

[Primary Care]



Ability of Preseason Body Composition and Physical Fitness to Predict the Risk of Injury in Male Collegiate Hockey Players

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Background: Injuries in collegiate ice hockey can result in significant time lost from play. The identification of modifiable risk factors relating to a player's physical fitness allows the development of focused training and injury prevention programs targeted at reducing these risks.

Purpose: To determine the ability of preseason fitness outcomes to predict in-season on-ice injury in male collegiate ice hockey players.

Study Design: Prognostic cohort study.

Level of Evidence: Level 3.

Methods: Athlete demographics, percentage body fat, aerobic capacity (300-m shuttle run; 1-, 1.5-, 5-mile run), and strength assessment (sit-ups, push-ups, grip strength, bench press, Olympic cleans, squats) data were collected at the beginning of 8 successive seasons for 1 male collegiate ice hockey team. Hockey-related injury data and player-level practice/game athlete exposure (AE) data were also prospectively collected. Seventy-nine players participated (203 player-years). Injury was defined as any event that resulted in the athlete being unable to participate in 1 or more practices or games following the event. Multivariable logistic regression was performed to determine the ability of the independent variables to predict the occurrence of on-ice injury.

Results: There were 132 injuries (mean, 16.5 per year) in 55 athletes. The overall injury rate was 4.4 injuries per 1000 AEs. Forwards suffered 68% of the injuries. Seventy percent of injuries occurred during games with equal distribution between the 3 periods. The mean number of days lost due to injury was 7.8 ± 13.8 (range, 1-127 days). The most common mechanism of injury was contact with another player (54%). The odds of injury in a forward was 1.9 times (95% CI, 1.1-3.4) that of a defenseman and 3 times (95% CI, 1.2-7.7) that of a goalie. The odds of injury if the player's body mass index (BMI) was ≥ 25 kg/m² was 2.1 times (95% CI, 1.1-3.8) that of a player with a BMI < 25 kg/m². The odds ratios for bench press, maximum sit-ups, and Olympic cleans were statistically significant but close to 1.0, and therefore the clinical relevance is unknown.

Conclusion: Forwards have higher odds of injury relative to other player positions. BMI was predictive of on-ice injury. Aerobic fitness and maximum strength outcomes were not strongly predictive of on-ice injury.

Keywords: hockey; prediction; risk of injury; fitness parameters

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Multiple studies have reported ice hockey injury rates across different age groups, skill levels, and countries.^{7,13,14,17,18,20,24,29-31,34,35,37,38} While a consensus on injury rate is difficult to determine, given the use of different definitions of injury and athlete exposure, a trend for a higher risk of injury during games compared with practices is consistent across all studies.^{7,14,17,18,20,30,37,38} Whether the risk of injury depends on the player position, however, has not been agreed on.^{7,14,17,18,20,29-31,37} Injuries in collegiate ice hockey can result in time lost from play ranging from minutes to a month or more. On average, the combined lost time for all players on 1 team injured in 1 year is equal to the loss of 1 player for almost the complete season.¹³ The identification of the risk factors for these injuries is therefore paramount to the prevention of future injuries, the reduction of player morbidity and lost time, and the success of the team.

A history of previous injury has been the most consistent risk factor for future muscular injury in multiple sports and physical activities.^{4,6,11,19,40} Previous injury is a nonmodifiable risk factor, and therefore, prevention strategies cannot change that risk. Inadequate rehabilitation, however, may be a modifiable risk factor that is related to previous injury.^{19,42} Modifiable risk factors such as body composition, aerobic and anaerobic fitness, muscular strength, and flexibility are physical properties that are modifiable with time and are modifiable relative to the type, intensity, and volume of training. The identification of risk factors relating to a player's physical fitness allows the development of focused training and injury prevention programs targeted at reducing these risks.^{13,19,41,42}

Two previous studies have evaluated predictive factors associated with injury in hockey. Ferrara and Schurr¹³ found that the body part injured and the injury type were both independent risk factors for lost time. In high school-level ice hockey, among the history of injury, anthropometric measures, and multiple psychosocial outcomes, only self-reported preseason fatigue was predictive of in-season injury.³⁵ Other studies report conflicting results regarding the role of fatigue in injury risk. The occurrence of injury may be higher near the end of each period and the end of the game.^{11,18,30,31,35,37} The incidence of groin injury in National Hockey League (NHL) players is higher during preseason than during in-season play.¹¹ The associations between injury and fatigue, early season activity, and the high-energy shock absorption of contact with the boards/players/ice surface may be related to physical fitness levels.

