrements in these variables are observed, total training volume, rest periods, and number of ground impacts can be manipulated to return athletes to an improved physical state. This is a concerted effort that must be made both by the sport coach and the strength and conditioning professional. Player input is free, fast, and effective as well (8, 39). Computer software programs have recently been developed to track and store daily feedback from players. In any case, the success or failure of a monitoring program is determined by player adherence to information collection requirements. While we have generally succeeded in our efforts to collect such information, we note that it remains a daily challenge when working with student-athletes. Alternatively, a simple survey system can be informative to the strength and conditioning coach, and there are a myriad of options. Examples include surveys of perceived exertion, soreness, fatigue, sleep quality, mood state, energy level, and more (13).

Summary

Division I collegiate men's ice hockey is a demanding sport that requires power, speed, and a high level of skill execution. Both the energy systems of the body and the functional anatomy are taxed in a way that creates a level of damage in the athlete. Appropriate recovery and regeneration must be a diligent effort made by both the strength and conditioning professional and the ice hockey student-athlete. The rate of recovery, mental state, and physical readiness will be individual to each player, dependent on many in-season factors. On-ice performance must be the primary objective of the in-season training plan as a segment of an annual training plan. Recovery techniques such as dynamic mobility work and self-myofascial release can serve to prepare the ice hockey player for the next contest. Without an evaluation of performance and physical state in-season, the strength and conditioning professional is not providing the best possible program for the student-athlete or program. Week-to-week performance must be monitored and proper athlete recovery made be a priority in order to withstand the effects of such a long, grueling season of play. The strength and conditioning coach must be concerned with the in-season maintenance and potential for development of both muscular strength and power.

The hypotheses of this study are the following:

1. Performance measures taken post-season will indicate the damage that occurs despite a consistent and scientifically-based in-season training protocol during a 5-6 month season of NCAA Division I ice hockey.
2. Post-season body mass will be lower than pre-season body mass due to the increased volume of ice hockey-related activities.

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Chapter III

METHODS

Experimental Approach to the Problem

A collegiate ice hockey team in the United States of America was utilized for all purposes of this study. During all time points during data collection, the team was competing in the Atlantic Hockey Association Conference and will be competing in the Hockey East Conference beginning the 2014-2015 season. Opponents during the season in which the physiological tracking occurred included the runner-up to the 2013 national champions as well as multiple recent NCAA Frozen Four participants. The season spanned a time-frame of twenty-one weeks from October to March and encompassed a total of thirty-six games played, including two post-season contests. All games are comprised of three twenty minute periods, for a total of sixty minutes of game play. The mean length of all thirty-six games played in the 2013-2014 season was 132.5 ± 12.33 minutes (two hours, twelve minutes).

Data was collected one week prior to the start of the season and two weeks after the conclusion of post-season play. All data was collected in the Greer Field House varsity weight room at the University of Connecticut. The primary strength and conditioning coach for the men's ice hockey program performed all tests and obtained all data to avoid inter-rater variability. The four performance tests were one repetition maximum front squat, one repetition maximum bench press, maximum vertical jump, and maximum horizontal (broad) jump. Body mass data was also collected in order to note changes throughout the season and post-season.

Out of the twenty-one weeks that the team was in-season, games were played in eighteen of those weeks. The team had two full weeks off from playing hockey during the university's winter intersession and a full week between regular season play and post-season play. Daily

practices run by the sport coaches occurred weekly and lasted one to one and a half hours. The intensity and the length of practices decreased during the week when there was a typical Friday/Saturday game sequence. Following a weekend of play, the sport coaches conducted a “light” one-hour skate on the ice on Sunday mid-morning and there was no practice or mandatory hockey activity on Monday. Tuesday’s practice was considered a hard, full-contact skate, Wednesday was a technical/strategy-focused session, and Thursday was a moderate skate with the coaches.

