Relationship of Physical Fitness Test Results and Hockey Playing Potential in Elite-Level Ice Hockey Players

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Abstract

Burr, JF, Jamnik, RK, Baker, J, Macpherson, A, Gledhill, N, and McGuire, EJ. Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *J Strength Cond Res* 22(5): 1535–1543, 2008—The primary purpose of this study was to determine the fitness variables with the highest capability for predicting hockey playing potential at the elite level as determined by entry draft selection order. We also examined the differences associated with the predictive abilities of the test components among playing positions. The secondary purpose of this study was to update the physiological profile of contemporary hockey players including positional differences. Fitness test results conducted by our laboratory at the National Hockey League Entry Draft combine were compared with draft selection order on a total of 853 players. Regression models revealed peak anaerobic power output to be important for higher draft round selection in all positions; however, the degree of importance of this measurement varied with playing position. The body index, which is a composite score of height, lean mass, and muscular development, was similarly important in all models, with differing influence by position. Removal of the goalies' data increased predictive capacity, suggesting that talent identification using physical fitness testing of this sort may be more appropriate for skating players. Standing long jump was identified as a significant predictor variable for forwards and defense and could be a useful surrogate for assessing overall hockey potential. Significant differences exist between the physiological profiles of current players based on playing position. There are also positional differences in the relative importance of anthropometric and fitness measures of off-ice hockey tests in relation to draft order. Physical fitness measures and anthropometric data are valuable in helping predict hockey playing potential. Emphasis on anthropometry should be used when comparing elite-level forwards, whereas peak anaerobic power and fatigue rate are more useful for differentiating between defense.

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Introduction

Ice hockey is a physically demanding contact sport involving repeated bouts of high-energy output, with shifts lasting from 30 to 80 seconds (11,15,17). Given the anaerobic nature of the sprint-based shifts (69% anaerobic glycolysis) and the aerobic recovery (31% aerobic metabolism) between shifts and periods, as well as the physicality of the game, success at the elite level requires players to develop well-rounded fitness including anaerobic sprint ability, a strong aerobic endurance base, and high levels of muscular strength, power, and endurance (7,10,15,19). Despite the overwhelming number of participants in amateur hockey, only the fastest, strongest, and most skilled players will ever achieve the goal of being drafted to play in the National Hockey League (NHL). Although there are infinite combinations of "real-world" factors that interact to make one player more skilled than another, there are specific, quantifiable characteristics that can be used to determine a player's physiological capacity.

At the elite hockey level, there have been long-standing debates among scouts, coaches, strength/conditioning specialists and physiologists as to the relative utility of off-ice tests for talent identification. On the basis of personal experience and point of view, the diverse professions often place different emphasis on test components, with the belief that one test result may be better suited to revealing hockey potential than another. Some believe that certain test results, either by themselves or in combination with others, are sufficient to distinguish overall hockey potential between players. As a result, fitness tests sometimes include duplicate measures of the same physiological components using different protocols to satisfy all points of view. An example of one such test is the vertical jump, which is used to calculate leg power and has repeatedly been shown to be related to skating abilities

(3,5,8,16). Many variations of the vertical jump test have been developed with differences such as simple jump and reach devices vs. electronic measuring devices, the allowance or forbiddance of arm swing, and complete cessation of movement before jumping vs. bouncing countermovements. Until recently (6), the answer to the question of "which jump protocol gives the most useful results for determining a player's potential?" would depend highly on who was asked.

Currently, much of the hockey-related fitness research focus is on off-ice testing and the relationship of these off-ice tests to on-ice measures of skating performance (2–5,8, 13,16,18). Although skating speed and acceleration are undoubtedly essential components of a successful hockey player, skating proficiency is not the only essential fitness-dependent variable determining ability. Given the quick pace, intensity, and physicality of the game of ice hockey, other physical factors such as size, strength, coordination, and muscular endurance play important roles in determining success. In a prior study, we examined the predictive capacity of various vertical jump protocols to determine which protocol was the most appropriate for use with elite hockey players and which showed the highest correlation with draft round selection order in an attempt to settle the debate surrounding this particular test (6). After our study of the vertical jump, the next step is to examine other commonly used testing protocols to determine whether any test, or combination of tests, more accurately predicts hockey success.

