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Research article

Multiple Off-Ice Performance Variables Predict On-Ice Skating Performance in Male and Female Division III Ice Hockey Players

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Abstract
The purpose of this study was to determine if off-ice performance variables could predict on-ice skating performance in Division III collegiate hockey players. Both men (n = 15) and women (n = 11) hockey players (age = 20.5 ± 1.4 years) participated in the study. The skating tests were agility cornering S-turn, 6.10 m acceleration, 44.80 m speed, modified repeat skate, and 15.20 m full speed. Off-ice variables assessed were years of playing experience, height, weight and percent body fat and off-ice performance variables included vertical jump (VJ), 40-yd dash (36.58m), 1-RM squat, pro-agility, Wingate peak power and peak power percentage drop (% drop), and 1.5 mile (2.4km) run. Results indicated that 40-yd dash (36.58m), VJ, 1.5 mile (2.4km) run, and % drop were significant predictors of skating performance for repeat skate (slowest, fastest, and average time) and 44.80 m speed time, respectively. Four predictive equations were derived from multiple regression analyses: 1) slowest repeat skate time = 2.362 + (1.68 x 40-yd dash time) + (0.005 x 1.5 mile run), 2) fastest repeat skate time = 9.762 - (0.089 x VJ) - (0.998 x 40-yd dash time), 3) average repeat skate time = 7.770 + (1.041 x 40-yd dash time) - (0.63 x VJ) + (0.003 x 1.5 mile time), and 4) 47.85 m speed test = 7.707 - (0.050 x VJ) - (0.01 x % drop). It was concluded that selected off-ice tests could be used to predict on-ice performance regarding speed and recovery ability in Division III male and female hockey players.

Key words: Speed, gender differences, predictive equations, anaerobic power testing, agility.

Introduction

Ice hockey is a dynamic sport that requires athletes to perform at a high intensity for 30-60 sec shifts interspersed with 2-3 min rest periods (Montgomery, 1988). Anaerobic conditioning is needed due to demands of high power output during play; however, recovery between shifts is affected by aerobic conditioning (Montgomery, 1988). Thus, maximizing both energy systems is essential for on-ice skating performance. For coaches, gaining an understanding of an individual player's overall capacity and development of these energy systems can be done through on-ice testing and possibly through select off-ice tests that may be more specific to evaluating the energetics of skating. Therefore, research dedicated to establish which off-ice tests are best and most specific at ascertaining this information is needed.

A relationship between on-ice performance and off-ice testing modalities has been suggested in previous work; however, the strength of relationship for certain off-ice tests remains unclear (Behm et al., 2005; Bracko and George, 2001; Burr et al., 2007; 2008; Farlinger et al., 2007; Hermiston et al., 1979). Understanding the nature of these relationships is important for coaches evaluating and selecting players from all skill levels. Off-ice testing can assist in identifying issues with skill or conditioning that can be improved through training (Bracko and George, 2001). For this reason, it is important for coaches or athletes to track off-season improvement due to training, and off-ice testing may be a more economical choice compared to on-ice testing (Farlinger et al., 2007).

The majority of research evaluating the predictive accuracy of off-ice testing has concentrated on measures of anaerobic performance. Bracko and George (2001) found the 40-yd dash (36.58m) as being the strongest predictor of skating speed and on-ice fitness in women's hockey players (ages 8-16 years). These results suggest that greater running speed will translate to greater skating speed. A later study utilizing young (15-22 years) male players showed similar results between running speed and on-ice sprinting ability (Hermiston et al., 1979). Krause et al. (2012) also found 40-yd dash (36.58m) to be the best predictor of on-ice forward skating, turning, and crossover performance. Burr et al. (2007) showed a strong correlation between vertical jump and three on-ice characteristics: acceleration, speed, and power. The evaluation of vertical jump is common due to the association between lower body power and skating performance.

To our knowledge, research focused on the relationship between aerobic power and on-ice performance are lacking. Therefore, aerobic power was evaluated in the current study to better understand its contribution to skating performance. Data involving performance characteristics of women hockey players are also lacking at both the elite and non-elite levels (Bracko and George, 2001; Bracko, 2001). Thus, to understand performance characteristics of less skilled players in comparison to The National Collegiate Athletic Association (NCAA) Division I and NHL players, both men and women NCAA Division III hockey players participated in this study.

