by Michael R. Bracko, EdD

Biomechanics powers ice hockey performance

Skating in ice hockey is a complex motor skill. Howie Green, of the University of Waterloo in Ontario has written,[1] "Hockey is uniquely stressful . . . the heat and humidity of the protective gear, the high level of coordination required, the repeated demands made on the muscles with little rest and the astounding requirement that it's played while balancing on skate blades are all factors (in fatigue)."

Many experts believe the most important skill in ice hockey is skating. The professional coach, general manager, and scout consider skating ability a significant factor when selecting a player for a team.[2]

Information on the game-performance skating characteristics of hockey players is important for the team practitioners and coaches, because there are implications for on- and off-ice fitness training. For the biomechanist, skating instructor, and coach, information on the biomechanics of skating is important for the development of future research and skating performance enhancement programs.

Game-performance skating research

Bracko et al[3] analyzed National Hockey League forwards to investigate the time and frequency of 27 skating characteristics during a game (Tables 1 and 2). Fifteen timed skating characteristics and 12 frequency characteristics were analyzed. For the timed skating characteristics, the total time spent performing each characteristic during a shift was measured. For the frequency characteristics, the total number of occurrences during a shift was counted.

The results of the study indicate that NHL forwards spend the highest percentage of ice time, 39%, gliding on two feet, suggesting that this position is an important characteristic in hockey. It is important for hockey players to maintain balance on two feet while moving straight ahead, turning, and engaging in body and stick contact. Each of the other skating characteristics is derived from a two-foot balance position. Body contact is initiated from a two-foot balance position. The typical balance position, while gliding and stationary, is for a player to have his or her skates positioned slightly wider than shoulder width apart, ankles dorsiflexed, knees flexed, trunk flexed, and the hockey stick close to, but not always on, the ice (Figure 1).

Characteristics of hockey players' game-performance skating have implications for on- and-off-ice fitness training.

The ability to maintain balance while placing the center of gravity outside the base

Figure 1. The most common characteristic in hockey is the two-foot glide. The player's skates are slightly wider than shoulder width, the ankles are dorsiflexed, hips and knees flexed, and the hockey stick is close to or on the ice.

TABLE 1. TIMED SKATING CHARACTERISTICS OF NHL FORWARDS

SKATING CHARACTERISTIC	% OF TOTAL TIME ON ICE
Two-foot glide	39
Cruise slide	16.2
Medium intensity skating	10
Struggle for puck or position	9.8
Low-intensity skating	7.8
Backward skating	4.9
High-intensity skating	4.6
Two-foot stationary	3
Two-foot glide with puck	1.4
Medium-intensity skating with puck	0.8
Cruise stride with puck	0.6
Struggle with puck	0.6
Low-intensity skating with puck	0.5
High-intensity skating with puck	0.4
Two-foot stationary with puck	0.4

of support appears to be important for game-performance skating.

Bracko et al[3] also analyzed the most commonly occurring skating characteristics during the first 30 seconds after a puck has been dropped in a face-off (Table 3). In this specific game situation, the two-foot gliding position was rarely sustained. Rather, it was interspersed with striding characteristics such as cruise strides, struggle for puck or position, medium-intensity skating, and low-intensity skating.

Even though high-intensity skating was utilized for a low percentage of total on-ice time, it is also considered an important characteristic as it relates to the nature of ice hockey. Using quick bursts of speed (followed by gliding) to maintain position or possession of the puck, to maintain speed, or to initiate body contact, is how hockey players gain advantage over opposing players.

Figure 2. The double-support portion of the propulsion phase finds the recovery skate on the ice in line with the flexed knee and hip and the shoulder.

Biomechanical research on forward striding

Marino and Weese[4] identified three phases in the skating stride: the single-support propulsion phase, the double-support propulsion phase, and the single-support glide/recovery phase. Their analysis indicates that propulsion starts while one skate is on the ice and the other skate is approximately halfway through the recovery phase. The recovery phase is the period of time immediately after the skate pushes off before it is brought forward to be put back on the ice to push off again. The propulsion phase continues as the recovery skate is put on the ice (double-support propulsion phase). When the propulsion skate is brought back onto the ice, it should be in line with the knee, hip, and shoulder (Figure 2). The single-support glide phase is the brief period of time during which one skate is gliding and the skater decelerates.

