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Relationship between off-season changes in power and in-season changes in skating speed in young ice hockey players.

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Abstract

The purpose of this study was to examine whether there exists a correlation between changes in off-season power and changes in in-season skating performance among young ice hockey players. Eighteen elite male players (15.8 ± 0.9) completed on-ice and off-ice performance tests on three separate occasions during a season. Forward and backward skating speed, on-ice agility test, 36 m sprint running performance, broad jump and countermovement jump (CMJ) were included. Off-season improvements in 36 m sprint running performance (r = 0.57, P= 0.02) and changes in broad jump (r = -0.48, P= 0.04) where significantly correlated with in-season improvements in forward skating speed. However, off-season changes in 36 m sprint running performance and jump ability were not significantly correlated with in-season improvements in backward skating speed or agility. These results suggest that an off-season training program that includes sprints and horizontal jumping exercises may have a positive effect on hockey players' linear skating speed.

Key words: Ice hockey, speed, agility, sprint, off-ice training

Introduction

Ice hockey is a team sport that requires multiple fitness components, such as speed, strength, endurance, balance and stability, in combination with sports-specific technical and tactical skills (Hedrick, 2002; Vescovi, Murray, Fiala, & VanHeest, 2006). In order to compete at an international level as a senior player, all factors that underpin success in ice hockey must be included in training from an early age (Potteiger, Smith, Maier, & Foster, 2010). However, based on the fact that ice hockey is a high-speed game, many coaches and experts believe that the players skating speed and agility are the most important factors (Bracko, 2004; Mascaro, Seaver, & Swanson, 1992). The speed of the game has increased substantially in recent years. Consequently, the players' skating speed is becoming increasingly important for successful match performance in modern ice hockey (Farlinger & Fowles, 2008). The players' capacity to produce explosive actions, such as maximal skating, acceleration and rapid change of direction, greatly influence match performance (Bracko, 2004). Proficiency in these areas allows players to compete for possession of the puck, create goal scoring opportunities and prevent goals being scored by the opposition(Matthews, Comfort, & Crebin, 2010; Upjohn, Turcotte, Pearsall, & Loh, 2008). As such, developing each player's skating speed should be a central component of a hockey team's training program throughout the year.

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The player's ability to produce high levels of power from the lower limbs is a prerequisite for developing skating speed (Matthews et al., 2010; Potteiger et al., 2010). Power is defined as the neuromuscular system's ability to produce the greatest possible force in the shortest amount of time, and is the product of muscle force (strength) multiplied by velocity (speed) (Bompa, 1999; Ronnestad, Kvamme, Sunde, & Raastad, 2008). Improvements in skating performance may therefore be a result of improvements either in strength, speed or a combination of these two. Several studies have examined the relationship between physical off-ice measures and on-ice skating speed over various distances (Behm, Wahl, Button, Power, & Anderson, 2005; Bracko & George, 2001; Burr et al., 2008; Farlinger, Kruisselbrink, & Fowles, 2007; Gilenstam, Thorsen, & Henriksson-Larsén, 2011; Haukali & Tjelta, 2015; Janot, Beltz, & Dalleck, 2015; Krause et al., 2012; Mascaro et al., 1992; Potteiger et al., 2010; Runner, Lehnhard, Butterfield, Shihfen, & O`Neill, 2015). Linear skating speed has been found to correlate with several physical off-ice measures, but is most frequently reported to correlate with sprint performance and jumping ability in both the vertical and horizontal direction (Bracko & George, 2001; Burr et al., 2008; Farlinger et al., 2007; Haukali & Tjelta, 2015; Krause et al., 2012; Mascaro et al., 1992; Potteiger et al., 2010; Runner et al., 2015). Farlinger et al. (2007) found that 35 m skating speed was strongly correlated with 30 m sprint (r =0.78), horizontal triple jump (r =-0.78), broad jump (r =-0.74), and vertical jump height (r = -0.71) among young hockey players (16.3 ± 1.7 years). Similar correlations were observed in a study of high school players by Krause et al. (2012), where 34.5 m forward skating speed was significantly correlated with 36.5 m sprint performance (r = 0.81) and vertical jump (r = 0.51). Considering the importance of agility in ice hockey, studies have also included tests that measure skating speed while performing crossovers, turns and changes of direction (Behm et al., 2005; Bracko & George, 2001; Farlinger et al., 2007; Haukali & Tjelta, 2015; Janot et al., 2015; Krause et al., 2012). However, the relationships between off-ice variables and skating agility are so far equivocal, and while some studies have reported significant correlations (Farlinger et al., 2007; Haukali & Tjelta, 2015; Krause et al., 2012),others have failed to find a significant relationship (Behm et al., 2005; Bracko & George, 2001; Janot et al., 2015). Krause et al. (2012) found that performance in short turn and crossover courses correlated significantly with 36 m sprint performance (r = 0.46-0.67), broad jump (r = -0.35-0.53) and balance (r = 0.35-0.52). The performance of junior elite players in the skate agility test used by the Norwegian Ice hockey Federation has also recently been found correlate with jump height in vertical squat jump (r = -0.70), countermovement jump (CMJ) (r = -0.55), and horizontal five jump (-0.54) (Haukali & Tjelta, 2015). Conversely, Behm et al. (2005) found no significant correlation between cone agility test and off-ice measures of sprint performance, strength and jump ability.

