KINEMATIC ANALYSIS OF MEN BOBSLED PUSH STARTS

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The purpose of this study was to provide a descriptive analysis of selected kinematic variables associated with the push start for brakemen in the two-man bobsled. Eleven male bobsledders served as subjects for this study. The subjects were videotaped at 120 Hz during competition at the Lake Placid, NY bobsled track as they were competing for positions on the men's 2004 National Bobsled Team. Selected groups of variables measured at specific events in this study included step length, frequency, and foot contact time; COM velocity; and trunk, knee, and elbow angles. A relationship of 0.63 was determined between start time and finish time; an exploratory correlational analysis between start time and COM velocity at 2nd step take-off (TO) was -0.63. Start time is of critical importance in determining final race time.

KEY WORDS: bobsled, push start technique, strength

INTRODUCTION: The push start in bobsled is a major factor in the determination of final time in a race. The importance of this aspect of bobsled performance has been routinely accepted by both coaches and athletes. Actual documentation of this relationship in the literature is somewhat limited with only three citations being found. Push time was significantly related to finish time in all four heats of the 4-man competition as well as the total group at the 1988 Winter Olympic Games in Calgary, Canada. For the four heats and the total group, correlation coefficients were 0.53, 0.74, 0.67, 0.55, and 0.46, respectively (Morlock & Zatsiorsky, 1989). Analysis of push and finish times at the 1994 Lillehammer Winter Olympic Games revealed that approximately 77% (r = 0.88) of the variance in final times was explained by start times (Bruggemann, Morlock, & Zatsiorsky, 1997). This was true for both the 2- and 4-man competitions when all four heats were considered as a group. Also, computer simulation experiments of 4-man bobsled runs were reported to confirm the importance of the initial push-force impulse during the start with final run time (Leonardi, Komor, & Dal Monte, 1985). Correlation coefficients for the four heats of the 2005 Bobsled World Championships in Calgary for women were 0.79, 0.76, 0.73, and 0.64, respectively (Smith, unpublished data). Despite the importance of push start times on bobsled performance, there is no known published research on analyzing push start technique from a biomechanical aspect. It was the primary purpose of this study to analyze men bobsled push starts from a kinematic perspective and to determine the relationship between start time and finish time. A secondary purpose was to explore other possible significant relationships between start time and the measured kinematic variables.

METHODS:

Data Collection Video data were collected at the 2004 United States men's national team selection races held in Lake Placid, New York. Eleven male athletes trying to secure positions as brakemen participated as subjects: they competed in six races over two days of competition. High-speed B&W video images (120 Hz sampling rate) of the right side of the brakemen were obtained for a two-dimensional (2D) biomechanical analysis. The camera was positioned 7.50m from and perpendicular to the movement plane of the brakemen. Because of the concrete wall enclosing the iced track, the camera was raised to a height of 3.12m and angled downward to include the feet of the bobsledder. Shutter speed was set to 1/500s, and the field of view was approximately 6.5m. A 2.09m by 1.54m calibration frame was videotaped prior to the actual video collection. Video images were recorded onto S-video tape by a Panasonic AG-1960 VCR that was modified to operate at 120 Hz.

Data Analysis One trial for each brakeman was selected for analysis based upon best start time along with input from a bobsled start coach. The Motus software (Version 8.5) from Peak Performance Technologies, Inc. was used to conduct the 2D biomechanical analysis. This software automatically corrected for the downward tilt of the camera based upon the rectangular calibration frame. A 20-point model of each brakeman was digitized from initiation of the push start movement until take-off (TO) of the athlete's fourth step or when his body was outside the field of view. Key events of push technique were identified through visual inspection during the digitizing process. Selected kinematic variables measured in the analysis were included in the following groups: (1) step length, (2) step frequency, (3) contact time, (4) COM velocity, (5) trunk angle, (6) knee angle, and (7) elbow angle. Trunk angle was defined by a segment drawn from the hip to the shoulder with respect to the right horizontal; knee and elbow angles were defined by their respective segments.

Statistical Analysis Descriptive statistics were calculated for each of the specific measures within each variable group. Measurements were determined for events in the push start that are recognizable and meaningful for both coaches and athletes. A correlational analysis was conducted to determine the relationship between start and finish times; all kinematic measured variables were compared with start time in an exploratory analysis. All statistical values were calculated using the analysis procedures in the 2003 Microsoft Office Excel software.

RESULTS: Descriptive statistics are shown in the following three tables for the variables measured in this kinematic analysis. Average values and standard deviations for step length, step frequency, and foot contact time are presented in Table 1.

Table 1 Means & Standard Deviations for Step Length, Step Frequency, and Foot Contact Time

	Step Length (m)	Step Frequency (steps/sec)	Foot Contact Time (sec)
Step 1	0.80 ± 0.13	3.31 ± 0.77	0.28 ± 0.05
Step 2	0.97 ± 0.19	3.93 ± 0.31	0.22 ± 0.07
Step 3	1.10 ± 0.15	4.22 ± 0.52	0.21 ± 0.02
Step 4	1.15 ± 0.25		0.18 ± 0.07

Brakemen initiate their start with both feet at the edge of a flat horizontal structure that is slightly raised above ice level; this structure is referred to as the block. Average values and standard deviations for the horizontal velocity of the COM of the bobsled brakemen at specific events for take-off (TO) are shown in Table 2.