The purpose of this study was to determine if off-ice performance variables could predict on-ice skating performance in Division III collegiate hockey players. We hypothesized that the strongest predictors of on-ice acceleration and speed would be the 40-yd dash (36.58m), vertical jump, and Wingate variables. Additionally, 1.5-mile (2.4km) run time would be a significant predictor of modi-

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fied Reed repeat sprint skate, and a significant relationship would exist between off-ice pro-agility and on-ice agility cornering S-turn time.

Methods

Participants

Nineteen men and 11 women (N = 30) NCAA Division III ice hockey players participated in the study. Four male players were excluded from the study due to failure to complete all testing sessions; thus 15 males finished the study along with all women players. Thus, the sample size included in the final analysis was 26 players. All players were approximately two weeks post-season during data collection and recruited through their respective coaches. Participants were instructed to sign a consent form approved by the University's Institutional Review Board prior to participation. Exclusion criteria included team goaltenders and those who with prior injury preventing participation in any test. For overall participant characteristics, see Table 1. A power analysis was administered to determine the minimum sample size required for multiple regression analysis. The desired statistical power number was set at 0.8 at a probability level of .05. The anticipated effect size value for the analysis was 0.8 with a maximum of three predictor (independent) variables for each regression model. Following power analysis, the minimum sample size for the current study was identified as 18 participants.

Table 1. Descriptive characteristics for women (n = 11), men (n = 15), and combined (n = 26). Data are means (±SD).

Variable	Women	Men	Combined
Age (yr)	19.4 (.8)	21.3 (1.1)	20.5 (1.4)
Player Exp (yr)	10.3 (4.2)	16.7 (1.4)	14.0 (4.3)
Height (m)	1.64 (.06)	1.81 (.05)	1.74 (1.0)
Body mass (kg)	67.1 (10.2)	88.8 (.06)	79.6 (13.5)
Body fat (%)	22.6 (7.8)	12.2 (.04)	15.9 (8.2)

Player Exp: Player experience

Instrumentation

Time was reported to the nearest .01 second for all tests, except for the 1.5-mile (2.4km) (nearest second). The 40-yd dash (36.58m) was timed using an electric speed trap system; otherwise, all tests were timed using manual stop watches (Accusplit Pro Survivor 601X). Anaerobic power was assessed using a Monark Ergonomic 894 EA stationary bicycle (Monark Sports and Medical, Vansbro, Sweden) and the Monark Anaerobic Test software (Monark Sports and Medical, Vansbro, Sweden). Percent body fat (%BF) was determined by skinfold measurement using a Lange caliper (Cambridge, MA). Height was measured using a stadiometer (Seca Corporation, Columbia, MD) and weight was measured using a digital scale (Seca Corporation, Columbia, MD). Vertical jump was measured using a Vertec device (Sports Imports, Columbus, OH).

Procedures

Prior to all data collection, participants were instructed to abstain from any alcohol, vigorous physical activity, and heavy lifting for 24 hours. Players were also instructed on the off- and on-ice tests they would be completing. No familiarization period was given during testing. All testing days were completed within one week of starting testing on Day 1.

Day 1: Anthropometric tests included height, body mass, reach height, and skinfold measurement. Height and weight were measured without shoes to the nearest 0.1 cm and 0.1 kg, respectively. For reach height, participants stood, in shoes, perpendicular to and against a wall with their right arm extended along a ruler. Each participant's arm was pulled upward by a researcher to ensure full extension before recording reach height.

Skinfold measurements were taken from the abdomen, chest, and thigh sites (men) and triceps, suprailliac, and thigh sites (women) and were recorded to the nearest 0.5 mm (Jackson and Pollock, 1985). Standardized procedures were followed for each measure and the sum of three skinfolds was converted to body density using the 3-site Jackson and Pollock skinfold equation (ACSM, 2009; Jackson and Pollock, 1985). Body density was converted to %BF using population-specific formulas for Caucasian men and women (Heyward and Wagner, 2004).