Previous research by Green et al. (12) has examined the relationship of various fitness results to hockey playing success as measured by total ice time and scoring chances (±) of a player's line while on the ice using NCAA hockey players. Despite the novel use of these outcome variables, which reflect an in-season quantifiable measure of success, this study was limited by the laborious nature of the data collection and the resulting fact that it only covered a single hockey season. As such, the study population is greatly limited, and so is the ability to generalize these results to other, similar populations. By using draft round selection order as an outcome variable, as opposed to individual success indicators or a discrete skill such as skating speed, Vescovi et al. (20) examined 3 years of National Hockey League Entry Draft (NHLED) combine fitness data to determine whether the physiological profiles of players could differentiate which round of the draft a player was selected in. These authors found that the combine variables were unable to predict draft order selection in elite athletes. However, because all 3 years of data were analyzed separately, there is a possibility that the sample sizes were not large enough to detect a significant difference even if one existed. Further, all playing positions were examined together, thus suggesting that all players, including skating players (forward and defense) and non-skating goalies, are expected to have similar physiological attributes, and that they are treated as such when drafted.

Given the differences in positional requirements, assuming that all players are similar may introduce error into the predictive ability of the fitness test results. It is our belief that further analysis of the test variables using numerous years of draft-eligible players and stratifying by player position may be able to more accurately determine the fitness-related factor, or factors, most highly predictive of hockey potential. As indicated by Geithner et al. (9), studies on positional differences in physical characteristics or performance among men's ice hockey players are limited. Further, the normative data that exist (1,14) were developed using relatively small numbers of players and are 20 or more years old.

Therefore, the primary purpose of this study is to determine which fitness variable, or group of fitness variables, is most useful for predicting hockey playing potential at the elite level as determined by draft round selection. Within this objective, we hope to highlight the differences associated with the predictive abilities of the test components between playing positions. Finally, we aim to provide an updated physiological profile of contemporary hockey players, both collectively and by playing position.

Methods

Approach to the Problem

Every June, the top 110–120 players worldwide are invited to the NHLED testing combine, where they participate in a battery of hockey-related tests designed to assess player fitness. These tests, which were all considered as possible predictor variables, include the Wingate 30-second anaerobic power test (peak watts and fatigue index), aerobic power ($\dot{V}O_2max$), physical development, height, weight, percent body fat, grip strength, bench press, sit-ups, push-ups, standing long jump, vertical jump leg power, upper-body power, flexibility, and isometric push and pull force. These specific measures were chosen for test inclusion on the basis of the expert opinion of a group of exercise physiologists, with feedback from NHL scouts and strength and conditioning coaches. Members of the human performance laboratory at York University carried out all tests and measures, thus making this a novel study because of the degree of control the researchers had in data collection and reporting. Throughout the combine, care is taken to ensure that protocol reliability is held to laboratory standards. Using test results from 1998 through 2006 allowed us to include the highest-possible combination of subjects and testing variables, with the exclusion of only the upper-body power variable, which was not introduced until 2002.

Draft selection order was designated as the outcome variable because it includes the combination of physical fitness variables as well as on-ice performance as assessed by central scouting and individual team scouts. It is commonly acknowledged that during the draft a team will always choose the best player still available for selection, thus essentially ranking the players on overall potential playing ability within each year's draft. Because the study period encompassed a total of 8 years, players were grouped by selection round as opposed to rank, to collapse all of the years together and to avoid having eight separate rank orders. Those players drafted in the earlier rounds are considered more successful than those drafted in the later rounds. Any player not drafted in the draft year in which he was tested was allocated to the last round of his draft year. Because of the selective nature of inviting participants to the NHLED combine, the upper rounds had a greater representation of players, with an average of 210 players per round in rounds 1–5 compared with an average inclusion of 46 per round in rounds 7–11.

Testing Procedure

The NHLED fitness testing combine is arranged as a circuit in which players attempt each test, in a designated order, one after the other. The circuit is designed so that appropriate recovery time is given between tests using similar muscle groups, and so that completion of one test does not lead to serious decrements in another. All players complete the testing in the same order, and only those players who were in good health and completed the majority of the tests (see below) were included in the analyses. A description of the tests including the associated measurement units is contained in Table 1.

