DIFFERENCES OF POSTURE ON PUSH-OFF PHASE BETWEEN ACTUAL SPEED SKATING AND SLIDE-BOARD TRAINING

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The slide-board training is a feasible technology to exercise skating during the off-season. While slide-board is much different from ice surface of the actual skating situation, it may distort actual skating posture. The purpose of this study was to analyze the differences in posture during push-off phase between an actual speed skating condition and on slide-board. The result showed that on the slide-board distance between two feet were shorter, so were the rotation angles of both feet, the hip angle was lower during the whole phase, while knee and ankle angles were higher. In conclusion, the restriction of the space on slide-board affected the position and rotation of both stable and push-off feet as well as the joint extension of the stable leg. Hence, the structural design of slide-board needs to be improved to facilitate the extension of knee and ankle in the medial-lateral direction.

KEYWORD: Motion Capture, Lower Limb Joints, Rotation Angle, Feet Position

INTRODUCTION: Similar to any other winter sports, speed skating athletes perform dry land training during off-season like summer. These dry land trainings include slide-board training, anaerobic training, weight training, and so on. Among them, slide-board training has been considered by coaches for skaters not only for maintaining but also for enhancing their technical skills. A slide board does not actually present the reality of like performing track sports, but rather embodies a situation similar to the ice rink. Hence, most of the off-season technical training are conducted on the slide board, as skaters can reproduce a sense of exercise required for skating with a limited environment and space (Panday, Yang et al. 2015). However, it is almost impossible to avoid the differences between slide-board training and actual performance.

One set of the differences between slide-board training and actual performance is the posture during the push-off phase. By kinematic analysis, it has been identified that while speed skating the angle of joints during a push-off phase are critical for higher power production and better performance (Noordhof, Foster et al. 2013). Irrelevancy in posture has some major effects on muscle physiology. It may result in local muscle fatigue and affect skating technique (Piucco, dos Santos et al. 2015).Many researches who are studying the effect of klapskate and conventional skates reported a significant role of foot rotation. A delayed onset of foot rotation coincided with an increase in angular displacement and peak angular velocity of the knee and hip joint, an increase in the flexion of the knee joint moment at the end of the push-off, and a reduction in work generated at the knee joint. Furthermore, the extension of knee angle can facilitate push off technique more effectively (Kandou, Houtman et al. 1987, Houdijk, Heijnsdijk et al. 2000, Houdijk, de Koning et al. 2002).

Hence, in order to maximize the benefits derived from slide-board training, it is necessary to investigate the differences in posture during push-off phase. The explicit of these differences can facilitate us redesign the slide-board more similar to an actual skating condition and develop the training program for enhancing the performance.

METHOD: Four subjects (age: 21±2.64 years, weight: 64±4.58 kg, height: 173±4.35 cm). The subjects did not have any history of physical problems. Experimental procedures and possible risks were communicated verbally and in writing to all study participants, who then gave their informed written consent. The experimental condition was divided into two sessions i.e. on actual speed skating rink and on laboratory session. The participants were given enough time to warm up and time to do test runs on the ice rink as well as slideboard. During the first session on the ice rink, direct linear transformation (DLT) method was used to perform analysis on the ice rink with three male speed skaters from the Korean National Team. The test took place at Taereung indoor ice rink at Seoul, Korea. Fifty meters of the straight part from the starting point was selected as experimental area and control points were placed. Their motions were recorded using eight video cameras (full HD, 60frames/sec. shutter speed 350) (HDR-PJ380, Sony, Japan). Prior to the test, test recording was conducted for 1 minute. The data were processed using Kwon3D 3.1(Kwon, 2005) and manual digitization of thirteen joint centers (Head, Right/Left (shoulder, hip, knee, ankle, heel, toe) was performed.

For the second session during laboratory condition, one female speed skater from the Korean National Team participated in the slide-board training test. A total of 8 infrared motion capture cameras were used to record the participant's performance, and motion data was sampled at 100 Hz (Model: Qualisys Oqus 500, Qualisys AB, Gothenburg, Sweden). The Qualisys Track Manager was used to capture the movement, and the kinematic data obtained from the three-dimensional coordinate values were processed using Visual 3D V.5 and Excel 2013 (Microsoft Inc., USA).

The push-off phase was defined from the frame, left toe contacted the ice surface to right toe off. Trunk angle is defined as the angle between pelvis and thigh. Knee angle is defined as the angle between thigh and shank. Ankle angle is defined as the angle between shank and foot. While standing in static position, trunk angle and knee angle was 180 degrees while ankle angle was 90 degrees.

RESULTS: Slide-board training: With respect to the stable foot (left foot), the central position of the push-off foot (right foot) moved from 0.69m to 1.05m from Left-to-right direction, and from -0.07m to 0.01m in the fore-and-aft direction. The rotation angle of push-off foot changed from 0 to 30 degrees. In the first half of push-off phase, the rotation was sustained to less than 10 degrees. In the second half, it changed counterclockwise much more quickly (Figure 1 (a)). The range of trunk angle was from 59 to 65 degree. The trunk angle increased slower at the end of the push-off phase than other parts. For knee angle, the range was from 116 to 119 degrees. Ankle angle decreased from 83 to 75 degree and then maintained the level at the end of the push-off phase (Figure 2 (a)).

