KINEMATIC ANALYSIS OF THE START FOR WORLD-CLASS SINGLE LUGE ATHLETES

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The purpose of this study was to kinematically analyse the luge start motion for world-class single luge athlete at an official competition. Thirteen male luge athletes were videotaped and analysed with the three-dimensional DLT method at the World Luge Championship. Athletes were assigned to two groups (fast or slow) based on their early start time. At the start bar release, the fast group showed significantly larger system CG velocity (4.3 ± 0.1 m/s, $p < 0.05$) than the slow group. The backward system CG velocity of the fast group tended to be larger (-2.8 ± 0.2 m/s vs. -2.6 ± 0.3 m/s, ES = 0.80), and the athletes of the fast group rotated the arms move medially and extended the elbow joint more than the slow group.

KEYWORDS: luge start, official competition, motion analysis, counter-movement.

INTRODUCTION: In the luge start, the athlete sits on the sled, grasps start bars, and pulls and pushes the bars vigorously to drive the body-sled system. Then, the sled is driven forward by scratching backwards on the ice track using sharp iron claws attached to the gloves with the body inclined forward. Following these starting sequences, the athlete lies on the back to slide down the track toward the finish. It is in the starting phase in luge that the athlete can intentionally accelerate the body-sled system. Brüggemann et al (1997) found a coefficient of determination between the start time and the goal time (r^2=0.55) in the data at the Lillehammer Winter Olympic Games. Therefore, there have been some studies on the luge start. Crossland et al (2001) investigated the relationship between the start time and the upper-body strength and reported that 1RM in bench press weight significantly related to the start time. Platzer et al (2009) found that the isometric bench pull strength could account for most of the variance in maximum push-off speed in the luge start.
Aoki et al (1997) reported from the measurement of reaction forces acting on the start bar that a high correlation (r=-0.86) was found between the maximum value of the horizontal component of the start bar reaction force and the start time. Haga et al (1996) compared the start bar reaction forces of an Olympic gold medalist with that of senior Japanese athletes. Based on the start bar reaction forces, Oguchi et al (2010) has investigated the start motion at the All Japan Luge Championship to reveal techniques of the start for Japan top athletes. However, there is little information on the luge start, especially for world-class athletes in official international competition.
The purpose of this study was to kinematically analyse the luge start for world-class single luge athletes at an official competition.

METHODS: Thirteen male luge athletes (Mean ± SD; 1.81 ± 0.04 m; 82.42 ± 5.78 kg) were investigated at the 37th World Luge Championship held at the Nagano Bobsleigh Luge Park in Japan. Videotaping athletes were approved and authorised by the local organizing committee of Nagano, Japan. The athletes were divided into two groups: the fast group (n = 7; Mean ± SD; 1.83 ± 0.03 m; 84.19 ± 6.05 kg; start time, 3.150 ± 0.012 second) and the slow group (n = 6; Mean ± SD; 1.78 ± 0.04 m; 80.37 ± 5.19 kg; start time, 3.181 ± 0.006 second), based on the early start time.
The videotaping volume was 1.2 m in height, 1.1 m in width and 3.9 m in length on the start table. To capture the start motion three-dimensionally, one digital video camera was set

diagonally in front of and other camera was placed obliquely behind athletes. The sampling rate of cameras was 60 Hz and the exposure time was 1/1000 second. The start time at the 40 m mark from the start bar and the goal time at the 1330 m mark from the start bar were measured with an official timekeeping system.
Twenty-three points on the body and two points on the sled (the tip and the tail end), were manually digitized by an experienced digitizer with Frame-DIAS (DKH, Co., Japan), and the DLT method was used to re-construct three-dimensional coordinates. The centre of mass of the sled was obtained following the method of Oguchi et al, 2010. The combined centre of gravity (CG) position of the body and sled system (henceforth, system CG) was calculated.
Normalization of kinematic data of the start motion was performed as follows: 0% when the system CG was the most forward, 100% for the most backward and 200% at the bar release.
A t-test was conducted to test the significant differences between two groups in kinematic variables with the significance level $p<0.05$. Effect size was calculated as Cohen's d.

