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Section I – Kinesiology

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Two-Man Bobsled Push Start Analysis

by
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The importance of push start times on bobsled performance was evidenced by some studies, but at this moment there is no article to the authors' knowledge that describes the bobsled push start. Thus, the objectives of this study were to describe the two-man bobsled push start, analyze the differences between teams, and estimate the most important variable analyzed. We hypothesized that the pilot and brakeman athletes' movement patterns during a bobsled pushing start can be described. The images used in this study were obtained during the men's two-man XIV World Championship of Bobsled (2004). Fifteen best teams participating in the championship were recorded, and four start runs for each team were analyzed. The videos were captured by two digital video cameras. The pilot athletes were analyzed during the moment that they touched the lateral push bar of the sled, and the brakemen were analyzed during the first take-off and first landing. The teams were pooled in three groups of five teams using the final ranking of pushing time. We concluded that there was a distinct pattern movement for pilots and brakemen. The initial position of the majority of the pilots was localized slightly behind the bar. After touching the lateral bar, the pilots remained in a semi-squat position, pushing the sled forward in a pattern of marching movement. All brakemen used the board attached to the track as a support for both feet at the start. The brakeman gave the greatest contribution to break the inertia of the sled. There was no significant difference of movement between the three groups analyzed for the pilot and the brakeman.

Key words: *bobsleigh, winter sport, biomechanics.*

Introduction

Nowadays, women compete in 2 Women Bob events, and men in both 2 Men Bob and 4 Men Bob sleds. In the two-man event, the first athlete, called the "pilot", runs a distance that ranges from 20 to 30 m, and is usually the first to get into the sled after the push-off stretch. This entry movement is made by means of a jump from the left side of the sled. The second athlete, responsible for stopping the sled at the end of the race, is known as the brakeman. The brakeman runs a longer distance during the push-off stretch, around 50 m, and runs until the speed is too high for them to keep running. At this moment the brakeman jumps into the sled from the rear (Dabnichki and Avital, 2006).

There are no rules in this modality that determine the body position of the athletes at the push-off phase. On the other hand, this can be contrasted with sprinting, where the position of the athletes at the start is determined by a number of rules (Harland and Steele, 1997; Mero et al., 1992). The importance of push start times on bobsled performance has been evidenced by some studies (Bruggemann et al., 1997; Morlock and Zatsiorsky, 1989), however, at this moment there is little data that describes the bobsled push start. To the author's knowledge there is only a conference abstract related to the movement description during the bobsled push start (Smith et al., 2006). There are other studies that have addressed bobsled athletes, but these articles focused on sports injury (Engebretsen et al., 2010;

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Piat et al., 2010; Soligard et al., 2015) and such physiological aspects as nutrition (Beketova et al., 2013), alactic capacity (Kibele and Behm, 2005) and bone mineral density (Meyer et al., 2004).

Thus, the objectives of this study were to describe the two-man bobsled push start, analyze the differences between teams, and estimate the most important variables analyzed. We hypothesized that the pilot and brakeman athletes' movement patterns during the bobsled push start could be described. Better understanding of the movement patterns during pushing may be helpful in improving bobsled performance.

Material and Methods

Participants

The images used in this study were obtained during the men's two-man XIV World Championship of Bobsled (2004). The competition took place in the city of Königssee (Germany), with participation of 37 teams from 23 countries. We recorded the 15 best teams participating in the championship according to the official results: Austria-1, Canada-1, Czech Republic-1, Germany-1, Germany-2, Germany-3, Italy-1, Latvia-1, Latvia-2, Monaco-1, Russia-1, Switzerland-1, Switzerland-2, USA-1 and USA-2. Four start runs for each team were analyzed. The data collection for the study was approved by the F.I.B.T. and organization of the XIV World Championship of Bobsled.

The videos were captured by two digital cameras, each with 60 Hz of acquisition frequency, positioned at different points along the track. Both cameras recorded the push-off stretch performed by the pilots and the brakemen. The cameras were mounted on the ceiling approximately 3 m from athletes aiming to capture the sagittal plane of both athletes (Figure 1).

The modified version of the direct linear transformation (DLT) technique was used for bi-dimensional analyses (2D-DLT) to calibrate the space (Brewin and Kerwin, 2003). We used nine points placed on a panel positioned on the track in a place that was equivalent to the midline of the athlete's body during the entire push-off process. We could not use retro-reflexive markers as the images were acquired during a competition, where athletes were required to wear official uniforms. APAS software (Ariel Inc.) was used to digitize and reconstruct the coordinates using the Dempster's algorithm.