The Wingate anaerobic power test immediately followed the anthropometric measurements. The seat of the bike was adjusted to hip height to provide an approximate 5-10^0 knee flexion with the pedal in the low position. Participants warmed up with minimal resistance on the flywheel for five minutes. During warm up, participants were given a 2-3 sec trial of the brake weight being used. Brake weight was set at 8.6% and 7.5% of body mass (kg) for men and women, respectively, in order to elicit high power output values (Dotan and Bar-Or, 1983). To begin, participants pedaled as fast as possible with no resistance. Once they reached maximum pedaling rate, a 3-sec countdown was given and the brake weight was dropped. Participants were instructed to remaining seated while pedaling at maximum effort for 30 seconds. Verbal encouragement was given during each test. At the conclusion, the brake weight was released and participants pedaled with minimal resistance for cool down. The variables gathered were peak power in Watts/kg of body weight and peak power percentage drop (% drop). The % drop is defined as the percent difference between the highest and lowest attained peak power and illustrates the relative amount of power that is lost over the 30 second anaerobic test.

Day 2: On-ice testing was completed on Day 2. A visual depiction of each test is included in Figure 1 (Janot et al., 2013). Intra-class correlations for each measure were: agility cornering S-turn: $r = 0.76$, $p < 0.01$; acceleration: $r = 0.68$, $p < 0.01$; speed: $r = 0.85$, $p < 0.01$; full speed: $r = 0.88$, $p < 0.01$. Reliability for the Reed repeat test has been reported as $r = 0.99$ ($p < 0.05$) (Power et al., 2012). Testing involved full hockey gear with stick in hand. Participants completed a 5-min skating warm-up led by researchers. Intensity was low to moderate with short bursts (~5 seconds) of high intensity skating. A 5-min rest period was given between each trial to ensure full recovery (Power et al., 2012). The on-ice tests were performed in the exact order as listed here and were not randomized: 1) agility cornering S-turn, 2) 6.1 m acceleration and

44.80m, 3) 15.2 m full speed, and 4) modified Reed repeat sprint. For all tests, participants were instructed to begin in a V-start position (heels touching) to maximize first step quickness. Time started on the participant's first forward movement of the front skate.

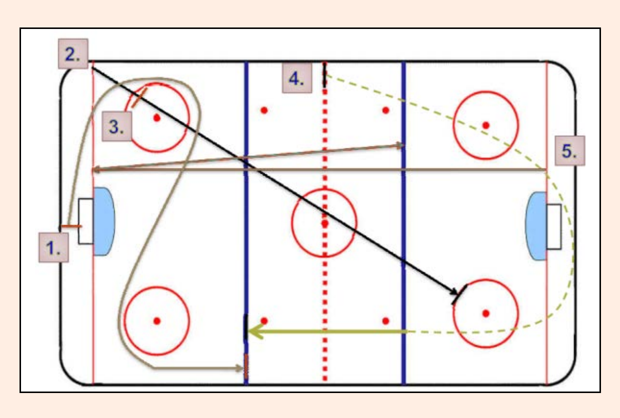

Figure 1. On-ice skating tests: (1) agility cornering S-turn, (2a) 6.1 m acceleration, (2b) 44.80 m speed test, (3) 15.2 m full speed test, and (4) modified Reed repeat sprint skate test. Adapted from Janot et al. (2013).

The first test was the agility cornering S-turn test (Figure 1, #1) (Greer et al., 1992). Participants started behind the goal line and net and skated around the two near faceoff circles an S-type fashion. Time was stopped once the front skate touched the blue line. A researcher was positioned (standing on skates) at the blue line to closely view the end point for timing purposes. If a player cut inside the face off circles or fell, the trial was restarted. Participants completed two trials and average time was recorded.

The second test combined both 6.1m acceleration test (Figure 1, #2a) and 44.80m speed test (Figure 1, #2b) (Bracko, 2001) and were timed in conjunction. Time was stopped once the front skate crossed the end point of each test. For the acceleration test, a researcher was positioned at the end of the measured distance to accurately stop and start timing. For the 44.8 m speed test, a different researcher was positioned at the half-way point to view the first forward movement. Once time was started, the researcher glided backward to the end point in order to view the skater crossing the line. The times for each test were averaged and recorded.