Table 2 Means & Standard Deviations for COM Horizontal Velocities at Take-off Positions

	COM Horizontal Velocity (m/s)
Block TO	2.48 ± 0.39
Step 1 TO	4.06 ± 0.43
Step 2 TO	5.03 ± 0.28
Step 3 TO	5.55 ± 0.33
Step 4 TO	5.59 ± 0.40

Average angular values and standard deviations for the trunk, knee, and elbow are given in Table 3. These measurements were calculated at specified events of take-off (TO) or touchdown (TD).

Table 3 Means & Standard Deviations for Trunk, Knee, and Elbow Angles

Trunk Angle (deg)		**Knee Angle (deg)**		**Elbow Angle (deg)**	
1st Block TO	4.02 ± 8.79	Step 1 TD	102.24 ± 15.58	1st Block TO	124.64 ± 32.29
2nd Block TO	28.73 ± 9.64	Step 1 TO	138.31 ± 14.44	2nd Block TO	76.53 ± 24.35
Step 1 TO	28.90 ± 9.69	Step 2 TD	100.65 ± 9.20	Step 1 TO	88.61 ± 15.94
Step 2 TO	30.65 ± 6.17	Step 2 TO	152.88 ± 6.42		
Step 3 TO	26.69 ± 7.41				
Step 4 TO	30.11 ± 10.00				

The relationship between start time and finish time was 0.63 and is statistically significant ($r_{2\text{-tail}}$ = 0.602, p = .05). Relationships between start time and other variables measured in the study were also explored. Of particular interest was an r of -0.63 between start time and COM horizontal velocity at TO of the second step. Although preliminary, this result indicates a promising relationship between kinematic variables and the most successful push starts. The relationships for these two comparisons are depicted in Figure 1.

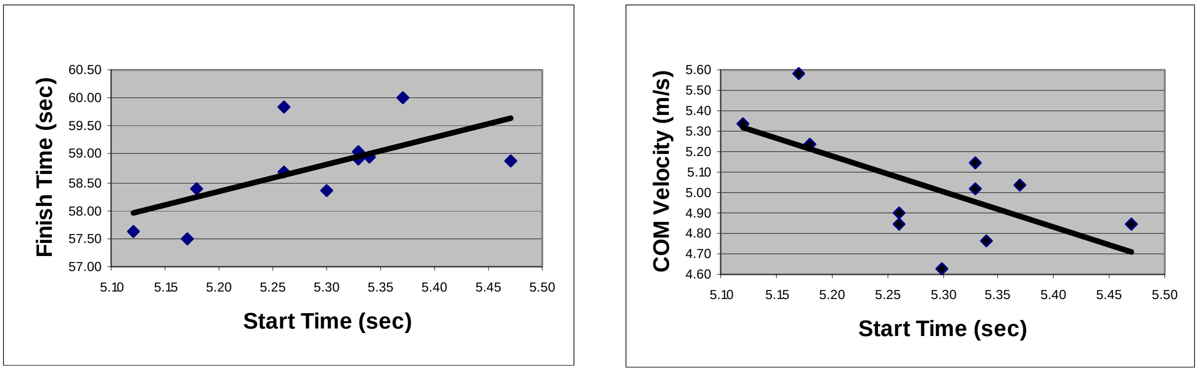

Figure 1 Relationship between Start Time with Finish Time and COM Velocity at 2nd Step TO

DISCUSSION: The results from this analysis have provided a kinematic description of the basic aspects underlying the mechanics of the bobsled push start as performed by elite male brakemen under competitive conditions. Average values for step lengths indicated a slight increase over the first four steps. As shown by mean values, step frequency also showed that step turnover rate increased over the first three steps. As was expected, foot contact time showed a decreasing trend over the same movement sequence.

Mean horizontal velocity values of brakemen COM indicated almost a two and a half fold increase from initial starting position until block TO. An additional increase in horizontal velocity of over one and a half times occurred from block TO until 1st step TO. After this event, COM horizontal velocity showed a slightly increasing trend through 4th step TO.

The brakemen's average trunk angle was slightly above horizontal at 1st block TO. By the time of 2nd block TO, trunk inclination was raised almost 25 degrees above the position at 1st block TO; trunk angle varied slightly over the next four steps. Mean knee angles were similar for the TD and TO positions of the initial three steps; average values indicated a lack of full leg extension for all three TD and TO positions.

A significant positive relationship between start and finish times was not unexpected based upon the limited information in the literature. However, the correlation reported in this study was determined from a combination of start and finish times from different races and different trials. The only statistically significant relationship of interest in the exploratory analysis was between start time and COM horizontal velocity at 2nd step TO.

CONCLUSION: The results of this study indicate the critical importance of the push start as a determinant of final race time in 2-man bobsled competition. Almost 40 per cent of the variance of final time was accounted for by start time. The necessity for explosive strength gained from an effective resistance training program cannot be overlooked by bobsled coaches and athletes.

Additional studies should be undertaken to determine which other kinematic variables are important in producing fast start times. If the relationship between start time and COM velocity at the 2nd step of TO can be substantiated, the need for explosive strength training becomes even more critical.

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