Parameters Analyzed

The teams were pooled in three groups of five teams using the final ranking of pushing time (Group 1: 1st to 5th ranking, Group 2: 6th to 10th ranking; and Group 3: 11th to 15th ranking). The kinematic events used were chosen based on sprinting events studies (Harland and Steele, 1997; Mero et al., 1992; Schnenau et al., 1994). The pilot athletes were analyzed during the moment that they touched the lateral push bar of the sled; the trunk angle, the knee angle of the lead leg, the knee angle of the rear leg, the right shoulder angle, the left shoulder angle, the right elbow angle, and the left elbow angle were measured. The convention adopted for the analysis of the angles is presented in Figure 2.

The brakemen were analyzed during the first take-off and first landing. The first take-off event was characterized by the moment the athlete lifted one foot that was performing propulsion. The first landing event was characterized at the moment that brakeman touched the ice with the limb that executed the first take-off. The trunk angle, the right elbow angle, the left elbow angle, the right shoulder angle, the left shoulder angle, the knee angle of lead and rear legs were measured.

Statistical Analysis

Normality assumptions were tested using histograms and the Shapiro-Wilk test. Joint angles were presented as means and standard deviation, or median and interquartile range. Analysis of variance (ANOVA) or the Kruskal-Wallis test was used in order to analyze the differences between the three groups. Post hoc tests at $\alpha < 0.05$ were applied where indicated. Regression analysis (enter selection method) was calculated to estimate the relationships among analyzed parameters, and to determine the most important ones. All tests were performed adopting $\alpha = 0.05$. Data analysis was performed with Matlab 6.5 and SPSS 17.0.1.

Results

Pilots

The pilots' start is on the left side of the sled, as this side has a lateral bar that the athletes can lean on to push the sled. We observed that the initial position of the 13 teams was with the athlete localized slightly behind the bar. The pilots started the movement behind the bar in a semi-squat position, with their lower limbs placed asymmetrically so that one leg was ahead of the body and the other was behind it (Figure 3). The trunk leant slightly forward and the upper limbs showed semi-flexed elbows and shoulders. The pilots initially moved toward the lateral bar, performing a step forward, as the main objective was to quickly place the upper limbs on the lateral bar so that they could make their contribution to starting the propulsion of the sled. There was no significant difference between the three groups analyzed. Table 1 shows the descriptive and comparison analysis for the pilot during the bar touch. After regression analysis none of the variables showed β of statistical significance (Table 3).

Brakeman

The brakeman starts the movement with their lower limbs parallel and semi-flexed, and the back of their feet supported by a board attached to the track. The hands hold the sled firmly, elbows and knees are semi-flexed and the trunk is slightly bent. During the initial movement there is a sudden flexion of the trunk and the hips toward the center of the sled, followed by a simultaneous extension of the lower limbs. This characterizes the beginning of the start, with the athletes pushing the sled and, therefore, performing the events used as parameters in this study.

