A Theoretical Review of the Physiological Demands of Ice-Hockey and a Full Year Periodized Sport Specific Conditioning Program for the Canadian Junior Hockey Player

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The recent growth of scientific athletic performance assessment methodology and technique procedures, and the proliferation of this innovation, has lead to an increase in the specificity with which sport, and the processes and mechanisms regulating performance with in it, is investigated and understood.

In recent years several investigators have conducted field and laboratory bioenergetic based physical demand research investigating both the physiologic (10,11,13,14,18,19,21,24, 30,31,34), and biomechanical (13,19,30,31) demands of ice hockey performance.

Time motion and physical task analysis research indicates that ice hockey is a start and stop, one-on-one, intermittent collision sport, where practice and competitive play consists of, and is characterized by, explosive dynamic movement patterns, and the technical skills of skating, shooting, passing, and body checking (11,30,31).

Task analysis data indicates that ice hockey game tasks are closed kinetic chain movements, and require high levels of absolute strength (14,18,22) and muscular power and endurance(14,18,19,22), and demanding highly conditioned aerobic and anaerobic energy pathways (11,14,18,22,24,28,30,31,34).

Further, Green et al. (13) report that measures of successful ice hockey performance, and level of competitive play can be correlated an athlete's physiologic profile.

A review of the time motion and physical demands analysis indicates that elite hockey performance is facilitated through a complex integration of neuromuscular and cardiovascular physiological processes

It is important for the practicing hockey specific strength and conditioning professional to have a comprehensive theoretical understanding and practical knowledge of the biomechanic and physiologic mechanisms that regulate athletic performance within the particular sport their athlete's are competing in.

The following review intends to present published ice hockey specific bioenergetic, and time motion and physical demands research to summarize the physiologic and physical demands required of successful ice-hockey performance. Further, this review will attempt to synthesize a series of practical applications and to provide a model 12 month periodized hockey specific conditioning program designed to enhance hockey specific physiological and performance attributes.

A case study, representative of a Canadian Junior Hockey League (Ontario Hockey League, Western Hockey League, and Quebec Major Junior Hockey League) athlete's full year schedule demands will be used to reference specific timing and sequencing of training periods, their respective training purposes, and their individual protocol design variables.

Particular attention will be made to exercise selection, training methodology, and intensity variables, in attempts of providing the practicing hockey strength and conditioning professional with a research supported hockey practical hockey conditioning reference.

Energy Systems

Time motion analysis conducted by Green et al. (11), and Twist and Rhodes (30,31) indicates that a typical shift lasts approximately 30-80 seconds, and is followed immediately by 4 to 5 minutes of passive recovery (19,28). While positional (30), and physiological (13) differences are reported to influence an athlete's playing time; Twist and Rhodes (30) report defensemen play close to 50% of a game, while forwards play approximately 35%, the reported 1:3.5 – 1:8 work to rest ratio, indicates ice hockey is powered transitionally through aerobic and anaerobic energy pathways.

Montgomery (19), and Twist and Rhodes (30) report that peak on-ice heart rates exceed 90% of maximum, with average heart rates above 85% of maximum. Heart rate assessment is a direct measure of metabolic demand; oxygen consumption, and an indication of the relative physical intensity endured during shift.

Due to the nature of a Canadian Hockey League shift, the high heart rate is reflective of the high energy requirements, and indicates that oxidative metabolism is not fully capable of satisfying an athlete's energy demands.

Green et al. (13) support the contentions of Montgomery (19), and Twist and Rhodes (30,31) in reporting that hockey athletes require both highly developed aerobic and anaerobic glycolytic and phosphagen energy pathways, as it is these energy systems which provide the ATP needed to sustain repetitive high energy power and endurance outputs incurred during practice and competitive play (31).

Pioneering work conducted by Seliger et al. (17), and Green et al. (11) quantified the metabolic demands of ice hockey performance, and concluded that the anaerobic glycolytic and Adenoside Triphosphate Phosphocreatine (ATP-PC) energy systems provide 69%, and oxidative phosphorylation 31% of the energy demand of ice hockey play (17).

Twist and Rhodes (31) report that 60-70% of the energy requirements of the body during periods of moderate activity within an ice hockey game are fueled by aerobic metabolism, but note that this contribution is subject to variability due to inter and intragame variations in intensity, level of competition, position, and the player's level of conditioning.

Bioenergetic functional capacity research (3) reveals that the ATP-PC, and the glycolytic energy system's ATP production peaks after 10-45 seconds, and provides the energy required for shifts lasting an average of 45 seconds.

Shifts lasting longer than 45 seconds are characteristic of fatiguing musculature, and representative of an inverse performance relationship (30). As ATP production continues to rely on the glycolytic pathway, lactate and hydrogen ion concentration increase (11), contributing to increased fatigue and decreased performance.

Green et al. (11), and Twist and Rhodes (30) report that in-game glycolytic energetics are reported to create blood lactate levels measuring 8.7mmol/L (11), to 15.1mmol/L (30), representing a significant increase above normal resting 1.0-2.0mmol/L values (3). While these values are below that which can be produced on a cycle ergometer (11), or other assessment methods, it provides a measure of performance intensity and fatigue rates; for further discussion on the relationship between lactate accumulation and fatigue refer to Chapter 5 of Essentials of Strength and Conditioning 2nd Edition (3).

Performance decrements are the product of increased reliance on the glycolytic pathway and concurrent utilization of intramuscular glycogen (19), intracellular phosphagen depletion, and symbiotic Hydrogen ion and lactate accumulation (11,17). These factors are known to alter intracellular acidity, and cause cellular disruption, ultimately leading to, and physically expressed as local muscular fatigue.

Aerobic energetics provides oxidative recovery between shifts. Aerobic strength is measured by the rate of oxygen consumption. The greater the volume of oxygen an athlete is able to consume over a shorter period of time, the more efficient they are in utilizing oxygen, rather than the substrates of phosphocreatine, or glycogen, for ATP metabolism.