Previous studies evaluating the role of strength in sports injury have primarily focused on hamstrings and groin strains.^{6,11,26,42} The relationship between hamstring strength and hamstring strains in Australian rules football players is conflicting.^{6,26} In NHL players, groin injury has been associated with weak hip adductor muscles and a low hip adductor to abductor muscle strength ratio.^{11,42}

While body composition was not related to injury in elite female soccer players, it is associated with groin strain in elite male players.^{4,27} Aerobic power (VO_2 max) was not associated

with injury in elite female soccer but is predictive of overuse injury during the basic training of army recruits.^{16,27}

A player's conditioning level, strength, and/or body composition may be related to risk of on-ice injury.^{13,18} Once the burden of disease and the factors affecting that burden have been identified, the appropriate injury prevention programs can be developed and tested. The purpose of this study was to determine the overall and seasonal injury rates for male collegiate ice hockey and to explore whether various measures of preseason fitness (eg, body composition, cardiovascular fitness, strength) play a role in the odds of sustaining an in-season on-ice injury in this group.

MATERIALS AND METHODS

All male ice hockey athletes from a single Division I university varsity team over 8 successive hockey seasons were included in this study. These athletes were identified from rosters and SIMS (Sports Injury Monitoring System V5.2; Flantech, Inc) database entries maintained by the team's head athletic trainer. Athletes were excluded if they did not participate in the preseason fitness assessments. Athletes were included as cases if they had a diagnosis of a hockey-related injury during the collegiate hockey season, including the preseason and postseason. All injuries were assessed by the team's head athletic trainer in consultation with the team physician as necessary. Athletes were excluded if they were injured during non-hockey-related activity or during off-ice hockey activity. An injury was defined as any event that directly resulted in the athlete being unable to participate in on-ice activity for at least 1 day following the event.^{2,5,9,14,18,25,29,38} An athlete exposure (AE) was defined as an officially scheduled on-ice practice or game in which the athlete at least partially participated (eg, 1 game in which 17 players participated for any period of time during the actual game = 17 AEs).^{5,21} Detailed hockey-related injury data as well as player-level practice and game exposure data had been collected in the SIMS computerized database by the team athletic trainer, who attended all practices and games over the 8 seasons. Additional injury information, if needed, was obtained from the athletic department's medical records for those athletes with injuries of interest. Ethical approval was obtained from the medical institutional review board.

Individual tracking of athlete participation at each session allowed for a direct calculation of athlete exposure.²¹ The total number of AEs per season from all players was tabulated from the athlete-level tracking data. The total number of qualifying injuries was then related to the total number of AEs for all players, resulting in an injury rate per 1000 AEs over the entire study period (8 seasons) and for each individual season.⁵

The following athlete demographic and injury variables were collected: (1) age, (2) year of eligibility, (3) mechanism of injury, (4) player position (forward, defense, goaltender), (5) whether injury occurred during a game (including period) or practice session, and (6) time lost before return to play.

Table 1. Variables used for injury modeling

Model 1 (8 Years)	Model 2 (4 Years) ^a	Model 3 (4 Years) ^a
Age, y	1.5-mile run	1-mile run
Height, m	5-mile run	300-m shuttle run
Weight, kg	Maximum sit-ups	Vertical jump, cm
Body mass index, kg/m ²	Maximum chin-ups	Olympic cleans
Player position	Grip strength, kg	3 RM bench press
Body composition		3 RM squats
Maximum bench press at 84.1 kg		
Stair run		

RM, repetition maximum.

^aModel 2 variables were assessed in the first 4 years of the study period, and model 3 variables were assessed in the later 4 years of the study period.

The mechanism of injury was categorized as having occurred by impact with another player, impact with the puck/stick, impact with the ice/boards/goal, a noncontact acute injury, or an overuse injury. The type of injury was categorized as fracture/dislocation, sprain, strain, laceration, contusion, concussion/closed head injury, or bursitis/synovitis. The body part injured was categorized as follows: leg/foot, knee, hip/thigh, arm/hand, shoulder, thorax, or head/neck.