The significant relationship between off-ice power and skating performance implies that the muscle function assessed by off-ice measures has some commonality with skating speed and agility (Behm et al., 2005; Bracko & George, 2001; Burr et al., 2008; Farlinger et al., 2007; Gilenstam et al., 2011; Haukali & Tjelta, 2015; Janot et al., 2015; Krause et al., 2012; Mascaro et al., 1992; Runner et al., 2015). However, to what extent increases in sprint running performance and jump ability influence skating performance remains unclear. Despite the advantage of having greater speed in ice hockey, only two studies to date have focused on the development of skating speed in ice hockey players (Farlinger & Fowles, 2008; Naimo et al., 2014). Farlinger and Fowles (2008) found that young ice hockey players improved their skating speed following a 16-week periodic off-season program involving resistance, plyometric and skating-simulator training. The participants were divided into two groups, and the group who followed a progression in specificity toward skating-specific training had significantly greater improvements in on-ice skating speed performance compared to the group who followed a reverse specificity sequence of training. Naimo et al. (2014) found that a 4-week high-intensity pre-season cycle sprint program had positive effects on anaerobic peak power (11.7%) and 33 m skating speed (4 %) in collegiate hockey players, while the control group who followed a traditional endurance training programme did not demonstrate significant improvements in on- or off-ice power.

Ice hockey is a winter sport with the competition season running from August to April. During the off-season (summer months), on-ice training is replaced with physical off-ice training (Krause et al., 2012). The objective of the off-season training is to optimise fitness and on-ice skating performance by the start of, and during, the on-ice season (Hedrick, 2002; Mascaro et al., 1992). However, this can be challenging since ice skating is a complex motor skill, involving movements and muscle actions that can be difficult to stimulate via off-ice training (Bracko, 2004; Pollitt, 2003). There is a general consensus that specificity in training is essential for transfer to competitive movements (Young, 2006). According to the principle of specificity, sport-specific training is key for improvements in competitive performance (Bompa, 1999). Given the importance of skating speed in elite ice hockey, it is critical that coaches develop hockey-specific off-ice training programs that can increase the players' skating speed.

Previous research suggests that skating speed may be affected by physical off-season training, but more research on the topic is necessary. As such, the aim of the current study was to examine whether there is a correlation between changes in off-season power and changes in in-season skating performance in young ice hockey players.

Material and methods

Study design

A longitudinal research design was used to examine the relationship between changes in off-season power and changes in in-season skating performance. All participants conducted performance tests on three separate occasions during a season:

- Pre-test in April (end of season, T1),
- Post-test 1 in August (one week into the new season, T2),
- And post-test 2 in December (midseason, T3).

The period between T1 and T2 was defined as off-season, while the period between T2 and T3 was defined as in-season.

Participants

Twenty-five male junior league hockey players recruited from a Norwegian ice hockey club gave their written, informed consent to participate in the study. Of these, 18 players were included in the final analyses, with six players excluded due to injuries and/or failure to complete all testing sessions. One player was excluded due to insufficient skating skills compared to other participants. The characteristics of participants are presented in Table 1.. All participants were competitive hockey players, playing in either the under 20 elite-, under 18 elite- or under 18 first division. The study was approved by the Norwegian social science data services.