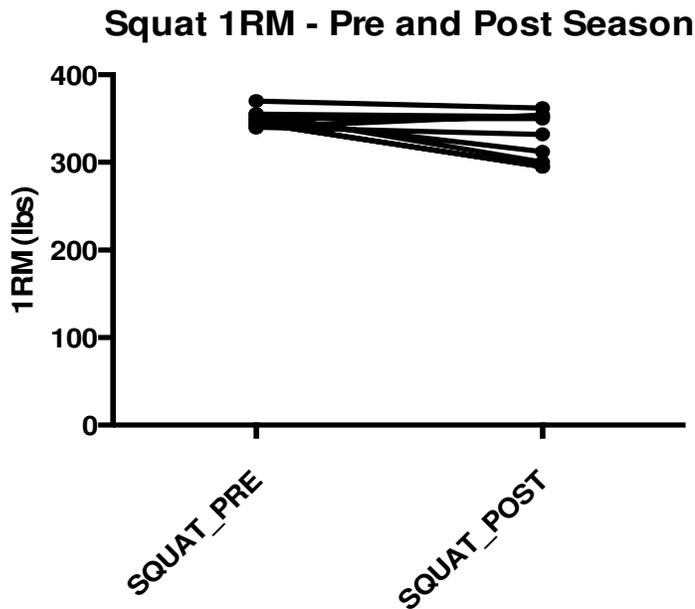


Figure 1. Individual differences observed in 1RM Squat Performance from Pre- to Post-Season

In the twenty-one weeks of the Division I ice hockey season, the team weight trained every week. In a standard week, the men’s ice hockey team was required to get two weight training sessions in within a specified time. Only one resistance training session took place if a Friday/Saturday game weekend was followed by a Wednesday mid-week game. If the game

schedule was Friday/Saturday, the first training session was on the Sunday following the Saturday night game and the second training session was to be performed prior to Wednesday at noon. The day and time of the second weight training session differed between the individual athletes due to class and work schedules but the Sunday session consistently occurred mid-morning Sunday. The focus of the strength and conditioning professional and these training sessions was the maintenance and development of force production, power, and speed on-ice. The program is lower-body focused with a significant portion designated to the continual risk reduction of ice hockey-specific injuries through dynamic stretching and small muscle group strengthening exercises.

The major exercises were performed up to 85% and no less than 70% of one repetition maximum during the in-season training segment. Variations of power clean, front squat, and bench were considered the core exercises and therefore were the only exercises that weights were prescribed for all sets. The program was undulating in nature, with intensity and volume varying weekly and dependent on the weekly opponent and the number of days between games. The weight training sessions comprised a total of two hours weekly while the on-ice practice sessions contributed 5-8 hours weekly. Factors such as diet and lifestyle were not controlled for during the course of this tracking study, as it was analyzed retrospectively. Per the head sport coach, a select few at-risk players were advised nutritionally by the primary strength and conditioning coach and team nutritionist in an effort to maintain body mass throughout the playing season.

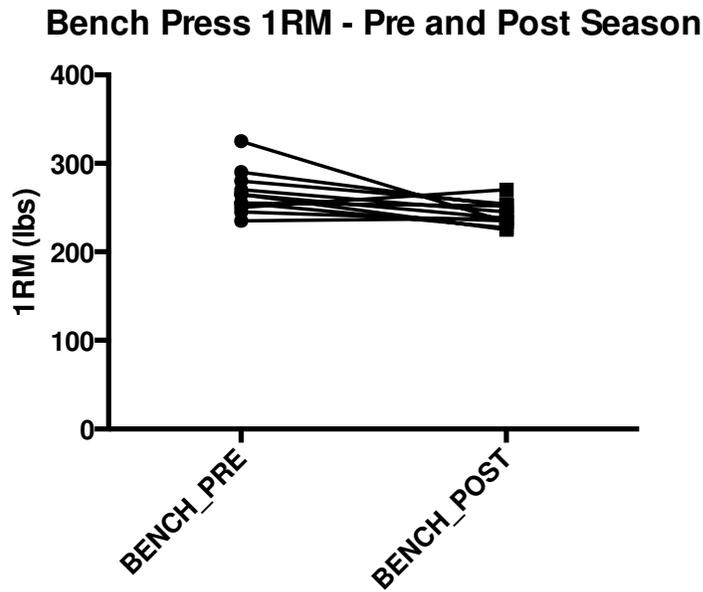


Figure 2. Individual differences observed in 1RM Bench Press Performance from Pre- to Post-Season