Body composition, aerobic endurance, and strength assessment data had been routinely collected on all varsity hockey athletes over the 8 seasons. These data were collected by the same strength and conditioning coach during standardized testing of all players during training camp each year. Some of the specific fitness variables assessed were exchanged after the first 4 years of the study period. As such, all variables were not available for all years. Three separate sets of data were therefore available for analysis (Table 1). Percentage body fat was measured using bioimpedance (Quantum II Bioelectrical Body Composition Analyzer; RJL Sciences, Inc). The 300-m shuttle run involved 6 laps of a 25-m course. Lower extremity power was measured using a maximal countermovement vertical jump (centimeters). While a complete review of the reported reliability of these outcomes is beyond the scope of this manuscript, intraclass correlation coefficients (ICCs) range from 0.94 to 0.99 for grip strength, maximum bench press and squats, Olympic cleans, and the shuttle run.^{1,8,33,39}

Statistical analyses were performed using Stata 6.0 (Stata Corp). Athlete demographic, injury, and fitness data were described with measures of central tendency, variance, and boxplots. The difference in the frequency of injury by player position was assessed with a chi-square analysis. Single-variable logistic regression analyses were employed to assess the ability of each independent variable to predict the probability of the occurrence of an on-ice injury (Table 1). In addition to the fitness variables, player position and the number of years of

play in collegiate hockey were also assessed. Significant predictor variables from the single-variable modeling were then entered into a multivariable regression model, and a backward stepwise regression was performed. Variables with the highest nonsignificant *P* values were dropped from the model until only significant variables remained. To assess the model fit, analyses of residuals were performed. Odds ratios for the significant predictor variables were determined from the logistic regression analyses. Logistic regression was performed both including and excluding reinjuries to control for the possibility of confounding. Given the retrospective nature of this study, our sample size was set. Previous epidemiological studies involving logistic regression have determined that 5 to 10 subjects per variable is acceptable for multiple logistic regression analysis.^{3,28}

While data from the same player over multiple seasons are not mutually exclusive, the modifiable risk factors that may have confounded injury risk year to year would be included in the analysis, and therefore controlled for. Also, an individual's anthropometric, cardiovascular, body composition, and strength variables may have changed from year to year, potentially modifying their risk for injury. In this manner, the independent variables associated with specific individuals could be paired with their injury history for the same year. To account for multiple observations for individual players across several years, the variables "player," "year," and the interaction term "player × year" were modeled on the probability of injury using logistic regression. This modeling of both the "player" and "year" variables account for the clustering associated with multiple years and having the same player present in multiple years.

RESULTS

Seventy-nine different players participated on the team over the 8 seasons (Table 2). This resulted in 203 player-years. There

Table 2. Subject anthropometric data (mean \pm SD)

Measure	Mean	Range
Age, y	20.2 \pm 1.6	17-24
Height, m	1.82 \pm 0.06	1.65-1.93
Weight, kg	85.6 \pm 7.0	67.7-106.8
Body mass index, kg/m ²	25.7 \pm 1.6	20.2-30.5

were 132 injuries in 55 players over the 8 seasons, with a mean of 16.5 injuries per season (range, 12-21 injuries). Fourteen (10.6%) of these were reinjuries. Appendix 1 lists the total number of injuries, AEs, and injury rates for each year and the cumulative results for the 8 seasons (available at <http://sph.sagepub.com/content/suppl>). For reference, there were usually 5 practices and 2 games per week during the season.

Forwards sustained a significantly higher proportion of injuries (68.2%, $\chi^2 = 19.91$, $P < 0.001$) compared with defensemen (25.8%) and goaltenders (6.1%). Given the differential in the number of players per position on the ice at one time, the expected frequency of injury under the null hypothesis would be 50% for forwards (3 of 6 players), 33.3% for defensemen (2 of 6 players), and 16.7% for goaltenders (1 of 6 players). Thirty-four percent of injuries occurred during practice sessions, while the remaining 66% occurred in games and were equally distributed across the 3 periods of play (21%, 21%, and 19%, respectively). One injury occurred in overtime, and the period of injury was not reported in 5 cases (3.8%).