The third test was the 15.2 m full speed test (Blatherwick, 1989). Top speed (Figure 1, #3) was assessed along the distance from one blue line to the next blue line (15.2 m). From the starting position, participants slowly gathered speed around the net area, whereupon participants progressed to top speed. Time was started once a skate touched the first blue line and stopped once the skate touched the following blue line. A researcher was positioned half-way between the blue lines, perpendicular to the direction of the skater, to start and stop timing. As with all testing, the researcher maintained a standing position on skates. The times for each test were averaged and recorded.

The fourth test was a modified version of the Reed repeat sprint skate test (Reed et al., 1980). For this test (Figure 1, #4), participants skated to the far goal line, made a full stop and touched the far goal line with their skate, and skated to the blue line closest to the starting goal line. Time was stopped when the front skate touched the blue line. Participants completed six trials with a 30-sec, passive rest period between trials. Researchers were positioned at the far goal line (to ensure complete stop) and at the near blue line (end point) for timing. Failure to come to a complete stop at the goal line required a repeat of the trial. The variables derived from this test were times for the fastest trial, slowest trial, average across all six trials, and the difference from the fastest to slowest trial.

Day 3: On Day 3, participants first completed a 5-min warm-up consisting of slow jogging around a 200-m indoor track. Testing order (40-yd dash (36.58m), vertical jump, pro-agility) was randomized for each participant to limit potential ordering effects on subsequent test results. A 5-min rest was taken between each trial and test for full recovery. Following these tests, the participants completed the maximum squat trial.

Participants completed two trials for the 40-yd dash (36.58m) and were timed using a speed trap timing system (Brower Speed Trap I timing system, Brower Timing Systems, Draper, UT). Participants were in an upright, crouched position with their right hand touching the pressure release pad. Time started once the participant removed their hand from the pad and stopped once they passed the infrared electric eye. The average of these two trials was recorded.

For the pro-agility test, three cones were placed in a line at 5-yd intervals (Baechle and Earle, 2008). Participants started at the middle cone with shoulders parallel to the cones and time was started at the first positive movement forward of the lead foot. Researchers were positioned at the middle cone for timing purposes. Upon reaching the first end cone, participants stopped, touched a line perpendicular to the cone, and then sprinted to the far cone. Upon reaching the far cone, participants stopped and touched a line perpendicular to this cone. Participants sprinted back to the start and time was stopped when the lead foot passed a line perpendicular to the middle cone. Two trials were complete and times were averaged.

Vertical jump was measured to the nearest 0.5 inch and converted to cm. The best result from three trials was recorded. Participants were not permitted to perform a gather step or steps prior to jumping. Following a countermovement, participants jumped as high as possible and touched the measuring device at the highest point. Maximum height from the jump was subtracted from their reach height to yield the vertical jump.

Standardized procedures were followed for the one repetition maximum squat trial (Baechle and Earle, 2008). Participants were evaluated on proper squat form prior to the day of testing. Each participant had more than one year of experience performing squat exercises. A repetition was counted when the thigh reached parallel with the floor at the bottom of the squat movement. Participants were allowed to use weight belts during the trial.

Day 4: On Day 4, participants completed a 1.5-mile run for time on a 200 meter indoor track. Participants

Table 2. Correlation matrix for on-ice and off-ice testing variables.