Testing protocol

On each of three occasions, participants completed performance testing on two consecutive days. All tests were performed at the same time of day, in the same order and by the same test leader, and preceded by a 10-15min warm-up. Anthropometric measures (height and weight) and on-ice tests were conducted on the first test day, while off-ice tests were performed on the second test day. Three on-ice tests (1-3) and three off-ice tests (3-6) were conducted. These were: 1) 36 m forward skating speed, 2) 36 m backward skating speed, 3) The Norwegian Hockey Federation`s (NIHF) skate agility test, 4) 36 m sprint running, 5) horizontal broad jump and 6) CMJ. For all on-ice tests, participants were required to wear full ice hockey equipment and carry a hockey stick. Off-ice tests were performed indoors on a synthetic running track. The participants performed each test (with the exception of skating agility) two to three times, separated by a recovery periods of 2-3 min, with the best result retained for analyses. .All participants were familiarised with test procedures prior to the start of the study.

36 m forward skating speed

The test was started from a stationary position behind the start line, with skates parallel to the direction of skating. Participants skated forward through the distance of 36 meter as fast as possible, starting on their own initiative and timed by a photoelectric timing system (Brower, Utah, USA) placed at the start and finish line. Two trials were performed. A trial was repeated if an athlete fell or lost balance during the test. This is a standard test used by NIHF with the purpose of measuring forward acceleration and maximum speed, which is an important ability for hockey players (Bracko, 2004; Matthews et al., 2010). Sprint performance tests using photocells are found to have high reliability (Mann, Ivey, Brechue, & Mayhew, 2015; Moir, Button, Glaister, & Stone, 2004).

36 m backward skating speed

The procedure for the 36 m backward skating speed test was identical to the 36 m forward test. The only difference was the skate direction. This test is also a standard test used by NIHF, with the purpose of measuring acceleration and maximal speed while skating backwards. The test was included because ice hockey players are required to skate fast backwards, especially in the defensive parts of the game (S. Nightingale, 2014).

Skating agility

Figure 1 shows in detail how the test is performed. One trial was performed, but repeated if a subject fell, lost balance or skated inside the face-off circles. The timing procedure was the same as for the other on-ice tests. The purpose of this agility test was to measure the athlete’s speed through twists and turns while doing both forward and backward crossovers. The test was selected because performing leg crossovers and changes of direction while skating forward and backward are common movements during ice hockey games (Kea, Kramer, Forwell, & Birmingham, 2001; Krause et al., 2012).

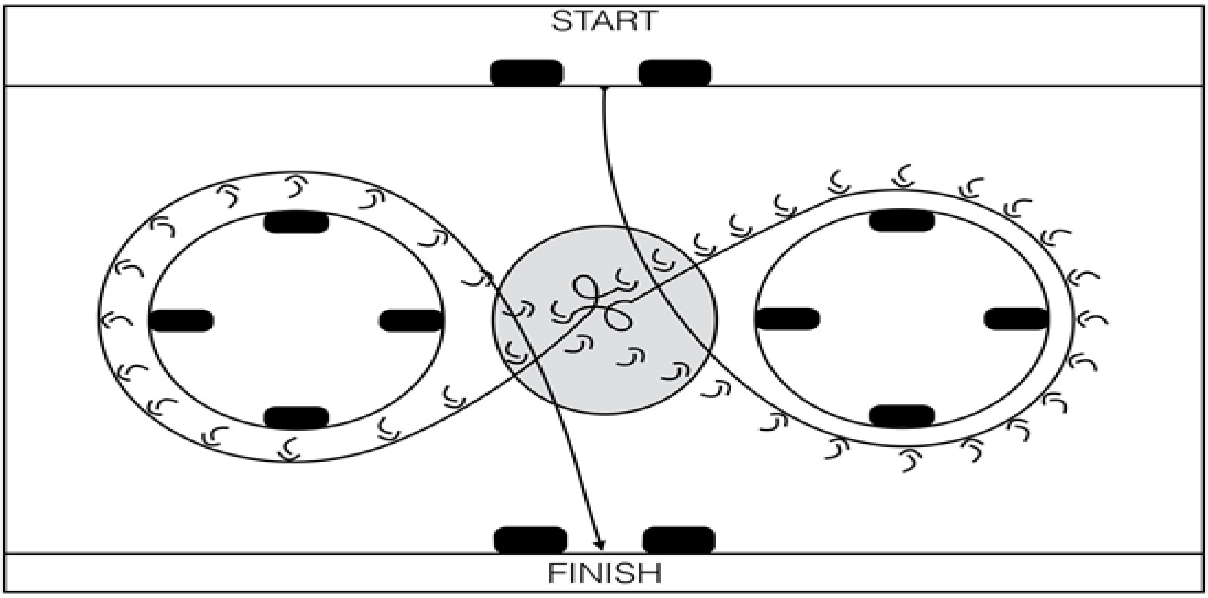

Figure 1. *The NHIF agility test. The test is carried out around the two "drop circles" in the attacking/defensive zone. The test starts with forward skating round the right circle, than the player turn 180° and skates backwards round the left and right circle, than the player again turns 180° and skates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

