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Correlation between "off-ice" variables and skating performance among young male ice hockey players

Eirik Haukali & Leif Inge Tjelta*
University of Stavanger, Norway

Abstract

The purpose of this study was to examine the relationship between specific off-ice variables and skating speed and agility among young ice hockey players. Fifteen male field players between ages 15 and 17 years took part in the study. Skating speed, agility test on ice, sprint, five-jump, squat jumps (SJ) and counter movement jump (CMJ) were included. Moderate to strong correlations were found between all the off-ice variables and skating speed. The strongest correlations were found between skating speed and 36 m sprint ($r = 0.81$, $p < 0.01$), and between skating speed and CMJ ($r = -0.86$, $p < 0.01$). There was no significant correlation between agility and speed skating, or between agility and sprint. Based on the results, there is reason to believe that an off-ice training program that includes sprint training and jumping exercises will have a positive effect on young hockey players' skating performance.

Key words: Speed, Agility, Plyometric, Ice hockey

Introduction

Ice hockey is a physically demanding contact sport characterized by many short work periods, frequent substitutions of players, high intensity and repeated explosive accelerations over different distances in different directions. To succeed in the sport at a national and international level, it is essential for today's hockey players to have great skating skills and great skating speed over various distances (Burr et al., 2008; Mascaro, Seaver, & Swanson, 1992). Development of skating speed and skating acceleration should therefore play an important role in training and development of young hockey players (Mascaro et al., 1992). However, due to crowded ice rinks and limited available training time on ice, specific speed training on ice is often given low priority by coaches of young players. It is therefore important to identify physical off-ice training that can increase skating speed and agility. Studies of male and female junior and college players (Behm et al., 2005; Bracko & George, 2001; Farlinger et al., 2007) conclude that maximal running speed is the off-ice variable with the highest correlation to skating speed. Behm et al. (2005) found a significant correlation between maximum skating speed and 36 m sprint among male competitive secondary school and junior hockey players (19.8 ± 3.5 years). They concluded that an increase in running speed would lead to a corresponding

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Correspondence : Leif Inge Tjelta (leif.i.tjelta@uis.no)

increase in skating speed. Mascaro et al. (1992), however, found no significant correlation between 36 m sprint and 54.9 m skating speed among professional players (23.3±1.6 years) in the National Hockey League (NHL). Although skating and running are biomechanically different, the aim in both skating and running is to generate the most power to the ground in a horizontal direction (Bracko & George, 2001).

Bret et al. (2002) found that muscular power is a determining factor of the acceleration phase in 100 m sprint. However, there are contradictory findings on the relationship between muscular power and skating acceleration (Bracko & George, 2001; Farlinger et al., 2007; Mascaro et al., 1992). Farlinger et al. (2007) found a strong correlation between horizontal jump and 35 m skating speed among young male (16.3 ±1.7 years) competitive hockey players. In addition, the correlation between standing triple jump and skating speed, as well as between standing long jump and skating speed were significant ($r = -0.78$ and $r = -0.74$ respectively). They also found a correlation between skating speed and vertical jump height ($r = -0.71$). Farlinger et al. (2007) concluded that explosive power and leg strength in the horizontal direction is important for the development of skating speed acceleration. Mascaro et al. (1992) also found that the test that best predicted 54.9 m skating speed for forwards and defenders was CMJ. Although these studies have demonstrated moderate to strong correlations between resilience and skating speed, Behm et al. (2005) found no significant correlation between 36 m skating speed and CMJ or between skating speed and drop jump. The researchers suggest that the stretch phase prior to the concentric work is of limited importance for the skating speed.