The importance of a well developed aerobic system in ice hockey is demonstrated be a decreased recovery time between shifts and by reduced fatigue in the latter stages of a game (22,29).

Green et al. (13) assessed the relationship between physiologic profiles and on-ice performance of National Collegiate Athletic Association (NCAA) division I hockey players, and found a positive correlation (r=0.41, p<0.03) between VO_{2max} and net scoring chances, and lactate concentrations (r=0.41, p<0.03) and ice time. The significance of these findings to the practicing ice hockey strength and conditioning is that aerobic capacity has a direct positive relationship to playing time, and net scoring chances.

The relationship between ice time and lactate concentration is found in the fact that coaches play those athletes who can perform with a higher intensity more frequently in more game situations; power plays, penalty kills, in strategic points in the game etc. over the course of the game. Further, the positive correlation between VO_{2max} and net scoring chances is speculated to be attributed to the athlete's ability to recover more efficiently, and participate in more game situations involving scoring chances for (playing on the power play, playing later in the game when the opponent is fatigued etc.), and playing with more intensity while in defensive situations, preventing the opposing scoring chances (13).

A review of positional demands; ice time, and physical task analysis, indicates that forwards and defensemen have different energy system utilization patterns. While the importance of having well conditioned aerobic and anaerobic systems are equally justified, recovery demands characteristic to the positions are different, and require a different work to rest ratios, and different VO_{2max} values.

Twist and Rhodes (30) report that forwards require a higher recovery time and play less shifts that defensemen due to the tasks they perform; they cover more surface area, are required to change directions and generate increases in skating velocity more frequently than defensemen. While Twist and Rhodes report that defensemen engage in similar activities, with similar intensities, the difference in frequency of the demands, necessitates forwards play less shifts, and recover longer.

Twist and Rhodes (31) report that elite ice hockey forwards and defensemen require a maximum oxygen consumption rate of 60ml/kg/min and 50ml/kg/min respectively.

Table 1.0

Comparison of VO_{2Max} Scores in Ice Hockey Players			
Reference	Level	Age (mean)	VO_{2Max} ml of O_2 /kg/min
Cunningham et al., 1976	Minor	11	56.6
Montpetit et al., 1979	University	21	58.1
Rusko, et al., 1978	National	22	61.5
Green et al., 2006	NCAA	N/A	59 +/- 4
Rhodes et al., 1988	NHL	25	54.1
Twist & Rhodes, 1993	NHL	N/A	57.4 +/1 3.1

In addition to the bioenergetic demands of ice hockey performance, the practicing strength and conditioning professional must have a biomechanical understanding of the movement patterns associated with the sport.

Task analysis indicates that hockey involves coordinated multi-joint, multi-limb movement patterns, and rapid rates of force development in executing the technical skills of skating, passing, shooting, and body checking

Biomechanical analysis indicates that hockey specific movements are classified as closed kinetic chain (14).

The Specific Adaptations to Imposed Demands (SAID) principle states that the adaptive response to training is specific to the demands of the training regimen. Effective ice hockey specific training must incorporate the SAID principle (14,19), and it is the role of the strength coach to identify the performance demands associated with successful performance, and integrate them into the athlete's training program.

Ice Hockey Specific Strength and Conditioning Programming Recommendations

Participation in Canadian junior hockey (CHL) necessitates full year athletic conditioning. More specifically, an athlete's conditioning regimen should be specific to the current demands of the athlete's season. The Canadian junior hockey season can be divided into 4 distinct season; the off-season, pre-season, in-season, and off-season, each of which, are representative of different training priorities.

Table 2.0

Summary of Training Phase Priority	
Season	Training Priorities
Off-Season	Muscle hypertrophy, strength, power and endurance Enhancing Aerobic and Anaerobic capacity Developing Agility, Speed, and Explosiveness Improving Technical Skills
Pre-Season	Returning to 'Game Shape' Refining sport specific skills and movement patterns Peaking in Aerobic and Anaerobic capacities Developing team chemistry and bonding
In-Season	Muscle strength, power, and endurance maintenance Aerobic and Anaerobic capacity maintenance Injury Prevention
Post-Season	Muscle strength, power, and endurance maintenance Aerobic and Anaerobic capacity maintenance Injury Prevention

Regardless of training priorities, outlined in Table 2.0, the purpose of training is to improve overall athleticism (14). Green et al. (13) report that a player's conditioning level may influence the coach's decision on the number of minutes they receive in a game, especially during double shifting and penalty-killing situations.

More specifically, the strength and conditioning coach is recommended to design conditioning programs that work the body as a linked system.

Human movement can be described as being the product of multiple joint and limb segments co-activated, moving the body synergistically as a linked system. This training paradigm is more appropriate, than open chain, machine based resistance training for sport specific conditioning, as it utilizes sport specific, and functional movement patterns as the basis for the development of performance based physiological attributes.

Linked system exercise patterns is more applicable and appropriate for sport, and more specifically ice hockey, as it's induced agonist / antagonist co-contraction synergy contributes to greater muscle balance and synchronization of motor unit contraction. This neuromuscular response, and adaptive response contributes to greater functional balance, and functional, sport specific strength. Sport-specific strength will help produce a lower centre of gravity and increase inertia, contributing to the development of greater dynamic stability (27).

Appendices 1.0 contains a sample of exercise movements applicable for developing total body muscular strength and power as a ‘linked’ system.

Daly et al. (5) report the injuries experience during ice hockey performance are related to direct trauma (80%) and overuse (20%), and that a participant can anticipate injury after 7 to 100 hours of hockey play. Daly et al (5) summarize the most common hockey upper extremity injuries as acromioclavicular joint dislocations, scaphoid fractures, lower extremities injuries predominately involve soft tissue, with strains of the hip adductor, tears in the medial collateral ligament of the knee, and contusions of the thigh.