Subjects

The study sample included 853 elite junior-level hockey players, all of whom were ranked by NHL central scouting as being among the top 120 players worldwide of their respective year. Within this population, 493 were forwards, 277 were defense, and 83 were goalies. Before inclusion in the study, players were screened so that any player who presented at the combine with an upper- or lower-body injury resulting in exclusion from more than two individual tests was removed. Those who missed two tests or fewer were included, and missing values were replaced with the overall group mean for that variable. An analysis of the consequential removal of players by round revealed that no round was any more affected by the removal of players than any other, thus dispelling the notion that either the top-ranked or bottom-ranked players may be more susceptible to avoiding a test because of an injury. In accord with York University policy, this investigation was approved by the office of human research ethics, and written informed consent was obtained from participants, as described by the ACSM guidelines, with the understanding that data would be used only in a summarized form and that participant names would remain confidential.

Statistical Analyses

All statistical analyses were conducted using SPSS 13.0. Basic descriptive statistics were calculated, and all variables were examined for normal distribution. Normality was further confirmed using measures of kurtosis and skewness. Simple analyses of variance using post hoc Bonferonni comparisons were used to examine positional differences in the descriptive data. Bivariate correlations were performed for each model to determine individual relations with draft outcome as well as colinearity of predictors. Values of $\leq r = 0.50$ were accepted as being linearly independent for inclusion, permitting the absence of overriding conceptual similarity. Accordingly, the anthropometric measures of height, lean body mass, and physical development were combined into a single index score (referred to herein as *body index*) by summing the z-scores for each measure. Stepwise regression was used to identify the significant predictor variables ($p \leq 0.05$) and R^2 for each of the four consecutive models, which were 1) all players ($n = 853$), 2) all skating players–no goalies ($n = 770$), 3) forwards ($n = 493$), and 4) defense ($n = 277$). Post hoc power analysis using PS Power and Sample Size Calculations software (version 2.1.31) was performed on the model with the smallest subpopulation and revealed a power of 1.0.

Results

Descriptive statistics of the anthropometric and physiological profiles of NHLED hockey players, both collectively and by position, are presented in Table 2. Descriptive statistics such as age, height, and weight of the study population are included. Positional differences by variable are highlighted in the rightmost columns, with significance reported at both the $p \leq 0.05$ and $p \leq 0.001$ levels. For variables in which there were no significant differences between any of the playing positions, the column contains "no differences," whereas for variables that have at least one significant difference between positions, the significant differences are marked with asterisks, and nonsignificant differences between positions are noted as being equal. Of particular interest, forwards have significantly greater relative aerobic powers than defense or goalies, as well as a lower percentage of body fat. Defense had a significantly greater absolute aerobic power than forwards, who, in turn, had significantly greater aerobic power than goalies. However, when expressed as a percentage of body weight, forwards have a greater relative aerobic power than either defense or goalies, who are not significantly different from one another. There are small standard deviations in aerobic power within the playing positions, signifying homogeneity of participants within groups on this measure. Forwards and defense are significantly more developed than goalies, further supporting the notion that the physical demands of goaltending are different than those for skating players. Defense are taller, heavier, and generally stronger on non–body-weight-dependent tests, but they have similar results to forwards on tests that require players to propel their own weight and are, as such, necessarily relative. There are significant differences in peak anaerobic power (PAnP) among the different playing positions.

A summary of the four regression models is presented in Table 3. Regression model 1, including all playing positions, accounts for roughly 5% of the variance in draft round selection order and only includes the predictor variables of body index and PAnP. When goalies are removed from the data, model 2 improves to account for approximately 7% of the variance and includes anaerobic fatigue rate (AnF) and long jump as significant predictors along with PAnP and body index. The standardized beta coefficients reveal that the relative importance of body index decreases and that PAnP increases with removal of the goalies. This model, which has

Table 1. Detailed descriptions of the National Hockey League Entry Draft fitness test procedures and associated measurement units.