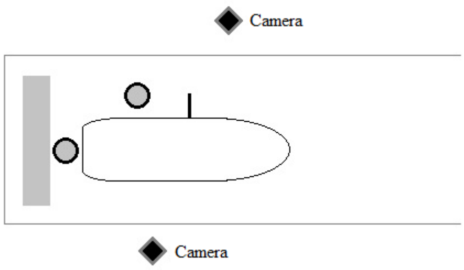

Figure 1

Layout of the cameras' location

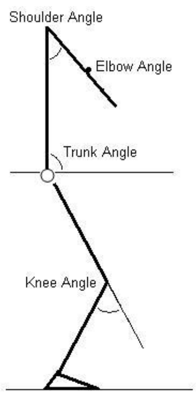

Figure 2

Convention adopted for the angles

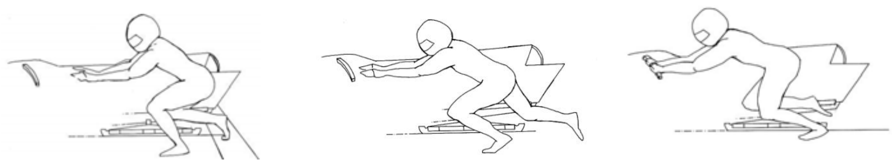

Figure 3

The pilot initial position

Table 1

Descriptive data and comparison analysis for pilots during the bar touch

Variable		p
Trunk angle (º)		
Group 1	38.0 (2.6)	
Group 2	40.5 (5.7)	
Group 3	35.5 (5.2)	
Overall	38.0 (4.8)	0.287
Right elbow angle (º)		
Group 1	180.1 (0.1)	
Group 2	180.1 (0.4)	
Group 3	180.1 (0.3)	
Overall	180.1 (0.3)	0.986
Left elbow angle (º)		
Group 1	178.3 (0.6)	
Group 2	178.4 (0.8)	
Group 3	178.6 (0.9)	
Overall	178.4 (0.7)	0.846
Right shoulder angle (º)		
Group 1	185.3 (0.2)	
Group 2	185.2 (1.5)	
Group 3	185.3 (3.4)	
Overall	185.3 (0.2)	0.275
Left shoulder angle (º)		
Group 1	184.2 (0.4)	
Group 2	183.8 (0.5)	
Group 3	184.5 (0.6)	
Overall	184.2 (0.5)	0.113

Values are expressed as mean and standard deviations for all variables and p values show ANOVA results. For the "Right shoulder angle", the median and interquartile range were used, and p values show the Kruskal Wallis test result. Group 1: 1st to 5th ranking, Group 2: 6th to 10th ranking; and Group 3: 11th to 15th ranking

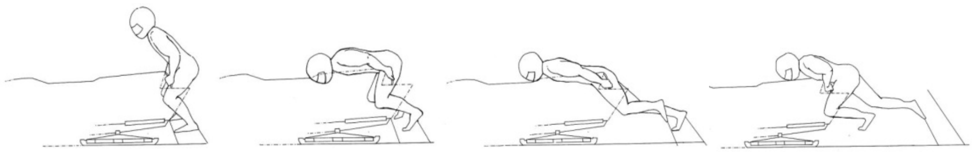

Figure 4

The brakeman initial position

Table 2

Descriptive data and comparison analysis for brakemen

Variable	First take off		First landing	
Trunk angle (º)		p		p
Group 1	9.9 (6.1)		29.8 (3.6)	
Group 2	9.9 (9.6)		32.1 (9.4)	
Group 3	7.8 (8.6)		33.0 (7.4)	
Overall	9.2 (7.7)	0.893	32.1 (6.7)	0.850
Right elbow angle (º)				
Group 1	179.6 (0.2)		179.2 (0.3)	
Group 2	179.6 (0.1)		178.8 (0.5)	
Group 3	179.5 (0.3)		179.1 (0.2)	
Overall	179.6 (0.2)	0.841	179.1 (0.4)	0.359
Left elbow angle (º)				
Group 1	179.7 (3.1)		179.6 (5.9)	
Group 2	179.8 (6.0)		179.2 (6.2)	
Group 3	185.4 (3.1)		178.8 (3.5)	
Overall	179.9 (5.8)	0.114	179.1 (6.1)	0.567
Right shoulder angle (º)				
Group 1	183.1 (3.1)		183.2 (0.1)	
Group 2	183.3 (3.2)		183.2 (0.1)	
Group 3	177.1 (6.1)		183.2 (0.1)	
Overall	183.1 (6.1)	0.221	183.3 (0.1)	0.803
Left shoulder angle (º)				
Group 1	182.9 (0.3)		182.8 (0.2)	
Group 2	182.9 (0.2)		182.7 (0.3)	
Group 3	182.8 (0.2)		182.6 (0.1)	
Overall	182.9 (0.2)	0.605	182.7 (0.2)	0.406
Knee angle of lead leg (º)				
Group 1	71.5 (2.2)		78.8 (14.3)	
Group 2	58.0 (6.4)		87.4 (10.7)	
Group 3	65.7 (9.4)		75.3 (18.6)	
Overall	65.1 (8.4)	0.026*	80.7 (14.8)	0.450
Knee angle of rear leg (º)				
Group 1	68.4 (4.1)		33.8 (13.4)	
Group 2	57.6 (7.7)		24.1 (10.9)	
Group 3	62.2 (6.0)		24.8 (9.2)	
Overall	62.8 (7.3)	0.051	26.6 (10.7)	0.455