Subjects

NCAA Division I male ice hockey players at the University of Connecticut were the participants in this retrospective study designed to effects of a Divison I ice hockey season on strength and power. Fourteen players were tested pre-season and then again post-season in the four performance measures and a body mass was obtained at the two time points. The study is approved by the University of Connecticut Institutional Review Board (IRB) on the basis of it being retrospective in nature and within the confines of standard operations of the strength and conditioning department. At the conclusion of the study, there were nine athletes tested in one repetition maximum front squat, eleven in one repetition maximum bench press, twelve in maximum vertical jump, eleven in maximum horizontal or broad jump, and all fourteen participated in body mass data collection. Any deviation from the fourteen original subjects tested in the performance measures was due to injury deemed serious enough by the athletic

training staff to exclude the subject from participating in post-season measures.

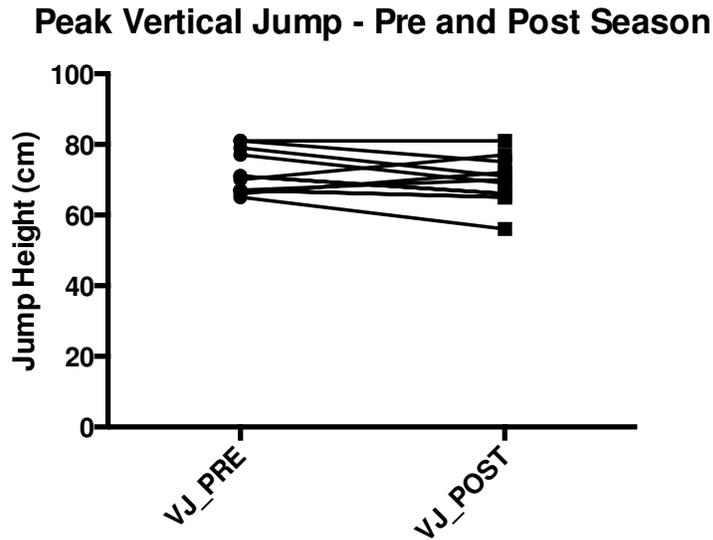


Figure 3. Individual differences observed in Peak Vertical Jump Performance from Pre- to Post-Season

Data Collection

One Repetition Front Squat Maximum Test

All subjects were advised to perform a standard warm-up consisting of a set of 5-10 repetitions at a light-to-moderate load, rest one minute, perform a set of 5 at a moderately heavy load, rest two minutes and a set of 3 at a heavy load prior to a max attempt for one repetition. In the pre-season test, athletes were instructed to perform their first one rep maximum attempt at a weight that was five pounds heavier than their previous personal record. Post-season testing allowed for the subjects to select their own one rep maximum starting testing weight following the standard warm-up. A successful attempt was ruled as a technically correct front-loaded squat

that achieved at least ninety degrees of knee flexion followed by full leg extension. A femur that is parallel to the ground was the technique consistently coached, but a ninety degree angle at the knee was accepted as a successful attempt. Subjects were allowed only two total missed lifts (barbell lands on safety racks/crash bars) in the attempts and if technique was sacrificed, the strength and conditioning coach ended the subject's attempt.



Figure 4. Squat Pre- and Post-Season Mean Values and Standard Deviation. Pre-values were 350 ± 9.35 lbs. and post values were 328 ± 27.67 lbs.

One Repetition Bench Press Maximum Test

All subjects were advised to perform a standard warm-up consisting of a set of 5-10 repetitions at a light-to-moderate load, rest one minute, perform a set of 5 at a moderately heavy load, rest two minutes and a set of 3 at a heavy load prior to a max attempt for one repetition. In the pre-season test, athletes were instructed to perform their first one rep maximum attempt at a weight that was five pounds heavier than their previous personal record. Post-season testing allowed for the subjects to select their own one rep maximum starting testing weight following

the standard warm-up. A successful attempt was ruled as a technically correct horizontal bench press that achieved ninety degrees of elbow flexion followed by full arm extension. The consistently coached technique was a barbell controlled to the chest and back up to full arm extension but ninety degrees of elbow flexion was accepted for the eccentric portion of the lift. Subjects were allowed only two total missed lifts in the attempts (assistance from a spotter) and if technique was sacrificed, the strength and conditioning coach ended the subject's attempt.