The various mechanisms of injury, the frequency of injury by body region, and the types of injuries sustained are shown in Tables 3 through 5. The mean lost time per injury was 7.8 \pm 13.8 days (median, 3 days; range, 1-127 days). This equated to 5.4 \pm 10.7 practices or games missed (median, 2; range, 0-99). Those players missing zero events (practices or games) would have had a scheduled "off" day following the day of injury and were able to return to play by the next on-ice event. Five players had injuries or surgery at the end of the season and therefore did not miss any practices or games. These players were included in the regression analyses, but their data were not included in the calculation of lost time.

Four variables were identified as significant predictors of the odds of on-ice injury in the 8-year data set (model 1, Appendix 2; available at <http://sph.sagepub.com/content/suppl>). These variables were body weight, body mass index (BMI), player position, and the maximum number of bench press repetitions with an 84.1-kg (185 lbs) load. The "player" and "year of play" variables were not significant, nor was the interaction term "player \times year." Therefore, these 3 variables were excluded from the models. Given that body weight is a component of BMI, the 2 variables were assessed for collinearity. The tolerance (0.956)

Table 3. Mechanism of injury

Mechanism of Injury	Number of Injuries	Frequency (%)
Impact with another player	71	53.8
Impact with the ice/boards	19	14.4
Noncontact acute	15	11.4
Not specified	15	11.4
Impact with the puck/stick	10	7.5
Overuse	2	1.5
Total	132	100.0

Table 4. Frequency of injury to specific areas of the body

Body Part	Number of Injuries	Frequency (%)
Thigh/hip	28	21.2
Shoulder	27	20.5
Head/neck	21	15.9
Knee	18	13.6
Arm/hand	16	12.1
Leg/foot	13	9.9
Thorax/spine	5	3.8
Abdomen	4	3.0
Total	132	100.0

and the variance inflation factor (1.61) for this relationship demonstrated that these variables were not collinear. The odds of injury increased 1.3 times for each increase of 5 kg in body weight ($P = 0.03$). Similarly, the odds of injury increased by 1.3 times for each increase of 1 kg/m² in BMI ($P = 0.002$). Players with BMI ≥ 25 kg/m² had an odds of injury 2.1 times higher than players with a BMI of < 25 kg/m² ($P = 0.02$). The odds of injury in a forward was 1.9 times that of a defenseman ($P = 0.03$) and 3 times the odds of injury in a goaltender ($P = 0.02$). The only strength variable to be predictive of injury was the maximum number of barbell bench press repetitions performed with a standard load of 84.1 kg (185 lbs). The odds of an in-season on-ice injury was 1.3 times higher for every increase of 5 repetitions ($P = 0.02$). There were no significant multivariable

Table 5. Frequency of the types of injuries sustained

Injury Type	Number of Injuries	Frequency (%)
Sprain	49	37.1
Strain	24	18.2
Fracture/dislocation	17	12.9
Contusion	14	10.6
Concussion/closed head injury	14	10.6
Laceration	5	3.8
Bursitis/synovitis	5	3.8
Other ^a	4	3.0
Total	132	100.0

^aTwo inguinal hernias, pneumothorax, cervical rib syndrome.

models. The exclusion of reinjuries did not change the variables that were significant predictors, and the associated odds ratios were minimally changed (Appendix 3, available at <http://sph.sagepub.com/content/suppl>).

The analysis of the 4-year data in model 2 demonstrated that only the maximal number of sit-ups was a significant predictor of on-ice injury. The odds of injury increased 1.3 times for each increase of 5 sit-ups ($P = 0.034$). In the analysis of the 4 years of data in model 3, both the 300-m shuttle run and the maximum weight used for an Olympic clean were the only 2 significant predictor variables for on-ice injury. With every 1-second increase in shuttle run time, the odds of injury decreased by 28% ($P = 0.014$). The odds of injury increased 1.1 times for each 4.5-kg increase in maximum Olympic clean ($P = 0.011$). There were no significant multivariable regression models in either model 2 or 3. Given the potential for BMI to confound the relationship of strength variables with injury, a post hoc logistic regression analysis was performed. There was no significant interaction, nor any sign of confounding, between BMI and either bench press, sit-ups, or maximum Olympic cleans. Regression summaries for each of the significant predictor variables for single-variable modeling are listed in Appendix 2. The exclusion of reinjuries did not change the variables that were significant predictors and the associated odds ratios were minimally changed (Appendix 3).

