KINEMATIC ANALYSIS OF THE SKELETON START

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The purpose of this study was to describe the kinematics of the skeleton start and to compare one-foot versus two-foot starting techniques. The first two steps of the start of six national team skeleton athletes were videotaped during competition and analyzed. There were similarities between the kinematics of skeleton starts and sprint starts; however, the results showed that despite similar 50 meter start times there were differences between the one-foot and two-foot groups in knee angles off the block, trunk angle, toe height during recovery, support and flight times, and step length. These results suggest that the one-foot and two-foot starts are unique yet both effective techniques.

KEY WORDS: skeleton, kinematics, start.

INTRODUCTION: The start in the sport of skeleton requires both fast sprinting speed and proper technique when loading onto the sled in order to be successful. The difficulty, however, is in the fact that skeleton athletes must remain bent over holding their sled while running. They typically start in one of two foot positions. The one-foot or staggered start is similar to the sprint start in track and field in which the two feet are separated with the rear foot fixed against a block and the front foot gripping the ice by the spikes on the bottom of the shoe. The two-foot start has the athlete starting with both feet against the block. From either position, the athletes rapidly accelerate to maximum velocity and then dive head first onto the sled which they are moving underneath them.

As a relatively new Olympic sport, skeleton has not received attention from researchers. In particular, the skeleton start has not yet been investigated. Therefore, the purposes of this paper are to (a) describe the kinematics of the skeleton start, and (b) to make comparisons between the one-foot and two-foot starting techniques.

METHODS: Six male subjects were recruited for this project, all of whom were members of the United States national skeleton team. Mean height was 1.80 0.04 m and mass was 78.6 4.5 kg. Four subjects used the one-foot start technique, whereas 2 subjects utilized the two-foot technique.

Testing took place during one of the national team selection races which were held in Lake Placid, New York in December of 2003. Video data of the sagittal plane motion was collected using a Pulnix TM-6701AN camera with a Fujinon 12.5-75mm zoom lens; video images were recorded using a Panasonic AG-1960 VCR modified by Peak Performance Technologies to operate at 120 Hz. The camera was located 8.5 meters from the track with the optical axis was perpendicular to the plane of movement. Data processing was completed using the Peak Motus 8.0 motion analysis program using a 22 point model for the body and sled. For each trial, the first two steps of the start were analyzed. The time-dependent coordinates of each point were smoothed using a low-pass digital filter with a cutoff frequency of 5 Hz to reduce small random errors that may have occurred during digitizing without introducing systematic bias. The cutoff frequency was determined by inspection of the raw and filtered data and comparison between the respective power spectrum. Mean values were calculated for variables selected for analysis based on previous studies of the sprint start.

RESULTS AND DISCUSSION: Mean 50 meter start times for the one-foot and two-foot groups were 5.22 and 5.24 seconds, respectively. Athletes in the one-foot technique group all started with the left foot staggered forward, and their first step was taken with their right foot coming off the block. In comparison, both athletes in the two-foot group both took their first step off the block with their left foot.

Table 1 outlines kinematic variables which describe the skeleton start. Foot spacing off the block is the horizontal distance from the starting block to the toe of the staggered foot in the

one-foot technique, with a mean distance of 0.68 meters. If comparing skeleton starts to the sprint start, this spacing would be categorized as "elongated" with a spacing of greater than 50 centimeters (Harland and Steele, 1997) The athletes using the two-foot technique had both feet on the block and therefore the foot spacing was zero.

Knee angle off the block is the maximum angle of knee extension seen prior to the foot leaving the block or the ice with larger values representing greater extension. The knee angle during the first step for both groups (Right for the one-foot group and Left for the two-foot group) was smaller than for the second step, and the two-foot group was considerably less extended than the one-foot group with a knee angle of 78.06 degrees. This leg remained more flexed in order to allow the athletes to swing the leg forward during the first step.

Table 1 Kinematic variables describing skeleton start.