Maximum Vertical Jump

A VertecTM vertical jump measuring system was used in order to objectively measure vertical jump height. The subjects were directed in a standard, dynamic warm-up prior to the attempts, complete with a vertical plyometric component. Athletes started directly underneath the vanes of the VertecTM and performed a maximal height counter-movement jump reaching and hitting the colored vanes. The colored vanes were labeled with their height and were moved out of the subject's reach with each successful attempt. The athletes continued performing maximal effort vertical jumps until they missed the vanes twice consecutively. At that point, a standing reach measure was taken with the subject's dominant hand for the test. This standing reach was subtracted from the number they achieved on the vertical jump test to reveal their vertical jump height.

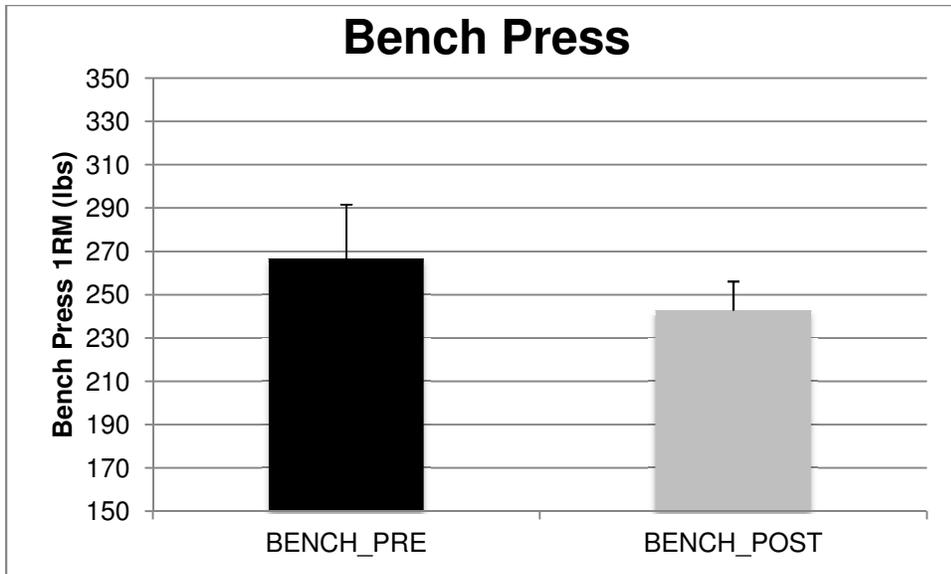


Figure 5. Pre- and Post-Season Mean Values and Standard Deviation. Pre-values were 266.82 ± 24.83 lbs. and post-values were 242.73 ± 13.38 lbs.

Maximum Horizontal (Broad) Jump

A measuring tape was used to objectively measure the distance traveled on a maximal effort counter-movement horizontal jump. Subjects were directed in a standard, dynamic warm-up prior to the attempts, complete with a horizontal plyometric component. Athletes then performed three maximal horizontal jumps from a flat-footed position and the position of their posterior heel was measured. The best attempt out of the three attempts was recorded as the subject's maximal horizontal jump. Due to other subjects testing concurrently, each athlete received 2-4 minutes between max attempts.

Body Mass Measurement

A body mass measure was taken pre- and post-season via the use of a Tanita™ scale. Subjects were instructed to remove their shoes on both time points of data collection to ensure accurate results.