	S-turn	6.1m	44.80m	15.2m	Repeat fast	Repeat slow	Repeat avg	Difference	1.5 mile	Squat	VJ	Pro-agility	40-yd	%BF	Peak power
S-turn	X														
6.1 m	.139	X													
44.80 m	.764	.221	X												
15.2 m	.717	.115	.672	X											
Repeat fast	.932	.244	.845	.704	X										
Repeat slow	.891	.183	.800	.686	.916	X									
Repeat avg	.930	.213	.839	.71	.975	.974	X								
Difference	-.106	.097	-.076	-.111	-.012	-.413	-.215	X							
1.5 mile	.670	.251	.641	.557	.746	.812	.782	-.329	X						
Squat	-.795	-.210	-.734	-.743	-.788	-.819	-.824	.253	-.649	X					
VJ	-.822	-.094	-.094	-.721	-.915	-.875	-.920	.106	-.672	.810	X				
Pro-agility	.749	.148	.148	.572	.872	.807	.845	.607	.671	-.687	-.853	X			
40-yd	.810	.269	.775	.637	.913	.931	.944	-.248	.725	-.829	-.911	.893	X		
%BF	.475	.209	.590	.437	.650	.665	.648	-.180	.663	-.434	-.629	.633	.670	X	
Peak power	-.373	.139	-.531	-.446	-.543	-.560	-.541	.163	-.507	.416	.583	-.570	-.631	-.705	X
% drop	-.012	-.017	-.375	-.302	-.110	-.071	-.093	-.071	.014	.099	.138	.041	-.097	-.145	.533

were instructed to give full effort during the duration of the test. Time was started following a countdown of three seconds to indicate the start of the test and stopped once the participant crossed the end line of the test. Only one trial was completed for the 1.5 mile (2.4km) run.

Statistical analysis

Data were analyzed using IBM SPSS version 19.0 (IBM Corp., Armonk, NY). A multiple regression analysis determined the amount of variance in skating performance that could be explained using off-ice testing variables. A combined data set (men and women) was used to generate the regression models due to no gender differences reported between the dependent variables. Seven regression models were calculated using the following dependent variables: 15.2 m top speed, slow repeat skate, fast repeat skate, average repeat skate, agility cornering S-turn, 6.1m acceleration, and 44.80m skate times. A Durbin-Watson test was used to evaluate if the independence of error assumption in the models was met. The calculated value was .05, which indicated that this assumption was met. A Pearson *r* correlation determined the individual strength of relationships between the independent (off-ice) and dependent variables (on-ice). Descriptive statistics were used to determine means and standard deviations of physiological variables. An alpha level of $p < 0.05$ was used in all analyses.

Results

Table 2 presents correlations between all off-ice and on-ice variables and Table 3 shows means, standard deviations, and ranges for these variables. Out of the seven dependent variables, only four generated significant ($p < 0.05$) regression models from the off-ice predictor variables. The independent variables included in the current study were years of playing experience, height, weight and %BF, VJ, 40-yd dash (36.58m), 1-RM squat, pro-agility, Wingate peak power and % drop, and 1.5 mile (2.4km) run. The dependent variables are listed previously.

The slow repeat skate time regression model used the following combination of predictor variables:

Repeat Skate - Slow = 2.362 + (1.68 x 40-yd dash time) + (.005 x 1.5-mile time)

This model was 95.2% accurate according to the Pearson test of predicted times to actual times. The

Table 3. Mean off-ice and on-ice variable responses for women (n = 11), men (n = 15), and combined (n = 26).

		Women		Men		Combined	
Variable	Variable	Mean	SD	Mean	SD	Mean	SD
Off-ice variables	Vertical jump (cm)	35.7	6.0	61.1	7.0	50.4	14.4
	40-yd dash (sec)	5.96	0.25	5.08	0.2	5.45	0.49
	Squat 1RM (kg)	79.54	14.66	150.45	20.31	120.45	39.92
	Pro-agility (sec)	5.38	0.22	4.79	0.19	5.04	0.36
	Peak power (W/kg)	9.24	1.46	11.35	1.78	10.46	1.94
	1.5 mile run (min:sec)	12:11	0.03	10:32	0.04	11:13	1.13
	% drop	43.08	6.70	45.16	12.28	44.28	10.17
On-ice variables	Agility cornering S-turn	9.42	0.32	8.36	0.27	8.81	0.61
	6.1 m acceleration	1.41	0.12	1.34	0.26	1.37	0.21
	44.80 m speed	6.66	0.18	6.1	0.3	6.34	0.38
	15.2 m full speed	2.07	0.24	1.67	0.13	1.84	0.27
Modified repeat	Fastest time	14.49	0.44	12.64	0.52	13.43	1.05
	Slowest time	15.72	0.67	13.71	0.45	14.56	1.15
	Average time	15.12	0.49	13.23	0.41	14.03	1.05

Note: All on-ice variables were measured in seconds.