36 m sprint running

The testing procedure was similar to the 36 m forward skating speed test. The subjects started on their own initiative from a standing position directly behind the start line and ran 36 meters as fast as possible. The sprint test was selected because sprint running performance has previously been shown to correlate strongly with on-ice skating speed (Farlinger et al., 2007; Haukali & Tjelta, 2015; Krause et al., 2012).

Counter movement jump

The CMJ test was performed on a "Bosco mat", which measures jump height based on contact and airtime (Bosco, Luhtanen, & Komi, 1983). From a standing position with both feet on the mat, participants performed a countermovement until the knee angle reached approximately 90 degrees, before immediately accelerating upward and jumping as high as possible. To ensure valid and accurate results, participants were instructed to keep their legs straight in the air and land on the mat with their legs in an extended position (Young, 1995), and to keep their hands on their hips throughout. Three attempts were performed. The CMJ test was selected because it provides a valid measure of leg power (Burr et al., 2008; Markovic, Drazan, Jukic, & Cardinale, 2004).

Horizontal broad jump.

Subjects started from a standing position with both feet parallel behind a start line, and jumped as far as possible in the horizontal direction. Arm swing was allowed. The jump length was measured to the nearest 0.01 m from the start line to the rear heel. To qualify as a successful attempt the subjects had to take off with two feet and maintain balance for at least two seconds upon landing (Farlinger et al., 2007; Krause et al., 2012). Three attempts were performed. Broad jump is a good measure of horizontal leg power and has previously proved to relate to skating speed (Farlinger et al., 2007; Runner et al., 2015), and was therefore included in the current study.

Analyses

Data are presented as means ± standard deviation (SD). All statistical analyses were performed using IBM SPSS Statistics 22.0.A repeated measures analysis of variance was used to determine whether there were significant differences in changes in mean score between T1, T2 to T3. A Pearson product-moment correlation test was used to determine whether there was a significant correlation between on-ice and off-ice tests. Absolute changes in test variables were also used to correlate changes in off-ice test performance to changes in on-ice test performance. Statistical significance was accepted at the $P <.05$ level. Normality was assessed based on a histogram and skewness value.

Results

On-ice and off-ice performance

Table 1 presents the mean values for the on-ice and off-ice tests at T1, T2 and T3. Participants significantly improved their 36 m sprint running performance from T1-T2 (5.4%, $P< 0.001$). There were no significant improvements in any other off-ice or on-ice tests from T1-T2.

There were significant improvements in on-ice 36 m forward skate (1.3%, $P =0.03$), 36 m backward skate (3.9%, $P=0.002$), skate agility (2.6%, $P=0.002$) and broad jump (5.1%, $P<0.001$) from T2-T3.

Correlations

Table 2 present a matrix of correlations between the different on-ice and off-ice tests.

Off-season changes in sprint running performance and broad jump were significantly correlated with in-season changes in forward skating speed, but not to in-season changes in backward skating speed or agility (Table 3).

Off-season changes in CMJ were not significantly correlated with competition phase changes in forward skating speed, backward skating speed or agility.

No significant correlations were found between off-season changes in sprint running performance or jumping ability and off-season changes in skating performance (Table 4).

Table 1. *Descriptive statistics from anthropometric tests and performance tests*

Test	T1	T2	T3
Age	15.8±0.9	16.0±0.7	16.2±0.6†
Weight(kg)	68.2±9.6	69.9±8.7*	70.7±9.0†
Height(cm)	176.7±7.7	177.0±7.6	178.0±7.7**†
36m forward skating speed(sec)	5.34±0.18	5.28±0.21	5.21±0.19**†
36m backward skating speed(sec)	6.44±0.42	6.41±0.39	6.16±0.31**†
Skateagility(sec)	24.03±0.95	24.02±1.28	23.39±0.86**†
36m sprint(sec)	5.58±0.39	5.28±0.23*	5.22±0.25†
CMJ(cm)	47.47±5.27	48.45±5.34	49.93±4.38†
Broadjump (cm)	2,35±0.18	2.33±0.15	2.45±0.14**†

Note: Values represent mean ± SD. *Represents significant improvements (P< 0.05) from T1-T2, **from T2-T3, and †from T1-T3. T1 = Pre test (end of season), T2 = Post test 1 (start of new season), T3 = Post test 2 (midseason).

