KINEMATICS OF THE FOOT AND ANKLE IN FORWARD ICE HOCKEY SKATING

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Three elite ice hockey players performed forward skating with twin axis electro-goniometers placed posterior to the right ankle and rear foot. The data were gathered at a sampling frequency of 200 Hz. The use of mini notebook computer and data acquisition card allowed for a completely portable system. Maximum and minimum range of motion data were averaged for inversion-eversion and dorsiflexion-plantarflexion motions were examined throughout one stride cycle.

KEY WORDS: skating, kinematics, ice hockey, ankle, foot

INTRODUCTION: Studies on the kinematics of ice hockey skating have focused mainly on the stride rate and stride length (Marino, 1977, 1979), and on the effectiveness of starts, turns and stops (Naud & Holt 1979, 1980). Hoshizaki et al. (1989) are among the few that have attempted to examine foot kinematics during skating using a two dimensional high-speed camera system. However, using a two dimensional system to evaluate a three dimensional form of locomotion is problematic (van Ingen Schenau et al., 1989). Deriving kinematic information becomes technically difficult using traditional film digitizing methods given that the large distance traverse while skating requires a large calibrated field of view thus reducing measurement resolution. In the present study, to avoid these problems, electrogoniometers were used. They allow for a direct measurement and can be arranged into a portable system thus removing the spatial limitations imposed by cinematography.
Improved quantitative data concerning skating foot and ankle kinematics may identify design changes to the skate that may lead to enhanced performance. The purpose of the study was to examine the kinematics of the foot and ankle using electrogoniometers during the start, forward skating, and stop.

METHODS: Three varsity level ice hockey players consented to be subjects. They were instructed to use a parallel start from their respective defensive zone face-off circle then to skate toward the respective offensive face-off circle (Figure 1) ending the trial with a crossover stop. The subjects wore Bauer 7000 skates and loose fitting clothing. Kinematic data were acquired through the use of bilateral twin axis goniometers (Penny and Gilles XM110) fixed on the rear foot along the longitudinal axis of the Achilles tendon (Figure 2). These goniometers allow for simultaneous measurement of angles in two planes. They were attached directly over the skin two-sided tape then covered in place with athletic tape. This arrangement allowed the goniometers to be located within the skate while worn by the subject. The raw signal was amplified 1000 times and collected at a sampling frequency of 200 Hz. The data were then logged on a portable mini notebook computer (Libretto Pentium), which the subjects carried in a backpack creating a completely portable system. A heel switch was used to identify stride cycles. The kinematic data were analyzed and filtered with a median filter at a weight of 0.05 using National Instruments BioBench software (Ver 1.0). Angular measures were reported with respect to the subject's on-ice neutral standing position. The acceleration phase occurred during the first 5 steps with steps 6 to 10 representing steady state. Maximum angular range of motion values in the sagittal and frontal plane were measured. Within a given phase, five steps were used to calculate the average maximum values within a subject for the right foot and ankle. Only data logged during the actual motion of deceleration were used in the calculations of the range of motion data for the parallel stop. An ensemble average was calculated following intrasubject calculations.

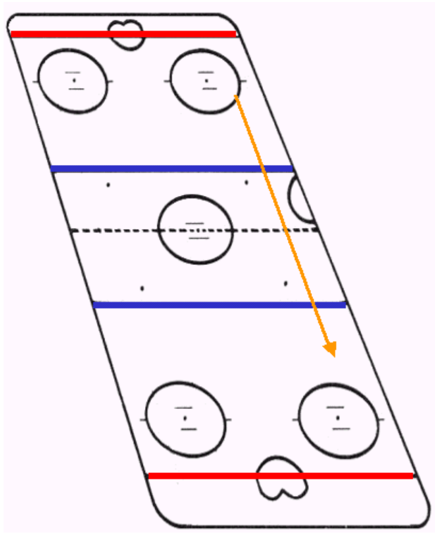

Figure 1 - Ice hockey task.

Figure 2 - Placement of twin axis goniometer.

RESULTS AND DISCUSSION: Figure 3 shows the dorsi- and plantar-flexion of a cycle of the skating stride for the right foot. The skating stride is biphasic in nature, consisting of alternating periods of single support and double support. The single support phase corresponds to a period of glide whereas the double support phase corresponds to propulsion (Marino, 1977).

The cycle in Figure 3 begins with initiation of the single support phase. At that instant, the data revealed that the skate was dorsiflexed 7.1°. As the single support phase ended and the double support phase began at about 31% of a completed stride, the right skate increased dorsiflexion reaching a cycle maximum of 11.8°. Once push off was completed, the blade of the right skate came off the ice to begin a swing phase. The skater quickly plantarflexed from 11.8 ° of dorsiflexion to 1.9 ° of dorsiflexion. The foot was dorsiflexed with respect to the neutral position throughout the cycle. This is likely a result of what van Ingen Schenau et al. (1989) have termed the skating position of the subjects. They revealed that speed skaters used a sitting position and leaned their trunks forward in order to counterbalance the effects of air resistance. During push-off, van Ingen Schenau et al. (1989) explained that a dorsiflexed skate was necessary to prevent scraping of the skate tip on the ice surface causing a large frictional force.

