Relationship Between Physiologic Tests, Body Composition Changes, and On-Ice Playing Time in Canadian Collegiate Hockey Players

Patrick Delisle-Houde, Nathan A. Chiarlitti, Ryan E.R. Reid, and Ross E. Andersen

McGill Health and Fitness Promotion Lab, Department of Kinesiology and Physical Education, McGill University, MontrHealtQuébec, Canada

Abstract

Delisle-Houde, P, Chiarlitti, NA, Reid, RER, and Andersen, RE. Relationship between physiologic tests, body composition changes, and on-ice playing time in canadian collegiate hockey players. *J Strength Cond Res* 32(5): 1297–1302, 2018—Hockey player's body composition and physical fitness are suggested to influence coaching decisions regarding on-ice playing time. The purpose of this study was to explore the relationship between seasonal body composition changes, off-ice preseason testing, and on-ice metrics. Twenty-one Canadian collegiate hockey players (22.70 ± 1.30 years old, 181.0 ± 5.92 cm, 86.52 ± 6.41 kg) underwent off-ice physical testing at the beginning of their season and had one total body dual energy x-ray absorptiometry scan at the beginning and end of the season. The team's statistician tracked all on-ice metrics. Pearson correlations were used to explore relationships between off-ice tests (long jump, vertical jump, beep test, and Wingate test), change in body composition (body fat percentage, visceral adiposity, and total lean tissue mass), and on-ice performance (average time on ice, average shift length, power play time, penalty kill time, and shot differential). Long jump was correlated with shot differential ($r = -0.532$, $p \leq 0.05$) and average shift length ($r = -0.491$, $p \leq 0.05$) while fatigue index was correlated with average ice time ($r = -0.476$, $p \leq 0.05$). Hockey performance is a complex interaction of player's body compositions and skeletal fitness that interact to affect on-ice playing metrics.

Key Words fitness testing, performance, strength and conditioning coach

Address correspondence to Nathan A. Chiarlitti, nathan.chiarlitti@mail.mcgill.ca.

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Introduction

Ice hockey is a competitive environment that requires players to continuously improve their physical abilities in an effort to optimize performance. Multiple physical fitness attributes (muscular endurance, flexibility, etc.) have been shown to be essential for ice hockey players (4,14), and because high-speed collisions occur throughout the game, players must also be strong and agile (9,15). Physiological characteristics of ice hockey players obtained from preseason fitness tests have been linked with different on-ice skills, such as skating speed, and with game performance statistics (6,12,13).

Off-ice physiologic assessments, such as the National Hockey League (NHL) combine, attempt to predict on-ice performance and help to determine players' career potential in the league (10). Off-ice testing is an important part of hockey as some field tests (standing long jump and Wingate) and body composition aspects have been linked to skating performance (1,10) while others have been linked to time on-ice and scoring chances (6). This shows a causal connection between off-ice testing and on-ice performance.

Hockey player's physical fitness and body composition have been suggested to influence coaching decisions regarding the amount of time players spend on the ice. Coaches seem to shuffle their lineups in responses to specific situations, such as power plays, penalty kills, or double shifting, where players with a lower blood lactate level under submaximal effort and lower body fat percentage are preferred (6). It may be possible that players in certain situations have higher physical fitness attributes or more favorable body compositions than players who do not play in these situations.

Strength and conditioning coaches have evolved and now monitor their players during the season instead of relying on preseason physical fitness scores. This not only helps keep players accountable, but allows strength and conditioning coaches to track necessary changes in relation to on-ice player performance. Thus, the primary purpose of this study was to determine the relationship between seasonal body composition changes and on-ice metrics. We hypothesized that improvements in body fat percentage, visceral adiposity, and lean tissue mass will be positively correlated with average shift length and average time on ice. A secondary purpose was to explore the relationship between preseason off-ice testing and on-ice time played during the season. We hypothesized that higher scores in the beep test and Wingate mean power output would equate to higher average ice-time, whereas higher jump scores, Wingate peak power, and lower fatigue index would be positively correlated with average shift length. We also hypothesized that seasonal body composition changes and preseason off-ice assessments are not related to special teams time (power play or penalty kill).