Table 2. *Correlation matrix between on-ice performance measures and off-ice performance measures on T1, T2 and T3*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
On-ice tests																		
1. 36 m FS T1	-	.79**	.64**	.79**	.72**	.58*	.80**	.77**	.65**	.68**	.53*	.62**	-.61**	-.64**	-.59**	-.70**	-.76**	-.73**
2. 36 m FS T2		-	.83**	.73**	.63**	.71**	.61**	.65**	.42	.69**	.71**	.76**	-.61**	-.63**	-.44	-.67**	-.64**	-.62**
3. 36 m FS T3			-	.47*	.45	.66**	.49*	.57*	45	.51*	.74**	.73**	-.42	-.52*	-.41	-.37	-.46	-.53*
4. 36 m BS T1				-	.78**	.82**	.66**	.73**	.66**	.58*	.37	.44	-.74**	-.72**	-.60**	-.76**	-.70**	-.72**
5. 36 m BS T2					-	.69**	.65**	.76**	.63**	.51*	.35	.52*	-.57*	-.69**	-.58*	-.55*	-.56*	-.50*
6. 36 m BS T3						-	.48*	.62**	.55*	.49*	.47*	.42	-.67**	-.74**	-.52*	-.57*	-.61**	-.65**
7. Agility T1							-	.91**	.85**	.52*	.33	.37	-.31	-.47*	-.41	-.53*	-.50*	-.64**
8. Agility T2								-	.85**	.46	.35	.44	-.39	-.62**	-.51*	-.52*	-.54*	-.67**
9. Agility T3									-	.36	.32	.33	-.34	-.55*	-.56*	-.40	-.46	-.68**
Off-ice tests																		
10. 36 m RS T1										-	.71**	.64**	-.66**	-.61**	-.55*	-.73**	-.59*	-.47*
11. 36 m RS T2											-	.89**	-.63**	-.58*	-.62**	-.57*	-.53*	-.52*
12. 36 m RS T3												-	-.56*	-.51*	-.63**	-.55*	-.49*	-.47*
13. CMJ T1													-	.81**	.80**	.72**	.64**	.56*
14. CMJ T2														-	.75**	.57*	.68**	.57*
15. CMJ T3															-	.56*	.47*	.52*
16. BJ T1																-	.81**	.72**
17. BJ T2																	-	.84**
18. BJ T3																		-

Note. Values represent Pearson correlation coefficient (r). Pre-test (end of season), T2 = Post-test 1 (start of new season), T3 = Post-test 2 (midseason). FS = Forward skate, BS = Backward skate, RS = Running sprint, CMJ = Countermovement jump, BJ = Broad jump.

**Correlation is significant at the .01 level (2-tailed).

*Correlation is significant at the .05 level (2-tailed).

Table 3. *Correlation between off-season changes in physical off-ice measures and competition phase changes in skating performance*

	T2-T3 Δ Forward skate	T2-T3 Δ Backward skate	T2-T3 Δ Skate agility
T1-T2 Δ Sprint	.51*	.25	.34
T1-T2 Δ Broad jump	-.48*	-.06	-.18
T1-T2 Δ CMJ	-.15	.16	.29

Note. Values represent Pearson correlation coefficient (r). T1-T2 Δ = off-season changes, T2-T3 Δ = competition phase changes. *Correlation is significant at the .05 level (2-tailed).

Table 4. *Correlation between off-season changes in physical off-ice measures and off-season changes in skating performance*

	T1-T2 Δ Forward skate	T1-T2 Δ Backward skate	T1-T2 Δ Skate agility
T1-T2 Δ Sprint	.08	.19	-.02
T1-T2 Δ Broad jump	.21	-.29	-.04
T1-T2 Δ CMJ	-.01	-.36	-.41

Note. Values represent Pearson correlation coefficient (r). T1-T2 = off-season changes.

