COMPARISON OF ANGULAR KINEMATIC PATTERNS BETWEEN CARVING TURN AND SKIDDING TURN DURING ALPINE SKIING

Joo-Nyeon Kim[1], Jin-Hae Kim[1], Jae-Hyeon Park[1], Sang-Kyoon Park[1], Jiseon Ryu[1] and Sukhoon Yoon[1]

Motion Innovation Centre, Korea National Sport University, Seoul, Korea[1]

The purpose of this study was to investigate the movement patterns between segments (lower spine, pelvis, thigh, shank) and ski using the relative angular displacement on anteroposterior and vertical axis. Fourteen alpine ski instructors were participated in this study. Eight inertial measurement units were used to measure kinematic variables. Each skier was asked to perform ten carving turns and ten skidding turns on the groomed 15°slope, respectively. On the vertical axis, relative angular displacement of lower spine-ski was significantly increased during carving turn, whereas relative angular displacement of shank-ski was significantly increased during skidding turn. On the anteroposterior axis, relative angular displacement of lower spine-ski, pelvis-ski and thigh-ski were significantly increased during carving turn.

KEY WORDS: alpine ski, carving turn, skidding turn, angular kinematics

INTRODUCTION: In alpine ski, the types of turning techniques are classified into carving turn and skidding turn depending on the skill of the skier. The racing ski is a competition for passing through the gates. The racers must turn to a limited radius depending on the gates installation type. So, it is necessary to use a combination of carving turns and skidding turns according to the skiing strategy (Hébert-Losier, Supej, & Holmberg, 2014). These turning techniques are accomplished through various body movements. Therefore, many biomechanical studies have been conducted to analyse alpine skiing techniques. However, in most Alpine skiing fields, even though most skiers were trained using terms that are relative to the direction of the ski, such as counter-rotation position or angulation, most biomechanical research has focused on the analysis of relative angle between adjacent segments (Kim et al., 2014; Scheiber, Seifert, & Müller, 2012; Schiefermüller, Lindinger, & Müller, 2005; Vodickova, Lufinka, & Zubek; 2004; Yoneyama, Kagawa, Unemoto, Iizuka, & Scott, 2009). The purpose of this study was to investigate the movement patterns between ski and segments using the relative angular displacement on anteroposterior and vertical axis.

METHODS: Fourteen Korean alpine ski racers (age: 29.36±3.85 yrs, body mass: 70.18±7.99 kg, height: 171.91±5.94 cm, career: 10.91±2.91 yrs) were participated in this study. Eight inertial measurement units (myoMOTION, Noraxon, USA) were used to measure kinematic variables at a sampling frequency of 200 Hz. Inertial measurement units were attached bilaterally to the thigh, shank and foot segments (ski), and to the pelvis and lower-spine using an underwear suit. One type of skis (HERO ELITE ST RACING, Rossignol, France; length: 167 cm) was used to minimize the impact of the different structural characteristics of the skis, and their own ski boots were used. Each skier was asked to perform turns including ten carving turns and ten skidding turns on the groomed 15°slope, respectively. To restrict the turning radius, the researchers installed short-poles (vertical distance: 15 m, horizontal distance: 4 m) which would not interfere the skier's turns. The data was analyzed using Myoresearch 3.8 (Noraxon, USA) and Matlab R2016a (The MathWork, USA). The orientation angles on vertical and anteroposterior axis of each segment and ski were filtered with a fourth-order low pass Butterworth filter (cut-off frequency of 6 Hz) to remove the noise. The relative angular displacements were calculated between the segments and the ski. The variables were analyzed a skiing cycle from the start-point to the end-point of turning. Each point was defined as when the orientation angle of the ski on the vertical axis becomes the peak value is end of turning and initiation of next turning. The differences between the carving turns and skidding turns were determined using paired t-test. The level of significance used was $p<.05$.

RESULTS: On the vertical axis, relative angular displacement of lower spine-ski (carving turn: -16.18±3.68 deg, skidding turn: -11.30±3.79 deg; t=-3.478 *p*=.004) was significantly increased during carving turn, whereas relative angular displacement of shank-ski (carving turn: 4.58±4.24 deg, skidding turn: 9.05±3.02 deg; t=-3.205, *p*=.007) was significantly increased during skidding turn. On the anteroposterior axis, relative angular displacement of lower spine-ski (carving turn: -18.35±2.34 deg, skidding turn: -6.94±1.18 deg; t=-14.752, *p*=.000), pelvis-ski (carving turn: -17.93±1.74 deg, skidding turn: -7.72±1.03 deg; t=-15.682, *p*=.000) and thigh-ski (carving turn: -20.68±1.66 deg, skidding turn: -10.82±2.05 deg; t=-13.531, *p*=.000) were significantly increased during carving turn.

