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Strength and Body Composition Changes of Junior Hockey Players during the Competitive Season

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STRENGTH AND BODY COMPOSITION CHANGES OF JUNIOR HOCKEY PLAYERS DURING THE COMPETITIVE SEASON

BY

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THESIS ACCEPTANCE PAGE

Dan Marquette

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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CONTENTS

ABBREVIATIONS

cm	centimeter
deg/sec	degrees per second
DXA	dual x-ray absorptiometry
FFM	fat free mass
ft*lb	foot pounds
g	grams
HII sports	high-intensity intermittent sports
HR_{max}	maximum heart rate
kcal	kilocalorie
Kg	kilogram
L	liter
LEA	low energy availability
lbs	pounds
Mmol	millimole
msec	milliseconds
SNKQ	Sports Nutrition Knowledge Questionnaire
$VO_{2\ max}$	maximum volume of oxygen consumption
1-RM%	percentage of maximum 1-repetition strength

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

STRENGTH AND BODY COMPOSITION CHANGES OF JUNIOR HOCKEY PLAYERS DURING THE COMPETITIVE SEASON

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Purpose: This study investigated the body composition and strength changes of NAHL junior hockey players across a competitive season. It was hypothesized that players would lose lean body mass loss from pre-season to end-season. The secondary hypothesis was that players would lose strength in relation to the anticipated loss in lean body mass.

Methods: Outcome measurements were taken at pre-season, mid-season, and end-season points of a competitive NAHL junior hockey season (n = 15, age = 19.1 years). Body composition was measured using air plethysmography (BodPod) and strength was measured using isokinetic strength testing (Biodex).

Results: No significant changes in body composition were observed during the competitive season. Knee-extension time to peak torque at 60 deg/sec was significantly higher during the pre-season (675.7 ± 250.8 msec) than during the mid-season (451.4 ± 96.5 msec) and post-season (465.7 ± 82.2 msec) ($p<0.05$). Time to peak torque showed no significant change at any other velocity in knee-extension measurements during the season. Knee-flexion relative peak torque at 60 deg/sec and 150 deg/sec significantly decreased from pre-season to mid-season (96.2 ± 19.3 ft*lb/kg to 72.8 ± 13.3 ft*lb/kg, 65.5 ± 9.0 ft*lb/kg to 49.6 ± 11.3 ft*lb/kg). During the second half of the season, relative peak torque at 150 deg/sec significantly increased to near pre-season levels (49.6 ± 11.3

ft*lb/kg to 67.4 ± 14.0 ft*lb/kg). Total work at 60, 150, and 300 deg/sec increased during the second half of the season (495.4 ± 158.3 ft*lb to 764.2 ± 127.0 ft*lb; 330.9 ± 149.0 ft*lb to 609.8 ± 72.7 ft*lb; 196.1 ± 130.8 ft*lb to 370.0 ± 114.4 ft*lb). There were no significant differences between the pre-season and end-season measurements of peak torque, relative peak torque, time to peak torque, or total work for knee flexion.

Conclusion: No significant changes in lean body mass or total body mass were observed in junior hockey players during their competitive season. This indicates that the players attained energy balance throughout the season. Additionally, players did not experience changes in peak torque, relative peak torque, or time to peak torque in knee-extension or knee-flexion. Players did, however, experience a significant increase of total work in knee extension. These results suggest lower body strength was successfully maintained throughout the season. Lastly, players displayed low levels of sports nutrition knowledge on the SNKQ.

LITERATURE REVIEW

Physiological Demands of Ice Hockey

Ice hockey is a physically demanding sport that involves frequent periods of acceleration, change of direction, and high-impact collisions between players.[1] Junior level competition consists of three 20-minute periods in which skaters continuously rotate on and off the ice. In a single game, each player completes 14-to-21 shifts averaging 85.4 seconds, each of which contains an average of 58.3 seconds of play and 27.1 seconds of stoppage time.[2] However, under circumstances such as a penalty kill, players can experience shifts exceeding 90 seconds.[3] Shift length can also vary depending upon a player's position.[1,2] Forwards typically remain on the ice for 35% of the game, whereas defensemen can remain on the ice for up to 50% of the game.[2] This variation can be explained by positional assignments on the ice. Defensemen are responsible for preventing opposing players from entering their defensive zone, and therefore cover less ground. Forwards, on the other hand, experience more frequent bursts of high-intensity skating in order to compete for the puck.[1,2]

On-ice shifts remain relatively short in order to maintain a high level of intensity. This pattern of play, known as high-intensity, intermittent exertion (HII), places a significant demand on both aerobic and anaerobic energy systems. On the ice, players experience heart rate values averaging 85% HR_{max}, with peak values averting 90% HR_{max}.[1,4] Skating at this intensity causes blood lactate levels to average 8.15 mmol/L and peak at 13.7 mmol/L, indicating a significant level of glycolytic metabolism.[3] During periods of recovery, skaters must rely on aerobic metabolism to replenish large amounts of ATP and metabolize the byproducts of anaerobic metabolism.[5]

Body Composition

Body composition is comprised of fat mass, muscle mass, total body water, and bone mineral mass. These measurements are commonly displayed using a two-compartment model that is divided into fat mass and lean body mass (a combination of muscle mass, total body water, and bone mineral mass). An individual's body composition is primarily influenced by age, sex, and activity level.[6] Decrements in lean mass and increases in fat mass are associated with aging.[7] Conversely, physical activity is associated with greater amounts of lean body mass and lower amounts of fat mass.[8]

An individual's body composition, especially body fat, can be an indicator of health status, nutritional status, and long-term disease risk.[9] This is because body fat plays a fundamental role in storing energy, nutrients, and acts as a chemical messenger.[10] In order to adequately perform these functions, males require a body fat level of 3-5%, whereas females require 10-13%.[6] This level of fat is known as *essential body fat*. It can be of concern when an individual does not have enough body fat because the physiological process dependent upon fat will be inhibited. Similarly, elevated levels of body fat can also be concerning because it increases the risk of developing cardiometabolic health conditions such as type-2 diabetes, hypertension, and heart disease.[9]

Body Composition & Ice Hockey Performance

Body composition has a significant impact on athletic performance in strength and power sports. Specifically, higher amounts of body fat or inadequate amounts of lean mass can negatively impact an athletes speed, strength, and power.[1,11,12] In order for ice hockey players to accelerate quickly and reach a high top speed, they must produce a significant amount of force. This requires a significant amount of muscle mass; however, too much mass can be detrimental to an athlete's ability to change direction. Therefore, ice hockey players must optimize relative power (power-to-weight ratio) over absolute power. This is achieved by having a moderate amount of lean mass and minimizing non-essential fat mass. For this reason, elite-level hockey players tend to be leaner and have more muscle mass than sub-elite players.[13,14] Division-I players tend to be heavier (184.92 lbs compared to 178.55 lbs) and leaner (11.46% compared to 14.36%) than division-III players.[13] Similarly, elite senior-level players to be leaner than sub-elite senior-level players (13.17% compared to 16.53%).[14] Player body composition also varies in regard to position. As previously mentioned, defensemen cover less ground and experience more physical contact while on the ice.[1] Therefore, they tend to be heavier and larger in stature than forwards, while forwards tend to be leaner and more agile.[15]

Nutritional Needs of Ice Hockey Players

Energy Balance. The foundation of an athlete's diet is energy balance. Energy balance is the difference between energy intake and energy expenditure (energy balance = energy intake - energy expenditure). Energy intake consists of the total number of calories consumed in the form of energy-containing macronutrients (carbohydrate, fat, and protein), and energy expenditure consists of an athlete's basal metabolic rate, thermic effect of food, and energy expenditure through physical activity. When energy intake is equal to energy expenditure, an individual is at energy balance. Maintaining energy balance over time will keep the body's energy stores (glycogen, fat, and amino acids) constant. When energy intake exceeds energy expenditure, a positive energy balance occurs, total body mass will increase. Conversely, when energy expenditure exceeds energy intake, total body mass will decrease. In order to achieve energy balance during periods of heavy training, male ice hockey players may need to consume up to 40-45 kcal/kg/day.[16]

Low Energy Availability. When energy expenditure significantly exceeds energy intake, the body has an insufficient amount of energy to support normal physiological functions, a condition known as low energy availability (LEA). To avoid starvation, the body will then decrease energy expenditure by blunting various physiological functions. This can result in the impairments of the endocrine,[17] hematological,[18] cardiovascular,[19] and gastrointestinal systems.[20] Additionally, LEA can also impact bone health,[21] metabolic function,[22] reproductive health,[23] and can increase the prevalence of illness and injury.[24] When an individual experiences health-related impairments related to low energy availability, it is termed *relative energy deficiency in sport* (RED-S).