Discussion

The purpose of this study was to examine whether there is a correlation between changes in off-season power and changes in in-season skating performance in young ice hockey players. The main findings of the study are that off-season (T1-T2) improvements in 36 m sprint running performance and off-season changes in broad jump were significantly correlated with in-season (T2-T3) improvements in 36 m forward skating speed. However, off-season changes in sprint running speed and jump ability were not significantly correlated with in-season improvements in backward skating speed or agility. These results can help ice hockey coaches to develop effective off-season training programs.

Ice hockey players use the off-season to develop and improve their strength, power and endurance (Hedrick, 2002), where the main objective is to transfer those gains into improvements in skating speed and overall ice hockey performance during the in-season. Success in ice hockey is highly influenced by the skating skills of the players (Matthews et al., 2010). Results from the present study indicate that off-season improvements in sprint running performance and horizontal jump ability transfer into improvements in forward skating speed during the in-season. This suggests that ice hockey players can benefit from including sprints and horizontal plyometric exercises in their off-season training. These findings are consistent with previous studies that have examined the relationship between physical off-ice measures and on-ice skating speed (Behm et al., 2005; Bracko & George, 2001; Farlinger & Fowles, 2008; Farlinger et al., 2007; Haukali & Tjelta, 2015; Krause et al., 2012). Sprint running performance and horizontal jump ability have been consistently found to correlate with linear skating speed. Farlinger et al. (2007) concluded that measures of horizontal leg power (i.e., sprint running performance and triple jump) where the best predictors of skating speed. This strong relationship may be a function of exercise specificity, since leg power applied in the horizontal direction is important for skating performance. Although maximal linear running and skating are biomechanically different, they share a similar underlying basis of force production in the horizontal direction, and are both a product of the two factors stride length and stride frequency (Behm et al., 2005; Farlinger et al., 2007; Haukali & Tjelta, 2015). The level of power generated during the push-off phase affects stride length, while leg recovery speed determines stride frequency

(Behm et al., 2005; Mascaro et al., 1992). Improvements in off-ice sprint running performance may therefore transfer to skating speed because it is related to both push-off leg power and recovery speed. Farlinger and Fowles (2008) also found that improvements in 30 m sprint running performance were significantly correlated to improvements in 35 m skating speed (r= 0.56: p= 0.01). The only other off-ice test variable that was found to correlate with improvements in skating sprint performance was lateral power (Edgren side shuffle) (r = -0.46: P = .040). Skating force is applied to the ice not only through the sagittal plane, but also through the frontal plane (Runner et al., 2015; Upjohn et al., 2008). To accelerate in skating, a postero-lateral push-off angle is needed, and lateral power may therefore be even more specific to skating than horizontal power (De Koning, De Groot, & Van Ingen Schenau, 1992; Farlinger & Fowles, 2008; Roy, 1977).

Although both the current study and previous studies indicate a clear link between skating speed and vertical jump height (Haukali & Tjelta, 2015; Janot et al., 2015; Mascaro et al., 1992; Runner et al., 2015), there was no significant correlation between off-season changes in CMJ and competition phase improvements in forward skating speed (r = -0.15, P = 0.55) in the present study. Vertical jump is traditionally viewed as a valid measure of power in the lower limbs, but might be less specific to skating power than horizontal power. Villarreal, Requena, and Cronin (2012) emphasize that athletes who require power for moving in the horizontal plane should engage in horizontal accelerations and exercises.