Subject	Foot distance off block (m)	Knee angle off block (deg)		Max trunk lean (deg)	Max toe height during recovery (m)	
		Right	Left		Step 1 (R)	Step 2 (L)
1*	0.58	133.40	157.39	-38.96	0.15	0.14
2*	0.52	120.23	168.42	-31.15	0.07	0.15
3*	0.79	141.59	163.17	-17.08	0.11	0.19
4*	0.83	142.47	154.50	-22.29	0.08	0.29
Mean	0.68	134.42	160.87	-27.37	0.10	0.19
		Right	Left		Step 1 (L)	Step 2 (R)
5**	0.00	167.32	78.06	-30.43	0.05	0.35
6**	0.00	164.47	73.69	-35.99	0.09	0.29
Mean	0.00	165.90	75.88	-33.21	0.07	0.32

* - one-foot starting technique
** - two-foot starting technique

Maximum trunk lean is the maximum angle of the trunk seen during the start, as measured from the horizontal. Athletes in the two-foot group showed more forward lean than the one-foot group with the results from both groups fitting within the range described by Atwater (1982) for sprinters in the set position.

Maximum toe height during recovery is the maximum height of the toe from the ice seen the recovery phase as the leg is swung forward in preparation for the next ground contact. The one-foot group showed a small increase in their toe heights between the first (Right) and the second (Left) step with mean values of 0.10 and 0.19 meters, respectively. In comparison, the athletes in the two-foot group kept their foot lower to the ice during the first (Left) step at a height of 0.07 meters; however, the foot recovered much higher during the second (Right) step at 0.32 meters, achieving a cyclical running stride earlier than the one-foot group.

Stride characteristics during the skeleton start for the one-foot and two-foot groups are reported in Table 2. Support and flight times were measured by the number of frames during which the athletes were in the air or in contact with the ice. Support times of 0.21 sec were seen for both the first and second steps of the two-foot group, whereas the one-foot group was in support for a shorter time for the first step (0.18 sec) than the second step (0.20 sec). For the flight time, the first step from right foot to left foot (R-L 1) of the two-foot group was noticeably shorter (0.04 sec) than the first step for the one-foot group (0.08 sec). Both groups were in flight for 0.05 sec during their second step. Elite male sprinters have shown similar support times of 0.16 sec to 0.19 sec for the first step and 0.15 sec to 0.18 sec for the second step. In addition, similar flight times of 0.06 to 0.07 sec for the first flight and 0.04 to 0.09 sec for the second flight have also been previously reported (Atwater, 1982; Balsevich, 1989).

Table 2 Skeleton start stride characteristics

Subject	Support time (sec)		Flight time (sec)		Step length (m)	
	Step 1 (R)	Step 2 (L)	Flight 1 (L-R)	Flight 2 (R-L)	Step 1 (L-R)	Step 2 (R-L)
1*	0.17	0.21	0.08	0.03	0.88	1.10
2*	0.13	0.22	0.10	0.06	1.00	1.19
3*	0.21	0.16	0.08	0.08	1.02	1.06
4*	0.19	0.20	0.05	0.04	0.90	1.06
Mean	**0.18**	**0.20**	**0.08**	**0.05**	**0.95**	**1.10**
	Step 1 (L)	Step 2 (R)	Flight 1 (R-L)	Flight 2 (L-R)	Step 1 (R-L)	Step 2 (L-R)
5**	0.19	0.18	0.05	0.06	0.96	0.86
6**	0.23	0.24	0.02	0.03	1.03	1.00
Mean	**0.21**	**0.21**	**0.04**	**0.05**	**1.00**	**0.93**

* - one-foot starting technique
** - two-foot starting technique

Step length is the horizontal distance from the contact of one foot to contact of the other foot. The first step for the one-foot group was shorter (0.95 meters) than the second step (1.10 meters). For the two-foot group, the opposite was true with the first step being longer (1.00 meter) than the first (0.93 meters). Elite sprinters have first step lengths ranging from 0.98 to 1.20 meters (Atwater, 1982).

Despite the differences seen between the two start techniques, the overall start times were comparable between the two groups. This finding suggests that both the one-foot and two-foot starts can be effective for skeleton athletes to achieve maximum running velocity and fast 50 meter times. The results of this study show that there are similarities between starts for sprinting and skeleton in maximum trunk flexion, support and flight times, and step length. The data indicates, however, that the two skeleton start techniques have fundamental differences between them. In the two-foot technique, the athlete starts in a lower body position (greater trunk lean) and pushes more horizontally by extending the right knee more fully off the block. The toes remain low to the ice which results in a very short flight time despite a longer first step. The one-foot technique has a slightly more horizontal body position at the start, the first step length is not as long, and the first support time is shorter. The toes are higher from the ice during the recovery phase, which results in a longer first step flight time. During the second step the foot recovers lower to the ice for the one-foot technique than the two-foot, with a longer step length. In comparison, the two-foot technique has the foot recovering much higher for the s econd step, and there is a shorter step length.

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