Actual performance: With respect to the stable foot (left foot), the central position of the push-off foot (right foot) moved from 0.25m to 0.58m in the Left-to-right direction, and from 0.06m to -0.49m in the fore-and-aft direction. The rotation angle of push-off foot changed from 24 to 87 degrees. In most parts of push-off phase, the rotation was sustained to less than 35 degrees. At the end of the push-off phase, it changed clockwise much more quickly (Figure 1 (b)). The range of trunk angle was from 58 to 64 degrees. The trunk angle decreased in most part of the push-off phase except the last 25 percent. For the knee angle, the range was from 95 to 103 degrees while the ankle angle decreased from 75 to 47 degrees (Figure 2 (b)).

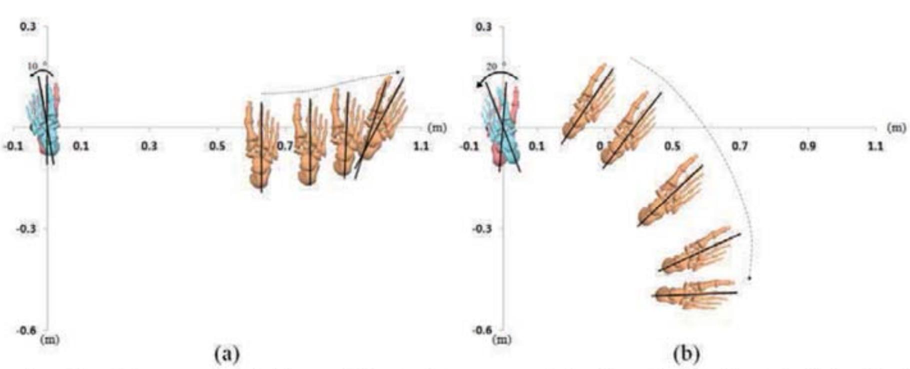

Figure1 – Position and rotation of feet with respect to the stable foot (left foot) during right foot push-off phase (a) on slide-board (b) in actual skating condition

Figure 2 – Postural of stable leg from the start to the end of push-off phase divided into five states symmetrical (a) on slide-board training (b) in actual skating situation

DISCUSSION: During actual skating situation, subjects needed to push backward in order to advance their body and glide in the forward direction. However, on the slide-board training, subjects glided only on lateral directions which could be the direct reason why the distance in a fore-and-aft direction between the central position of the push-off and stable foot was further on slide-board than in actual situation. However, the difference of distance in left-and-right direction was also distinct. One was less than 0.6m while another was larger than 0.6m. The results suggest that subjects were anxious to contact the board when performing slide-board in order to reduce the risk of fall. As stable foot was restrained by the edge of the board, it is dangerous to increase the hover time of another foot, as well as the time of push-off phase which leads higher instantaneous velocity at the moment contacting the edge. Therefore, enlarging the space may facilitate to decrease the effect of edge.

In addition, the rotations of both feet were much smaller on slide-board than in actual situation. In fact, the push-off foot rotated clockwise on the slide-board at the end of the push-off phase while it rotated counterclockwise in an actual situation during the whole phase. It suggests that subjects tried to restrain the trend of moving forward. Moreover, a great deal of scientific research proved that skaters use gravity for smooth propulsion in the first part of push-off phase while producing explosive force at the end of the push-off phase. However, on slide-board subjects must produce large force at first at the beginning of the motion which in fact leads to distortion of skating technique. Considering this fact, it is considered that finding a way to free the forward movement may make slide-board training more efficient.

Appropriate lower limb joint angles of stable leg facilitate in decreasing the air resistance and producing stable push condition. In the actual skating situation, it was difficult to maintain appropriate angles because of fatigue. In the first part of the push-off phase, i.e. the gliding part, the hip, and ankle angle were quite high. At the end of the push-off phase, explosive part, all angles were adjusted. However, on the slide-board, the hip angle was appropriate though the knee and the ankle angle kept high. Knee and ankle produced force later than hip and are considered as a key factor for explosive propulsion during later end of the push-off phase. The result suggests that there is almost no explosive push-off phase when performing on slide-board, and present slide-board training is adverse for postural adjustment training of knee and ankle joints. It may also be due to the need of controlling the instantaneous velocity while contacting the edge. Therefore, present slide-board can only be used to train the posture of hip joint for gliding part of the push-off phase.

CONCLUSION: The study shows some differences in the posture during the push-off phase of speed skating and slide-board motion. The limitation of space on slide-board leads to restriction of movement, velocity, and joint stretch which changed skaters' kinematics parameters. Comparing to actual condition, on slide-board the amplitude of foot rotation decreased, and the trend of stretching backward was limited. Present slide-board is in favor of hip bending practice but is not conducive to the knee and ankle's stretch training. Thus, it is considered that the present slide-board needs a structural redesign for making slide-board training more similar to an actual skating condition.

In this study, there are still many areas for improvement, such as the results cannot be statistically analyzed because there were only a few participants; the differences of COM cannot be analyzed because the whole body was not digitized; other insufficiencies including failure to compare chronologically and dynamics analysis. We will perform more analysis to evaluate and develop slide-board training program later.

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