Participants in the current study did not improve their skating performance during the off-season and there was no significant correlation between off-season changes in off-ice power and off-season changes in skating speed. This suggests that gains in force and power attained during the off-season will not provide an immediate transfer to skating performance at the start of the season. This could be explained by the absence of on-ice training in this period. It is difficult to target skating-specific muscles and movements through physical off-ice training, and lack of available on-ice training time in the off-season forces players to train less specifically (Hedrick, 2002; Pollitt, 2003). The results from the present study suggest that a period of on-ice training is required to transfer off-season improvements into skating performance. According to periodization theory, this period is defined as the conversion phase (Bompa, 1999). The main objective of the conversion phase is to transfer the non-specific gains in strength and power attained during the off-season into sport-specific performance at the start of and during the season. According to Bompa (1999), a successful conversion phase is dependent on the use of specific training methods. Specificity is particularly important for maximum transfer from general training to sport-specific skills, especially in terms of neural adaptations (Bompa, 1999; Young, 2006). Specific training can be expected to increase activation of relevant motor units and improve intramuscular coordination to ensure that muscles are tuned to newly gained force-generation capacity (Delecluse, 1997; Young, 2006). Farlinger and Fowles (2008) stresses that specificity in training is of particular importance for optimal transfer to a complex sport-specific performance task such as skating. They found that a progressively specific training program from conventional strength and power training to more skate-specific simulation training (SkateSIM tool), optimized transfer to skating speed at the start of the season. The SkateSIM was designed to target the muscles and the push-off angle applied during powerful skating (Farlinger & Fowles, 2008). Research literature on field players (soccer, handball, rugby) similarly emphasize that transfer from resistance and plyometric training to sprint performance is maximized when the training exercises are specific (Villarreal et al., 2012; Young, 2006). A meta-analyses of Villarreal et al. (2012) concluded that sprint performance gains are optimized by the use of horizontal plyometric exercises. Naimo et al. (2014) however, observed improvements in skating speed after a pre-season period of cycling intervals. This transmission from the non-specific cycling training protocol may have occurred because of concurrent on-ice training once a week in the same period. The combination of non-specific physical training and specific team trainings has also been shown to be beneficial for sprint performance in field players (Chelly et al., 2010; Chelly, Hermassi, Aouadi, & Shephard, 2014; Christou et al., 2006; Kotzamanidis, Chatzopoulos, Michailidis, Papaiakovou, & Patikas, 2005; Mchelly, Hermassi, Aouadi, & Shephard, 2014; Meylan & Malatesta, 2009; Ronnestad et al., 2008; Villarreal et al., 2012; Young, 2006).

Plyometric training can be an effective training method to improve sprint agility (Miller, Herniman, Ricard, Cheatham, & Micheal, 2006; Thomas, French, & Hayes, 2009; Vàczi, Tollàr, Meszler, Juhàsz, & Karsai, 2013). Although NIHF`s agility test includes multiple explosive accelerations which are found to correlate to jump ability (Haukali & Tjelta, 2015), the present study did not find that improvements in jump ability transferred to increased skate agility performance. Off-season improvements in running speed and changes in jump ability were not significantly correlated with in-season improvements in backward skating speed or agility. This could be because performances in these tests are more likely to be influenced by effective skating technique than physiological strength and power. Previous studies indicate a clear link between skating agility, playing experience and competition level (Bracko & George, 2001; Farlinger et al., 2007; Gilenstam et al., 2011; S. Nightingale, 2013), implying that players get gradually more skilled and develop more advanced motor programs for skating as they gain experience. The agility test combines high speed with technical elements such as crossovers and turns, while maintaining balance. Performance is therefore a product of speed, technique, coordination, flexibility and power. There appears to be limited transfer between linear speed and agility training(Young, Mcdowell, & Scarlett, 2001). This emphasises the importance of specificity in training, and suggests that athletes must train specifically with the movement pattern required in their sport (Sheppard & Young, 2006; Young & Farrow, 2006). Off-ice training to increase backward skating speed and agility should involve highly specific training that replicates the specific movements as closely as possible. Bracko, Fellingham, Hall, Fisher, and Cryer (1998) found that professional ice hockey players accelerate and decelerate frequently, and spend the majority of time gliding and doing crossover turns. Strength and conditioning coaches are therefore advocated to develop off-ice agility training and testing that simulate these movements.

A limitation to the current study is the limited sample size which includes only male junior hockey players. As a result, the data has a relatively narrow range, limiting the generalizability of the results. Additionally, a controlled intervention study is necessary to examine whether there exist a causal relationship between physical off-ice training and skating speed.

Conclusions

Considering the importance of skating speed in modern ice hockey and the lack of available on-ice training time during off-season, coaches are faced with the challenge of developing effective off-ice training programs. The current findings indicate that off-season improvements in sprint performance and horizontal jump ability will transfer to improvements in linear skating performance after a period of specific on-ice training. No significant relationship was found between off-season changes in off-ice power and competition phase changes in backward skating speed or agility. This indicates that highly specific training is required in order to improve these skills. The findings of the current study further demonstrate that sprint running performance and horizontal broad jump are appropriate measures of linear skating speed during periods of limited access to on-ice training time, or following periods of off-ice training. These findings can help coaches to better understand the impact of physical off-season training on skating performance.

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