Mascaro et al. (1992) argue that skating speed is one of the most important prerequisites for success in professional hockey. However, analysis of hockey matches shows that surprisingly little time is spent skating straight forward at maximum speed. Bracko et al. (1998) found that only 4.6% of the playing time of professional players was high intensity skating, and that skating at maximum speed occurred over very short distances. Most of the time was spent doing cruise striding, gliding turns, crossover turns and fighting for puck and position. The fact is that ice hockey is an "open" and unpredictable sport. Players' reactions and movements will constantly change as the puck, teammates and opponents move. Thus, accelerations, rapid changes of direction, agility and swivel capabilities will often be more important than actual top speed. It may therefore be more appropriate to use technical skating tests that include bends and twists to evaluate performance skating. "Cornering S test" has previously been used in studies of skating skills (Bracko & George, 2001; Farlinger et al., 2007). These studies have not found strong correlations between cornering S test and various off-ice variables such as vertical jumps, horizontal jumps and various agility tests (Bracko & George, 2001; Farlinger et al., 2007). However, Farlinger et al. (2007), did find a strong correlation ($r = 0.70$) between cornering S test and 35 m skating speed. Findings from previous studies conflict and do not include series of step jumps in the horizontal direction and agility skating test (Behm et al., 2005; Bracko & George, 2001; Farlinger et al., 2007; Mascaro et al., 1992). The purpose of this study was to examine the correlation between selected off-ice variables and skating speed and agility speed in young hockey players. The findings may be used to design appropriate off-ice training to improve skating speed.

Methods

Participants

The participants were 32 male junior hockey players. Of these 32 players, 15 field players completed all tests and these 15 players are included in the study. Players' mean (± SD) age, height and weight were 16.4 (± 0.6) years, 179.3 (± 5.2) cm and 70.9 (± 7.3) kg. They were all players in the Norwegian junior (under 18 years) elite series. This is the highest-level national series for this age group. The participants were informed about the details of the procedure and purpose of the project. They all gave their written informed consent.

Testing protocol

Six different tests were carried out: 1) 36 m speed skating from standing position, 2) The Norwegian Ice Hockey Federation's (NIHF) agility test on ice, 3) 36 m sprint, 4) five- jump (hop, step, step, step and jump), 5) squat jumps (SJ) and 6) counter movement jump (CMJ). All testing took place in the middle of the hockey season (January). The two ice tests (tests 1 and 2) were conducted the first test day, while the remaining off-ice tests were performed ten days later. The subjects performed all tests twice and the best result was used in the statistical analysis. The subjects rested for three minutes between tests, and the order of the tests was structured to minimize the effect of fatigue. On ice, the 36 m speed skating test was performed as the first test, because it is an explosive test of maximum effort that should not be affected by previous activity. Subjects were thoroughly introduced to the test procedures, so they were familiar with the criteria for correct execution. Both test days started with individual warm up.

36m skating speed

The subjects started from stationary position five cm behind the start line with their skates parallel to the direction of skating. They started on their own initiative and skated 36 m as fast as possible. The test was performed with photocells at the start and finish lines (Browser timing systems). This is a standard test used by NIHF with the purpose of measuring acceleration and maximum speed over 36 m. This test is among hockey coaches commonly regarded as an indicator of overall skating ability. Sprint performance test using photocells are found to have high reliability (Moir et al., 2004).

Skating agility

The start position and timing procedure is the same as for the 36 m speed skating test. Figure 1 shows how the test is performed. The test is also a standard test used by NIHF where the purpose is to measure the subjects' speed through technical elements like twists and turns with both forward and backward crossovers. The skating agility test was selected because the combination of agility and speed is a major component of ice hockey and important for game performance.

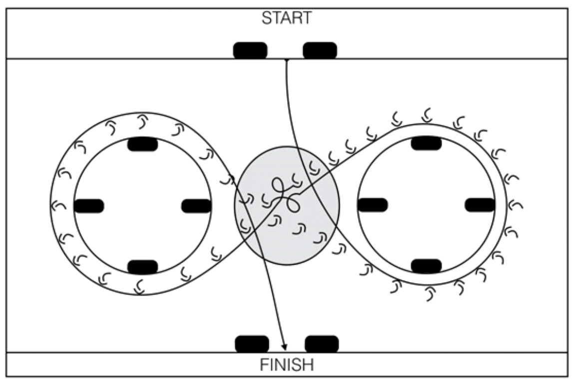

Fig 1. *The NIHF agility test. The test is carried out round the two "drop circles" in the attacking/defensive zone. The tests starts with forward skating round the right circle, than the player turn 180° and skates backwards round the left and right circle, than the player again turns 180° and skates forward round the left circle to the finishing line.*

36m sprint

The testing procedure was as for 36 m skating speed test. The subjects started from a standing position five cm behind the first photocells. They started on their own initiative and ran 36 m as fast as possible.