Test	Description	Measurement units
30-s Wingate	Standard Wingate test. Flying start. Loaded to 9% of body weight.	Peak watts (PAnP), fatigue index (AnF) (% drop-off, maximum − minimum)
Aerobic power	Cycle ergometer graded exercise testing, using direct gas analysis. Incremental loading. Starts continuous, ends discontinuous.	Absolute $\dot{V}O_2max$ ($L \cdot min^{-1}$); not relative $\dot{V}O_2$ because weight is an independent factor
Physical development*	Determined by medical doctors. Players rated as below average, average, above average, or extensive. Both upper and lower body.	Upper- and lower-body combined score for analysis. Coded from 1 to 4, with 1 = below average, 4 = extensive.
Height*	Measured with shoes off, feet together. Highest point of head.	Reported to the nearest 0.25 in
Weight	Scale recalibrated for each player.	Measured to the nearest 0.1 lb
Percent body fat (lean mass*)	Harpenden skinfold calipers. Calculations based on the Yuhasz six-site skinfold formula.	Pounds used to calculate lean mass* (weight − % fat)
Grip strength	Grip strength dynamometer, set to second knuckle. Two trials, maximum recorded.	Pounds left and right combined for analysis
Bench press	150 lb, standard grip, lowered to chest at axillary line. Performed with metronome to pace of 25 per minute.	Maximum consecutive repetitions
Push-ups	Hands under the shoulders, fingers forward, elbows in. Cadence of 25 per minute.	Maximum consecutive repetitions. Differs from bench press because emphasis is on triceps and core stability.
Sit-ups (curls ups)	Arms crossed with hands on opposite shoulders. Knees at 90°. Sit up until elbows touch knees, down until shoulder blades contact mat. Cadence = 25 per minute.	Maximum consecutive repetitions
Standing long jump	Countermovement permitted. Maximum of three trials recorded.	Distance (cm)
Vertical jump	Vertek apparatus used for analyses (see Burr et al.). Stand and reach measured with shoes on. Stand and reach subtracted from highest jump of three trials.	Vertical distance (nearest 0.5 inch); converted to watts using Sayer's equation for peak power
Upper-body push and pull (isometric)	Specialized strain gauge apparatus is strapped to player's chest and adjusted so that elbow is bent to a standardized angle. Maximum force of three trials (push/pull) recorded.	Force converted to pounds
Flexibility	Lower back and hamstrings using a sit-and-reach flexibility test	Measured to the nearest 0.5 cm

*Variables used to make a combined body index score for analysis.

the largest subpopulation of players (all skating players), is the only model to include standing long jump as a significant predictor variable. It is probable that the further division of skating players into forwards and defense in models 3 and 4, respectively, lack sufficient numbers to detect this variable as a significant predictor, thus explaining its later disappearance. Model 4, which includes only defense, accounts for the highest variance in draft round and includes the predictor variables of PAnP, AnF, and body index. Examination of the changes in the standardized beta coefficients in models 3 and 4, which look at forwards and defense separately, reveal that the relative importance of body index increases for forwards, and PAnP and AnF become more important for defense compared with the combined model. The variables of aerobic power, grip strength, push-ups, bench press, flexibility, vertical jump, or isometric push and pull were not significant in any of the models.

Discussion

The results of the present study differ from those of Vescovi et al. (20), who found no significant predictive capacity of any of the NHLED combine testing variables to predict draft round. These differing results may be attributable to the fact that our study population included 8 years of data and, as such, had the power to detect smaller differences. It is important to note, however, that despite finding statistically and theoretically significant variables useful in helping to predict draft success in hockey, the variance explained by even the best model was less than 10%. This draws attention to the fact that physiological potential is only a small part of what composes a skillful hockey player and that draft-day decisions are based not only on physical capacity but also on comprehensive reports of past performance, game observation, player aggression, psychological factors, and professional scouting intuition.

The variance explained between players' fitness tests and draft round in the current study is also artificially depressed because only the top 120 players worldwide are invited to the combine each year. As a result, this selection narrows the variation in ability from one player to the next, and it is expected that the best players would share similar attributes and physiological traits. This might explain why some variables that logically seem as if they should have an impact on draft order were not found to be significant predictors, and why such effects may not be detected with smaller sample sizes. As such, another value of the physical testing may actually be its ability to identify those players with serious deficiencies that would set them apart from all other players with high values in the "elite" category.