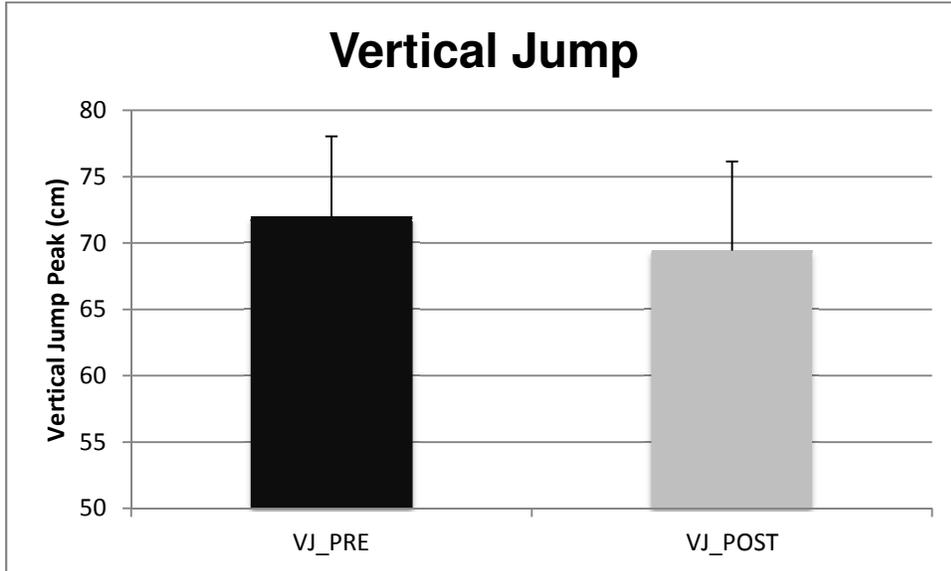


Figure 6. Pre- and Post-Season Mean Values and Standard Deviation. Pre-values were 71.97 ± 6.09 cm and post-values were 69.43 ± 6.73 cm.

Statistical Analyses

A paired sample T-test was performed on all four performance tests as well as the two data points for body mass measurements. Mean, standard deviation, and standard error of the mean values were obtained via the use of SPSS software. A two-tailed T-test was performed for all dependent variables in order to assess the difference in means from pre- to post-season testing values.

Chapter IV

RESULTS

During the twenty-one week competition period, each player in the study participated in a total of 38 weight training sessions, at an average of 1.8 weight training sessions per week. At least one session took place in each week of the competitive season. During the university's winter intersession, there was no practice or game play for a two week period in December but athletes performed two weight training sessions per week. On the season, all athletes involved in this examination played in an average of 1.7 games per week.

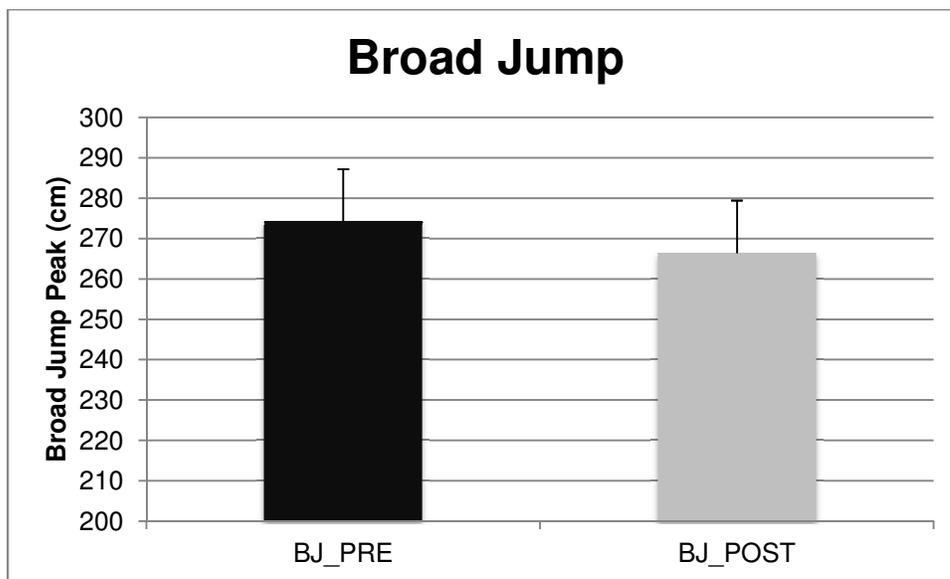


Figure 7. Pre- and Post-Season Mean Values and Standard Deviation. Pre-values were 274.32 ± 12.89 cm and post-values were 266.35 ± 13.06 cm.