Carbohydrates. Carbohydrates are the primary source of energy during high-intensity exercise. During intense training, carbohydrate utilization drastically increases. For example, plasma glucose and muscle glycogen supply about 50% of energy during moderate intensity exercise (65% $VO_{2\ max}$) and about 65% of energy during high-intensity exercise (85% $VO_{2\ max}$).[25] Due to the high rate of glycogen utilization during high-intensity exercise, glycogen stores can become depleted within 30-60-minutes.[25] This impairs high-intensity exercise performance and can increase the rate of amino acid metabolization.[26] Based on current recommendations, competitive male ice hockey players training 1-2 hours per day should consume 6-10 g/kg/day of carbohydrate to maintain glycogen stores.[27]

Protein. The primary role of dietary protein is to provide amino acids for lean tissue maintenance and repair. However, protein's function changes when glycogen stores are depleted. When glycogen stores become insufficient, the body must instead rely on triglycerides and amino acids.[28] This prevents some amino acids from being utilized for their intended purpose of lean tissue maintenance and repair. Overtime, this may lead to a net loss of amino acids and, therefore, lean mass.[28] When carbohydrate consumption is adequate, recommendations suggest competitive male ice hockey players consume 1.2-2.0 g/kg/day of protein during competitive season training.[27] However, protein intake levels as high as 2.3 g/kg/day have helped athletes maintain lean body mass during periods of negative energy balance.[29] Therefore, a protein intake towards the upper end of 1.2-2.0 g/kg/day may be beneficial during competitive season training.

Dietary Fat. Dietary fat provides a significantly lower energy contribution than carbohydrate during high-intensity exercise. Nonetheless, dietary fat is an important component of a well-rounded diet. The general recommendation for dietary fat consumption is 20-35% of an individual's total caloric intake.[30]

Dietary Intake Patterns of Ice Hockey Players

Competitive athletes often segment their annual training plan into phases to best develop the physiological adaptions required to excel at their sport.[31] Commonly, these phases consist of a preparatory (off-season), pre-competitive (pre-season), competitive (main competition), and transition phase (active recovery). Each phase varies in respect to the type, overall volume, and intensity of training in order to achieve a specific physiological adaption. For example, preparatory training utilizes a higher volume of less-intense training to increase aerobic endurance, speed, and strength through lower-intensity training sessions.[31] During pre-season training, the goal is to increase sport-specific endurance in preparation for competitive season training demands.[31] This requires a gradual increase of training intensity with a lower overall training volume. As an athlete enters the competitive season, training is focused on maximizing an athlete's sport performance.[31] This requires a higher volume of sport-specific training sessions, which for ice hockey players, is extremely demanding.

The variations in training volume and intensity cause significant fluctuations in nutritional need.[32] Limited studies exists analyzing the specific dietary practices of ice hockey players; however, current literature suggest other HII athletes struggle to accommodate these changing during periods of heavy training .[32–37] Reed et al. reported division-I female soccer players to maintain a very low energy intake (<30 g/kg/FFM) throughout their competitive season.[33] According to self-reported diet records, players consumed less energy as the season went on even though energy expenditure increased. Players consumed 2794 ± 233 kcal/day during the pre-season, 2208 ±156 kcal/day during the mid-season, and 2161 ±143 kcal/day during the post-season, which resulted in a more severe energy deficit as the season progressed.[33] Zabriskie et al. reported similar struggles amongst division-II female lacrosse players.[32] Players in this study self-reported consuming consistent amounts of energy, carbohydrate, protein, and fat throughout an annual training plan even though energy expenditure significantly varied. A nutrient analysis of their dietary intake revealed they maintained a negative energy balance ranging from -366 to -719 kcal/day (22.9 to 30.6 kcal/kg) throughout the entirety of their competitive season.[32] Similar findings have also been reported in collegiate basketball players,[34] triathletes,[38] volleyball players,[38] basketball players,[38] handball players,[38] and swimmers.[38]

While many HII athletes have been reported to experience negative energy balance during training, the severity varies in relation to their age, sex, and sport.[38] Silva et al. analyzed variations amongst the energy balance of 80 athletes (54 male, 26 female) competing at the national and international level. Using double labeled water, researchers observed the 80 athletes to have an average negative energy balance of -17.4 +/- 72.7 kcal/day. Upon further analysis of this data, researchers found age, sex, and sport to have a significant impact on the magnitude of an energy deficit.[38] These findings demonstrate the importance for analyzing dietary intake patterns of each cohort of athletes in order to assess their risk of developing physiological impairments related to LEA.

Competitive Season Body Composition Changes

Only two studies have assessed the longitudinal body composition changes that ice hockey players experience during their competitive season, neither of which being junior hockey players. Delisle-Houde et al. observed collegiate male players to experience significant body composition changes during a 43 game season (no specific time frame noted).[39] Researchers in this study compared body composition measurements at pre-season, mid-season, and end-season points using Dual-Energy X-Ray Absorptiometry (DXA). Throughout the season, player body fat reportedly decreased by 1.2% during the first half of the season increased by 1.2% during the second half of the season.[39] Players in this study did not experience any changes in lean mass. Prokop et al. observed similar trends in a group of Canadian collegiate hockey players.[40] Regional DXA analysis showed players lost fat mass (-0.79 kg) and upper body mass (-0.25 kg), but gained a lower body mass (+0.29 kg) during their seven-month competitive season.[40] Although there was no significant change in total lean body mass, there was a significant change in lean mass distribution.[40]

While studies observing ice hockey players may be limited, other HII sport athletes sports experience fluctuations in body composition throughout an annual training plan.[41–45] Carling and Orhant observed body composition changes to occur in professional male soccer players during a seven-month competitive season based on skinfold measurements.[43] While player body mass stayed consistent, lean mass and relative fat mass fluctuated throughout training. Lean body mass increased from pre-season to post-season (+0.89 kg), while body fat decreased from pre-season to mid-season (-0.62 kg) and increased from mid-season to end-season (+0.61 kg).[43] Minett et al. also reported significant body composition changes amongst division-I female soccer players during their competitive season.[42] Starting players in this study lost 1.7% (-1.2 kg) of their lean mass and maintain body fat levels during a 3-month period according to DXA measurements.[42] The non-starters in this study did not experience any significant changes in body composition.

