KINEMATIC COMPARISONS BETWEEN FORWARD AND BACKWARD SKATING IN ICE HOCKEY

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The purpose of this study was to examine the kinematics of lower body and trunk between forward and backward skating. Seven male collegiate ice hockey players skated both forward and backward (C-cut) four times each. A standard two-dimensional kinematic analysis was conducted to examine the lower body extremity and trunk at the instants of weight acceptance and propulsion. No significant differences in the joint angles were found at the weight acceptance. At the propulsion, significant differences were found in the joint angles of hip, knee, ankle and trunk between forward and backward skating. Hence, these findings indicate the importance of strengthing lower body joints and trunk, particularly for forward skating. Future studies are warranted to examine the mechanics of forward and backward skating using a 3D analysis.

KEY WORDS: backward, forward, ice hockey, skating.

INTRODUCTION: Hockey is a fast paced sport requiring low intensity striding and gliding movements, interspersed with bursts of high intensity skating, and other major hockey skills such as body checking, stick handling, passing and shooting. Many professional coaches, general managers, and scouts consider skating as the most important skill of all. From a biomechanical perspective, having fundamental stable skating mechanics can contribute to fast skating and may reduce both head and lower body joint injury. Pearsall, Turcotte, and Murphy (2000) conducted a kinematic analysis of forward ice skating in hockey. The authors described the ice skating stride as consisting of three functional phases: 1) glide during single support, 2) propulsion during single support, and 3) propulsion during double support. The glide during single support phase coincides with the full extension of the propulsion leg, and the beginning of recovery of the leg back to the support position. The propulsion during the single support phase consists of drawing back the recovery leg while the support leg that has been gliding externally rotates and begins to push out and back. Finally, the propulsion during double support phase occurs once the recovery leg again contacts the ice under the body, and the propulsion continues with the other leg. This pattern is repeated as forward motion continues. The kinematics of forward ice skating have been examined in previous literature but not extensively (McPherson, Wrigley, & Montelpare, 2004; Pearsall, et al., 2000; Upjohn, Turcotte, Pearsall, & Loh, 2008). However, the kinematics of backward ice skating (C-cut technique) are not well understood. Marino and Grasse (1993) is the only evident study on backward skating. Ten skilled hockey players participated in the study, and the authors found that mean backward skating cycle time was 0.86 s and mean displacement of one cycle was 5.65 m. The authors also indicated that mean backward skating velocity was 6.57 m/s, which was approximately 81% of the mean forward skating velocity at 8.03 m/s. Since in this study the camera was suspended from overhead, the body mechanics of backward skating were not examined. Understanding the body mechanics of backward skating is crucial because it enables players to have proper balance on the ice while skating backward efficiently without falling, which could cause serious head (i.e. concussion) and body joint injuries. The mechanics of forward and backward skating can be similar but yet substantially different due to the direction of the skating motion. However, due to the lack of empirical evidence on backward skating mechanics, this observation has yet to be examined and validated. Therefore, the purpose of this study was to examine and compare both kinematics of forward and backward ice skating in the lower extremity and trunk segment. Results will enable coaches to provide comprehensive skating instruction for developing minor hockey players and beginners, and also trainers can prescribe better conditioning programs to reduce body joint injury.

METHODS: Seven male, Division II, intercollegiate club hockey players (mean age: 20.6 ± 2.6 years old; height: 1.8 ± 6.6 m; mass: 82.9 ± 15.7 kg) participated in the study. The Institutional Research Board approved the study, and written informed consent was obtained from the participants prior to the study. Data collection took place at a local ice arena. Upon arrival, the participants were fitted with reflective joint markers on both sides of the body at the shoulder, hip, knee, ankle and toe. Participants wore skates and gloves and carried a hockey stick. Participants were instructed to skate both forward and backward (C-cut technique) four times each at their highest intensity from one end of the goal line to the other end of the goal line on the ice. Participants had three minutes rest between each trial and five minutes rest between each type of skate. The order of the skate (forward or backward) was randomized to reduce any order effect. A total of 56 trials (7 participants x 2 types of skate x 4 trials/skate) were collected and the three best trials with similar kinematic joint angles from each participant were selected for statistical analyses. Video of the skating trials were collected using standard two-dimensional videography with one high-speed JVC (Model: GR-D371U) digital video camera operating at 60 Hz and positioned at the center ice line to capture the sagittal view of the skating motion. Additionally, a 650W artificial spot light was used in conjunction with the camera to assist joint marker identification. Video trials were analyzed using APAS^{TM} (Ariel Performance Analysis System). A previous literature examined instants of weight acceptance (foot fully contact with the ice in the beginning of stance phase) and propulsion (toe off the ice in the beginning of swing phase) to understand the mechanics of forward skating (Upjohn, Turcotte, Pearsall, & Loh, 2008), and this research study used the same instants for forward and backward skating analysis. Since backward skating skill (C-cut) does not have a swing phase only a stance phase due to the foot contact with the ice the whole time, the instants of weight acceptance and propulsion could not visually be identified from video trials. Hence, this study used the instants of maximum hip flexion as the weight acceptance and maximum hip extension as the propulsion for analysis because these two instants best represented the motion occur at the weight acceptance and propulsion, and it also provided objectivity and consistency across trials for data analysis. Moreover, the coordinate data were then smoothed with a digital filter function with appropriate cut off frequencies (x = 8 Hz and y = 8 Hz). Smoothed data were used in the kinematic analysis to generate joint angles and angular velocities at the hip, knee, and ankle joints and trunk segment. A paired samples *t*-test with $\alpha = 0.05$ was conducted using SPSS (v. 22) software to examine significant differences between forward and backward skating for the body joint kinematic variables.