Marino[5] studied the kinematics of skating at different velocities. He found that stride rate increased with velocity, but that there was no change in stride length. Therefore, velocity depends more on the number of strides than the length of the stride.

Page[6] used 14 youth, college, recreational, and professional players to determine the differences between fast and slow skaters. Players were filmed while skating as fast as possible over a distance of 12.19 m. The film was used to measure hip abduction angle, knee flexion angle, hip-skate forward inclination angle, trunk angle relative to the ice, and the time it took the propulsion skate to get back on the ice after push-off. The markings made by the skates on the ice were used to measure left, right, and total stride width. Stepwise multiple regression and multiple stepwise discriminant analyses were used to distinguish the differences between the fastest skaters in each group and for the entire group (Table 4).

The authors found that four of the eight characteristics distinguishing fast skaters from slow skaters were related to stride width: left stride width, right stride width, width between

TABLE 2. FREQUENCY SKATING CHARACTERISTICS OF NHL FORWARDS

SKATING CHARACTERISTIC	% OF TOTAL OCCURRENCES
Left cross-over turn	20.2
Gliding left-turn	17.8
Right cross-over turn	17.7
Gliding right-turn	16.4
Stop and start	10.4
Forward to backward pivot	7.6
Backward to forward pivot	6.3
Gliding left turn with puck	1
Right cross-over turn with puck	1
Left cross-over turn with puck	1
Gliding right turn with puck	0.4
Stop and start with puck	0.2

strides, and hip abduction angle. This study also found that the propulsion skate spent less time in recovery phase after push-off in faster skaters than in slow skaters. This is corroborated by Marino and Weese,[4] who found that fast hockey skaters kept their recovery skate close to the ice to ensure a rapid completion of the recovery phase and quickly reposition the skate for further propulsion. Page[6] also found that fast skaters had more knee flexion immediately prior to the propulsion phase, and slow skaters did not flex their knees as much during fast skating. The faster skaters in the study also flexed their trunks, or had more forward lean, whereas slow skaters were more upright with less trunk flexion during fast skating (Figure 3).

Figure 3. During fast skating, a flexed trunk or forward lean is characteristic of faster skaters.

Shoulder movement

Newton's Third Law of Motion dictates that for every action, there is an equal and opposite reaction. As this relates to hockey skating, fast skaters have wide strides because they push to the side, abducting the hip during propulsion and adducting and flexing the hip during recovery. The equal and opposite reaction to hip abduction and adduction is shoulder abduction and adduction. The shoulders have to abduct and adduct with the hips to maintain balance, momentum, and increased velocity, whether the player has one or two hands on the stick[7] (Figures 4, 5).

Bracko et al[8] studied the effect of different shoulder movements on acceleration in high school hockey players. Each subject was randomly instructed to accelerate with one of two shoulder movements, either abduction/adduction or flexion/extension. No significant differences were found between the two acceleration techniques, but the researchers did find differences between groups that approached statistical significance, indicating that the athletes who performed shoulder abduction/adduction were faster than those who performed flexion/extension. It is of interest to note that 13 subjects were eliminated from data analysis due to an inability to perform the flexion/extension acceleration technique, which involved forward and backward shoulder movement. This may be an indication that the natural movement of the shoulders during acceleration is abduction and adduction, or "side to side" shoulder movements.

Science to practice

Although the biomechanics and game-performance movement patterns of hockey players have been well established by researchers, this information has gone unused by many coaches and skating instructors.[9] Typically, coaches and skating instructors will use figure skating and speed skating skills, drills, and techniques to enhance hockey skating performance.[7,9] However, figure skating and speed skating skills and body positions are rarely, if ever, used during a hockey game and their use in skating performance enhancement programs should be questioned.[7,9] Marteniuk[10] indicates practicing non-game-like skating drills on the ice during practice can introduce artificial situations that may inhibit the acquisition of a high-performance motor program. In order to develop an effective motor program, a hockey player should have on-ice practices that use the same skills, and under the same conditions, that he or she experiences during a game.[9]