Although the majority of this paper focuses on the talent-identification abilities of the NHLED testing in relation to physiological capabilities, it is important to keep in mind that this is not the sole utility for the NHLED testing combine. During the physical testing, team scouts and officials carefully observe players to look for important markers of team fit and other attributes that could impact future success such as apparent motivation, attitude, and ability to perform under pressure. It has also been suggested that because scouts already have a good idea of how players are ranked on the basis of game play, if deciding between two equally ranked players, scouts may actually choose a player who scores lower on a given test. In theory, if a player has significant room to improve on a particular physical attribute compared with an equally ranked rival, he can be coached to work on his weakness, thus raising it to a level equal to, or better than, the other player. Given that the two players were originally considered to be of equal ability, the underdeveloped player who made great improvements may ultimately be the better player. The selection technique of choosing the less developed player is another potential reason why the predictive abilities of the regression models are not exceedingly high, and, thus, the conclusion that physical testing is of little importance should not be made. Lastly, the testing data are valuable not only in a predictive capacity but also to be used as benchmark measures that teams can refer back to when examining changes in fitness throughout the season, or even throughout a career. This sort of "benchmark fitness" can be useful in evaluating off-season training effectiveness and when returning to play from injury.

Comparable with the study by Green et al. (12), we found that percent body fat (as part of the body index score) had an influence on success, as did anaerobic power (PAnP and AnF in our study vs. lactate at a given stage in Green et al.). However, in contrast to Green et al., we found no significant relation between aerobic power and success in hockey. As mentioned above, this may be because our study examined only players at the elite level and because aerobic power, which allows players to recover between shifts, is a necessary universal trait to compete at this elite level. Thus, all players in our cohort would possess necessarily high levels of this trait. To test this possibility, future research should draw comparisons between different levels of players (amateur, Junior A, semipro, and professional) and a common indicator of success to increase the range in ability and determine the effects of the various physiological predictors.

The removal of goalies between model 1 and model 2, and the consequent increase in the predictive power of the model, underlines the low predictive power of the fitness testing for goalies. Subsequent, unreported analysis of the goalies alone revealed no significant predictor variables. Not surprisingly, goalies were able to generate the lowest leg-power values, had significantly lower $\dot{V}O_2max$ values, were less muscularly developed, were poorer jumpers, and were generally weaker than forwards and defense. This is not to suggest that they are lower-caliber athletes, but they clearly have different positional demands aside from the strength, power, and endurance measures used with the other players. It would seem logical that goalie-specific fitness testing should focus more on flexibility, reaction time, hand-eye coordination, and skill. However, physical fitness may still play an important role in combating fatigue, preventing injury, and maintaining optimal cognitive functioning under physical stress.

Model 4, which analyzed defense alone, had the highest predictive power of any of the models and suggests that this type of testing is better suited for defense. Defense are generally taller and heavier than forwards, albeit with slightly more fat mass (Table 2); as such, it is not surprising that body index was less important in this equation than it was for forwards. The ability to generate high amounts of power was universally related to hockey success in all models, but more so for defense than forwards. The relative increases in the importance of PAnP and AnF when forwards are removed from the model make logical sense in that defense, who are bigger, will be required to generate more power to keep pace with the lighter, speedier forwards (17). Given that there are fewer defense players per team, and that defensive players are often required to take more frequent and longer-duration

TABLE 2. Anthropometric and physiological profiles of contemporary National Hockey League Entry Draft hockey players, with comparisons between playing positions.