Table 4. The set of predictor components for all significant on-ice performance regression models (n = 26).

	Variable	B	β	Part r^2	t	p
Slow repeat	**40-yd dash**	1.680	.723	.248	7.812	< .05
	1.5 mile run	.005	.288	.039	3.111	< .05
Fast repeat	**VJ**	-.089	-.485	.040	-2.701	< .05
	40-yd dash	-.998	-.471	.038	-2.625	< .05
Average repeat	**40-yd dash**	1.041	.490	.035	3.34	< .05
	1.5 mile run	.003	.197	.018	2.419	< .05
	VJ	-.063	-.342	.141	-2.506	< .05
44.80 m speed	**VJ**	-.050	-.752	.555	-6.477	< .05
	% drop	-.010	-.271	.071	-2.335	< .05

Note: VJ = vertical jump; % drop = peak power percentage drop. Alpha level was set at .05 to determine statistical significance.

standardized beta for the 40-yd dash (36.58m) was 0.723 and 0.288 for the 1.5-mile (2.4km) run. The part r^2 value, which shows the unique variance explained for each variable in the equation, was 0.248 for the 40-yd dash (36.58m) and 0.039 for the 1.5-mile (2.4km) run. The R^2 for this model was 0.907.

The next regression model was fast repeat skate time, which used vertical jump height and 40-yd dash (36.58m) time:

Repeat Skate - Fast = 9.762 - (.089 x VJ) - (.998 x 40-yd dash time)

This model was 93.5% accurate according to the Pearson test of predicted times to actual times. The standardized beta for the vertical jump was -0.485 and 0.471 for the 40-yd dash (36.58m). The part r^2 value for the vertical jump was 0.04 and 0.038 for the 40-yd dash (36.58m). The R^2 for this model equaled 0.874.

The average repeat skate time regression model used the following combination of predictor variables:

Repeat Skate - Average = 7.770 + (1.041 x 40-yd dash time) - (.63 x VJ) + (.003 x 1.5-mile time)

This model was 93.1% accurate according to the Pearson test of predicted times to actual times. The standardized beta for the 1.5-mile (2.4km) run was 0.197, 0.490 for the 40-yd dash (36.58m), and -0.432 for the vertical jump. The part r^2 values for the 1.5-mile run (2.4km), 40-yd dash (36.58m) and vertical jump were 0.018, 0.035, and 0.141, respectively. The R^2 for the model was 0.867.

Finally, the last model calculated was 44.80m speed skate time and used the following combination of predictor variables:

44.80m speed test = 7.707 - (.050 x VJ) - (.01 x %drop)

This model was 83.4% accurate according to the Pearson test of predicted times to actual times. The standardized beta for the vertical jump was -0.752 and -0.271 for %drop. The part r^2 value for the vertical jump was 0.555 and 0.071 for the percent drop in the Wingate anaerobic test. The R^2 for the total model equaled 0.696.

Discussion

The current study examined whether select off-ice variables would be important predictors of skating performance in Division III collegiate hockey players. Ice hockey is a sport that requires about 69% anaerobic fitness with aerobic endurance making up approximately 31% of the energy needed to play (Leger et al., 1979). Thus, all energy systems are used during play and recovery, as intensity varies from low to very high (Bogdanis et al., 1996). Vertical jump, 40-yd dash (36.58m) time, % drop, and 1.5-mile (2.4km) run time were the best predictors of on-ice performance for this population of hockey players. Vertical jump and 40-yd dash (36.58m) time were significant predictors of on-ice speed tests (see Table 4). Additionally, off-ice variables were not effective predictors of on-ice performance in the 6.1m acceleration, 15.2 m top speed, and S-turn agility tests. In particular, skating agility may be very difficult to predict using ground based or off-ice performance tests because of the significant task specificity that comes with skating on an ice surface. Thus, it appears that further research should focus on identifying more discerning off-ice tests to predict these areas of on-ice skating performance.