Harley et al. analyzed the body composition changes of professional rugby players across a seven-month competitive season using DXA analysis.[44] During the first half of the competitive season, player total body mass, lean body mass, fat mass, and relative body fat remained consistent.[44] During the second half of the season, players gained relative and total fat mass (+4.98% and +4.09%) and lost lean body mass (-1.51%).[44] Binkley et al. found comparable results in division-I football players using DXA.[41] Players in this study lost 1.3 kg of total body mass (-1.2%) and 1.4 kg of lean body mass (-1.6%), but did not experience any significant changes in absolute fat mass across their competitive season.[41]

Trexler et al. observed the body composition of division-I football players to improve from pre-season to post-season (eight-months).[46] DXA analysis showed players became leaner (-0.6% relative body fat) and gained lean mass (+1.7 kg) during their competitive season.[46] Similarly, Devlin et al. reported professional male soccer players maintained both lean mass and fat mass during a seven-month competitive season.[47] The authors in both studies attributed the favorable mid-season body composition changes to individualized strength and nutrition programs followed throughout their season.[46,47]

The unfavorable body composition changes that many athletes experience during their competitive season should be of major concern. Decrements in lean mass negatively impact an athlete's power-to-weight ratio, strength, and can increase the risk for injury.[48,49] A loss of total body mass over a period of time suggests an athlete has experienced a prolonged period of negative energy balance and is at risk of experiencing LEA-related health complications. As previously mentioned, this can include impaired functioning of the endocrine,[17] hematological,[18] cardiovascular,[19] and gastrointestinal systems,[20] and can impact bone health,[21] metabolic function,[22] and reproductive health.[23] LEA can also increase the prevalence of illness and injury.[24]

INTRODUCTION

Energy demands to support training during the competitive season of athletics can exceed 5,000 calories per day depending on the intensity level, and duration of training. This can subject athletes to prolonged periods of negative energy balance, resulting in the loss of lean body mass, strength, power, and an increased risk for injury and illness.[24] Previous findings have demonstrated that soccer,[42,43] football,[41,46] rugby,[44] and ice hockey players[39,40] competing at the collegiate and professional level experience body composition changes during their competitive seasons, however, these changes remain inconsistent across sports, sexes, and age groups.[38] Thus, it is important to understand the specific physiological changes that occur in each sport to ensure athletes are able to perform optimally and stay healthy.

The intensity and duration of an ice hockey training establishes a high energy demand for players. Ice hockey players experience heart rate values averaging 85% HR_{max}, with peak values averting 90% HR_{max}.[1,4] Play at this intensity causes blood lactate levels to average 8.15 mmol/L and peak at 13.7 mmol/L, indicating a significant level of glycolytic metabolism.[3] Similarly demanding sports, such as football, soccer, and rugby have also demonstrated a high-energy requirement for athletes.

While research has reported some athletes to experience a consistent negative energy balance during training,[32–34,37] research observing the dietary intake patterns of ice hockey is limited. The goal of this study was to monitor changes in body composition, strength, and energy intake across the competitive season of a North American Hockey League (NAHL) team to determine if any physiological changes were related to energy balance. In comparison to other sports, there was expected to be a greater change in both strength and body composition due to the high energy demand of ice hockey and grueling eight-month competitive season. This study included current NAHL players aged 17-to-20 and monitored strength and body composition at two-month intervals. Additional variables measured were nutrition knowledge, dietary intake, and training volume. Isokinetic strength testing was used to measure lower body strength and air plethysmography was used to analyze body composition. The specific aims of this study were:

1) To determine the change in body composition over a NAHL junior hockey season. It was hypothesized that the subjects will experience a loss in overall body mass and lean body mass during their competitive season. This hypothesis was made based on the observed physiological changes in sports with similar energy system demands.[39–44]
2) To determine if player strength changes over a NAHL junior hockey season. It was hypothesized that the subjects will experience a decrease in strength proportional to their anticipated loss in lean body mass.

METHODS

Study Design

The overall aim of this study was addressed using a prospective cohort study design. Players from a local tier-two junior hockey team was observed throughout an 8-month competitive season (mid-September to early-April). The outcome measurements of this study were changes in muscular strength and body composition, which were measured at baseline (mid-October), mid-season (mid-December), and end-season (late-February). Body composition was tested using air displacement plethysmography. Muscular strength of the knee extensors and flexors of each athlete's dominant leg were tested using an isokinetic dynamometer. Body composition and muscular strength measurements were conducted within one week of each other. Additional covariates that were tracked included dietary intake using a three-day diet record, total training volume (on-ice and off-ice), and sports nutrition knowledge using a validated sports nutrition questionnaire. This study was approved by the South Dakota State University Institutional Review Board.

Subjects

The participants were recruited from the Brookings Blizzard NAHL Hockey Team. The roster size consisted of 25 players, 18- to 20-years of age. Of the 25 total players, 15 enrolled in the study at the start of pre-season (n = 15, age = 19.1 years). Of these 15 players, five were excluded from the mid-season measurements due to being cut or traded during the first half of the season (n = 5). An additional three players were excluded from the end-season measurements due to being cut or traded during the second half of the season (n = 3). There were seven players who tested at all three testing sessions (n = 7). Recruitment was performed by word of mouth and promoted by the Brookings Blizzard coaching staff. To increase participation, prospective participants were provided an opportunity to observe an isokinetic strength test and air displacement plethysmography test on the internet to familiarize them with the testing procedures. They were also given an opportunity to meet with a registered dietitian during the season to discuss their individual body compositions in relation to their on-ice performance.

Training Schedule. During the competitive season, players maintained a physically demanding weekly schedule (see Table 1). Players participated in four high-intensity, on-ice practices per week that consisted of sport-specific drills, scrimmages, and on-ice conditioning. Prior to competition, the team had a 45-minute low-intensity on-ice practice to review player assignments and game strategy. Players averaged two games per week, typically at the same location, and competed in 60 games throughout the entirety season. Away games included an additional two-to-five hours of travel to and from the host site.

Table 1. Sample weekly schedule during the competitive season

	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Morning	Resistance Training (45-min)		Resistance Training (45-min)		Pre-Game Skate	Competition	Off
Afternoon	On-Ice (75-min)	On-Ice (75-min)	On-Ice (75-min)	On-Ice (75-min)			
Evening				Travel (if away)	Competition	Travel (if away)	

Players also engaged in a 30-minute, full-body strength training twice per week throughout the duration of the competitive season. Each strength training session was preceded by a 15-minute dynamic warm up. The goal of the strength training program was to prevent on-ice injury and maintain strength and power. The population being trained were considered novice lifters and had limited experience completing an off-ice sports performance program. The workout structure consisted of plyometric exercises, Olympic-style full-body movements, multi-joint strength variants of squats, hip-hinges, pushes, presses, and pulls, with additional supplementary exercises targeting core and hip muscles. Weeks 1-4 focused on anatomical adaptions at 65-80% of 1-rep max (1-RM), week 5 was a recovery week, weeks 6-9 focused on base strength at 65-85% 1-RM, week 10 was a recovery week, weeks 11-14 focused on maximal strength at 80-85% 1RM, weeks 15-18 players returned home for holiday break and did not resistance train, weeks 19-22 focused on strength and power maintenance at 65-85% 1-RM, week 23 was a recovery week, and weeks 24-27 focused on strength and power maintenance at 65-85% 1-RM. During recovery weeks, both strength training sessions was replaced with a 45-minute yoga session. The workout structure, training volume, and training intensity were developed in accordance with the National Strength and Conditioning Association guidelines.[31] An example of the competitive season strength training program is provided in Table 2.

Table 2. Example of the strength training program used during the competitive season.