Predictor/ descriptive variable	Position	Mean	*SD*	Minimum	Maximum	Positional differences	Predictor/ descriptive variable	Position	Mean	*SD*	Minimum	Maximum	Positional differences
Wingate peak (W)	D	1000	126	638	1380	D > F*	Vertical jump (in)	D	24.5	2.9	18	36	F = D
	F	974	137	547	1515	D > G†		F	24.6	3.1	15	36	F > G†
	G	897	114	642	1175	F > G*		G	23	2.7	17.5	29	D > G†
	All combined	975	135					All combined	24.4	3			
Fatigue index (% drop-off)	D	38.3	7	19.1	68.9		Vertical jump power (W)	D	5822	575	3607	8046	D > F†
	F	38.1	6.6	16.8	58.7	No differences		F	5646	572	4153	7778	D > G†
	G	38.1	6.7	18	54.3			G	5338	507	3936	6494	F > G†
	All combined	38.1	6.7					All combined	5673	582			
Absolute $\dot{V}O_2$max	D	5.13	0.52	3.83	6.9	D > F*	Bench press (reps)	D	10	4	0	22	D > F†
	F	5.01	0.54	3.44	6.92	D > G†		F	9	4	0	22	D > G†
	G	4.73	0.53	3.59	5.73	F > G†		G	5	5	0	18	F > G†
	All combined	5.02	0.54					All combined	9	5			
Relative $\dot{V}O_2$max	D	56.7	5.3	41.9	70.7	F > D*	Sit-ups (reps)	D	24	14	0	100	
	F	58.1	5.6	41.4	77.3	D = G		F	24	15	0	100	No differences
	G	55.9	6.1	43.6	69.3	F > G*		G	24	11	4	50	
	All combined	57.4	5.6					All combined	24	15			
Muscular development (scored 1–8)	D	4.5	1.6	2	8	F = D	Sit and reach (cm)	D	38.1	7.7	18.1	54	G > F†
	F	4.5	1.7	2	8	F > G†		F	38.4	7.3	15	54	G > D†
	G	3.6	1.3	2	8	D > G†		G	44.7	7	24	61	F = D
	All combined	4.4	1.7					All combined	38.9	7.6			
Age (y)	D	18	1	17	20		Push-up (reps)	D	25	5	9	42	F = D
	F	18	1	17	20	No differences		F	26	6	10	43	F > G†
	G	18	1	17	20			G	21	6	3	37	D > G†
	All combined	18	1					All combined	25	6			
Height (in)	D	74	1.7	69.5	79.8	D > F†	Standing long jump (in)	D	100	6	80	116	F = D
	F	72.8	1.8	68	78.6	G > F†		F	100	7	76	122	F > G†
	G	73.2	1.7	68.5	78	D = G		G	96	7	71	115	D > G†
	All combined	73.3	1.9					All combined	100	7			
Weight (lb)	D	199	15.4	99	244	D > F†	Isometric push force (lb)	D	294	82	136	553	D = F
	F	190.1	13.5	142	229	D > G†		F	282	77	121	537	F > G†
	G	186.6	13.9	153	220	F = G		G	244	69	118.9	451	D > G†
	All combined	192.6	14.9					All combined	282	79			
Body fat (%)	D	10	1.7	6.9	15.8	G = D	Isometric pull force (lb)	D	267	33	184	425.3	D > F*

	F	9.4	1.5	6.7	16.9	G > F†		F	260	35	103	373	F > G†
	G	10.4	2.1	6.6	16.3	D > F†		G	244	35	176	368	D > G†
	All combined	9.7	1.7					All combined	261	35			
Lean mass (lb)	D	90	1.7	84.2	93.1	F > D†	Body index (combined Z-scores of height, lean mass, and development)	D	0.23	1.63	−5.16	5.29	D > F ($p = 0.056$)
	F	90.6	1.5	83.1	93.3	F > G†		F	−0.07	1.71	−6.59	4.45	F > G†
	G	89.6	2.1	83.7	93.4	D = G		G	−1.00	1.68	−5.88	3.68	D > G†
	All combined	90.3	1.7					All combined	−0.06	1.71			
Combined grip (lb)	D	267	29	180	352	D > F†							
	F	257	29	157	364	D > G†							
	G	242	31	172	302	F > G†							
	All combined	259	30										

D = defense; F = forward; G = goalie.
*$p \leq 0.05$.
†$p \leq 0.001$.

shifts, those defense players with the ability to maintain high levels of leg power should be more successful than those without this ability. Further, it is logical that the PAnP be more heavily weighted than the AnF, given that the aerobic energy system would help compensate during recovery time between shifts and periods. The absence of aerobic power as a predictor variable suggests that among elite, draft-age hockey players, there is little variation in $\dot{V}O_2$max within a given playing position. Examination of the standard deviation of $\dot{V}O_2$max in Table 2 confirms the homogeneity of this population in regard to aerobic power.