RESULTS: Figure 1 shows the change in the system CG velocity for two groups. The right one (b) shows the average system CG velocity of two groups. The negative peak system CG velocity (backward velocity) for the fast group tended to be smaller than the slow group (-2.8 ± 0.2 m/s vs. -2.6 ± 0.3 m/s, ES = 0.80). The system CG velocity in the fast group (4.3 ± 0.1 m/s) at the start bar release was significantly higher ($p < 0.05$, ES = 2.00) than the slow group (4.1 ± 0.1 m/s). Comparing changes in system CG velocity between two groups, that of the fast group indicated significantly higher velocity ($p < 0.05$) from 161 to 200% time than the slow group.

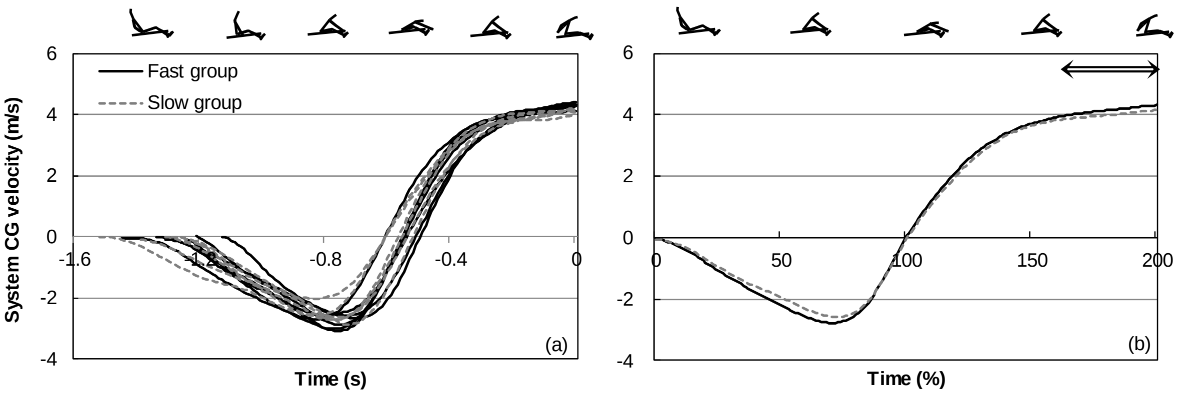

Figure 1: System CG velocity from most forward to start bar release in luge start.

Figure 2 shows the averaged change in angles and angular velocities of the elbow (a, b), shoulder (extension / flexion (c, d) and abduction / adduction (e, f)), hip (g, h) and knee (i, j) joints. The significant differences between two groups were found in the elbow (72 to 95%, a), abduction–adduction of the shoulder (69 to 128% and 140 to 194%, e) and the knee (134 to 150%, i) joints. In joint angular velocities, there were significant differences in the elbow (98 to 103%, b) and abduction–adduction of the shoulder (61 to 76% and 118 to 123%, f) joints ($p < 0.05$) between two groups.

