Development of bobsleigh shoe in preparation for the 2018 Pyeongchang Winter Olympics

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ABSTRACT

In this study we aimed to provide necessary basic data by elucidating the relationship between toe spring angle (TSA) and start sprint lap time in bobsleigh shoes, in order to develop Korean-specific bobsledding shoes. The participants of the present study consisted of 6 reserve members of the Korean national bobsleigh team who received sufficient explanation on the objective of the study and volunteered to participate. The bobsleigh shoes used in the experiment were prototypes developed by “T” Corporation, which consisted of types A, B, and C with TSAs of 30°, 35°, and 40°, respectively. To analyze the time taken during the start, digital run-time meters (SR-500SP, Seed Tech, Korea) were set up at intervals of 0–5, 5–10, and 0–10 m for data collection. Moreover, to measure the fore foot bending angle (FBA) during the bobsleigh start motion, a high-speed camera (S-pri, AOS, Switzerland) was set up on the outside of the track, approximately 5 m from the start line, for collection of data at a rate of 1,000 frames/sec. For the FBA measurements, 7 markers (points 1–7) were attached on the sides of the outsole in the forefoot and midfoot areas. The internal angle created by lines connecting 3 points in the central area of the 7 attached markers was defined as a single angle and analyzed accordingly. The results of the analysis of the time required in the bobsleigh start stage showed significant differences between the shoes at the interval of 5–10 m, with post hoc test results indicating a statistically significant difference between the type C and A shoes (*p < .05). Moreover, the results of the analysis of FBA in the bobsleigh start stage showed significant differences between the shoes at angles 2, 3, 4, and 5. The post hoc test results indicated significant differences between types B and C at angle 2 (**p < .01); types A and C at angle 3 (**p < .01); types A and C, and types B and C at angle 4 (***p < .001); and types A and B, and types B and C at angle 5 (**p < .01). As running speed increases, FBA should also increase, but excessive forefoot bending can lead to plantar fasciitis injury and increased fatigue. Meanwhile, excessive bending restriction can reduce the efficiency of using the ground reaction force and cause limited range of motion, which act as obstacles to sports performance. Type C shoes were designed to have a TSA of 40°; as such, they induced the most suitable FBA at angles 3 and 4, which correspond to the metatarsal joint, in providing the bending moment for the driving force of the bobsleigh athletes, which contributed to the shortening of the time record in the start stage.

Keywords: Bobsleigh, Toe spring angle, forefoot bending angle, Footwear, High speed camera

1. Introduction

Bobsleigh is one of the fastest winter sports where the difference of only 1/1000th of a second identifies the winner (Dabnichki, 2015). A bobsleigh run lasts approximately 60 seconds, and the sleigh should run along the ice track at a mean speed of 135 km/h for competitive speed and decreased completion time. This is closely associated with the postures, weights, and steering techniques of the players, as well as aerodynamic variables of the sleigh. Efforts have been made to improve these factors and ultimately shorten the time (Chowdhury et al., 2015; Ubbens et al., 2016). However, recently, the importance of the start stage is being emphasized (Dabnichki and Avital, 2006). In the start stage, the explosive power of the athletes for pushing the sled is considered important, but the role of a shoe that can thrust...
the explosive power of the athletes to the slippery ice surface is equally important. Selection of appropriate shoes could act as a variable in improving the players' performance and times. In consideration of the various mechanical variables of each sport, toe spring angle (TSA) has been modified in the general selection and development of athletic shoes. TSA is related to the Forefoot bending angle (FBA). FBA in shoes is associated with ground reaction force and advancing force acceleration in terminal stance and pre-swing in running and jumping; ultimately, the angle has a close association with the athlete's performance (Goldmann et al., 2011).

The objective of the present study was to provide basic data for the development of bobsleigh shoes exclusive for Korean bobsleigh athletes by identifying the relationship between forefoot bending angle (FBA) and bobsleigh start stage based on various toe spring angle (TSA).

2. Method

The participants of the present study consisted of 6 reserve members of the Korean national bobsleigh team who received sufficient explanation on the objective of the study and volunteered to participate. The experiment was conducted in the bobsleigh start track training facility located in Gangwon Province, where the 2018 Winter Olympics will be held. In consideration of the conditions of the participating athletes, the experiment was conducted during the regular training time of the athletes. The bobsleigh shoes used in the experiment were prototypes developed by “T” Corporation, which consisted of types A, B, and C with TSAs of 30°, 35°, and 40°, respectively (Figure 1).

To analyze the time taken during the start, digital run-time meters (SR-500SP, Seed Tech, Korea) were set up at intervals of 0–5, 5–10, and 0–10 m for data collection. Moreover, to measure the FBA during the bobsleigh start motion, a high-speed camera (S-pri, AOS, Switzerland) was set up on the outside of the track, approximately 5 m from the start line, for collection of data at a rate of 1,000 frames/sec. For the FBA measurements, 7 markers (points 1–7) were attached on the sides of the outsole in the forefoot and midfoot areas. The internal angle created by lines connecting 3 points in the central area of the 7 attached markers was defined as a single angle and analyzed accordingly (Figure 2).