Slowest repeat skate

The modified Reed repeat sprint skate test is a good indicator of an individual player's ability to recover from a skating activity as this test involves a repeated series of trials that are timed. The player who can best maintain their speed from trial to trial would have the greater capacity to recover following each skating trial. The performance of this test, considering that both speed and recovery ability are main components, incorporate both aerobic and anaerobic energy systems.

The 1.5-mile (2.4km) time and the 40-yd dash (36.58m) were significant predictors of the time during the slowest repeat skate trial. Thus, those individuals who had a faster time during their slowest trial elicited a better time in both the 1.5 mile (2.4km) run and 40-yd dash (36.58m) time. As measures of anaerobic and aerobic performance, these off-ice variables were effective at predicting the players' ability to skate fast and recover faster between trials as a means to maintain their overall speed over time. Beta values for the 1.5-mile (2.4km) run and 40-yd dash (36.58m) in this model were 0.288 and 0.723, respectively. The part r^2 value for the 1.5-mile run and 40-yd dash (36.58m) were 0.039 and 0.248, respectively, and when combined explain 28.7% of the unique variance within this dependent variable. This suggests that while both are predictors of slowest repeat skate time, 40-yd dash (36.58m) has a stronger unique contribution.

These results were similar to Bracko and George (2001) who examined predictors for skating ability in 61 female participants, ages 8-16. Approximately 20-30 of these players were considered “elite” for their age group. The results showed that 40-yd dash (36.58m) time was the strongest predictor of skating speed and anaerobic fitness in these players.

Fastest repeat skate

Vertical jump and 40-yd dash (36.58m) were both significant predictors of fastest repeat skate performance. The fastest time for all players in the current study was during the first skating trial because each skater was fresh and not fatigued at that point in the test. Vertical jump and 40-yd dash (36.58m) are traditionally viewed as measures of power and the ability to produce power is important in skating acceleration and speed. In the current study, beta values for vertical jump and 40-yd dash (36.58m) were -0.485 and -0.471, respectively; thereby, illustrating an inverse relationship between fastest repeat skate time and these independent variables. Interpretatively, stronger predictive variables are associated with higher beta values. The part r^2 value for vertical jump was 0.040 and 0.038 for 40-yd dash (36.58m). These data suggest that both variables have similar unique contributions to overall variance explanation and are strong predictors of the fastest repeat skate time.

Previous research by Burr et al. (2008) determined the validity of vertical jump in predicting elite hockey players' leg power and performance as evaluated using draft selection order. Four different jump protocols were administered to 95 entry-level NHL players. All protocols were found to be good predictors of leg power, yet vertical jump correlated most closely to a hockey player's leg power. This study demonstrated a relationship between vertical jump ability, leg power, and hockey performance. In addition, findings by Krause et al. (2012) support the current study regarding the use of 40-yd dash (36.58m) as a predictor of on-ice speed. Krause et al. (2012) showed that 40-yd (36.58m) time was a good predictor of 34.5m forward skate, as well as short radius turning and crossover performance to a lesser degree.

Average repeat skate time

Vertical jump, 40-yd dash (36.58m), and 1.5-mile run were all significant predictors of average skate speed performance. To elicit a low average time, the player must maintain a lower time for each trial across the duration of the repeat sprint skate test. Due to the number of trials and limited rest between trials, players must be able to recover in a short period of time. As a measure of aerobic power, the 1.5-mile run may be an important predictor of repeated skate performance due to this component of recovery. Since 40-yd (36.58m) dash is a measure of speed and power and vertical jump a measure of power, these remain important predictors of repeat skate time, in this case the average time. Collectively, this may elucidate why both anaerobic and aerobic measures are strong off-ice predictors of the average repeat skate time (Bogdanis et al., 1996) and may suggest the type of training that players should engage in to improve these abilities. According to past research, improvements in both glycolytic and aerobic energy potential may be more associated with high intensity interval training (Carey et al., 2007). Interval training activity is very similar to the modified repeat skate used in the cur-rent study.