DISCUSSION

The injury rate of 4.4 injuries per 1000 AEs is consistent with the rates found by 2 previous studies of US collegiate hockey (2.69/1000 AEs and 6.4/1000 AEs)^{2,5} and further supports that

the majority of injuries occur during games.^{2,5,7,14,17,18,20,30,37,38}

Two controversies in the hockey injury literature involve whether players in a certain position (eg, forward) are more likely to sustain injury^{2,5,7,14,17,18,20,29-31,37} and whether more injuries occur later in the game, suggestive of fatigue being a factor related to the risk of injury.^{2,14,18,24,29,31,37,38} This study demonstrated that forwards do suffer a higher percentage of injuries, even after adjusting for the increased number of players in that position on the ice at any one time.² Published data on impacts to the head during hockey demonstrate that forwards sustain either the same or more hits compared with defensemen.^{23,32} It is unknown how these data relate to receiving body checks in general. Players delivering body checks are more likely to be prepared and brace for the impact compared with those who are trying to escape the body check and play the puck. In youth hockey, 97% of injuries related to body checking were sustained by the player receiving the check.¹² Video and kinetic data show that accelerations due to head impacts are significantly less when players anticipate the impact with good body positioning compared with unanticipated impacts.²² Injury rates are higher in leagues that allow body checking,^{10,44} and the majority of injuries that occur in those leagues are caused by player contact.^{2,7,14,18,20,24,37}

Fatigue has been suggested as a possible factor related to injuries in ice hockey. Three studies show that more injuries occur in the third period than either of the first 2 periods.^{24,31,37} Forty-five percent of the injuries in Junior A hockey occurred in the last 5 minutes of the period.³¹ Injuries later in the period or later in the game could also be related to an increased urgency to score or protect a lead, which may lead to increased physical intensity and aggression.^{24,37} This study found an equal distribution of injuries across all 3 periods of play, in line with other previous studies.^{2,14,18,29,38} There may be a relationship between the amount of an NHL player's ice time per game and his risk of concussion.³⁶ It is not clear, however, whether the increased risk of concussion was related more to an increase in exposure time or to fatigue.

An increase in body weight and BMI were related to an increased likelihood of injury. Superficially, those players who weighed more and potentially had an increase in body fat were less fit and were therefore more likely to be injured. Body composition, however, was an independently assessed variable and was not a significant predictor of injury. It is therefore difficult to fully explain the relationship between body weight or BMI and injury. Given the relative increase in lean muscle mass in athletes compared with the general population, it is important to note that BMI in this athletic population is regarded as a general measure of the body mass to height ratio and not specifically a measure of body composition or body fat percentage.

The fact that better scores in the tests of physical fitness (ie, bench press, sit-ups, Olympic cleans, shuttle run) were related to an increased odds of injury further clouds the result. While the relationship between groin strains and adductor muscle strength and hip adductor to abductor muscle imbalance varies

among studies,^{11,42} an increased volume of preseason sport-specific training and a focused functional adductor strengthening program have both been shown to reduce the rate of groin strain in NHL players.^{11,41} A small pilot study in junior hockey players also demonstrated a reduction in the number and severity of injuries following a hockey-specific 12-week preseason training program.¹⁵

The findings of this study present 2 possible explanations: (1) preseason fitness levels are not strongly predictive of on-ice injury or (2) the general fitness measures included in this study are not sufficiently specific to hockey to strongly predict those players who have an increased likelihood of on-ice injury.

As with any retrospective study, there are limitations. There were 203 player-years and 19 variables assessed in the logistic regression analyses. While this sample size is within the 10 samples per variable rule of thumb,^{3,43} the study may be underpowered to detect other variables that are predictive of in-season injury. Given the retrospective nature of the study, our sample size was set, and as such, we did not perform an a priori sample size calculation. Confounding of the relationship between injury and player fitness by unknown risk factors is a possibility. An attempt was made to control for the influence of player-specific and team factors by including the “player” and “year” variables in the modeling. We did not assess for any change in intraplayer fitness variables in cases where players competed in multiple years. The variable number of players who played multiple years made the inclusion of these data in the analysis difficult.

CONCLUSION

Division I male collegiate ice hockey teams can expect approximately 17 lost-time injuries per season, with a median of 2 practices or games missed per injury. Forwards are more likely to be injured than are those playing other positions. Injuries tend to occur in games, and involved sprains or strains to the hip, thigh, or shoulder regions. Players with higher body weight and BMI are more likely to be injured.

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