Twist and Rhodes (31), report that the major cause of injury during the skating action results from inadequate strength and flexibility in the leg adductors and abductors, and that hockey players skate with a slight back flexion, placing demands on lower back strength and flexibility. Twist and Rhodes claim that without preparatory and preventative attention to the lower back area, the players back is predisposed to injury, as the lower back will not withstand the continual isometric contraction of the back extensors in the skating position and the stressful twisting actions throughout a game

The practicing strength coach must be aware that the pathology of hockey injuries is related to inadequate muscular strength and size, and flexibility profiles. Lean muscle mass is critical for reducing the risk and severity of injury, as it has the ability to absorb potential compression and shear forces preventing uneven distribution.

It is reported that both consistent participation in stretching and strength training may help prevent injury. Manners (14) concludes that absolute strength is of greater importance to the hockey player than relative strength, as it is absolute strength that is able to more efficiently absorb high impact forces, and the physical contact associated with the game at the Canadian Junior level.

Twist and Rhodes (31) further suggest that muscle balance is important for injury prevention and athletic performance. A joint may be more susceptible to injury when there is a strength imbalance between muscle groups. Hockey players should strive towards a hamstring / quadriceps strength ratio of 60 % to prevent injury to the hamstrings.

Table 3.0 is an full-year schematic training model outlining the training schedule of a typical Canadian Junior hockey player.

Table 3.0

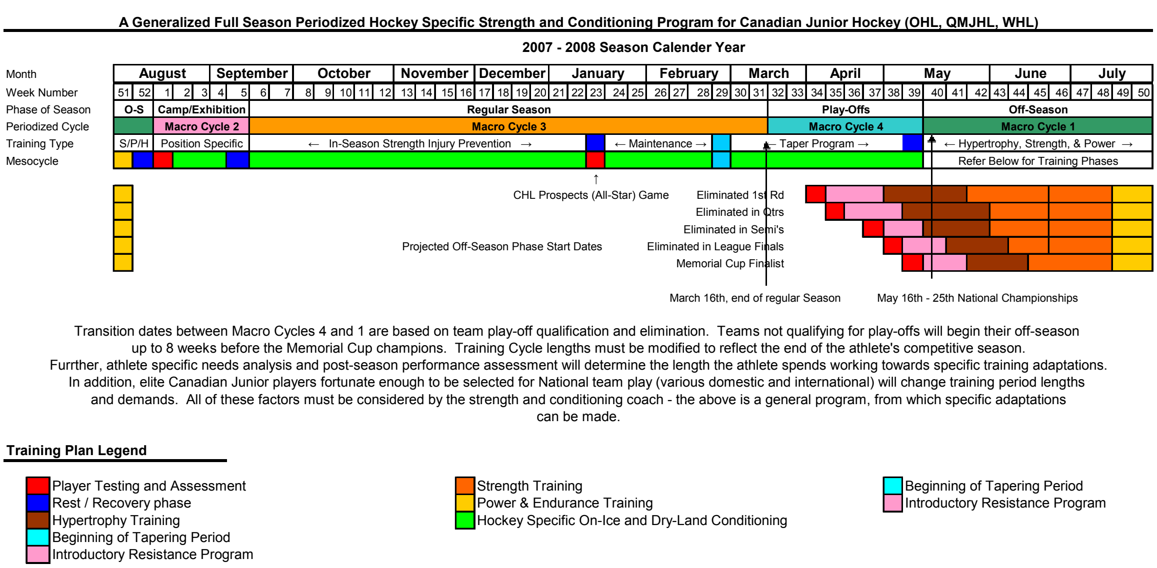


Table 3.0 outlines 4 ‘Marco’ training cycles within the training year. The following discussion will identify the training program modality differences and program design variables characteristic to each cycle, and will

attempt to provide a theoretical justification for their inclusion.

The concept of periodization is used in efforts of working towards peaking in aerobic and anaerobic capacity and muscular strength, power, and endurance at the start of the in-season, and maintaining those peak, and high percentages of those peak values throughout the entire in-, and post-season (14), while minimizing inter and intra game fatigue (4).

Ice Hockey full-season conditioning begins with the start of training camp, identified as Macro Cycle 1, and 'Week 1' in Table 3.0.

The purpose of training camp is to prepare the athlete for competitive performance. Training camp is characterized by athlete assessment, and on-ice performance.

Rosene (22) suggests that preseason assessments have become an integral part of an athlete's preparation for the upcoming competitive season, as they for the basis of physiologic performance assessment.

Green et al. (13) suggest that both on- and off-ice physiological testing should focus on aerobic capacity, blood lactate, and body composition evaluation, Rosene (22) suggests that strength testing also be included.

The pre-season testing results are the reference point. It should be expected that the athlete possess their highest strength measures during pre-season.

Table 4.0 contains a summary of physical tests that are recommended to assess the pre-season athlete's physiological attributes.

Table 4.0

Preseason Strength & Conditioning Assessment Battery

1. Anthrometric Measurements	Height Weight Body fat %
2. Strength Measurements	Bench press - body weight x 5 reps
3. Anaerobic Measurements	Wingate (peak anaerobic power) Vertitcal Jump Standing Long Jump
4. Aerobic Measurements	Maximal Oxygen Consumption

Reference: Rosene, John M. In-Season, Off-Ice Conditioning for Minor League Professional Ice Hockey Players. *Strength and Conditioning Journal*. 2002. 24(1). 22-28.

Due to the favorability of absolute strength and muscular power and endurance rather than relative strength, it is recommended that athlete testing include multiple repetition bench press and leg press exercises. Rosene (22) suggests that multiple repetition testing reduces the stress displaced on the joints and musculoskeletal system in relation to the stresses incurred from traditional 1RM testing. For the bench press it is recommended that all players be required to press 200lbs many times as possible, and 450lbs used for the leg press.

Players are measured for standing vertical jump, and standing long jump as these tests are considered to be effective field tests to provide base line data regarding short-term, explosive, anaerobic power (22).

The strength and conditioning coach can assist the coaching staff about decisions made about player's ability based on their pre-season testing performance. By comparing athlete results to published performance correlations (Table 1.0,) the work of Green et al. (13) the strength coach can assess strength and weakness characteristics.