	Weeks 1-4 sets X reps X 1-RM %	**Weeks 6-9** sets X reps X 1-RM %	**Weeks 11-14** sets X reps X 1-RM %	**Weeks 19-22** sets X reps X 1-RM %	**Weeks 24-27** sets X reps X 1-RM %
Plyometrics					
Medball side throw	2-5 X 3-5	2-5 X 3-5	2-5 X 3-5		
Medball squat throw	2-5 X 3-5	2-5 X 3-5	2-5 X 3-5		
Band-assessted squat jump	2-5 X 3-5	2-5 X 3-5	2-5 X 3-5		3 X 3-5
Medball chest throw	2-5 X 3-5	2-5 X 3-5	2-5 X 3-5		
Medball overhead slam				3 X 3-5	3 X 3-5
Dumbbell squat jumps				3 X 3-5	
Body weight squat jumps				3 X 3-5	3 X 3-5
Bodyweight broad jumps				3 X 3-5	3 X 3-5
Full-Body Exercises					
Dumbbell push press	2-4 X 3-5 X 65-75%	2-4 X 3-5 X 65-75%			
Hang clean pull	2-4 X 3-5 X 65-75%	2-4 X 3-5 X 65-75%			
Dumbbell push jerk				3 X 3-5 X 65-75%	
Dumbbell power clean				3 X 3-5 X 65-75%	
Dumbbell snatch					3 X 3 X 65-75%
Upper-Body Exercises					
Dumbbell single arm row	3-4 X 6-8 X 70-80%	3-4 X 6-8 X 80-85%			
Dumbbell bench press	3-4 X 6-8 X 70-80%	3-4 X 6-8 X 80-85%			3 X 6 X 80-85%
Pull ups			2-4 X 4-6		3 X 6
Dumbbell single arm bench press			2-4 X 4-6		
Dumbbell renegade row					3 X 6-8
Dumbbell bent over row				3 X 6-8	
Cable single arm row				3 X 6-8	
Push ups					3 X 15
Lower-Body Exercises					
Dumbbell split squat	3-4 X 6-8 X 70-80%	3-4 X 6-8 X 80-85%		3 X 6 X 80-85%	3 X 6 X 80-85%
Dumbbell RDL	3-4 X 6-8 X 70-80%	3-4 X 6-8 X 80-85%		3 X 6 X 80-85%	3 X 6 X 80-85%
Nordic hamstring extensions	2-3 X 4-6	2-3 X 4-6			
Goblet squat			2-4 X 6-8 X 80-85%		
Single leg box squat			2-4 X 4-6		
Kettlebell swing				3 X 6	3 X 6
Core Exercises					
Plank + kettle bell drag	2-3 X 10	2-3 X 10			
Cable chop	2-3 X 10	2-3 X 10			
Prone back extension ISO hold	2-3 X :30 seconds	2-3 X :30 seconds			3 X :30 seconds
Towel adductor slide	2-3 X 6-8	2-3 X 6-8			
Carpet slider glute bridge			2-3 X 10	2 X 10	
Carpet slider mountain climber			2-3 X 10		
Single leg glute bridge				2 X 10	3 X 10
Adductor side plank				2 X :20	3 X :20
Russian Twist				2 X 15	
Cable anti-rotation ISO hold					3 X :30 seconds

*There was no resistance training performed during weeks 5, 10, 15-18 (Holiday Break), or 23.

Procedures

Anthropometrics. Body composition was measured using BodPod® air displacement plethysmography (COSMED USA, Inc., Concord, CA). Prior to arriving at the testing lab, individuals were provided instructions, in writing, of proper preparation and clothing guidelines in accordance with the BodPod operator manual. All body composition measurements were scheduled at a similar time in the morning throughout the study to reduce variability. Participants' height was recorded to the nearest 0.5 cm using a wall mounted stadiometer and their mass recorded to the nearest 0.1 kg using the connected BodPod scale. A two-point calibration of the BodPod was preformed prior to each participants measurement. Proper instructions to abide by while in the air plethysmography chamber were given to the participant by the researcher.

Strength Testing: Strength testing was conducted using a Biodex System 4 Quick-Set isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY). All strength measurements were scheduled at a similar time in the morning throughout the study to reduce variability. The testing protocol consisted of five repetitions of concentric knee flexion and extension at angular velocities of 60°/sec, 150°/sec, and 300°/sec. The Biodex seat back, fore aft, and leg length adjustments were adjusted according to the Biodex operator manual. These adjustments were recorded and replicated in each testing session to improve test reliability.

Dietary intake. Athletes were to complete a three-day (two consecutive weekdays and one weekend) dietary intake using ASA24 dietary recording software. The three-day diet records were to be completed at pre-season, mid-season, and end-season. Athletes were requested to include dietary supplements in the recording of food intake. The

Harris-Benedict equation was used to determine each subject's estimated daily energy requirement, using "extremely active" as the activity factor classification.

Nutrition knowledge. A validated nutrition knowledge questionnaire, the Sports Nutrition Knowledge Questionnaire (SNKQ), was administered to test each subject's sports nutrition knowledge.[50] Additional questions specific to hockey were included from another validated nutrition knowledge questionnaire, the Nutrition Knowledge Questionnaire for Athletes (NKQA).[51]

RESULTS

A one-way repeated measures analysis of variance was used to analyze changes in player body composition and lower body strength (JMP®Pro 14.0.0, SAS Institute, Cary, NC). When a significant F-ratio was observed, a Tukey-Gramer HSD post-hoc test was used to locate significant differences among time points. A p-value of <0.05 was used to determine significance. Descriptive statistics of each outcome variable and potential covariates included means and standard deviations.

Body Composition

Pre-season, mid-season, and end-season body composition measurements are shown in Table 3. There were no significant changes in total body mass, lean mass, fat mass, or body fat % at any point throughout the season.

Table 3. Body composition measurements during the competitive season.

	Pre-Season (mid-October)	Mid-Season (mid-December)	End-Season (late-February)
Height (cm)	183.5 ± 3.1	183.9 ± 3.1	184.0 ± 3.1
Body Mass (kg)	86.6 ± 13.0	86.6 ± 13.5	85.9 ± 14.5
% Body Fat	10.3 ± 5.9	9.9 ± 4.9	9.8 ± 5.6
Total Fat Mass (kg)	9.3 ± 6.1	9.0 ± 5.5	8.9 ± 6.5
% Lean Mass	89.7 ± 5.9	90.1 ± 4.9	90.2 ± 5.6
Total Lean Mass (kg)	77.3 ± 8.9	77.5 ± 9.0	77.0 ± 9.4
Body Volume (L)	80.6 ± 12.8	80.5 ± 13.3	79.9 ± 14.3
Body Density (kg/L)	1.1 ± 0.0	1.1 ± 0.0	1.1 ± 0.0
Body Surface Area (cm^2)	20913 ± 1896	20950 ± 1959	20880 ± 2010

Data is reported as (mean ± standard deviation)
Bolded data indicates a significant change
[a] indicates a significant difference from pre-season (p<0.05)
[b] indicates a significant difference from mid-season (p<0.05)

Strength

Knee Extension. Pre-season, mid-season, and end-season isokinetic measurements of knee flexion is shown in Table 4. Time to peak torque at 60 deg/sec was significantly higher during the pre-season (675.7 ± 250.8 msec) than during the mid-season (451.4 ± 96.5 msec) and post-season (465.7 ± 82.2 msec). Time to peak torque showed no significant change at any other velocity. Similarly, peak torque, relative peak torque, and total work remained consistent throughout the competitive season.

Table 4. Knee-flexion peak torque, relative peak torque, time to peak torque, and total work measurements during the competitive season.