RESULTS: Joint angles and angular velocities were compared between forward and backward skating skills. At the instant of weight acceptance there were no significant differences in the trunk and lower body joint angles, Table 1, but the significant differences were observed in the hip and knee joint angular velocities. At the instant of propulsion significant differences were observed in the trunk and lower body joint angles, Tables 3. Additionally, significant differences were observed in the angular velocities of the hip, ankle and trunk, Table 4.

Table 1
Angular Displacement between Forward and Backward Skating at Weight Acceptance

Joint	Forward vs Backward Angular Displacement Mean (SD)°	*p*
Hip	85.4 (10.7) vs 83.8 (9.4)	.683
Knee	96.4 (9.0) vs 93.4 (8.3)	.327
Ankle	78.9 (7.7) vs 78.7 (10.0)	.949
Trunk	50.6 (8.3) vs 51.7 (9.4)	.625

**Statistical significant at $p < 0.05$*

Table 2
Angular Velocity between Forward and Backward Skating at Weight Acceptance

Joint	Forward vs Backward Angular Velocity Mean (SD)°/s	*p*
Hip	68.3 (37.0) vs -38.3 (62.5)	.017*
Knee	36.2 (68.2) vs -88.0 (59.4)	.020*
Ankle	-14.1 (69.2) vs -21.2 (82.4)	.856
Trunk	-4.3 (33.6) vs 24.5 (35.5)	.275

**Statistical significant at $p < 0.05$*

Table 3
Angular Displacement between Forward and Backward Skating at Propulsion

Joint	Forward vs Backward Angular Displacement Mean (SD)°	*p*
Hip	128.2 (11.1) vs 113.3 (10.8)	.006*
Knee	137.2 (12.3) vs 123.8 (3.0)	.025*
Ankle	90.2 (10.7) vs 75.4 (11.6)	.039*
Trunk	27.2 (7.5) vs 49.6 (8.8)	.000*

**Statistical significant at $p < 0.05$*

Table 4
Angular Velocity between Forward and Backward Skating at Propulsion

Joint	Forward vs Backward Angular Velocity Mean (SD)°/s	*p*
Hip	275.5 (177.2) vs 6.8 (24.0)	.008*
Knee	-68.1 (223.8) vs 36.8 (59.2)	.209
Ankle	533.7 (264.8) vs 44.7 (67.0)	.008*
Trunk	68.7 (18.5) vs -35.3 (49.7)	.001*

**Statistical significant at $p < 0.05$*

DISCUSSION: The motion between forward and backward skating may be similar but yet substantially different. The skill of forward skating is characterized by both swing and support phases, and each phase is further divided into single and double periods of leg support (Pearsall, et al., 2000), whereas, the skill of backward skating (C-cut technique) consists of continuously double leg contact with the ice surface during the support phase only and alternately shifting leg from one side to the other (Marino & Grasse, 1993). In this study similar kinematic lower body joint angles and trunk segment were found at the instant of weight acceptance between forward and back skating. However, forward skating skill showed greater hip and knee angular velocities comparing to backward skating skill. The difference in the hip and knee joint angular velocities may explain why forward skating (10.1 ± 1.9 m/s) has a higher skating velocity than backward skating (8.2 ± 0.2 m/s). In addition, at the instant of propulsion skaters showed significantly greater hip, knee and ankle extension movements in forward skating than backward skating. Also, the trunk segmental angle (with respect to the horizontal axis) in forward skating is significantly less than backward skating, which indicates the skaters leaned their upper body forward while skating forward. The forward trunk lean allowed the skaters to almost fully extend their push off leg at propulsion to propel their body forward at the end of stance phase. This also explains why at the instant of propulsion significantly higher amount of angular velocities were observed in the hip, ankle and trunk in forward skating than backward skating, which further contributed to higher forward skating velocity. The knee joint also showed a higher angular velocity but with a negative knee angular velocity, and this indicates that at propulsion the knee began to flex while hip and ankle continued to extend for allowing a quicker leg recovery in the skating cycle. In the backward C-cut skating skill the foot does not leave the ice since there is no swing phase, so there is less forward trunk lean and the leg is not fully extended at propulsion, which reduces the backward skating velocity. Due to the limited previous literature on skating mechanics, the authors have selected literatures that were conducted with similar kinematic analysis in the methodology (i.e. joint angles were defined the same way.), which enables the authors to compare the current study with previous research work. In this study the joint kinematics in forward skating at weight acceptance were similar with Hagg, Wu, and Gervais (2007)'s study of trunk, knee and ankle joint angles (38°, 110°, and 67°, respectively) and McPherson, Wrigley, and Montelpare (2004)'s study of hip and knee joint angles (91° and 103°, respectively). Also, similar results were found in forward skating at propulsion when comparing to McPherson, Wrigley, and Montelpare (2004)'s study of hip, knee and ankle joint angles (149°, 156° and 99°, respectively). There are some limitations that should be considered in this study. This research study was conducted in two dimensions rather than in three dimensions. Since the main joint movements occurred in the sagittal plane of motion as indicated by Upjohn, et al., 2008, for forward skating, this study provides important preliminary findings on comparisons between forward and backward skating mechanics. Future studies are warranted to conduct a three-dimensional analysis to compare both forward and backward skating skills.

CONCLUSION: This research study compared the kinematics of forward and backward skating for male varsity ice hockey players. The results showed that the skaters demonstrated significantly greater hip, knee, and ankle extension movements at propulsion in forward skating than backward skating. Additionally, the skaters showed greater forward trunk lean in forward skating than in backward skating to maximize their skating velocity. This indicates the importance of prescribing strength and conditioning programs that match lower body joint action for both forward and backward skating skills. Future studies are warranted to conduct a three dimensional analysis in both forward and backward skating.

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