All analyses in the present study were performed by using PASW Ver. 19 for Windows. Data processing consisted of a comparative analysis by using one-way repeated-measures analysis of variance with a significance level of $\alpha = .05$. 

Figure 1. Shoes used in the experiment

Figure 2. Definitions of the markers attached to the sides of the experimental shoes used for measuring forefoot bending angle
3. Results

The results of the analysis of the time required in the bobsleigh start stage showed significant differences between the shoes at the interval of 5–10 m, with post hoc test results indicating a statistically significant difference between the type C and A shoes (*$p < .05$). Moreover, the results of the analysis of FBA in the bobsleigh start stage showed significant differences between the shoes at angles 2, 3, 4, and 5. The post hoc test results indicated significant differences between types B and C at angle 2 (**$p < .01$); types A and C at angle 3 (**$p < .01$); types A and C, and types B and C at angle 4 (**$p < .01$); and types A and B, and types B and C at angle 5 (**$p < .01$; Table 1).

Table 1. Analysis results of time required during the bobsleigh start time according to toe spring angle (Mean ± SD)

|         | 0 ~ 5 m   | 5 ~ 10 m  | 0 ~ 10 m  |
|---------|-----------|-----------|-----------|
| Type A  | 1.41 ± 0.45 | 1.00 ± 0.01 | 2.42 ± 0.59 |
| Type B  | 1.41 ± 0.33 | 1.00 ± 0.01 | 2.41 ± 0.04 |
| Type C  | 1.41 ± 0.69 | 0.99 ± 0.03$^b$ | 2.40 ± 0.10 |
| F       | .058      | 3.217     | .450      |
| $p$     | .944      | .04$^*$   | .638      |

$^*$ signifies significant difference between Type A and Type B, $^b$ signifies significant difference between Type B and Type C.

Table 2. Analysis results of forefoot bending angle during the bobsleigh start time according to toe spring angle (Mean ± SD)

|         | Angle 1 | Angle 2 | Angle 3 | Angle 4 | Angle 5 |
|---------|---------|---------|---------|---------|---------|
| Type A  | 13.55 ± 5.62 | 12.37 ± 3.84 | 11.21 ± 4.54 | 12.88 ± 7.02 | 13.65 ± 3.41 |
| Type B  | 12.49 ± 4.25 | 13.93 ± 3.40 | 13.00 ± 2.59 | 9.60 ± 3.34 | 20.46 ± 11.68$^a$ |
| Type C  | 13.01 ± 1.18 | 10.06 ± 1.18$^b$ | 14.71 ± 1.18$^c$ | 18.62 ± 1.18$^b,c$ | 13.38 ± 1.18$^b$ |
| F       | .241     | .6405    | 5.529    | 14.530   | 5.678   |
| $p$     | .78      | .00$^**$ | .00$^**$ | .000$^{***}$ | .00$^**$ |

$^*$ signifies significant difference between Type A and Type B, $^a$ significantly different between Type B and Type C, $^c$ significantly different between Type A and Type C.

In normal walking, the entire foot is in contact with the floor during the stance phase. To move the body forward, only the forefoot comes in contact with the floor, and the rearfoot lifts to increase the propulsive force. In 100 or 200 m short-distance running, runners gain propulsive force by using forefoot strike gait pattern, which decreases contact time with the floor while increasing stride rate (De Wit et al., 2000; Squadrone and Gallozzi, 2009; Bonacci et al., 2013). Bobsleigh players push the sleigh in forefoot gait pattern to reach maximum speed within the short starting area. To increase running performance, bobsleigh players also conduct training programs including vertical jumping and 30 m sprint testing, which were originally designed to improve starting performance in short-distance runners (Sanno et al., 2013).

4. Discussion

The findings of the present study showed that bobsleigh start while wearing type C shoes shortened the time record. Anatomically, forefoot bending occurs in the metatarsophalangeal joint and is controlled by the foot intrinsic muscle and calf muscles (Goldmann et al. 2013). As running speed increases, FBA should also increase, but excessive forefoot bending can lead to plantar fasciitis.
injury and increased fatigue. Meanwhile, excessive bending restriction can reduce the efficiency of using the ground reaction force and cause limited range of motion, which act as obstacles to sports performance. Type C shoes were designed to have a TSA of 40°; as such, they induced the most suitable FBA at angles 3 and 4, which correspond to the metatarsal joint, in providing the bending moment for the driving force of the bobsleigh athletes, which contributed to the shortening of the time record in the start stage.

5. Conclusion

To provide basic data required for developing Korean-specific bobsledding shoes, this study analyzed start sprint lap time and forefoot bending angle with prototypes developed by “T” Corporation, which consisted of types A, B, and C with TSAs of 30°, 35°, and 40°, respectively worn by bobsleigh players during practice, and obtained the following results: Type C shoes were designed to have a TSA of 40°; as such, they induced the most suitable FBA at angles 3 and 4, which correspond to the metatarsal joint, in providing the bending moment for the driving force of the bobsleigh athletes, which contributed to the shortening of the time record in the start stage. Future studies are needed to develop appropriate hardness based on the type C shoes, and to thoroughly investigate their functionalities.

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