PERFORMANCE ANALYSIS OF THE START PHASE OF SKELETON ATHLETES AT INTERNATIONAL COMPETITIONS

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The purpose of this study was to investigate characteristics of the skeleton start motion from the viewpoint of step frequency and step length. Twenty-six male and twenty female skeleton athletes at international competitions were videotaped and analysed their start motion with the three-dimensional DLT method. There were high significant correlations between the start time and the goal time in both men ($r = 0.947$, $p < 0.001$) and women ($r = 0.741$, $p < 0.001$). As for the start time, men showed a significant correlation with the step length at the 1st step ($r = -0.606$, $p < 0.01$) while women showed significant correlations with the step frequency at the 1st ($r = -0.475$, $p < 0.05$), 3rd ($r = -0.590$, $p < 0.01$) and 5th ($r = -0.620$, $p < 0.01$). These result indicated that men emphasized step length at the 1st step, while women relied more on step frequency.

KEYWORDS: skeleton start, videography, step frequency, step length.

INTRODUCTION: Skeleton is one of the Winter Olympic events that an athlete slides a sled on an iced track like bobsleigh and luge. The athlete explosively dashes to accelerate the sled, pushing it in deeply-flexed hip position. About 25 m after the release from the start block, the athlete loads on the sled in a head-first position. A winner is decided with the shortest time of the sum of a few runs, where the time of one run will be fifty to sixty seconds. Skeleton became an official event of Winter Olympic games from Salt Lake in 2002. Because of a later introduction to Winter Olympic Games compared to bobsleigh and luge, there is sporadic scientific information on this event. Zanoletti et al. (2006) found a significant relationship between the start time (the section time of 15 m and 65 m from the start block) and the goal time in men ($r = 0.48$) and women ($r = 0.63$) for twenty-four international competitions. Oguchi (2015) investigated the effect of the start time on the goal time for men and found that there were significant positive correlations ($r = 0.351 \sim 0.712$) between the start time and the goal time for ten different tracks. From these studies, the start time is likely to be one of the important factors in skeleton.
Colyer et al. (2017) investigated effects of the physical-test score on the start time. Bullock et al. (2008) found that the velocity at the 15 m mark accounted for 86% of the variance of the start time at the track in St. Moritz. Coler et al. (2018) studied the relationship between the start time and the speed at the instant of loading on a dry-land. Oguchi (2015) found that the start time significantly related the average step length before loading ($r = -0.865$, $p < 0.001$) at the Japan Championship. However, there has been little information on changes in step frequency and step length of men and women athletes at international level. The purpose of this study was to investigate characteristics of the skeleton start motion from the viewpoint of step frequency and step length.

METHODS: The 2018 Intercontinental cup (round 1 and 2) and Europe cup (round 1 and 2) held in Innsbruck, Austria (15-17, Nov., 2018) were selected as target competitions, which were conducted under the authorization of the International Bobsleigh & Skeleton Federation (IBSF). The informed consents were obtained from twenty-six male (height 1.80 m ± 5.1, mass 78.9 kg ± 8.0) and twenty female skeleton athletes (height 1.69 m ± 5.8, mass 66.1 kg ± 5.4) before the competitions with the cooperation of national coaches.

The videotaping area was 1.6 m in height, 2.5 m in width and 17.0 m in length from the start block, which was covered with four video cameras (AX-700, Sony) to capture the start motion and analyse it using the three-dimensional DLT method. The sampling rate of cameras was set at 120 Hz and the exposure time was 1/1000 second. Twenty-three points on the body and four points on the sled (the right and left tips and tail ends) were manually digitized by an experienced digitizer with Frame-DIAS (DKH, Co., Japan). The sled speed of the right front tip, step frequency, step length were obtained and running speed was calculated as a product of the step frequency and the step length. The official timing began at the 15 m mark from the start block, and measured times at the 65 m mark for the start time and the 1218 m mark for the goal time.
Pearson's correlation coefficient was calculated to see relationships of performance descriptors such as step frequency and step length to the goal time. The significance level was set at $p < 0.05$.

RESULTS: Figure 1 shows relationships between the start time (men, 5.16 ± 0.22 s; women, 5.60 ± 0.21 s) and the goal time (men, 54.01 ± 1.27 s; women, 55.23 ± 0.95 s) in the international class skeleton athletes. There were high significant correlations in both men ($r = 0.947$, $p < 0.001$) and women ($r = 0.741$, $p < 0.001$).
Table 1 shows the sled speed at the marks of 5, 10 and 15 m from the start block and correlation coefficient between the sled speed and the start time. The sled speed increased .