Performance Measures

Following analysis of pre- and post-season performance measures, the mean for pre-season front squat values was 350 lbs. ± 9.35 lbs. and the post-season mean was 328 ± 27.672 lbs. Greater variance was seen in the post-season front squat values in comparison to the pre-season

values and the percentage decrease in mean front squat values was 6.3% from pre- to post-values. The mean for bench press pre-season values was 266.82 ± 24.83 lbs. and the mean for post-season values was 242.73 ± 13.38 lbs., indicating greater variance in the pre-season testing values. The percentage decrease for the mean maximum bench press values was 9%. The pre-season mean value for vertical jump in all subjects was 71.97 ± 6.09 cm and post-season mean value was 69.43 ± 6.73 cm. The percentage decrease for the mean values was 3.5% from pre- to post-season measures. The pre-season mean value for the broad jump test was 274.32 ± 12.89 cm and the post-season mean was 266.35 ± 13.06 cm. A 2.9% decrease in mean values was observed for broad jump from pre- to post-season measures of horizontal power.

Body mass results indicated that there was a .09 kg increase in mean values from pre-season to post-season values, with a pre-season mean of 87.33 ± 6.19 kg and a post-season mean of 87.42 ± 6.51 kg. There was a .01% increase in body mass observed over the course of the Division I ice hockey season.

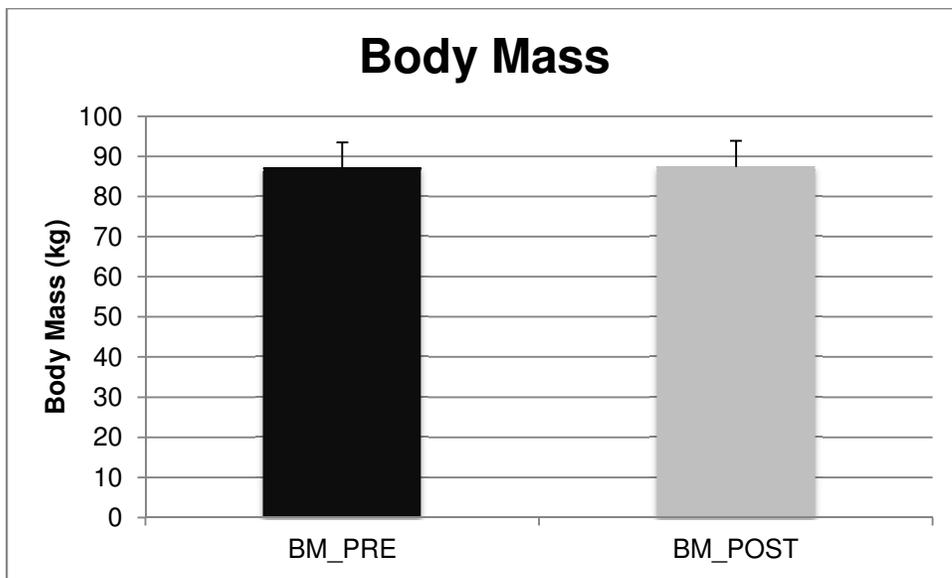


Figure 8. Pre- and Post-Season Values and Standard Deviation. Pre-values were 87.33 ± 6.19 kg and post-values were 87.42 ± 6.51 kg.

The mean difference observed in measures of front squat maximum strength was 22 ± 26.09 lbs. The mean difference observed in measures of bench press maximum strength from pre- to post-season was 24 ± 28.76 lbs. The mean difference observed in pre- and post-season measures of vertical jump height was 2.54 ± 5.6 cm and the mean difference observed in broad jump distance was 7.97 ± 6.67 . Mean difference observed in body mass measures was $-.097 \pm 2.99$ kgs. Significant differences in front squat, bench press, vertical jump, and horizontal from pre- to post-season values were observed as indicated by a two-tailed paired samples test.