Peak Torque (ft*lb)	Pre-Season (mid-October)	Mid-Season (mid-December)	End-Season (late-February)
60 deg/sec	96.2 ± 21.1	101.2 ± 21.6	99.4 ± 18.0
150 deg/sec	69.3 ± 19.5	77.0 ± 19.8	77.4 ± 11.9
300 deg/sec	55.8 ± 12.7	57.2 ± 19.4	55.5 ± 15.4
Peak Torque/ Body Mass (ft*lb/kg)			
60 deg/sec	49.8 ± 5.9	52.6 ± 11.6	52.5 ± 11.5
150 deg/sec	35.8 ± 7.8	40.0 ± 10.0	41.2 ± 8.9
300 deg/sec	29.0 ± 4.7	29.8 ± 10.3	29.6 ± 9.4
Time to Peak Torque (msec)			
60 deg/sec	675.7 ± 250.8	**451.4 ± 96.5 [a]**	**465.7 ± 82.2 [a]**
150 deg/sec	384.3 ± 97.8	285.7 ± 45.0	321.4 ± 126.8
300 deg/sec	332.9 ± 93.8	314.3 ± 106.3	344.3 ± 127.5
Total Work (ft*lb)			
60 deg/sec	389.3 ± 117.3	448.3 ± 117.3	510.4 ± 86.2
150 deg/sec	322.5 ± 112.0	334.9 ± 106.3	403.0 ± 58.8
300 deg/sec	190.3 ± 75.2	218.1 ± 89.6	203.6 ± 107.7

Data is reported as (mean ± standard deviation)
Bolded data indicates a significant change
[a] indicates a significant difference from pre-season (p<0.05)
[b] indicates a significant difference from mid-season (p<0.05)

Knee Flexion. Pre-season, mid-season, and end-season measurements of knee flexor strength are shown in Table 5. Relative peak torque at 60 deg/sec and 150 deg/sec decreased from pre-season to mid- season (96.2 ± 19.3 ft*lb/kg to 72.8 ± 13.3 ft*lb/kg, 65.5 ± 9.0 ft*lb/kg to 49.6 ± 11.3 ft*lb/kg). During the second half of the season, relative peak torque at 150 deg/sec significantly increased to near pre-season levels (49.6 ± 11.3 ft*lb/kg to 67.4 ± 14.0 ft*lb/kg). Total work at 60, 150, and 300 deg/sec increased during the second half of the season (495.4 ± 158.3 ft*lb to 764.2 ± 127.0 ft*lb; 330.9 ± 149.0 ft*lb to 609.8 ± 72.7 ft*lb; 196.1 ± 130.8 ft*lb to 370.0 ± 114.4 ft*lb). There were no significant differences between the pre-season and end-season measurements of peak torque, relative peak torque, time to peak torque, or total work for knee flexion.

Table 5. Knee-extension peak torque, relative peak torque, time to peak torque, and total work measurements during the competitive season.

Peak Torque (ft*lb)	Pre-Season (mid-October)	Mid-Season (mid-December)	End-Season (late-February)
60 deg/sec	187.2 ± 52.0	140.0 ± 24.9	166.0 ± 32.3
150 deg/sec	126.8 ± 29.5	96.1 ± 24.9	126.7 ± 19.5
300 deg/sec	83.0 ± 26.5	56.8 ± 25.9	84.9 ± 20.0
Peak Torque/ Body Mass (ft*lb/kg)			
60 deg/sec	96.2 ± 19.3	**72.8 ± 13.3 [a]**	86.8 ± 15.2
150 deg/sec	65.5 ± 9.0	**49.6 ± 11.3 [a]**	**67.4 ± 14.0 [b]**
300 deg/sec	43.1 ± 12.1	29.4 ± 13.1	45.1 ± 12.0
Time to Peak Torque (msec)			
60 deg/sec	532.8 ± 220.1	444.3 ± 151.9	414.3 ± 102.3
150 deg/sec	271.4 ± 65.2	225.7 ± 71.4	237.1 ± 55.6
300 deg/sec	187.1 ± 79.1	190.0 ± 83.3	200.0 ± 67.8
Total Work (ft*lb)			
60 deg/sec	633.7 ± 184.2	495.4 ± 158.3	**764.2 ± 127.0 [b]**
150 deg/sec	502.9 ± 166.9	330.9 ± 149.0	**609.8 ± 72.7 [b]**
300 deg/sec	312.0 ± 126.2	196.1 ± 130.8	**370.0 ± 114.4 [b]**

Data is reported as (mean ± standard deviation)
Bolded data indicates a significant change
[a] indicates a significant difference from pre-season ($p<0.05$)
[b] indicates a significant difference from mid-season ($p<0.05$)

Dietary Intake

Dietary intake data was insufficient and could not be reported.

Nutrition Knowledge

There were 10 athletes that completed the SNKQ. The mean SNKQ score was 60% (15 out of 25). All athletes had previously taken a health class in school, but only 50% (5 of 10) had taken a specific nutrition course. Overall, athletes were more knowledgeable (> 50% correct) in categories pertaining to micronutrient functions, post-workout fueling guidelines, the function and safety of ergogenic aides, rehydration guidelines, possible side effects of dehydration and electrolyte loss, and body composition measurements. Athletes commonly missed questions (≤ 50% correct) in categories pertaining to the optimal macronutrient distribution ranges for athletes, micronutrient toxicity, the regulation of ergogenic aids, strategies to increase muscle mass, and safe weight loss.

The athletes' primary sources of nutrition information, the person(s) with whom they felt most comfortable discussing their nutritional needs, and their perceived adequacy of sources are displayed in Figures 1, 2, and 3. Players stated their primary sources of nutrition information to be athletic trainers, parents, and strength coaches (Figure 1), and felt most comfortable discussing nutritional needs with their athletic trainer (Figure 2). Of the possible sources of nutrition information, athletes perceived athletic trainers to provide the most adequate information (Figure 3). When judging the adequacy of information from each source, athletes selected "cannot judge" if they had not previously received nutrition information from that source.

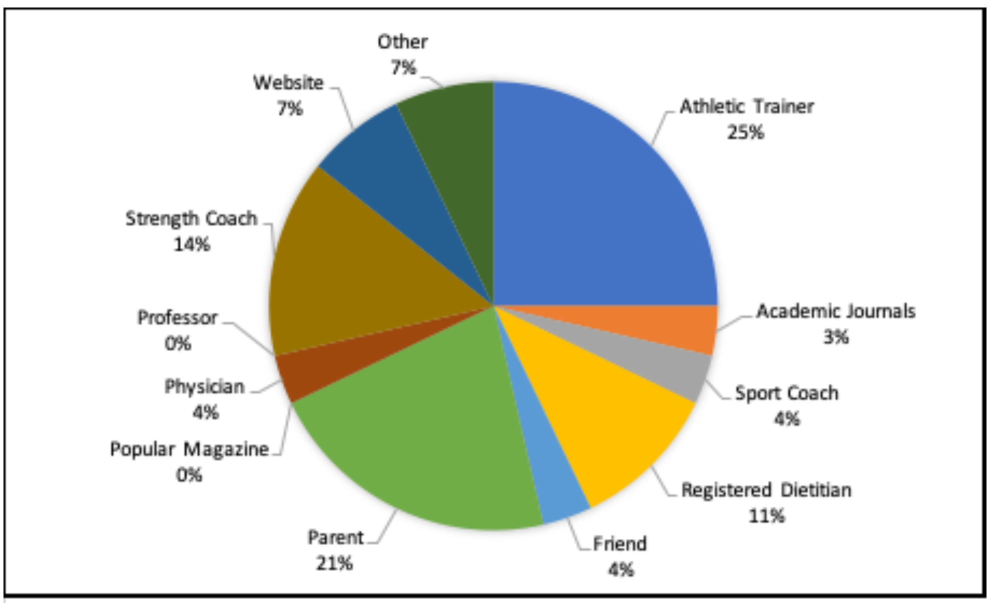

Figure 1. Primary sources of nutrition information.