Many coaches and skating instructors will have hockey players practice flexion and extension of the shoulders and hips when striding.[7,9] Their reasoning is that since a hockey player is moving forward, his or her movements should be forward (flexion and extension of the hip and shoulder). However, it is clear that flexion and extension of the shoulders and hips while striding are counterproductive, and in fact impossible, in skating. The proper movement of the shoulders and hips during striding is abduction and adduction. A player who can perform smooth coordinated abduction and adduction of the hips and shoulders will be a more efficient skater than a player who cannot produce these movements. Van Ingen Schenau et al[11] have stated that because the propulsion skate is gliding forward, it cannot exert a force straight backward. An essential technical aspect of skating is that the direction of the push-off is perpendicular to the gliding direction of the skate; in fact, De Boer et al[12] and Bracko and Moeller[13] have indicated that it is impossible for the propulsion skate to push straight backward during forward striding. This unique characteristic of skating is caused by the low coefficient of friction of the ice. That being so, for performance enhancement, smooth,

TABLE 4. BIOMECHANICAL DIFFERENCES BETWEEN FAST AND SLOW SKATERS

SKATING VARIABLE	FAST SKATERS	SLOW SKATERS
Left stride width	21.21 in	17.76 in
Right stride width	29.21 in	20.46 in
Width between strides	21.21 in	17.76 in
Hip abduction angle	48.33°	35.33°
Total recovery time after push-off	0.37 sec	0.48 sec
Knee flexion angle	106.11°	123.6°
Hip—skate forward inclination	57°	65.33°
Trunk angle	38.67°	49.2°

Figures 4, 5. Because a skate cannot be pushed straight back due to the low friction coefficient of ice, skaters push to the side, abducting the hip during propulsion (adducting during recovery), to gain speed. Abducting and adducting the shoulders in concert with the hips helps skaters maintain balance and momentum and gain velocity.

coordinated abduction and adduction movements of the shoulders and hips are required for high-performance hockey skating.

Coaches and skating instructors will also have players practice skating with an "upright" trunk, similar to the position of a figure skater. This is counterproductive because it has been established[3,6] that maintaining a flexed trunk, or forward lean, during two-foot gliding and striding are characteristics of high-performance hockey skaters.

Some examples of hockey-specific drills recommended for enhancing performance include:

• Alternating striding and gliding on the command of a whistle while turning left and right around cones on the ice so that players skate around the entire surface of the ice as they would in a game;

• Skating with a deep knee bend while maintaining a wide stride with quick recovery after push-off from one end of the rink to the other;

TABLE 3. SKATING CHARACTERISTICS 30 SECONDS FROM PUCK DROP

SKATING CHARACTERISTIC	TIME ON ICE (SECONDS)
Struggle for puck/position	2
Two-foot glide (gliding left turn - right turn)	2
Cruise stride (left cross-over turn)	1
Two-foot glide (gliding left turn)	2.5
Cruise stride (left cross-over turn)	1
Two-foot glide (gliding left turn)	2.5
Cruise strides (right cross-over turn)	1
Two-foot glide (gliding left turn, right turn)	2
Struggle for puck/position	2
Medium-intensity skating (left cross-over turn)	2.5
Two-foot glide (gliding right turn)	1.5
Medium-intensity skating (right cross-over turn)	1
Two-foot glide (gliding left turn, right turn)	1.5
Cruise strides	1.5
Low-intensity skating (left cross-over turn)	3.5
Two-foot glide (gliding left turn)	2.5
Two-foot stationary with puck	0.4

• For young hockey players, skating with one hand on the hockey stick to practice a smooth, coordinated movement pattern of the shoulders and hips (arms and legs);

• Practicing forceful shoulder/arm movement by keeping the skates on the ice and forcefully abducting and adducting the shoulders to produce forward movement while maintaining a deep knee bend;

• Accelerating with quick strides to skate down the ice with wide strides, maneuver through three or four cones with quick gliding turns, then accelerate again and practice the same movement again on the other side of the ice; and

• Practice all the above skating drills while handling a puck with the hockey stick.

Conclusions

Game-performance skating is characterized by two-foot gliding, striding characteristics (low-, medium-, and high-intensity skating), and struggling for puck or position. Fast skaters have wide strides, quick recovery after push-off, deep knee flexion prior to push-off, and significant forward lean. A wide stride (using hip abduction) with quick recovery is characteristic of a fast skater. The propulsion skate is moving, making it impossible to push straight back when striding. Shoulders abduct and adduct in a smooth movement pattern coordinated with the abduction and adduction of the hips. Skating instruction should emulate, as much as possible, the game-performance skating characteristics that have been found in the research literature.

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