Five- jump (hop, step, step, step and jump)

The purpose of the test was to measure horizontal power. Subjects started from a standing position, with feet parallel and toes behind a starting line. The aim was to jump as far as possible. The jumps took place alternately on the right and left leg, landing on a soft gym mat. The lengths of the jumps were measured from the starting line to heel of the rear foot in the landing, and were recorded to the nearest 0.01 m. The five-jump test was selected because it is a valid measure of repetitive horizontal single leg power and provides information about athletes stride power (Chamari et al., 2008).

Squat jump (SJ) and counter movement jump (CMJ)

These tests were performed on a "Bosco mat", which allows measurement of contact and air time (Bosco et al., 1983). SJ: subjects bent their knees to 90° and stabilized this position for at least 2 seconds before jumping. CMJ: From standing position the subjects rapidly squatted downwards until they reached a 90° knee position, and then jumped as high as possible. In both tests the hands were kept on the hips throughout the tests, and the subjects were required to land on the take-off point with straight legs in order to avoid knee bending and inaccurate measurements. CMJ and SJ, measured by a contact mat with accurate test procedure, are a highly reliable and valid field tests for estimation of explosive power in lower limbs (Markovic et al., 2004).|

Statistical analysis

SPSS was used for statistical analysis. The results of the tests are presented with mean and standard deviation. Correlation analysis with Person's r was used to assess the correlations between the two ice tests, between each of the two ice tests and the off-ice tests and between the different off-ice tests. The variables were considered as being normally distributed based on a Q-Q plot, a histogram, and values of skrewness.

Results

The mean values for the ice tests and the off-ice tests and the correlations between the different tests are presented in Table 1. There was no significant correlation between the two ice tests, 36 m skating speed and agility. All off-ice variables were significant correlated with skating speed, and three of the off-ice variables were correlated with agility. The off-ice tests that correlated most strongly with 36 m skating speed were 36 m sprint, CMJ and SJ. A moderate correlation was found between the 36m skating speed and five-jump.

There was no significant correlation between agility and 36 m sprint. However, there was a significant correlation between agility and SJ, between agility and CMJ and between agility and five-jump.

Table 1. *Descriptive statistics from on- ice and off-ice tests and Pearson's correlations between the different tests*

Test	Mean	SD	1.	2.	3.	4.	5.	6.
1. 36 m skating speed (sec)	5.28	0.21	-	.40	.81**	-.74**	-.86**	-.57*
2. Skating agility (sec)	22.95	0.75		-	.41	-.70**	-.55*	-.54*
3. 36 m sprint (sek)	5.21	0.22			-	-.76**	-.73**	-.64*
4. SJ (cm)	48.32	4.96				-	.86**	.70**
5. CMJ (cm)	51.36	5.52					-	.81**
6. Five Jump (cm)	12.10	0.84						-

Note. $*p < .05$. $**p < .01$

Discussion

The purpose of this study was to examine the correlation between skating speed and agility and sprint and jumping tests in young hockey players. The main finding of the study was a high correlation between skating speed and the off-ice variables running speed (r = 0.81) and CMJ (r = -0.86). The variable with highest correlation with skating speed was CMJ (r = -0.86). The result can help coaches to develop effective off-ice training programs for developing these essential characteristics.

The results suggest that an improvement in running speed will generally lead to an improvement in skating speed. The findings in the present study are consistent with results found in other similar studies of female, youth and college ice hockey players (Behm et al., 2005; Bracko & George, 2001; Farlinger et al., 2007). These findings are, however, not supported by Mascaro et al. (1992) who did not find any significant correlation between 54.9 m skating speed and 36 m sprint. However, a skating distance of 54.9 m used in their study makes higher demands for the maximum speed and less demand for acceleration speed than a distance of 36m.