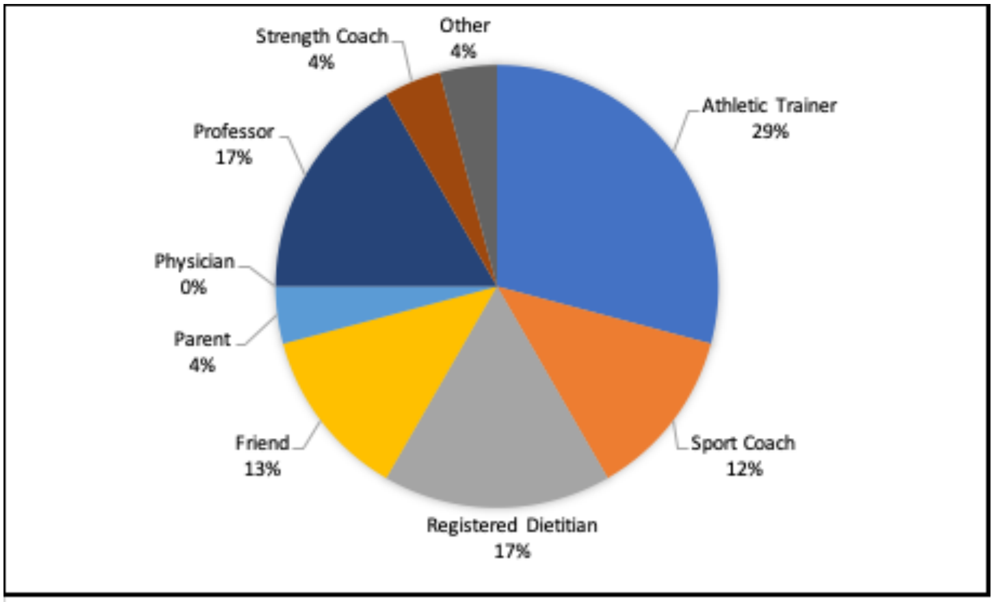

Figure 2. Person(s) with whom athletes felt most comfortable discussing nutritional needs with.

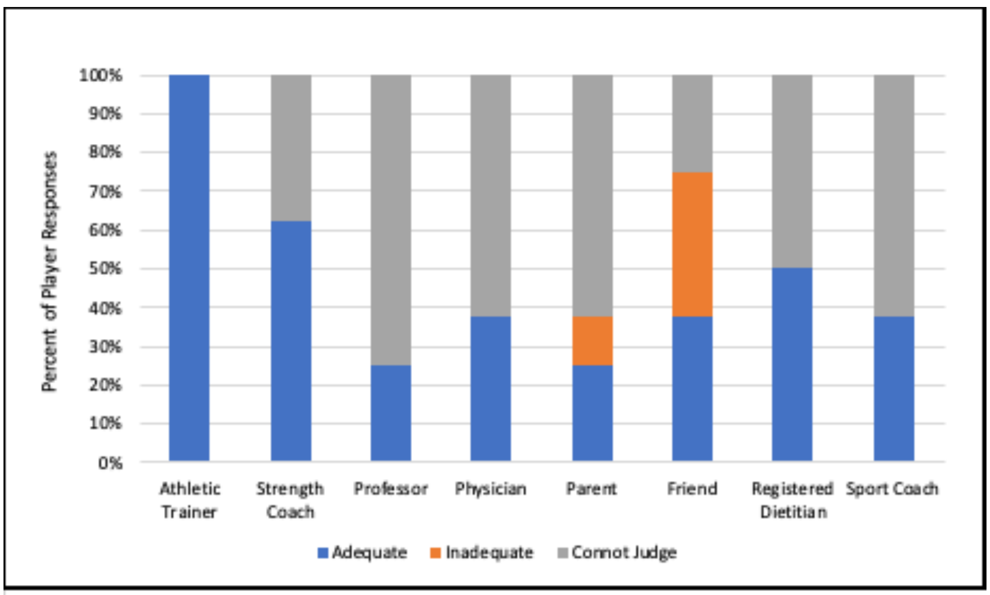

Figure 3. Perceived adequacy of nutrition information.

DISCUSSION

The impact a competitive ice hockey season has on an individual's aerobic and anaerobic fitness has been well documented,[39,52–54] yet, only two studies have assessed the impact on body composition. This study aimed to observe the body composition and strength changes that occur in junior hockey players during a competitive season. The main findings in this study were that junior hockey players (a) did not experience any significant body composition changes during their competitive season, (b) maintained their lower body strength from preseason to post-season, and (c) displayed a low level of sports nutrition knowledge. The hypothesis that body composition and strength would significantly decrease across the competitive season was not supported.

Body Composition

The players in this study did not experience any significant changes in body mass, fat mass, or lean mass during their season. Based on the equation of energy balance (energy balance = energy intake - energy expenditure), these findings suggest players were able to maintain energy balance throughout their season. Maintaining body composition is an important component of on-ice performance. A loss of lean mass during the season can have a negative impact on a players speed, strength, and power.[1,11,12] Similarly, unnecessary gains of fat mass during the season can negatively impact aerobic fitness.[55] Such changes can lead to performance decline during the season. Therefore, it is ideal for athletes in high intensity to maintain an optimal body composition throughout the competitive season. Furthermore, a loss of total body mass over time indicates an athlete has experienced a negative energy balance and may be at risk of developing RED-S. This can compromise functioning of the endocrine,[17] hematological,[18] cardiovascular,[19] and gastrointestinal systems.[20] LEA can also negatively impact bone health,[21] metabolic function,[22] reproductive health,[23] also increase the prevalence of illness and injury.[24]

This is the first known study to have observed longitudinal body composition changes of junior hockey aged players. Previously, two studies have reported collegiate ice hockey players to experience significant body composition changes during their competitive season, suggesting collegiate ice hockey players may be failing to attain energy balance during competitive-season training.[39,40] Delisle-Houde et al. reported male collegiate hockey players to experience fluctuations in fat mass during a 43-game season. Player body fat lost 1.2% body fat during the first half of the season and gained 1.2% body fat during the second half of the season. During this timeframe, players did not experience any change in lean body mass.[39] Prokop et al. observed comparable findings in Canadian male collegiate hockey players. Player fat mass decreased by a total of 0.79 kg across the entire seven-month season.[40] Although these players also did not experience a change in total body lean mass, their lean mass was significant redistributed during the season. They gained 0.29 kg of lower body muscle mass and lost 0.25 kg of upper body muscle mass.[40] While these results differed from those in the current study, it is worth noting that collegiate players have a significantly different training environment than junior hockey players. Collegiate players are often subjected to more regimented schedules, have additional access to a sports medicine staff, and have the addition of academic stress. This addition of academic stress may contribute to overtraining, which has been observed to negatively impact metabolic health.[56,57]

Strength

Athletes in this study did not experience major pre-season to post-season changes in peak torque, relative peak torque, or time to peak torque in knee-extension and knee-flexion. These results suggest lower body strength was successfully maintained throughout the season. No prior study has analyzed the longitudinal changes in the strength of ice hockey players across a competitive season; however, this could be reasonably expected based on the maintenance of lean body mass. These results may be related to their in-season strength training plan. Although a specific program has not been deemed the most effective, similarly designed programs (low-volume, moderate-high intensity) have been credited with helping division-I football players and professional male soccer players maintain lean mass during their respective competitive seasons.[46,47]

Nutrition Knowledge

The mean SNKQ score was 60% (15 out of 25). Participants in this study commonly missed questions relating to optimal macronutrient distribution ranges for athletes, micronutrient toxicity, the regulation of ergogenic aids, strategies to increase muscle mass, and safe weight loss. While many different questionnaires are used to gauge nutrition knowledge, a review of 29 studies utilizing similarly worded quizzes suggested athletes in general lack knowledge of these topics.[58] All athletes would benefit from receiving education on these topics provided by a sports dietitian. Finally, participants in this study reported obtaining a majority of their nutrition information from strength coaches and athletic trainers. These findings are consistent with poles of athletes in other sports.[59,60] These results display the importance for all members of the sports medicine staff to understand the basics of nutrition. Additionally, the lack of nutrition information being obtained from a non-nutrition professional highlights the need for an increased presence of sports dietitians on sports medicine staffs.