Body index (height, lean mass, muscular development) was a significant predictor in all four models, which is likely associated with the full-contact nature of ice hockey. In physical altercations for control of the puck, and at the moment of collision during a body check, larger, stronger players who possess greater muscle mass will generally be at an advantage. Although some degree of fat mass may be advantageous for injury protection during collision or as added mass for inertia while hitting, muscle mass is what helps propel players across the ice, and it can stabilize joints at impact. Interestingly, body index was most important in the model with only forwards, suggesting that being a larger, leaner forward may be important for success in trying to fend off opposing forwards and defense. Traditionally, many coaches and parents have encouraged physically mature youngsters into defensive roles, however, this finding may lend more support to further developing sturdy players into the "power forward" role because it has a higher relation to draft success with forwards than with defense. Once again, this disparity may be partially explained by the fact that all defense at this level are fairly large, but it does not take away from the finding that larger, leaner forwards found more success. It is, however, possible that players' body types continue to change after their draft year because many players will not yet have reached full maturational status at this age.

Standing long jump was found to be a significant predictor variable when all skating players were analyzed together. Although long jump only explained approximately 8.5% of the variation of this model, it is an interesting predictor and speaks to the value of long jump as a test of hockey potential. Standing long jump is a complex maneuver that requires players to combine components of vertical leg power, horizontal leg power, and a complex motor scheme (involving rudimentary calculations of impulse and take-off angle) in combination with a full-body coordinated movement to jump to maximum potential. Although the vertical jump is a popular test for assessing leg power because of its ease of administration and correlation to skating performance, the standing long jump may be a superior alternative to test a player's overall hockey-related athletic ability. As opposed to quantifying power in watts in an effort to predict a discrete skill, standing long jump distance may give a better overall impression of an athlete's current abilities. However, testers would not be able to separate the components of

Table 3. Multivariate models comparing National Hockey League Entry Draft predictor variables and draft-selection-order outcome.

Model	R	R^2 (adjusted R^2)	Predictors	B (*SE*)	Standardized β (α)
One: all positions	0.219	0.048 (0.046)	Constant	5.385 (0.563)	−0.137 ($p = 0.000$)
			Body index	−0.176 (0.045)	−0.136 ($p = 0.000$)
			Peak watts	−0.002 (0.001)	
Two: skating players (no goalies)	0.263	0.069 (0.064)	Constant	7.707 (1.277)	−0.170 ($p = 0.000$)
			Peak watts	−0.003 (0.001)	−0.111 ($p = 0.000$)
			Body index	−0.144 (0.050)	0.087 ($p = 0.004$)
			Fatigue	0.028 (0.012)	−0.084 ($p = 0.028$)
			Long jump	−0.028 (0.013)	
Three: forwards	0.234	0.055 (0.051)	Constant	5.272 (0.724)	−0.155 ($p = 0.001$)
			Body index	−0.199 (0.059)	−0.134 ($p = 0.004$)
			Peak watts	−0.002 (0.001)	
Four: defense	0.300	0.090 (0.080)	Constant	6.159 (1.078)	−0.258 ($p = 0.000$)
			Peak watts	−0.004 (0.001)	0.139 ($p = 0.027$)
			Fatigue	0.043 (0.019)	−0.118 ($p = 0.049$)
			Body index	−0.159 (0.080)	

a successful jump to determine where the player's strengths lie. Further research with a larger population, solely examining the results of the standing long jump in relation to draft order, may provide further insights.