*Values are expressed as mean and standard deviations for all variables and p values show ANOVA results. For the "Left elbow angle" and the "Right shoulder angle" during the first take off, and the "Left elbow angle" during first landing the median and interquartile range were used, and p values show Kruskal Wallis test results. Group 1: 1st to 5th ranking, Group 2: 6th to 10th ranking; and Group 3: 11th to 15th ranking. * statistically significant*

Table 3

Regression analysis

Pilot		
Bar touch		
Trunk angle	0.038	0.837
Right elbow angle	-0.051	0.881
Left elbow angle	0.094	0.807
Right shoulder angle	0.097	0.614
Left shoulder angle	0.151	0.532
Constant	-619.381	0.541
Brakeman		
First take off		
Trunk angle	0.037	0.926
Right elbow angle	-0.421	0.378
Left elbow angle	0.743	0.293
Right shoulder angle	-0.686	0.061
Left shoulder angle	0.386	0.625
Knee angle of the lead leg	0.138	0.828
Knee angle of the rear leg	-0.336	0.628
Constant	2202.949	0.936
First landing		
Trunk angle	-2.444	0.130
Right elbow angle	-4.123	0.094
Left elbow angle	-1.264	0.047*
Right shoulder angle	-1.756	0.143
Left shoulder angle	-0.474	0.304
Knee angle of the rear leg	-3.391	0.081
Knee angle of the lead leg	0.035	0.922
Constant	22863.289	0.079

** statistically significant*

Their first step was usually observed to happen simultaneously with the forward propulsion of the sled, immediately followed by the take-off of the first step, a motion that also involved the upper limbs and the trunk. It was observed that the brakemen in all the teams started the movement, and were responsible for imparting the initial inertia of the sled. Figure 4 shows the initial position of the brakeman. Only the knee angle of the lead leg during the first take-off was significantly different between the three groups, but Tukey post hoc testing determined that the groups were not significantly different (p=0.211). Table 2 shows the descriptive and comparison analysis for brakemen during the first take-off and during first landing. Only one variable shows a statistically significant β after regression analysis for brakemen, i.e., a "left elbow angle" (p=0.047) variable (Table 3).

Discussion

The initial position of the 13 pilots was localized slightly behind the bar. All of the brakemen used the board attached to the track as a support for both feet at the start. It was observed that pilots touched the lateral bar with an extension of the elbow and great flexion of the shoulder. The trunk angle of the pilots remained practically constant leaning forward.

The initial movements of the upper limbs of pilots, i.e., the initial contact of the pilots with the side bar of the sled, was performed with the shoulder flexed at 180o and the elbow almost fully extended. The trunk angle of the pilots practically remained leaning forward 40o during the pushing start. After touching the lateral bar, the pilots remained in a semi-squat position, pushing the sled forward in a pattern of marching movement. Thus, two pilots that started ahead of the support board did not use the board as a posterior support. All of the brakemen used the board attached to the track as a support for both feet at the start. Their arms were close to the body, but with the elbows still almost fully extended. This lack of similarity between pilots and brakemen can be attributed to the different start positions of the two athletes during the push start.

Great variability was observed in the trunk angle of the brakeman when compared with the pilot, especially during the first take-off. This difference might be accounted for by the fact that the brakeman exerts great strength to move the sled from the start, while the pilot starts moving without any additional load. As observed, the pilots gave a small contribution to break the inertia of the sled. We suggested that optimizing the initial propulsion of the sled can be accomplished by the conception of new positions and/or better synchronization of the teams.

We observed that the brakeman touched the ground with a flexed leg. This pattern is also adopted by track race athletes (Williams, 2000). This behavior can be attributed to the fact that the athletes start from a semi-squat position.

There are some limitations to this study. Firstly, a small number of participants; secondly, only the best teams were analyzed, which may limit the generalizability of our results; thirdly, we could not use retro-reflexive markers on the athletes as the images were acquired during a competition, which could have affected the quality of analysis conducted.

We concluded that there was a distinct movement pattern for pilots and brakemen. The initial position of the majority of the pilots was localized slightly behind the bar. After touching the lateral bar, the pilots remained in a semi-squat position, pushing the sled forward in a pattern of marching movement. All brakemen used the board attached to the track as a support for both feet at the start. The brakemen gave the greatest contribution to break the inertia of the sled. There was no significant difference of movement between the three groups analyzed for pilots and brakemen.

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We also hereby confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission. The authors would like to thank Reginaldo K Fukuchi for his contribution during data acquisition.

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