Pre-Season Conditioning Recommendations

Pre-season resistance training programs are recommended to be designed to maximize strength gains yet allow for adequate recovery based on the training schedule (22).

Training camp is consistent with a heavy training schedule; practices, split squad and exhibition games, team meetings, travel time, and off-ice conditioning, so it is imperative that the practicing strength coach communicate the training needs associated with pre-season preparation, and the coach's athlete training demand expectations. It is only after the strength coach has a working knowledge of the athlete's schedule, that they can effectively integrate resistance and cardiovascular training sessions. Table 5.0 outlines the base pre-season resistance training program.

Table 5.0

Sample Pre-Season Resistance Training Program

Total Body Strength

All Pre-Season

Exercise	Volume (Sets x Reps)
Warm-Up (Jog or Bike)	10 mins
Flat Bench	3 x 6-8
Lat Pull-Downs	3 x 6-8
Seated Dumbbell Shoulder Press	3 x 6-8
Shoulder Shrugs	3 x 6-8
Squats	3 x 6-8
Biceps Curls	3 x 6-8
Triceps Push-Downs	3 x 6-8
Abdominal Crunches	2 x 75
Back Extensions	3 x 12-15

The set and repetition ratio is set at 3, and 6-8, in efforts of developing peak muscular strength. Relative training loads are to be set at approximately 80-85% of 1RM values.

The pre-season resistance training program encourages the athlete to lift heavy resistance as quickly as possible. Increased movement velocity, mimics sport tasks, and in theory, will assist in the development of the athlete's rate of force development and overall power output, contributing to the goal of the pre-season in developing peak strength and power profiles.

Aerobic and anerobic energy system development is also integrated into the pre-season phase. While the athlete will be engaged in significant on-ice skating drills designed to prepare the physiologic demands of performance, it is highly recommended that the athlete participate in high intensity cycling twice a week.

High intensity interval training is designed to target the oxidative, glycolytic, and phosphagen energy systems, with the intent of enhancing their efficiency and co-activation. Table 6.0 is a sample high intensity interval cycle program designed to induce a metabolic adaptive response favoring enhanced aerobic and anaerobic capacity.

Rosene (22) recommends that participation in the interval cycling session be at a local community training facility, as it is a means for team bonding, and for exposure to the local fan base. Distraction of this nature has the ability to provide the athlete with a way of enjoying the volume and magnitude of physical training endured during the course of the pre-season.

Table 6.0 is a sample 1 week pre-season training expectations model. It outlines the volume of physical activity demands characteristic of this phase

Sample Pre-Season High Intensity Interval Cycle Training Program

Time	Intensity
0 - 0:30	RPM 150 all out
0:30 - 1:30	RPM 90 at 85% HR
1:30 - 2:00	RPM 150 all out
2:00 - 3:00	RPM 90 at 80% HR
3:00 - 3:30	RPM 150 all out
3:30 - 4:30	RPM 90 at 80% HR
4:30 - 5:00	RPM 150 all out
5:00 - 6:00	RPM 90 at 80% HR
6:00 - 6:30	RPM 150 all out
6:30 - 7:30	RPM 90 at 80% HR
7:30 - 8:00	RPM 150 all out
8:00 - 9:00	RPM 90 at 80% HR
9:00 - 9:30	RPM 150 all out
9:30 - 11:30	RPM 90 at 80% HR
11:30 - 12:00	RPM 150 all out
12:00 - 14:00	RPM 90 at 80% HR
14:00 - 14:30	RPM 150 all out
14:30 - 16:30	RPM 90 at 80% HR
16:30 - 17:00	RPM 150 all out
17:00 - 19:30	RPM 90 at 80% HR
19:30 - 20:00	RPM 120 all out
20:00 - 22:00	RPM 90 at 80% HR
22:00 - 22:30	RPM 120 all out
22:30 - 24:30	RPM 90 at 80% HR
24:30 - 25:00	RPM 120 all out
25:00 - 27:00	RPM 90 at 80% HR
27:00 - 27:30	RPM 120 all out
27:30 - 29:30	RPM 90 at 80% HR
29:30 - 30:00	RPM 120 all out
Cool Down	RPM 90, easy pace
A warm-up is performed so that the Heart Rate is at 80% of age-predicted maximum or 80% of Hrmax as determined on a VO_2max test. Once 80% Max is reached, interval program begins.	

Reference: Rosene, John M. In-Season, Off-Ice Conditioning for Minor League Professional Ice Hockey Players. *Strength and Conditioning Journal*. 2002. 24(1). 22-28.

Table 6.0

Sample Pre-Season Weekly Training Expectations Model

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Heavy Resistance Training	Morning Skate Skill / System Practice	Morning Skate Practice	Heavy Resistance Training	High Intensity Interval Cycle Class	Morning Skate	Morning Skate
Group High Intensity Interval Cycle Class	Afternoon Split Squad Scrimmage	Exhibition Game	Afternoon Practice	Afternoon Split Squad Scrimmage	Exhibition Game	Exhibition Game

In-Season Conditioning Recommendations
In-Season

As the athlete transitions from pre-season to in-season competition and the associated change in physical demands, their resistance and cardiovascular training programs must transitions to reflect this change.

The athlete must no longer be concerned about developing an increase in muscular strength, power, or energy system capacity, rather to maintain the physiological abilities developed through the off-, and in-seasons.

As with the scheduling demands of the pre-season, the in-season is characteristic of similar scheduling difficulties. Travel, game, practice, and for some, high school academic schedules make it difficult to adhere to a consistent training regimen.

Table 7.0 is a sample 2 week training cycle of the in-season.

Table 7.0

A Sample 2 Week Training Cycle During the In-Season of A Canadian Junior Hockey Athlete

Week 1

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Off-Day (On-Ice Practice)	**Game** Post Game Workout	Heavy Resistance Training Program	High Intensity Interval Ride	**Game** (10-20 min post game ride)	Total Body Dynamic Strength Training Program Moderate Interval Cycle	**Game** (10-20 min post game ride)
Flexibility Trianing	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training

Week 2

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Game Post Game Workout	Off Day (On-Ice Practice)	Total Body Dynamic Strength Training High Intensity Interval Ride	**Game** (10-20 min post game ride)	Heavy Resistance Training Program Moderate Intensity Training Ride	**Game** (10-20 min post game ride)	**Game** (10-20 min post game ride)
Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training	Flexibility Training

Review of this sample training cycle it can be noticed that there are several different training programs; each with specific program designs, incorporated into the athlete's training programming.