Inspection of the anthropometric, physiologic normative data and the associated positional differences (Table 2) reveals that the population analyzed in the current study differs from those in previous studies. Contrary to both Agre et al. (1) and Houston and Green (14), who found no significant differences between playing positions in $\dot{V}O_2$max and percent body fat, we found forwards to have significantly greater relative aerobic powers and to have lower percentages of body fat than defense and goalies. Geithner et al. (9) similarly found forwards to be the leanest players in a study examining elite women's hockey players. Alternatively, in our comparison of players using absolute aerobic powers, defense were found to have significantly greater oxygen consumption than forwards, and forwards were significantly higher than goalies. Accounting for the weight and body fat differences between positions (defense higher than both forwards and goalies), the switch from defense with the highest "absolute" $\dot{V}O_2$ to forwards with the highest "relative" $\dot{V}O_2$ makes logical sense.

The finding that defense are significantly taller, heavier, and generally stronger on non–body-weight-dependent tests supports some previous findings and refutes others (1,9,14,17). On body-weight–dependent tests such as the vertical jump, standing long jump, push-ups, and sit-ups, forwards and defense had similar results and were generally more proficient than goalies. This further shows the positional differences between skating players and goalies as well as supporting the notion that defense need superior absolute strength to keep pace with lighter forwards, who require less overall force to move a smaller mass. Contrary to the results found by Houston and Green using Major Junior-A and university-level players (14), our study found significant differences in PAnP between defense, forwards, and goalies, respectively.

In general, the updated normative data presented in Table 2 of this paper reveal the current composition of an elite-level hockey player of draft age. Using these data as a reference, coaches, general managers, team trainers, and off-season conditioning specialists can compare current fitness levels with expected norms to help improve deficiencies and focus training on the most positionally important areas. By tailoring training regimens to focus on important physiologic characteristics of previous draft-successful players, training programs will likely evolve to help improve hockey-specific physiological capacities. However, it is important that practitioners still use logical, well–thought-out program design, rather than simply tailoring the program to target adaptations leading to physical measures similar to those seen in the elite draft-age players, so as not to perpetuate training mistakes of the past. Hockey is a constantly evolving sport, and success at the elite level depends on players evolving with, or even ahead of, the changing game. The measured physiological variables included in off-ice testing are merely proxies for the components of performance in hockey and are only valuable to the extent that they accurately reflect the skills they are intended to measure. Furthermore, simply because an off-ice test may be highly correlated to a discrete skill, such as skating, does not necessarily translate directly to on-ice performance.

Practical Applications

Hockey is a multidimensional sport that requires the contribution of many different components, both physical and psychological, for success at the elite level. The results of this study illustrate the importance of physical fitness testing and also illustrate that fitness is only one component of what comprises a successful hockey player. We have further shown that the necessary anthropometric and physiological attributes required for draft success vary by playing position. While using fitness testing for talent identification at the elite level, coaches, scouts, strength and conditioning experts, and sports scientists should assess forwards, defense, and goalies accordingly. Specifically, more consideration should be given to anthropometric measures when comparing between forwards than defense, and although peak anaerobic power output is important for all hockey players, it should be given more influence when comparing within the group of defense. Further, defense who can maintain a higher percentage of their peak output tend to have more success than those who cannot. Physiological capacities have little relation to draft success with elite-level goalies, but, as with any position, deficits in ability that rank one player far below the average may make that player less desirable. The standing long jump demonstrates potential as an easily administered field test that might give a good indication of overall athletic ability in relation to hockey. Given the current popularity of the vertical jump in hockey-related fitness testing, both as part of an overall test and even as a stand-alone measurement, further research is warranted to determine whether the standing long jump might be a superior alternative.

When performing talent identification at levels other than among elite athletes, practitioners should remember that other variables such as aerobic power and upper- or lower-body strength and power tests may have a greater ability to discriminate between players than in the current study. In less-select populations, there will likely be more variation between players, both in terms of hockey skill and physiological attributes, compared with the highly homogeneous group examined at present. Further research is needed to determine the relative importance of these physical fitness testing variables at less-elite levels of play.

Table 2, which presents a physiological profile of contemporary entry-level NHL players, should be of use to coaches and strength and conditioning specialists to compare upcoming players against elite-level norms. By using the breakdown of positional averages, training programs can be specifically adapted to help teams and individual players alike. Players who are particularly strong or weak in an area can be coached to help focus training on areas that may result in the greatest improvement.

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