The present study and previous studies (Behm et al., 2005; Bracko & George, 2001; Farlinger et al., 2007) point to a clear link between skating speed and running speed. This may be due to the fact that skating and running share a similar underlying basis of force production in the horizontal direction (Bracko & George, 2001), and that skating and running speed are both a product of step length and step frequency (Behm et al., 2005; Farlinger et al., 2007). Off-ice sprint will thus be one of the best predictors for speed skating (Farlinger et al., 2007).

The results also show strong correlations between 36 m skating speed and vertical jumping ability. CMJ is the variable most strongly correlated with skating speed (r = -0.856). In addition, a significant (r = -0.735) correlation between SJ and skating speed was also found. The negative correlation coefficient (r) implies that an increase in vertical jumping ability leads to a decrease in time for 36 m skating speed. A correlation between CMJ and skating speed has also been reported in previous studies (Bracko & George, 2001; Farlinger et al., 2007; Mascaro et al., 1992). Mascaro et al. (1992) claim that the variable that best predicts 54.9 m skating speed for professional hockey players is CMJ. However, Bracko and George (2001) found divergent correlations between vertical jump height and skating speed over various distances among young (12.2±2.0 years) female hockey players. They found a moderate (r = -0.66) correlation between CMJ and 91 m skating speed, but no significant correlation between 6 m acceleration and CMJ. Of these findings, it seems that the correlation between skating speed and vertical jump is greatest with longer skate distances.

In the present study no correlation was found between running speed and skating agility, or between skating speed and skating agility. This contradicts previous findings by Robbins and Young (2012), who claim that most studies have found a correlation between speed and agility.

Vertical jump height is a good indicator of muscle strength (Behm et al., 2005). According to Farlinger et al. (2007), CMJ is a less specific indicator of leg muscle strength than SJ because CMJ is more dependent on muscle plyometric properties. Nightingale, Miller, and Turner (2013) believe plyometric properties are less important for skating, which they claim places a greater emphasis on impulse (force produced over a given time) rather than a "stretch-shortening cycle". This also supported by Behm et al. (2005) who did not find any significant correlation between CMJ and 36 m skating speed. However, the present study and previous research (Bracko & George, 2001; Farlinger et al., 2007; Mascaro et al., 1992), found a strong correlation between CMJ and skating speed. This might indicate that some degree of plyometric muscle activity takes place in skating.

The present study shows a moderate (r = -0.572) correlation between five- jump and 36 m skating speed. Farlinger et al. (2007) and Mascaro et al. (1992) also found correlation between skating speed and various horizontal jumping tests. Farlinger et al. (2007) concluded that horizontal resilience and sprinting speed are important for the development of skating speed over distances that include accelerations.

Bracko et al. (1998) found, in their match analysis, that professional hockey players use only 4.6% of playing time at high intensity skating straight forward, and that most of the time is spent gliding, doing static and dynamic accelerations and rapid twists, crossover turns and changes of direction. These movements are tested in the agility test. The present study found no significant correlation between agility and 36 m skating speed ($r = 0.40$, $p = 0.145$) or between agility and 36 m sprint ($r = 0.41$, $p = 0.125$). There were, however, moderate correlations between agility and SJ ($r = -0.70$), between agility and CMJ ($r = -0.55$) and between agility and five-jump ($r = -0.54$). These correlations are not strong, but nevertheless do suggest that an improvement in vertical and horizontal power will increase speed through turns, stops and accelerations. These correlations are also supported by previous research by Farlinger et al. (2007) who found a moderate correlation between cornering S test and the variables: broad jump (-0,59), off-ice 30 m sprint (0,54), triple jump (-0.53) and vertical jump height (-0.52). However, they concluded that the unique variance in cornering S test performance could not be predicted by any of the separate off-ice variables. On the other hand they found a strong ($r = 0.70$) correlation between the cornering S test and 35m skating speed. In the study by Bracko and George (2001) there was no correlation between the cornering S test and vertical leg power.