Successful ice hockey performance requires peak muscular strength and power efforts, and energetic system efficiency. For these abilities to be maintained throughout the season, they must be continuously worked within a frequency that allows for adequate neuromuscular recovery to avoid neurological and physical fatigue.

Muscular strength and endurance is maintained through participation in a heavy resistance training program, where the training load is set at 70-85% of 1RM values, and the volume is relatively high for the training load, set at 2 sets of 10-12 reps. This high training volume and training load is intended to maintain the high strength and muscular endurance profiles assessed during pre-season and developed over the off-season.

In addition, a 'dynamic strength' training program is integrated into the in-season training regimen intended to increase joint stability, and muscular power. Utilizing the principles of plyometic movement techniques, and complex training, the dynamic strength program is designed to enhance and maintain peak power, and joint stability strength.

Tables 8.0 and 9.0 are example In-Season Heavy Resistance and Dynamic Strength training programmes.

Table 8.0

In-Season Heavy Resistance Training Program

Start of Season to All-Star Break (~Sept 21st - Jan 18th, 2008)

Training load should be set at 80-85% of 1RM, where each rep is completed through a 4-1-2-1 eccentric to concentric tempo. Completing full sets before moving to next exercise. Exercises are to be completed in the order listed.

Exercises	Volume Sets x Reps	Load % 1RM
Warm-Up (Bike or Jog)	10 mins	
Bench Press	2 x 10-12	80-85
Lat Pull Downs	2 x 10-12	75-80
Seated Dumbbell Shoulder Press	2 x 10-12	70-75
Shoulder Shrugs	2 x 10-12	70-75
Back Squats	2 x 10-12	80-85
Biceps Curl (vary technique/dumbbell or barbell)	2 x 10-12	75-80
Triceps Extensions (vary the technique)	2 x 10-12	75-80
Abdominal Crunches (vary the tecniques	2 x 10-12	N/A
Back Extensions	2 x 10-12	BW

Table 9.0

Sample In-Season Resistance Training Program
Total Body Dynamic Strength
Start of Season to All-Star Break (~Sept 21st - Jan 18th, 2008)

	Exercise	Volume (Sets x Reps)
	Warm-Up (Bike or Jog)	10 mins
	Kneeling Medicine Ball Passes	2 x 20
	Kneeling Overhead Medicine Ball Throws	2 x 15
	Rapid Body Squats Holding a weight plate	2 x 25
	Olympic Bar Explosive 45^o squat to standing press	2 x 10
	***Rest* -Variable on condition of athlete**	>1 min <2min
Complex Training →	Olympic Bar Lateral Lunges	2 x 15
	Lateral Bounds on BOSU	2 x 10
	Bi-Lateral Olympic Bar Chest Press	2 x 12
	Uni-Lateral Lateral Load Chest Press	2 x 12
	***Rest* -Variable on condition of athlete**	>2 min <4 min
	Diagonal Dumbbell Lunges	2 x 10
	Plyometric Push-up (alternate each rep)	2 x 20
	Close Grip Pull-Ups - Perform Rapidly	2 x 10
	Olympic Bar Torso Twists	2 x 10
	2 Step Run-Ups on Plyo Box (fast as possible)	2 x 35
	Rapid Body Squats Holding a weight plate	2 x 20
	Intensity can be increased by wearing a weighted vest or by decreasing the rest intervals	

Table 3.0 indicates that the in-season is characterized by 3 distinct phases; from the start of the season to the all-star break, from the all-star break to the start of a taper program, and a taper program through to the end of the play-offs.

Strength training program design is changed after the all-start game. This is done in efforts of preventing neuromuscular plateau, and to trigger continuous stress at the myofibular level, and progressive training adaptations.

The differences that are included include changes in exercise selection, rather than training intensity. Changes in movement pattern and technique are a more appropriate method of program design change than changing the intensity or training load. The second half of the competitive season is associated with prolonged fatigue and recovery from game play. Increasing training intensity and training load at this point in the season would be counterproductive. However, making changes in exercise selection, changes reflective of movement pattern allow from changes in muscle co-activation and synchronization, and allow for continued neuromuscular adaptations, and the associated performance attributes; power, strength, speed etc.

Table 10.0 is a sample dynamic resistance training program for the period following the all-star game to the start of the taper period.

Table 10.0

Sample In-Season Resistance Training Program
Total Body Dynamic Strength
After All-Star Break to Start of Taper (Jan. 20th to Mar. 15th, 2008)

Exercise	Volume (Sets x Reps)	Load %1RM
Warm-up (Bike or Jog)	10 mins	
Back Squat on Inverted BOSU	2 x 12	33 - 45
Push-ups on Stability Ball with Feet Elevated	3 x 8	N/A
45^o Lateral Lunge on Stability Ball holding Dumbbell	2 x 12	N/A
Traditional Bench Press with Dynaband Tubing	3 x 12	75 - 85
Cable 45^o Strides	2 x 15	15 - 40lbs
Squat Stance to Standing Cable Back Row on Inverted BOSU	2 x 12	70 - 80
Single Leg Plyo Box Drop Steps	3 x 8	N/A
Inverted Pull-Up on Stability Ball	3 x 10	N/A
Dumbbell Chest Fly on Stability Ball	2 x 10	70 - 80
1/4 Squat Stance Uni-lateral Back Row	2 x 10	70 - 80
Push-Up position on Dumbbells, into full uni-lateral external rotation of the shoulder and torso	2 x 8	N/A
Standing Cable Axe Chops	2 x 15	30 - 60lbs
Standing Olympic Bar Torso Twists	2 x 15	45+lbs

Rosene (22) suggests that a taper period is required for ice hockey athletes as they approach post-season competition. A taper program is designed to reduce the intensity of the work-outs and to allow for optimal recovery. The taper period ideally begins 3 weeks prior to the 1st play-off game.