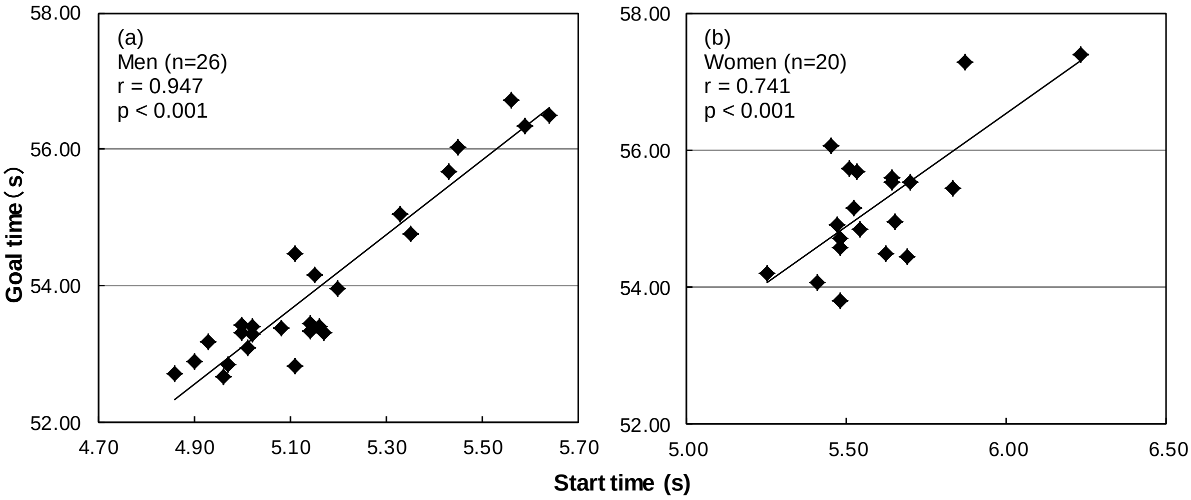

Figure 1: Relationships between the start time and the goal time in men (a) and women (b).

Table 1: The sled speed at 5, 10 and 15 m marks from the start block and the relationships to the start time.

	Sled speed (m/s)	Range (m/s)	Correlation coefficient
Men (n = 26)			
5m	4.1 ± 0.2	3.6 ~ 4.6	-0.385
10m	6.5 ± 0.4	5.8 ~ 7.1	-0.625 ***
15m	8.3 ± 0.5	7.3 ~ 9.1	-0.675 ***
Women (n = 20)			
5m	3.9 ± 0.2	3.6 ~ 4.1	-0.286
10m	6.0 ± 0.3	5.1 ~ 6.3	-0.861 ***
15m	7.7 ± 0.4	6.4 ~ 8.2	-0.666 ***

*** p < 0.001

with the distance from the start block. Significant correlations to the start time were found in speed of 10 and 15 m mark for both men and women.

Figure 2 shows changes in step frequency, step length, running speed with the increase in the number of steps in men and women. The asterisks indicate a significant correlation with the start time. The step frequency for men (Figure 2a) and women (Figure 2b), it sharply decreased from the 1st to 2nd step, followed by no remarkable change from the 3rd step to the 6th step. The men's step frequency at the 4th (4.05 ± 0.28 Hz, r = -0.506) and 6th (4.09 ± 0.28 Hz, r = -0.465) steps showed significant correlations with the start time. That of women