Limitations

It is important to highlight several limitations of this study. First, the purpose of this study was to observe the body composition and strength changes that junior hockey players experience during their competitive season and the relation of an athlete's energy intake. Therefore, hormonal changes were not measured. This is important to note because hormonal fluctuations can influence basal metabolic rate and therefore, energy balance.[57] Secondly, these results may not be generalizable to athletes competing in other sports due to the homogeneity of the participants in this study. It is more appropriate to utilize studies that observe the physiological changes of athletes competing in the same sports. Thirdly, nutritional data was inadequate due to subject compliance and could not be reported; hence, the exact energy balance of the participants could not be determined. In future research studies analyzing the dietary data of athletes, it is recommended that researchers put in extra effort maintaining compliance. Lastly, the nature of junior hockey involving frequent roster turnover led to significant challenges with subject retention rates. Even though almost all players on the pre-season roster volunteered to participate in this study, a majority were traded, cut, or moved to an affiliate team during the season.

Conclusion

No significant changes in lean body mass or total body mass were observed in NAHL junior hockey players during their competitive season. This suggests that players attained an overall energy balance throughout the season. Additionally, players did not experience pre-season to post-season changes in peak torque, relative peak torque, or time to peak torque in knee-extension or knee-flexion. Players did experience an increase of total work in knee extension. These results suggest lower body strength was successfully maintained throughout the season. Lastly, players struggled on the SNKQ, indicating a low level of sports nutrition knowledge.

Future Research & Considerations

The amount of research specifically pertaining to junior hockey is limited, warranting future research in this population. Future research should further assess the dietary intake patterns of junior hockey players and should continue to assess arthrometric changes experienced during their season. This would provide sports dietitians to more applicable data when providing sport-specific dietary recommendations. On a larger scope, anthropometric changes and the prevalence of low energy availability in all sports should continue to be heavily investigated. Health consequences relating to LEA can become severe and warrant immediate intervention from a sports dietitian. Junior hockey players, like many athletes, are often under educated on the topic of performance nutrition. Sport coaches would see a significant benefit by coordinating team nutrition education sessions with a sports dietitian.

REFERENCES

1. Montgomery DL. Physiology of Ice Hockey. *Sport Med*. 1988. doi:10.2165/00007256-198805020-00003

2. Twist P, Rhodes T. The bioenergetic and physiological demands of ice hockey. *Natl Strength Cond Assoc J*. 1993. doi:10.1519/0744-0049(1993)015<0068:tbapdo>2.3.co;2

3. Noonan BC. Intragame blood-lactate values during ice hockey and their relationships to commonly used hockey testing protocols. *J Strength Cond Res*. 2010. doi:10.1519/JSC.0b013e3181e99c4a

4. Paterson DH. Respiratory and cardiovascular aspects of intermittent exercise with regard to ice hockey. *Can J Appl Sport Sci*. 1979.

5. Peterson BJ, Fitzgerald JS, Dietz CC, et al. Aerobic capacity is associated with improved repeated shift performance in hockey. *J Strength Cond Res*. 2015. doi:10.1519/JSC.0000000000000786

6. Manning JM. ACSM Resource Manual for Guidelines for Exercise Testing and Prescription. *J Athl Train*. 1999.

7. Goodpaster BH, Park SW, Harris TB, et al. The loss of skeletal muscle strength, mass, and quality in older adults: The Health, Aging and Body Composition Study. *Journals Gerontol - Ser A Biol Sci Med Sci*. 2006. doi:10.1093/gerona/61.10.1059

8. Appleby B, Newton RU, Cormie P. Changes in strength over a 2-year period in professional Rugby Union players. *J Strength Cond Res*. 2012. doi:10.1519/JSC.0b013e31823f8b86

9. Poirier P, Giles TD, Bray GA, et al. Obesity and cardiovascular disease: Pathophysiology, evaluation, and effect of weight loss: An update of the 1997 American Heart Association Scientific Statement on obesity and heart disease from the Obesity Committee of the Council on Nutrition, Physical. *Circulation*. 2006. doi:10.1161/CIRCULATIONAHA.106.171016

10. Gropper SS, Smith JL. *Advanced Nutrition and Human Metabolism*.; 2009.

11. Cox MH, Miles DS, Verde TJ, Rhodes EC. Applied Physiology of Ice Hockey. *Sport Med*. 1995. doi:10.2165/00007256-199519030-00004

12. Pearsall D, Turcotte R, Murphy SD. Biomechanics of ice hockey. *Exerc Sport Sci*. 2000.

13. Peterson BJ, Fitzgerald JS, Dietz CC, et al. Division I hockey players generate more power than Division III players during on- and off-ice performance tests. *J Strength Cond Res*. 2015. doi:10.1519/JSC.0000000000000754

14. Roczniok R, Stanula A, Maszczyk A, et al. Physiological, physical and on-ice performance criteria for selection of elite ice hockey teams. *Biol Sport*. 2016. doi:10.5604/20831862.1180175

15. Chiarlitti NA, Delisle-Houde P, Reid RER, Kennedy C, Andersen RE. Importance

of body composition in the national hockey league combine physiological assessments. *J Strength Cond Res*. 2018. doi:10.1519/JSC.0000000000002309

16. Macedonio M, Dunford M. *The Athlete's Guide to Making Weight: Optimal Weight for Optimal Performance*. Champaign, IL: Human Kinetics; 2009.

17. Allaway HCM, Southmayd EA, De Souza MJ. The physiology of functional hypothalamic amenorrhea associated with energy deficiency in exercising women and in women with anorexia nervosa. *Horm Mol Biol Clin Investig*. 2016. doi:10.1515/hmbci-2015-0053

18. Åkermark C, Jacobs I, Rasmusson M, Karlsson J. Diet and muscle glycogen concentration in relation to physical performance in Swedish elite ice hockey players. *Int J Sport Nutr Exerc Metab*. 1996. doi:10.1123/ijsn.6.3.272

19. Rickenlund A, Eriksson MJ, Schenck-Gustafsson K, Hirschberg AL. Amenorrhea in female athletes is associated with endothelial dysfunction and unfavorable lipid profile. *J Clin Endocrinol Metab*. 2005. doi:10.1210/jc.2004-1286

20. Ackerman KE, Holtzman B, Cooper KM, et al. Low energy availability surrogates correlate with health and performance consequences of Relative Energy Deficiency in Sport. *Br J Sports Med*. 2019. doi:10.1136/bjsports-2017-098958

21. Papageorgiou M, Dolan E, Elliott-Sale KJ, Sale C. Reduced energy availability: implications for bone health in physically active populations. *Eur J Nutr*. 2018. doi:10.1007/s00394-017-1498-8

22. Melin A, Tornberg B, Skouby S, et al. Energy availability and the female athlete triad in elite endurance athletes. *Scand J Med Sci Sport*. 2015. doi:10.1111/sms.12261

23. Loucks AB, Thuma JR. Luteinizing hormone pulsatility is disrupted at a threshold of energy availability in regularly menstruating women. *J Clin Endocrinol Metab*. 2003. doi:10.1210/jc.2002-020369

24. Drew M, Vlahovich N, Hughes D, et al. Prevalence of illness, poor mental health and sleep quality and low energy availability prior to the 2016 summer Olympic games. *Br J Sports Med*. 2018. doi:10.1136/bjsports-2017-098208

25. Coyle EF. Substrate utilization during exercise in active people. In: *American Journal of Clinical Nutrition*. ; 1995. doi:10.1093/ajcn/61.4.968S

26. Ali A, Williams C, Nicholas CW, Foskett A. The influence of carbohydrate-electrolyte ingestion on soccer skill performance. *Med Sci Sports Exerc*. 2007. doi:10.1249/mss.0b013e31814fb3e3