However, the strength and conditioning coach must be perceptive to the ever evolving physical condition status of the athlete, and remain in constant communication with the coaching staff. Games at the end of the season rarely are with out significance, alterations in one's training regimen, whether too early or too late, may have negative consequences on athlete performance. Tapering must be done in consideration of on ice performance.

Rosene (22) suggests that to accomplish an effective taper for all athletes, the team must be divided into 3 separate groups; a) players who play more that 20 min/game, b) players who play 10-20 min/game, and c) players who play less that 10 min/game. Players who play 20 min/game need more recovery than those who play less than 10, therefore those players who have higher playing times begin to focus on maintaining their cardiovascular fitness levels rather than lifting heavy weight, where players who play 10 to 20 mins a game incorporate slight reductions in weight training intensity and volume, and increase their cardiovascular fitness. Players who play for less than 10 minutes a game, do not taper any aspect of their 2nd half of the in-season program as they do not need extended recovery (22).

The taper phase continues into the 3rd season, the post-season. A taper based conditioning program is specific to this phase of the competitive year, as the physical demands of these games is the most intense of the year, within the shortest time period. Post season 'series'' are competed as a best of 7, within 14 days. The high intensity of play-off hockey, and the frequency of the games dictates that the athlete focus and schedule, adequate recovery. Continued heavy resistance or power training would be counterproductive and increase neuromuscular and neurological fatigue and associated performance decrements.

The taper phase continues to the end of the post season, and is completed with the conclusion of post-season fitness testing.

Off-Season Conditioning Recommendations

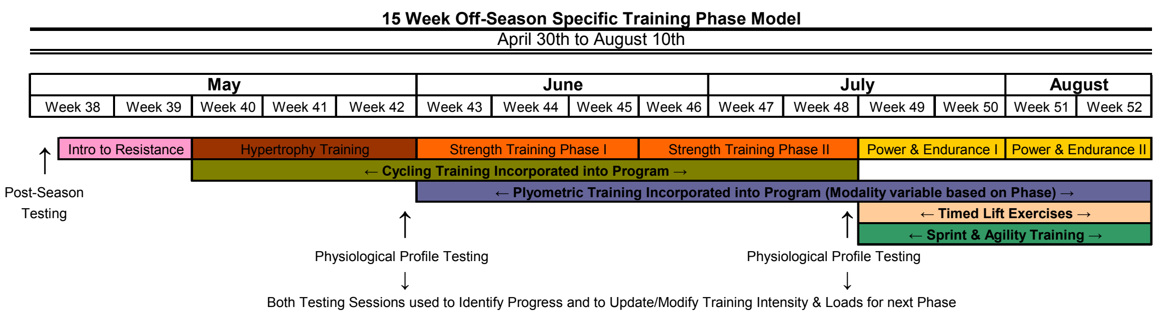
Off-season conditioning is the training phase that is structured to develop increases in lean muscle mass, peak strength, peak power, and peak aerobic and anaerobic profiles.

Depending on the end date of the athlete's season, they are subject to a longer or shorter off-season. For example, for an athlete not making the play-off their off-season will start in mid March, while the athlete who competes in the 4 team Memorial Cup National Championship will have an off-season the begins at the end of May. This constitutes a 10 week difference in off-season training time.

Ideally, the strength coach will develop, and cycle hypertrophy, strength, and power and endurance phases. The length of these phases is subject to the length of the total off season, and as such, the strength coach must be innovative with an element of creativity, in developing the off-season conditioning program.

Table 11.0 represents the off season training phase schedule of an athlete who's team was eliminated after the 1st round of league play-offs, and has a 15 week off-season.

Table 11.0



The off-season begins following post season testing and a week or two of rest. Rest and recovery is important at this time of the season as players have been physically and psychologically engaged in intense competition, and have been away from family, and require time to recover from the volume of the year.

The volume of rest a player takes at the end of the season will be dependant on the coaching staff's recommendation after consultation with the strength coach's evaluation of post-season performance testing, and consideration of the athlete's role on the team; whether they are returning the following season, whether they'll be cut or traded, or if they will be advancing to higher levels of competition.

The 1st 2 to 3 weeks of the off-season conditioning program is characterized by a 'Resistance Intro' program, designed to get the athlete used to pushing heavy resistance again after tapering for the previous 5-6 weeks. Volume and intensity are both moderate, and exercise selection is fairly basic (4).

The 2nd off-season phase is a 3 week hypertrophy phase. Hypertrophy is scheduled before strength phases due to the positive relationship between muscle size and strength profiles (14). Training intensity is set to 70-75% 1RM, where the athlete completes 4-5 sets of 8-10 reps of 3-5 exercises per muscle group in a given training day.

Training speed is purposefully slowed down to extend the duration of the training stimulus and to eliminate any momentum that might reduce training intensity. Rest periods are reduced; short rest, combined with high-repetition training have positive effects on levels of testosterone and human growth hormone. Repetitions are increased, because of the positive effects on levels of testosterone and human growth hormone. Training protocol is adjusted. To further stimulate muscle hypertrophy, supersets (2 exercises back to back with no rest) are performed during the hypertrophy cycle (14).

Table 12.0 outlines the weekly training expectations of a typical hypertrophy training phases Due to the increase in training time availability, the training cycle is divided as a split program, with upper and lower body strength training both being completed 2 times a week.

It can be argued that the training volume outlined above is not significant enough to induce hypertrophy training gains. While other protocols may develop greater hypertrophic responses, the off-season of a Canadian Junior hockey player requires them to seek employment outside of hockey. Due to these various demands, it can be difficult to participate in more than 4 dedicated weight training sessions in a week.