Methods

Experimental Approach to the Problem

To participate in this observational study, subjects were recruited to take part in one off-ice testing session at the beginning of their hockey season and participate in at least 7 regular season games (quarter of a collegiate season). The off-ice testing session was composed of lower-body field-based tests that are routinely used in hockey settings and in the NHL combine. The players also received one total body dual energy x-ray absorptiometry (DXA) scan at the beginning and at the end of their season. The players were then followed during their hockey season by the team's official statistician as he recorded ice-time metrics and performance variables. The ice-time and performance metric variables recorded in this study are listed below:

- Average shift length (seconds): the average time a player spends on the ice at 1 time, before they return to the bench.
- Average ice-time per game (minutes): the amount of time a player spends on the ice during an entire game. This includes special teams play (power play and penalty kill) and is affected by how individuals are playing, the opposition, and the score of the game.
- Shot differential (± shots): This metric involves players receiving a (+) if they take a shot on goal, and a (−) if the opposition take a shot on goal during even strength play.
- Power play ice-time (minutes): the total time per game a player spends on the ice when the opposing team has been given a penalty.
- Penalty kill ice-time (minutes): the total time per game a player spends on the ice when their team has been given a penalty.

These variables were used because of their importance to the training and coaching staff and because they were believed to be some of the best individual-player performance indicators in the sport. Goals, assists, and shot differential were not used because overall player talent cannot be assumed by these variables as each player may have a different role and opportunity on a team. This reality could make these statistics inherently biased depending on position or player characteristics. Goaltenders were not included in this analysis because of their unique positional demands. The on-ice variables (average shift length, average time on-ice per game, shot differential, power play time, and penalty kill time) were correlated with preseason fitness assessments and seasonal body composition changes to explore potential relationships.

Subjects

All participants were ice hockey players (ranging from 20 to 25 years of age) who were part of a nationally ranked team competing at the highest Canadian collegiate level. Twenty-one elite Canadian collegiate hockey players (age = 22.70 ± 1.30 years, height = 181.0 ± 5.92 cm, body mass = 86.52 ± 6.41 kg) participated in this study. The McGill Medical Ethics Institutional Review Board approved the study, and written informed consent was obtained from the subjects to participate in this project.

Procedures

Testing sessions were conducted in the preseason of the hockey team's schedule, before the start of training camp, while postseason testing was conducted in the following week of their last playing game. At preseason testing, all players were in the completion of the tapering phase of their off-season training programs, whereas postseason testing was executed when player just finished their maintenance phase of their in-season training programs.

Anthropometric Assessments. Participants were all tested in the morning (8 AM–12 PM) in the preseason (late August) of their hockey schedule. The off-ice testing began with anthropometric measures such as height and body mass. Participant's height was recorded to the nearest centimeter using a Seca 216 wall-mounted stadiometer, and body mass was assessed to the nearest tenth kilogram using a Seca 635 platform and bariatric scale (Seca, Hamburg, Germany) after the American College of Sports Medicine's guidelines (Lippincott Williams & Wilkins 2013).

Field-Based Assessments. The field-based assessments began with the standing long jump and vertical jump. Participants started the standing long jump test with their toes behind the start line and were instructed to jump as far as possible. Distance was measured from the start line to the participant's heels. Participants were allowed 2 jumps (with a minute rest in between), with the best jump being recorded. The vertical jump was performed on force plates (OR6-7; AMTI, Watertown, MA, USA) with data acquisition through custom software (Matlab, MA, USA). Participants were instructed to perform 6 countermovement jumps and told to keep both their hands on their hips. The best 3 jumps were averaged.

The Wingate Anaerobic Test immediately followed the jump assessments. The bike seat was adjusted to preference and participants engaged in a 5-minute standardized warm-up. To begin the test, participants pedaled as fast as possible until 180 revolutions per minute were reached. At this point,

Table 1. Body composition and anthropometric characteristics of elite male collegiate hockey players ($n = 21$).