Chapter V

DISCUSSION

As a season of ice hockey progresses, student-athletes and their physical state can be compromised. This is evidenced by our results that indicated that all four measures of strength and power that were taken pre-season significantly decreased over the course of the collegiate ice hockey season. This was determined by the primary strength and conditioning coach proctoring the same tests two weeks after the final ice hockey game in 2014. The measures of muscular strength were a maximum front squat and a maximum bench press, which decreased by 6.3% and 9%, respectively. Power was assessed by way of a bodyweight vertical jump as well as a horizontal (broad) jump and these measures showed a 3.5% and 2.9% decrease from pre- to post-season testing, respectively. Due to injury that led to restriction over the course of the season, four athletes did not perform specific post-season tests, and therefore their data is not considered.

Body mass was the only dependent variable examined in this study that was not only maintained but had an average increase of .09 kg. Although the increase is not statistically significant, the maintenance of body mass during a twenty-three week season of collegiate men's ice hockey is worth noting. At the time of body mass data collection in the post-season, we were not able to determine if the mass maintenance or gains were due to lean muscle mass or fat mass and that is an area worth exploring in future research.

The vast majority of the men's ice hockey literature focuses on the epidemiology of injuries sustained in season and the statistics regarding injuries sustained during game play (6,18,42). The extent that researchers have examined strength and power in men's ice hockey athletes is limited to the relationships between measure of strength or power and on-ice performance. Peyer specifically found that leg, press, chin ups, bench press, and repeated sprint

performance were the most highly correlated with NCAA Division I ice hockey performance, as determined by a (+/-) scoring system (32). A second study conducted by Potteiger and colleagues found that superior muscular strength as measured by an isokinetic dynamometer was also indicative of superior playing performance in Division I men's ice hockey athletes (33). These findings implicate the importance of maintaining both strength and power during an entire season of ice hockey. It would be reasonable to suggest that decrements in measures of muscular strength and power could lead to decrements in ice hockey performance. The limitations that we face with comparing our results to the literature are clear. The methods of performance testing differ and an entire season of collegiate ice hockey is not a variable in the above-mentioned studies.

Conclusions that can be made based off of the numbers are that even with a periodized and scientifically-grounded in-season training program, men's ice hockey is a sport in which decrements in performance measures can be observed following the conclusion of that year of play. This speaks to the need for accurate and effective methods by which to monitor athletes week-to-week in-season, rather than after the conclusion of play. Based on the body of knowledge that already exists, many strength and conditioning professionals have had success maintaining or increasing force and power production during a team's in-season training segment. This is supported by research in male and female sports, contact and non-contact sports, and college and professional programs (7, 17, 27). Baker and colleagues tested maximal strength pre- and post-season in both collegiate and professional male rugby players and with concurrent, in-season training were able to increase or maintain in max bench press, bench throw, and jump squat. (2) Given that rugby is an activity in which the level of contact matches if

not exceeds that of ice hockey, this case study shows that gains can be made during in-season training in the most physically demanding contact sports.

These results indicate that athletes must be in peak physical condition to not only compete in a season of Division I hockey come October but also to train concurrently with practice and play. Resistance training in order to maintain a level of force production as well as explosive power is essential to on-ice performance and success. The decrements in strength and power measures may be due to the low average weight training sessions that were performed on average each week during the in-season training segment. A consistent in-season training protocol that accounts for the weekly game schedule as well as the needs of individual athletes will be the most successful in both maintaining and developing muscular strength and power in the collegiate athlete.

Practical Applications

The results of this examination can be used to indicate the importance of a prioritized, scientifically-based in-season resistance training protocol. The benefits of superior muscular strength and power are clear in the literature in the sport of collegiate men's ice hockey. In future research, we believe it would be crucial to take multiple measures of performance during the in-season training segment in order to more accurately and consistently track what is happening with the student-athletes. That way, adjustments to the non-linear program format could be made based upon performance needs and what will benefit the student-athletes most. A more proactive approach to in-season strength and power development could be taken in order to assure that the primary goals of the training segment are met. Performance in Division I men's ice

hockey is tied to muscular strength as well as the ability to produce that force at high velocities. Therefore, the weekly maintenance and development of these two variables needs to be prioritized. Decrements will be seen if a reactive approach to the effects of a season is taken rather than an aggressive evaluation-based approach in-season.

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