Table 12.0

Sample Off-Season Weekly Hypertrophy Phase Training Expectations Model

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Specialized Training * If the Athlete has 'special' training requirements ie. Balance, Core/Rotational strength	Lower Body Strength Training High Intensity Cycle (80-85%) Flexibility Training	Upper Body Strength Training Light Cycle (70-75%) Flexibility Training	Off Day Interval High Intensity Cycle Training Class Flexibility Training	Lower Body Strength Training Light Cycle (70-75%) Flexibility Training	Upper Body Strength Training High Intensity Cycle (70-75%) Flexibility Training	Off Training

In addition to hypertrophic gains, the athlete is recommended to participate in high intensity interval training along side lighter aerobic conditioning to stress both the anaerobic and aerobic energy systems.

Based on the 15 week off-season schedule, 2 strength phases are to be incorporated; strength phase 1 beginning at Week 43, and phase 2 beginning at Week 47 (Table 3.0). Each of these strength phases are 3 weeks in length, and are characterized by changes in training intensity (14).

It is recommended that athletes select a resistance that will allow full completion of repetitions on the 1st set only. By not having to complete the full number of reps on each set, the athlete's are able to train with greater intensity.

Further, speed of movement is increased. A faster training speed allows the athlete to train with greater resistance on the bar. Rest periods are extended to allow for greater recovery time between sets, thus increasing subsequent set intensity. The number of reps is decreased. As the in-season approaches, the resistance becomes more movement specific. As the competitive phase draws nearer it makes sense to select exercises that will result in increases in strength and power in movement patterns that are specific to the sport (14). Appendix 1.0 contains a collection of hockey specific exercises.

It is during these strength phases that plyometic training exercises are incorporated into the training program (14). Plyometric training is associated with activating the stretch shortening cycle and harnessing the energy contained within the series elastic components of the myotendinous unit.

Plyometic training is performed on lifting days, but prior to any resistance training. Finally, beginning with the 1st in-season cycle and continuing during the competitive phase, plyometric training is complexed with resistance training. This sequence is followed to provide a less stressful introduction to plyometric training, followed by a gradual progression to complex training (14).

Two player assessment testing sessions are scheduled during the strength phases, one at the initiation of phase. The purpose of these assessment sessions is to evaluate 1RM values to individually modify the athlete's training program.

The final phase of the season long training program is the power and endurance phase. This phase (Table 3.0), is divided into 1 three week phase, which precedes the start of training camp.

Hedrick (14) reports that to match the demands of the sport, emphasis is placed on developing a combination of power and endurance, so that the athletes can play a high-speed physical style of hockey over 3 periods.

Power and endurance is facilitated through continued participation in plyometric exericise, and the inclusion of timed exercise (14).

Timed exercise shift the emphasis from how much resistance the athlete can lift to how quickly the athlete can lift a resistance. During a timed exercise, the athlete selects as heavy a resistance as possible that allows completion of the full number of required reps in good form in the specified time period. This shifts the emphasis from how much resistance can be lifted, to how quickly the resistance can be lifted. By decreasing the rest between sets and between reps, the athlete can induce a greater anaerobic adaptive response, physically expressed as being able to produce more work over a longer period of time.

At the end of this power / endurance phase, the athlete is ready to enter training camp with highly developed aerobic and anaerobic energy systems and muscular strength and power profiles.

Practical Applications

A review of time motion, and physical demands analysis indicate that elite ice hockey performance is characteristic of closed kinetic chain movement patterns powered through highly developed aerobic and anaerobic energy systems.

Applying the principle of specificity, hockey training programs are recommended to include elements of periodization where linked system movement patterns are utilized in a program design characteristic of the demands a particular training phase. Distinct training guidelines exist for pre-, in-, post-, and off-season phases, and if structured and scheduled appropriately, are capable of inducing enhanced performance attributes.

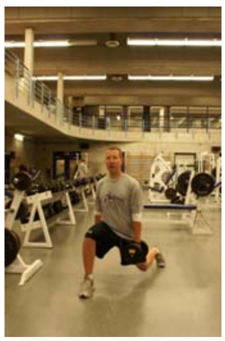
Appendices 1.0

The following is a collection of exercise movement patterns and techniques that are associated with ice hockey specific movements. Each exercise will induce a varying degree of muscular strength, power, or endurance adaptive responses. The magnitude of adaptive response will be subject to the speed of the lift, the training load and volume, and the length of recovery between subsequent repetitions, and sets.

Body Squat with Weight Plate Press



Dumbbell Forward Diagonal Lunges

Bi-Lateral Olympic Bar Press (Alternating)

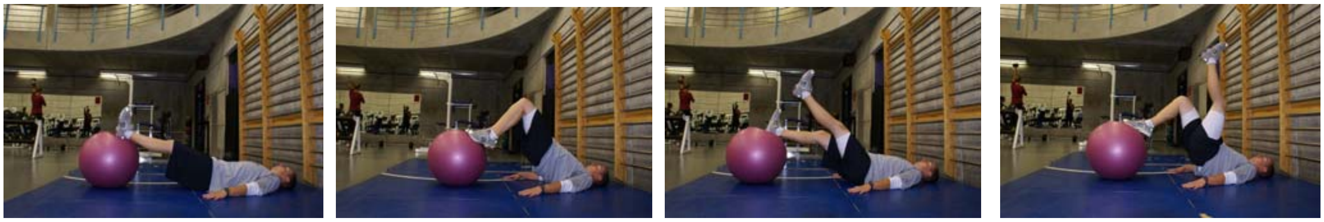


Uni-Lateral Olympic Bar Press (Lateral Load to Press)





Stability Ball Hamstring Curl (Single Leg Curl)