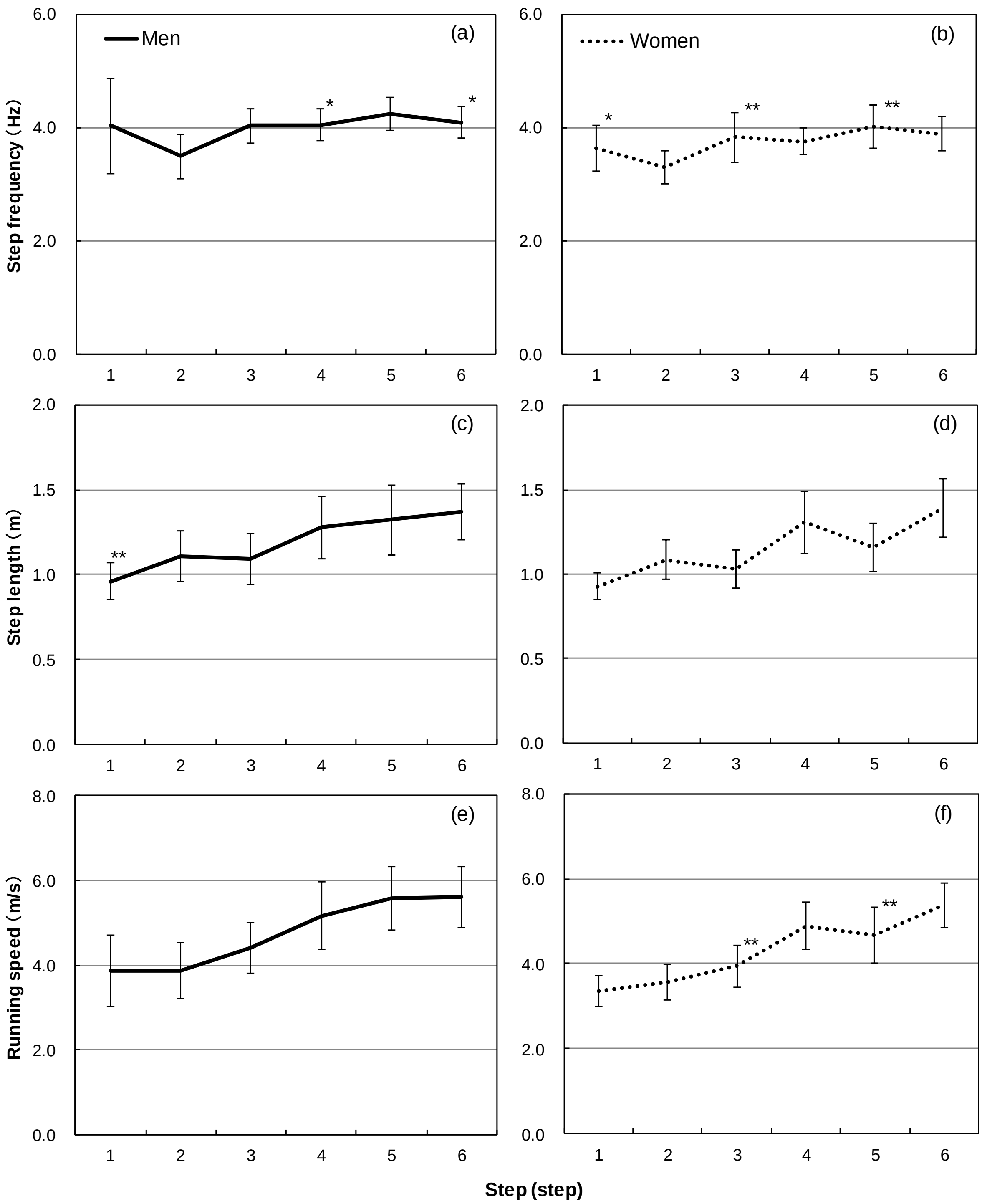

Figure 2: Changes in step frequency (a, b), step length (c, d), running speed (e, f) with the increase in the number of steps in men and women. The asterisks indicate the significant correlations to the start time (* p < 0.05, ** p < 0.01, *** p < 0.001).

showed high significant correlations with the start time at the 1st (3.63 ± 0.41 Hz, r = -0.475), 3rd (3.84 ± 0.44 Hz, r = -0.590) and 5th (4.02 ± 0.39 Hz, r = -0.620) step. The step length for both men (Figure 2c) and women (Figure 2d) gradually increased from the 1st to 6th step with some variations. There was a high significant correlation of step length with the start time only at the 1st step of the men (0.96 ± 0.11 m, r = -0.606). As for the running speed, women (Figure 2f) showed a significant correlation with the start time at the 3rd (3.94 ± 0.50 m/s, r = -0.691) and 5th (4.66 ± 0.66 Hz, r = -0.632) steps.

DISCUSSION: There were high significant correlations between the start time and the goal time in both men and women. This indicated that the start time was one of the limiting factors of competitive performance in skeleton of this class. A significant correlation found between the sled speed at 10 m mark and the start time in both men and women implies that obtaining a large speed at the 10 m mark would be led a shorten start time.

At the 1st step, the speed of men and women showed the significant correlation with the start time, and men's step length and women's step frequency significantly related to the start time. In skeleton, the combined mass of the sled and the athlete was restricted by the IBSF to a maximum of 120 kg for men and 102 kg for women. The men could take the large step length at the 1st step, pushing the heavy sled to accelerate the sled. In the case of the women who would not be as strong as the men, it would be inferred that the sled was accelerated by increasing the step frequency rather than step length. From the 3rd step, both men and women showing significant correlations of the step frequency to the start time may indicate that the step frequency was a contributing factor to the start time. Different from the start motion of a sprinter of athletics, a skeleton athlete has to start running with pushing the sled in deeply-flexed hip position. Therefore, since it is difficult for skeleton athletes to acquire a large step length from the beginning, they may rely more on the step frequency to accelarate the sled. These findings imply that coaches should be aware of the importance of running in deeply-flexed hip position, even in off-season and dry land training.

CONCLUSION: To obtain a large sled speed at the 10 m mark which contributed to shorten the skeleton start time and goal time as a result, the men emphasized step length at the 1st step, while women relied more on step frequency. These may be caused by the characteristics of the skeleton start motion with the hip deeply-flexed.

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