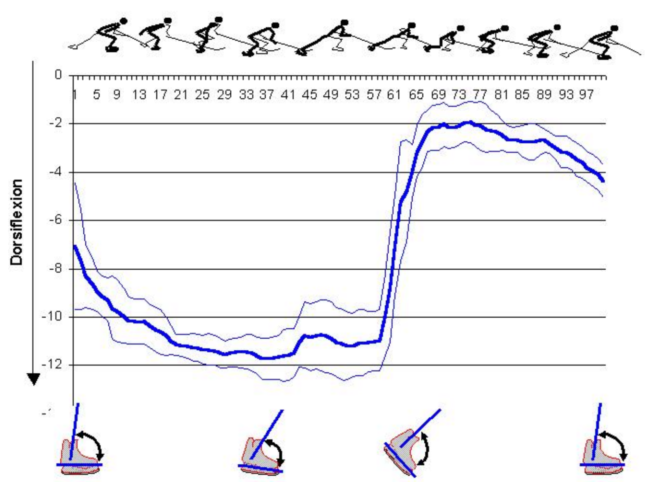

Figure 3 - Average (±SD) dorsi- and plantar-flexion at the foot and ankle during forward skating.

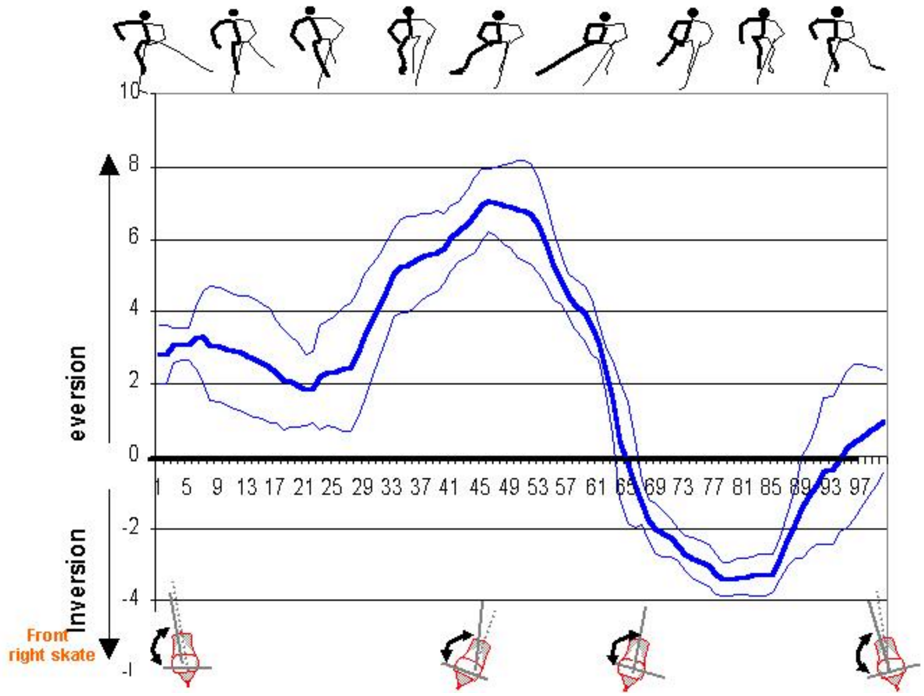

Figure 4 - Average (±SD) inversion and eversion at the foot and ankle during forward skating.

Table 1 shows the average values for maximum range of motion data for the crossover start, forward skating at steady state, and parallel stop.
Figure 4 shows inversion and eversion at the ankle during forward skating. During the glide phase, from approximately 0 – 22% of the stride cycle, the foot was slightly everted and there was relatively little change in the ankle. As the skater approached a double support phase, preparing the right foot for push off, the foot reached maximum eversion at 7.1 °. The maximum eversion was likely a result for the need to generate a resultant force on the ice. Once the foot reached a swing phase, the ankle underwent inversion, exceeding neutral position, orientating itself in an inverted state. In preparation for the gliding phase, the foot was positioned in a near neutral position.

Table 1 Summary Range of Motion Data (degrees) for Forward Skating Following a Parallel Start

PHASE	Skate	Eversion	Inversion	Total ROM	Plantar	Dorsi	Total ROM
Parallel Start	Lead Foot	2.6	8.0	10.6	5.9	15.8	21.7
	Rear Pushoff	5.6	2.0	7.5	2.7	10.2	12.9
Steady State		6.1	6.9	13.0	3.1	17.4	20.5
Parallel Stop	Inside Edge	0.4	3.1	3.5	-3.1	10.6	7.5
	Outside Edge	4.1	-0.1	4.1	-2.2	10.7	8.5

CONCLUSION: The electrogoniometer proved to be relatively simple to use and provided direct measurement of the foot and ankle kinematics during ice hockey skating. Further investigation of other ice hockey skating skills adopting this technique are warranted.

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