27. Nutrition and Athletic Performance. *Med Sci Sports Exerc*. 2016. doi:10.1249/MSS.0000000000000852

28. Lemon PWR, Mullin JP. Effect of initial muscle glycogen levels on protein catabolism during exercise. *J Appl Physiol Respir Environ Exerc Physiol*. 1980. doi:10.1152/jappl.1980.48.4.624

29. Mettler S, Mitchell N, Tipton KD. Increased protein intake reduces lean body mass

loss during weight loss in athletes. *Med Sci Sports Exerc*. 2010. doi:10.1249/MSS.0b013e3181b2ef8e

30. Agriculture USD of H and HS and USD of. 2015 – 2020 Dietary Guidelines for Americans. *2015 – 2020 Diet Guidel Am (8th Ed*. 2015. doi:10.1097/NT.0b013e31826c50af
31. Phillips N. Essentials of Strength Training and Conditioning. *Physiotherapy*. 2005. doi:10.1016/s0031-9406(05)66120-2
32. Zabriskie HA, Currier BS, Harty PS, Stecker RA, Jagim AR, Kerksick CM. Energy status and body composition across a collegiatewomen's lacrosse season. *Nutrients*. 2019. doi:10.3390/nu11020470
33. Reed JL, de Souza MJ, Williams NI. Changes in energy availability across the season in Division I female soccer players. *J Sports Sci*. 2013. doi:10.1080/02640414.2012.733019
34. Zanders BR, Currier BS, Harty PS, et al. Changes in Energy Expenditure, Dietary Intake, and Energy Availability Across an Entire Collegiate Women's Basketball Season. *J Strength Cond Res*. 2018. doi:10.1519/jsc.0000000000002783
35. Russell M, Pennock A. Dietary analysis of young professional soccer players for 1 week during the competitive season. *J Strength Cond Res*. 2011. doi:10.1519/JSC.0b013e3181e7fbdd
36. Jagim AR, Zabriskie H, Currier B, Harty PS, Stecker R, Kerksick CM. Nutrient Status and perceptions of energy and macronutrient intake in a Group of Collegiate Female Lacrosse Athletes. *J Int Soc Sports Nutr*. 2019. doi:10.1186/s12970-019-0314-7
37. Silva AM, Matias CN, Santos DA, et al. Energy balance over one athletic season. *Med Sci Sports Exerc*. 2017. doi:10.1249/MSS.0000000000001280
38. Silva AM, Matias CN, Santos DA, et al. Energy balance over one athletic season. *Med Sci Sports Exerc*. 2017. doi:10.1249/MSS.0000000000001280
39. Delisle-Houde P, Reid RER, Insogna JA, Chiarlitti NA, Andersen RE. Seasonal Changes in Physiological Responses and Body Composition During a Competitive Season in Male and Female Elite Collegiate Ice Hockey Players. *J strength Cond Res*. 2019. doi:10.1519/JSC.0000000000002338
40. Prokop NW, Reid RER, Andersen RE. Seasonal changes in whole body and regional body composition profiles of elite collegiate ice-hockey players. *J Strength Cond Res*. 2016. doi:10.1519/JSC.0000000000001133
41. Binkley TL, Daughters SW, Weidauer LA, Vukovich MD. Changes in body composition in division i football players over a competitive season and recovery in off-season. *J Strength Cond Res*. 2015. doi:10.1519/JSC.0000000000000886
42. Minett MM, Binkley TB, Weidauer LA, Specker BL. Changes in body composition and bone of female collegiate soccer players through the competitive season and off-season. *J Musculoskelet Neuronal Interact*. 2017.

43. Carling C, Orhant E. Variation in body composition in professional soccer players: Interseasonal and intraseasonal changes and the effects of exposure time and player position. *J Strength Cond Res*. 2010. doi:10.1519/JSC.0b013e3181cc6154

44. Harley JA, Hind K, O'Hara JP. Three-compartment body composition changes in elite rugby league players during a super league season,measured by dual-energy X-ray absorptiometry. *J Strength Cond Res*. 2011. doi:10.1519/JSC.0b013e3181cc21fb

45. Stanforth PR, Crim BN, Stanforth D, Stults-Kolehmainen MA. Body composition changes among female NCAA division 1 athletes across the competitive season and over a multiyear time frame. *J Strength Cond Res*. 2014. doi:10.1519/JSC.0b013e3182a20f06

46. Trexler ET, Smith-Ryan AE, Bryanmann J, Ivey PA, Hirsch KR, Mock MG. Longitudinal body composition changes in ncaa division i college football players. *J Strength Cond Res*. 2017. doi:10.1519/JSC.0000000000001486

47. Devlin BL, Kingsley M, Leveritt MD, Belski R. Seasonal changes in soccer players' body composition and dietary intake practices. *J Strength Cond Res*. 2017. doi:10.1519/JSC.0000000000001751

48. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: A prospective biomechanical-epidemiologic study. *Am J Sports Med*. 2007. doi:10.1177/0363546507301585

49. Maughan RJ, Watson JS, Weir J. Strength and cross-sectional area of human skeletal muscle. *J Physiol*. 1983. doi:10.1113/jphysiol.1983.sp014658

50. Torres-McGehee TM, Pritchett KL, Zippel D, Minton DM, Cellamare A, Sibilia M. Sports nutrition knowledge among collegiate athletes, coaches, athletic trainers, and strength and conditioning specialists. *J Athl Train*. 2012. doi:10.4085/1062-6050-47.2.205

51. Furber MJW, Roberts JD, Roberts MG. A valid and reliable nutrition knowledge questionnaire for track and field athletes. *BMC Nutr*. 2017. doi:10.1186/s40795-017-0156-0

52. Daub WB, Green HJ, Houston ME, Thomson JA, Fraser IG, Ranney DA. Specificity of physiologic adaptations resulting from ice-hockey training. *Med Sci Sports Exerc*. 1983. doi:10.1249/00005768-198315040-00007

53. Durocher JJ, Leetun DT, Carter JR. Sport-specific assessment of lactate threshold and aerobic capacity throughout a collegiate hockey season. *Appl Physiol Nutr Metab*. 2008. doi:10.1139/H08-107

54. Green HJ, Houston ME. Effect of a season of ice hockey on energy capacities and associated functions. *Med Sci Sports*. 1975. doi:10.1249/00005768-197500740-00011

55. Miller TA, Thierry-Aguilera R, Congleton JJ, et al. Seasonal changes in V̇O2max among Division 1A collegiate women soccer players. *J Strength Cond Res*. 2007.

doi:10.1519/00124278-200702000-00009

56. Green HJ, Batada A, Cole B, et al. Muscle cellular properties in the ice hockey player: A model for investigating overtraining? *Can J Physiol Pharmacol*. 2012. doi:10.1139/Y2012-017

57. Cadegiani FA, Kater CE. Body composition, metabolism, sleep, psychological and eating patterns of overtraining syndrome: Results of the EROS study (EROS-PROFILE). *J Sports Sci*. 2018. doi:10.1080/02640414.2018.1424498

58. Heaney S, O'Connor H, Michael S, Gifford J, Naughton G. Nutrition knowledge in athletes: A systematic review. *Int J Sport Nutr Exerc Metab*. 2011. doi:10.1123/ijsnem.21.3.248

59. Burns RD, Schiller MR, Merrick MA, Wolf KN. Intercollegiate student athlete use of nutritional supplements and the role of athletic trainers and dietitians in nutrition counseling. *J Am Diet Assoc*. 2004. doi:10.1016/j.jada.2003.11.013

60. Abbey EL, Wright CJ, Kirkpatrick CM. Nutrition practices and knowledge among NCAA Division III football players. *J Int Soc Sports Nutr*. 2017. doi:10.1186/s12970-017-0170-2