Characteristic	Mean ± *SD*	Range
Age (y)	22.70 ± 1.30	21 to 25
Height (cm)	181.0 ± 5.92	170.18 to 190.50
Preseason		
Body mass (kg)	86.52 ± 6.41	74.50 to 99.50
Visceral adipose tissue (kg)	0.42 ± 0.17	0.14 to 0.79
Body fat (%)	17.61 ± 4.36	10.30 to 26.10
Total body lean mass (kg)	68.09 ± 4.10	62.62 to 75.81
Difference between end-season and preseason		
Body mass (kg)	0.90 ± 2.67	−2.40 to 7.70
Visceral fat (kg)	0.04 ± 0.10	−0.10 to 0.33
Body fat (%)	0.23 ± 1.97	−4.20 to 5.20
Total body lean mass (kg)	0.34 ± 1.77	−2.64 to 4.11

the added weight (9% of body weight) was dropped on the bike, and participants were verbally encouraged to continue pedaling while remaining seated (3). The test lasted 30 seconds, and after, each participant was encouraged to continue pedaling for a 2-minute cool-down period. From this test, relative peak power ($W \cdot kg^{-1}$), relative mean power ($W \cdot kg^{-1}$), and fatigue index (% drop) were obtained. Peak power was the highest output achieved in the test, mean power was the average output across the 30 seconds, and fatigue index was how much the power output dropped throughout the test.

The final test was the 20-m shuttle run (beep test) and was administered according to Léger and Lambert's procedure (8). Participants ran from line to line (20 m apart) while paced by audible beeps, which became faster as the test extended. When participants did not reach the end lines on time for 2 consecutive trials, the test was terminated and the audible level that was previously reached was recorded.

Body Composition Assessments. Within 1 week after physical assessments, each athlete received one total body DXA scan (GE Healthcare, Madison, WI, USA). Each scan was administered in the morning (between 8:00 AM and 12:00 PM), and each athlete was instructed to be fasted 3 hours before the scan. The DXA is a gold standard for assessing body composition in a research setting (2) and has an intraclass correlation of 0.807 (5). From the DXA, total lean tissue mass, regional fat mass (visceral), and total body fat percentage were measured. After the team's season, within the course of a week, one follow-up, total body DXA scan was administered to each team member in the same time period as the original scan. The changes from preseason to end-season in each player's weight, body fat percentage, visceral adipose tissue, and total lean tissue mass were calculated to give an indication of player progression throughout the season.

Statistical Analyses

Descriptive statistics for all sample characteristics, off-ice assessments and on-ice variables were calculated to give a better indication of the study participants. Pearson correlations were used to explore relationships between off-ice physiologic tests (long jump, vertical jump, beep test, and Wingate test), change in body composition variables (body fat percentage, visceral adiposity, and total lean tissue mass), and on-ice performance variables (average time on ice, average shift length, power play time, penalty kill time, and shot differential). Stepwise regression analysis evaluated the variance explained by the physiologic tests and body composition changes in on-ice performance variables. All analyses were conducted using SPSS 23.0, confidence intervals (CIs) were set at 95.0%, and a p value of <0.05 was assumed for all statistical tests.

Table 2. Off-ice assessments and on-ice playing metrics in Canadian collegiate hockey players ($n = 21$).

Variable	Mean ± *SD*	Range
Beep test (level)	12.01 ± 1.30	9.9 to 14.60
Vertical jump (Ns)	38.34 ± 3.46	30.90 to 43.70
Wingate peak power ($W \cdot kg^{-1}$)	12.44 ± 0.73	10.82 to 14.20
Wingate mean power ($W \cdot kg^{-1}$)	9.59 ± 0.47	8.80 to 10.37
Wingate fatigue index (%)	49.64 ± 6.66	38.35 to 61.30
Shot differential (±)	18.52 ± 14.08	−2 to 53
Average shift length (s)	42 ± 2.30	39 to 48
Average ice-time per game (min)	15.75 ± 3.94	6.57 to 21.53
Power play ice-time per game (min)	2.14 ± 1.45	0 to 5.24
Penalty kill ice-time per game (min)	1.69 ± 1.45	0 to 4.51