In the current study, beta values for the 40-yd Dash (36.58m), vertical jump, and 1.5-mile (2.4km) run were 0.490, -0.342, and 0.197, respectively. The part r^2 value for 40-yd dash (36.58m), vertical jump, and 1.5-mile (2.4km) run were 0.035, 0.141, and 0.018, respectively. These values indicate that each variable plays some role in determining average repeat skate time with 40-yd dash (36.58m) having the most substantial unique contribution.

44.80m speed skate test

Vertical jump and % drop were independent variables that best predicted 44.80m speed skate performance. The beta value for vertical jump and % drop was -0.752 and -0.271, respectively. These data indicated an inverse relationship with 44.80m skate time; thus, the greater the jump height and % drop, the lower time associated with the 44.80m test. The part r^2 value for vertical jump was 0.555 and 0.071 for % drop illustrating that vertical jump has a greater contribution to speed during skating. The % drop is a measure of a player's ability to maintain maximum power over 30 seconds, but also reflects maximum power output. To be fast in the 44.80m test, the player must accelerate effectively and generate maximal power. For these reasons, the ability to generate the greatest power through vertical jump and the Wingate anaerobic power test will have a lower time in the 44.80m test.

Potteiger et al. (2010) examined similar variables in 21 male Division I ice hockey players and found comparable results to those in the current study. Body composition, leg strength, and power production were measured to predict on-ice skating performance. The on-ice test was six, 89m sprints with a 30-sec rest between sprints. Data was analyzed according to two skating segments: 1) first 54 meters and 2) full 89 meters. Poetteiger et al. (2010) concluded that % drop from the Wingate power test had a low-moderate correlation (r = -0.48) with the fastest 54m skate time and that the relative peak power was low-moderately correlated (r = -0.43) to average 54m skate time.

Limitations

The main limitations for this study included a small sample size with which to generate regression models from and the assumption that participants gave maximal effort. Participants that did not complete all tests or were injured had their data excluded from this study. These circumstances left a smaller sample size than anticipated from the start of the study. However, statistical power analysis exhibited a minimum number of participants needed for the current study at 18 total. Thus, even with the study participant attrition, the final number (N = 26) of participants used in the analysis was above this minimal value. Also, on-ice tests were not randomized due to time constraints regarding ice usage and testing was ordered according to maximize efficiency of set up and test to test transition for players. Thus, there may have been an unknown ordering effect that could have influenced test results. Furthermore, even though recovery time was provided between tests, overall fatigue may have been a factor over each testing session, which may have affected results to an unknown degree.

Practical applications

In today's youth and small college hockey environment, ice time is limited and expensive for coaches to use to practice, play, and evaluate the skill of their players. This study demonstrates that select off-ice tests may be a viable way to evaluate player skating abilities in the areas of speed and recovery ability. On-ice testing requires prior scheduling, money, and time away from other activities such as practice and game play. In contrast, off-ice tests are not only less expensive, but may be easier to administer than on-ice tests. Most off-ice tests, excluding the Wingate, do not require specialized equipment or training and can be performed in many locations such as a track or gym. For these reasons, coaches could elect to use off-ice tests for their initial assessment of players.

Although, there are many skills in hockey that cannot be effectively tested through off-ice means such as skating technique, shooting, and passing. Many of these skills must be evaluated on the ice. However, for coaches looking to choose their teams from a large list of candidates or evaluate their current team, there are options to use off-ice tests to narrow their focus by using these tests.

Conclusion

In conclusion, the use off-ice testing has been shown to be a potential strategy to evaluate on-ice performance in male and female ice hockey players. It was found that vertical jump, 40-yd dash (36.58m) time, % drop, and 1.5-mile (2.4km) run time were the best predictors of select on-ice skating variables. Thus, these measures are recommended for use in the overall evaluation of an ice hockey player.

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Key points

- The 40-yd dash (36.58m) and vertical jump tests are significant predictors of on-ice skating performance specific to speed.
- In addition to 40-yd dash and vertical jump, the 1.5 mile (2.4km) run for time and percent power drop from the Wingate anaerobic power test were also significant predictors of skating performance that incorporates the aspect of recovery from skating activity.
- Due to the specificity of selected off-ice variables as predictors of on-ice performance, coaches can elect to assess player performance off-ice and focus on other uses of valuable ice time for their individual teams.

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