A difference in testing procedures may explain why the correlation between agility and vertical leg power are higher in the present study than in previous studies (Farlinger et al, 2007: Bracko & George, 2001). The agility test in the present study (NHIF test, figure 1) contains several turns with crossover steps (forward and backward), twists and accelerations, while the cornering S test used in previous studies does not (Bracko & George, 2001; Farlinger et al., 2007). There is reason to believe that correlations between the three jumping tests (SJ, CMJ and five-jump) and the agility test in the present study are due the fact that the NHIF test includes multiple explosive accelerations, which demand more agility and more power than the cornering S test.

A limitation of the present study is that the sample size is quite small and homogeneous which has resulted in restricted range of data and limited generalizability. It should also be mentioned that the horizontal test (five-jump) are technically demanding. Some of the participants in the present study had more experience with jumping exercises than others. This may have affected the reliability of the results in the present study. Experimental designs are needed to determine if a change in off-ice performance over time would affect skating performance.

Conclusion

Findings in the present study indicate that hockey players will benefit from an off-ice training protocol that includes sprint and horizontal and vertical jumping exercises. Such a training program may have a positive effect on skating speed and the ability to do fast turns and accelerations. It is important to note, however, that a player with poor technical skating skills will be unable to skate fast even if he or she has good running speed and power (Bracko & George, 2001).

References

Behm, D. G., Wahl, M. J., Button, D. C., Power, K. E., & Anderson, K. G. (2005). Relationship between hockey skating speed and selected performance measures. Journal of Strength and

Conditioning Research, **19(2)**, 326-331.

Bosco, C., Luhtanen, P., & Komi, P. V. (1983). Simple method for measurement of mechanical power in jumping. European Journal of Applied Physiology, **50(2)**, 273-282.

Bracko, M. R., Fellingham, G. W., Hall, L. T., Fisher, A. G., & Cryer, W. (1998). Performance skating characteristics of professional ice hockey forwards. Sports Medicine, Training and Rehabilitation, **8(3)**, 251-263.

Bracko, M. R., & George, J. D. (2001). Prediction of ice skating performance with off-ice testing in women's ice hockey players. Journal of Strength and Conditioning Research, **15(1)**, 116-122.

Bret, C., Rahmani, A., Dufour, A. B., Messonnier, L., & Lacour, J. R. (2002). Leg strength and stiffness as ability factors in 100 m sprint running. The Journal of Sports Medicine and Physical Fitness, **42(3)**, 274 - 281.

Burr, J. F., Jamnik, R. K., Baker, J., Macpherson, A., Gledhill, N., & McGuire, E. J. (2008). Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. Journal of Strength and Conditioning Research, **22(5)**, 1535-1543.

Chamari, K., Chaouachi, A., Hambli, M., Kaouech, F., Wisløff, U., & Castagna, C. (2008). The Five-jump test for distance as a field test to assess lower limb explosive power in soccor players. Journal of Strength and Conditioning Research, **22(3)**, 944-950.

Farlinger, C. M., Kruisselbrink, L. D., & Fowles, J. R. (2007). Relationships to skating performance in competitive hockey players. Journal of Strength and Conditioning Research, **21(3)**, 915-922.

Markovic, G., Drazan, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. Journal of Strength and Conditioning Research, **18(3)**, 551-555.

Mascaro, T., Seaver, B. L., & Swanson, L. (1992). Prediction of skating speed with off-ice testing in professional hockey players. Journal of Orthopaedic and Sports Physical Therapy, **15(2)**, 92-98.

Moir, G., Button, C., Glaister, M., & Stone, H. M. (2004). Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. Journal of Strength and Conditioning Research, **18(2)**, 276-280.

Nightingale, S. C., Miller, S., & Turner, A. (2013). The usefulness and reliability of fitness testing protocols for ice hockey players: a literature review. Journal of Strength and Conditioning Research, **27(6)**, 1742-1748.

Robbins, D. W., & Young, W. B. (2012). Positional relationships between various sprint and jump abilities in elite american fotball players. Journal of Strength and Conditioning Research, **26(2)**, 288-397.