Table 3. Correlations between seasonal body composition changes and ice-time metrics in elite male collegiate hockey players ($n = 21$).*

Difference between end-season and preseason	Shot differential	Average shift length	Average ice-time	Average PP time	Average PK time
Body mass (kg)	0.417	0.435†	0.115	0.371	−0.255
Body fat (%)	0.524†	0.649‡	0.304	0.596§	−0.202
Visceral adipose tissue (kg)	0.065	0.103	−0.240	0.042	−0.306
Total lean mass (kg)	−0.049	−0.100	−0.189	−0.165	−0.159

*PP = power play; PK = penalty kill.
†Relationship significant at the 0.05 level.
‡Relationship significant at the 0.001 level.
§Relationship significant at the 0.01 level.

Results

Descriptive statistics of the sample population, off-ice assessments and on-ice metrics are presented in Tables 1 and 2, respectively.

Correlations revealed relationships between seasonal body composition, and preseason off-ice tests and on-ice playing metrics (Tables 3 and 4, respectively).

An increase in body fat percentage from the beginning of the season to the end of the season was positively correlated with shot differential ($r = 0.524$, 95% CI: 0.12–0.93; $p \leq 0.05$), and average shift length ($r = 0.649$, 95% CI: 0.28–1.01; $p < 0.001$), while body mass gain was also correlated with average shift length ($r = 0.435$, 95% CI: 0.01–0.87; $p \leq 0.05$). Long jump was correlated with shot differential ($r = -0.532$, 95% CI: −9.4 to −0.13; $p \leq 0.05$), and average shift length ($r = -0.491$, 95% CI: −91 to −0.07; $p \leq 0.05$), while fatigue index was correlated with average ice-time ($r = -0.476$, 95% CI: −0.90 to −0.05; $p \leq 0.05$).

An increase in body fat percentage was positively correlated with average power play time ($r = 0.596$, 95% CI: 0.21–0.98; $p < 0.01$), while long jump was negatively correlated ($r = -0.459$, 95% CI: −0.89 to −0.03; $p \leq 0.05$). Fatigue index was the only variable that was correlated with average penalty kill time ($r = -0.478$, 95% CI: −0.76 to 0.15; $p \leq 0.05$).

The stepwise regression model for average shift length used the following predictor:

$$\text{Average shift length} = 41.83 + (0.76 \times \text{difference in body fat})$$

The standardized beta for the difference in body fat was 0.649, and the r^2 value, which shows the variance explained by the predictor, was 0.42. Difference in body mass and long jump did not predict average shift length.

The stepwise regression model for shot differential used the following predictor:

$$\text{Shot differential} = 159.32 - (53.56 \times \text{long jump})$$

The standardized beta for the long jump was −0.532, and the r^2 value was 0.28. Difference in body fat did not predict shot differential.

Table 4. Correlations between preseason off-ice fitness assessments and ice-time metrics in male collegiate hockey players ($n = 21$).*

	Shot differential	Average shift length	Average ice-time	Average PP time	Average PK time
Long jump (m)	−0.532†	−0.491†	−0.069	−0.459†	0.366
Beep test (level)	−0.042	0.022	0.385	0.018	0.348
Vertical jump	−0.313	−0.238	−0.255	−0.379	0.165
Wingate peak P	−0.290	0.009	−0.056	−0.159	−0.130
Wingate MP	−0.044	0.175	0.235	0.056	−0.028
Fatigue index (%)	−0.209	−0.067	−0.476†	−0.174	−0.478†

*PP = power play; PK = penalty kill; peak P = peak power; MP = mean power.
†Relationship significant at the 0.05 level.

The stepwise regression model for average power play ice-time used the following predictor:

$$\text{Average power play ice-time} = 122.36 + (26.43 \times \text{difference in body fat})$$

The standardized beta for the difference in body fat was 0.596, and the r^2 value was 0.32. Long jump did not predict average power play ice-time.