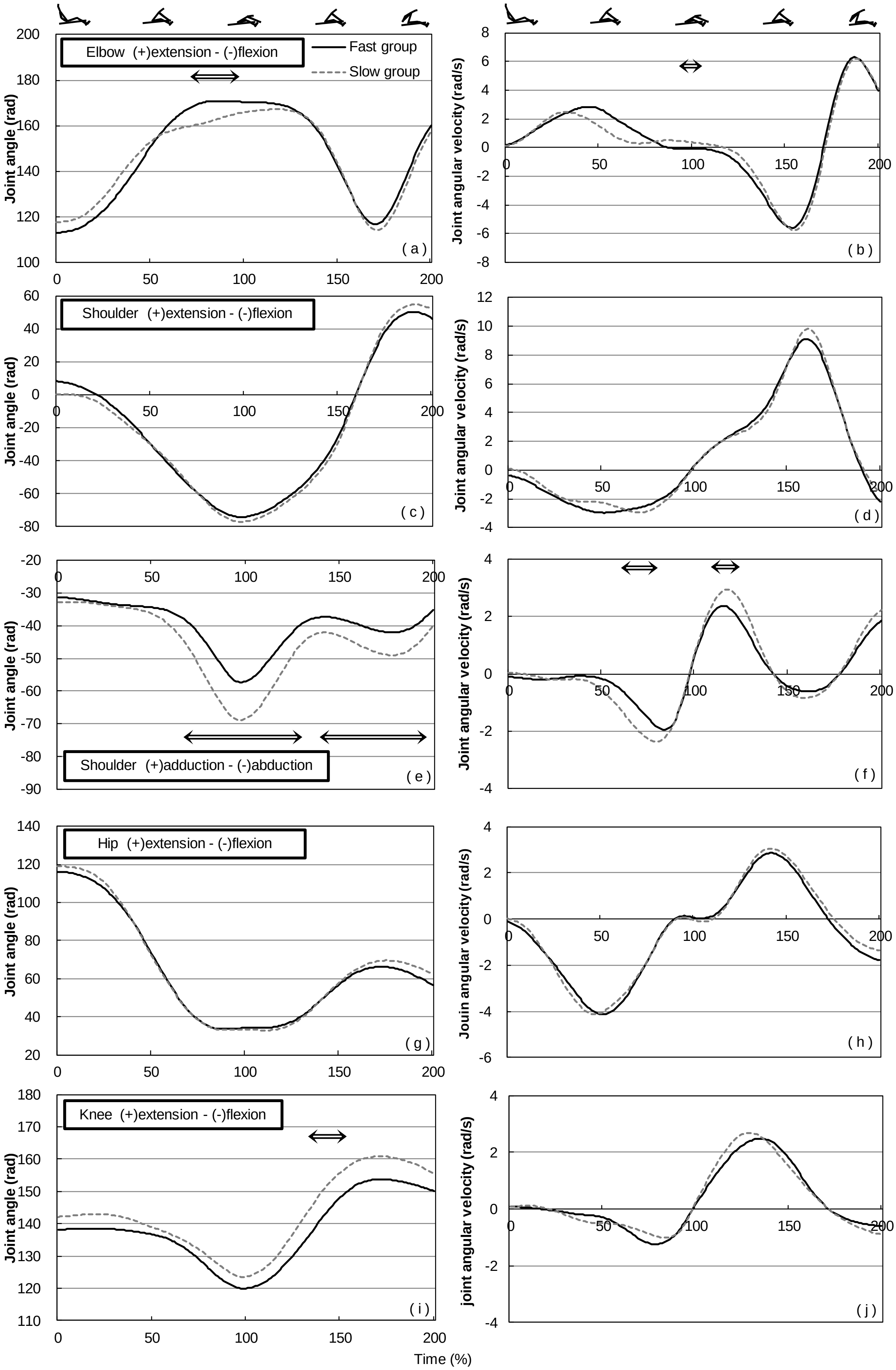

Figure 2: Average changes of angle and angular velocity of each joint in luge start.

DISCUSSION: Oguchi et al (2010) reported that a significant correlation was found between the system CG velocity at the start bar release and the start time on Japanese athletes. The fast group of the world-class athletes showed significantly larger system CG velocity than the slow group, indicating that larger system CG velocity at the start bar release would be one of the most important factors for the shorter start time.

The movement of the athletes from 0% time to the start bar release was likely to be similar to a counter-movement in a vertical jump. Since the fast group had a larger system CG velocity in the backward direction, it could be speculated that the faster athletes reached the large forward system CG velocity by utilizing a stretch-shortening technique with the high backward system CG velocity. At 100% time, the athletes of the fast group rotated the arms more medially and extended the elbow joint. In order to obtain a large forward system CG velocity, it would be important to use a counter-movement effectively and to pull a start bar in the appropriate direction. It is speculated that faster athletes could use the stretch-shortening technique more effectively by pulling the start bar straight ahead along the body.

CONCLUSION: To obtain a large system CG velocity at the start bar release of the luge, the faster athletes pushed the body backward with more effective use of the stretch-shortening technique and pulled the start bar straight ahead along the body.

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