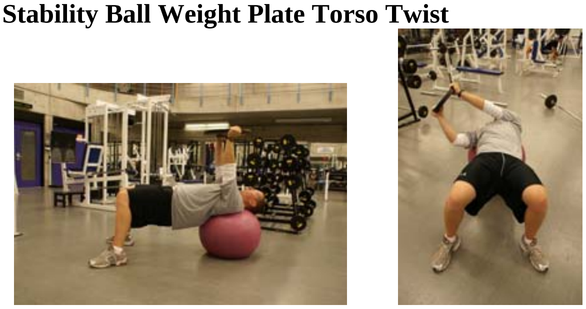


Stability Ball Stick Push-Up

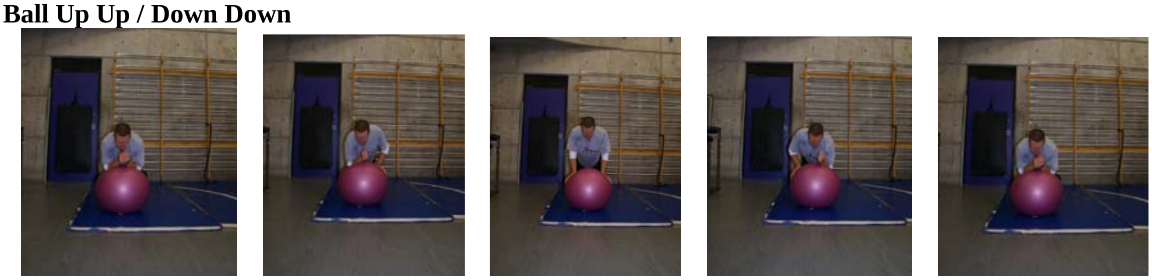
Partner Assisted Stick Press (on inverted BOSU)

Olympic Bar Torso Twist

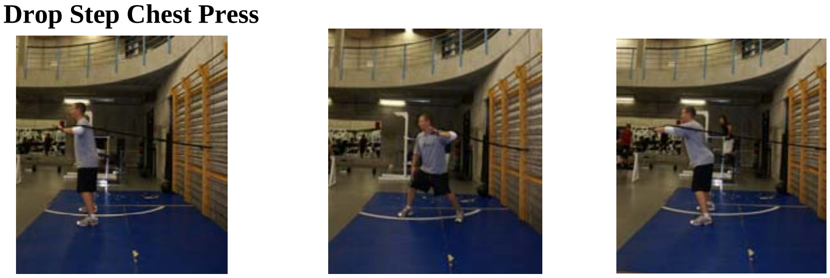
Stability Ball Weight Plate Torso Twist



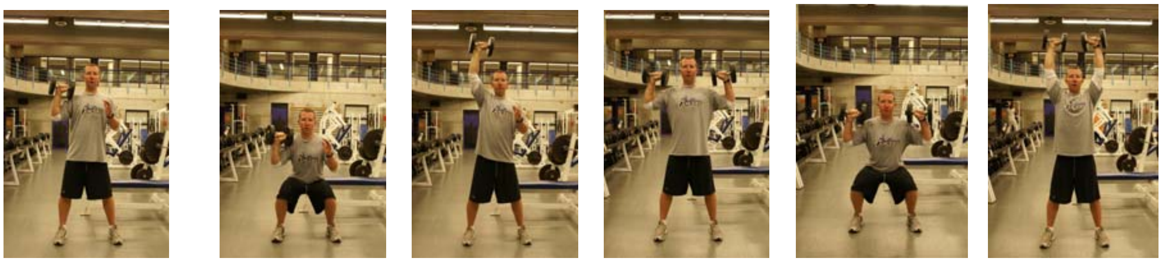
Stability Ball Up Up / Down Down



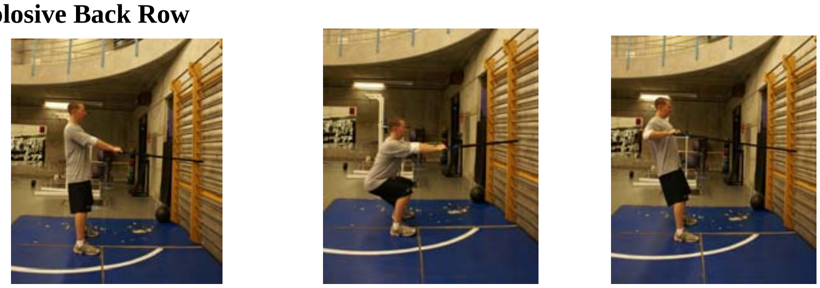
Dynaband Uni-Lateral Drop Step Chest Press



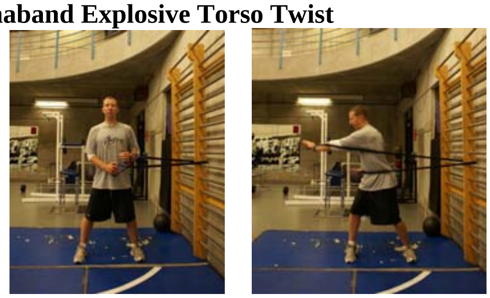
Body Squat to Uni- and Bi-Lateral Dumbbell Shoulder Press



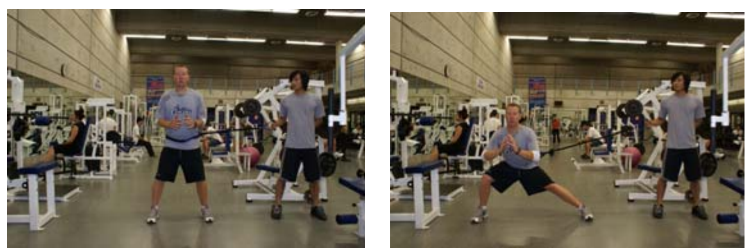
Dynaband Squat to Explosive Back Row



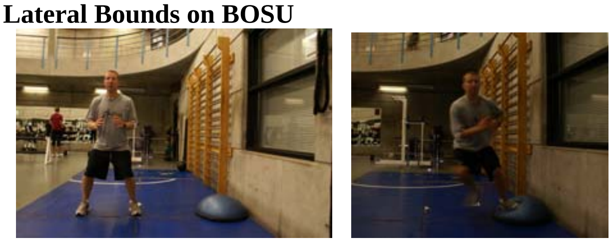
Dynaband Explosive Torso Twist



Dynaband Resisted Lateral Lunge



Lateral Bounds on BOSU



Dynaband Resisted Sprints

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