Discussion

Investigating the relationship between seasonal changes in body composition and on-ice playing metrics revealed that as players gained weight and body fat, shot differential, and average shift length increased. It could be hypothesized that larger players would be more advantageous in front of the net to take and redirect shots and have a more favorable chance to win puck battles from their opponents; however, to our group, this seems counterintuitive as there are many other components that affect playing time. It could be argued that player's work ethic, on-ice skill level, and role on the team may all affect playing time but may not always relate to positive body composition changes. It is important to consider that personal characteristics, player skills, and coaching strategies may all contribute to playing time.

A secondary purpose was to explore possible relationships between preseason off-ice fitness tests and playing time. Our hypothesis was not corroborated as there was a lack of relationship between preseason off-ice fitness testing and playing time. Although significant correlations between preseason off-ice assessments ($\dot{V}O_2max$, lactate concentrations) and on-ice playing variables have been reported (6), the on-ice metrics were different than the ones in this study. In addition, preseason testing for collegiate hockey usually occurs at the end of August (or early September), whereas the season begins in October and continues as far as mid-March (14). It is possible that the off-ice testing results completed earlier in the season may not be as large of an indicator as once thought as athletes have the opportunity to train and progress to higher fitness levels after off-ice testing and throughout the season. Preseason physiologic tests have been shown to be good opportunities to observe off-season fitness progress, as well as identifying athlete's strengths and weaknesses; however, it is important to continue these tests throughout the season to monitor the athletes and adjust their workout programs (7,14). Continually monitoring off-ice assessments may give coaching personnel insight into which players may be more capable to play in certain roles (6).

When exploring the possible relationships between seasonal body composition changes, preseason off-ice assessments, and special teams play, it is important to consider that power play and penalty kill are incredibly dependent on player's skill levels. For example, the team's highest skilled players are usually on the team's power play while the team's lesser skilled players are on the penalty kill. This is important to consider as it is possible that a player's role on the team (skilled or otherwise) may be unrelated to body composition changes or off-ice assessments. The amount of time a player spends on the ice during special teams may be more indicative of player characteristics, coaching philosophies, and skill level.

In accordance with Green et al. (2006), in-season fitness monitoring may be essential to improve individual specific physiological attributes to corporate these findings we incorporated novel on-ice performance variables including special teams time and average shift length. Interestingly, our sample's height, weight, and shift length were very similar to other studies with similar samples (6,11), whereas body fat percentage was higher, possibly due to the differences in body composition assessment (DXA compared with skinfolds). Our study was not without limitations, as our sample size was relatively small and homogenous potentially limiting our generalizations to different leagues, caliber levels, age groups, and sex. One of the strengths of the study was the multiple body composition assessments, which allowed seasonal changes to be tracked and related to playing time, something past research, to our knowledge, had not explored. In addition, the same statistician evaluated all the games, reducing bias and eliminating interevaluator differences.

Practical Applications

Monitoring player's physiologic and off-ice testing results throughout the season could have important implications for player's on-ice times. If certain players are registering high minutes on the ice and are showing poorer physiologic profiles or fitness scores, changes can be made to ensure optimal shape for higher performance. For strength and conditioning personnel and hockey coaches, it is important to recognize that preseason off-ice assessments may not be the best indicators of certain on-ice metrics throughout the season. With this in mind, even if an athlete tests poorly, coaches should understand that significant improvements could be made to influence their on-ice time for the regular season. It might be beneficial to routinely perform body composition and fitness assessments throughout the season to identify whether athletes should improve certain aspects (i.e., increase lean tissue mass, or upper body power). Players' monitoring assessment can directly influence the weekly training plan of the athlete. Also, hockey coaches can use these assessments to ensure a follow-up with players of their current team or with players from their farm club to ensure good physical fitness development of their top prospects or use a player in a crucial situation knowing that he has the fitness attributes to accomplish the task required.

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