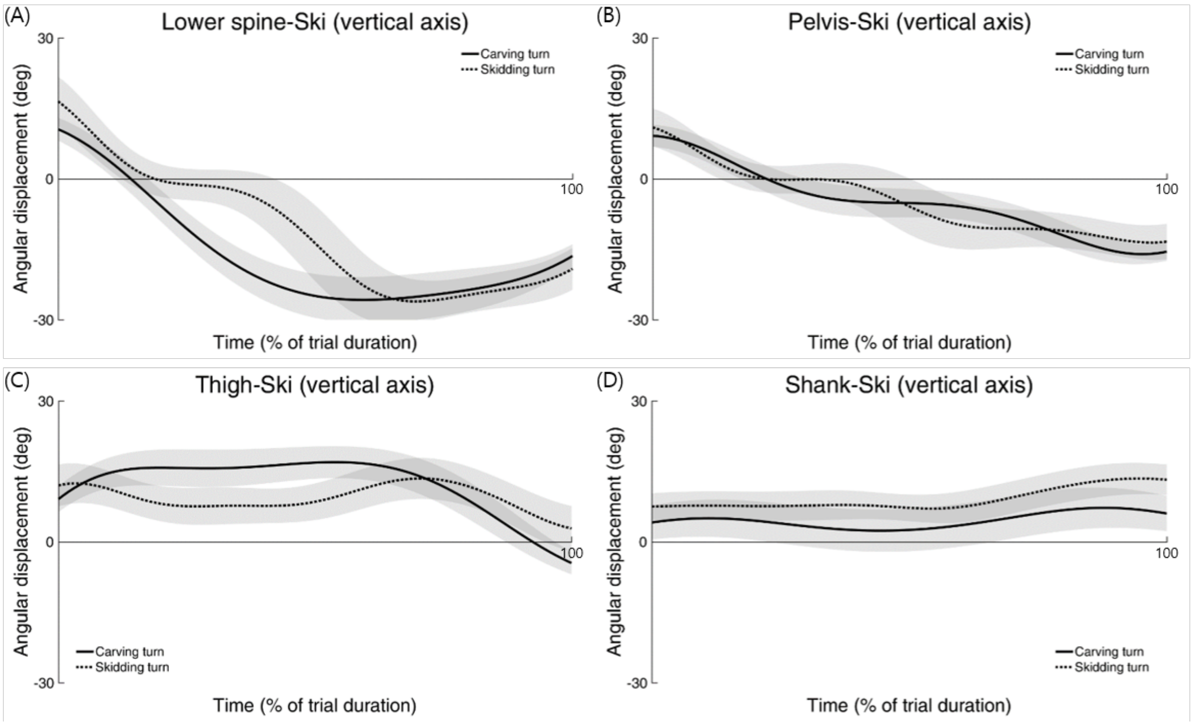

Figure 1: Relative angular displacement between segments and ski on vertical axis during carving turn (solid line) and skidding turn (dot line). Average±standard deviation (gray area) through a skiing cycle (0-100%) for (A) lower spine-ski, (B) pelvis-ski, (C) thigh-ski, (D) shank-ski.

DISCUSSION: In this study, the relative angular displacements between each segment (lower spine, pelvis, thigh, shank) and ski were investigated and quantified in order to describe the skiing movement using the terms especially used in alpine ski field such as counter-rotation position or hip and knee angulation. Also, we have presented the difference in relative angular displacement patterns between the techniques (carving vs skidding turn) to allow alpine ski racers to strategically use the techniques.

The counter-rotation position is preferred to make a large edging angle by increasing inward inclination, knee angulation and hip angulation (LeMaster, 2010; Lind & Sanders, 2004; Müller et al., 1998). The carving turn is faster and is dependent only on the bending of the ski compared to the skidding turn. Therefore, when skiers perform the carving turn, it is required a larger edging angle and inward inclination than the skidding turn. Therefore, it suggests that carving turn allows performing a larger angle of counter-rotation position in a relatively short time. Thus, skiers should increase the lower-spine and pelvis movements to the

outward orientation angle of ski to increase the inward inclination and edging angle using the counter-rotation position (Yoon et al., 2017).
In alpine skiing, skiers perform certain type of action to generate torque on a ski using the rotation of segments. Leg rotation is defined the action of further rotating the outer leg inward the direction of turning. It is used as a technique to perform skidding turn in modern alpine ski because it is used to increase attack angle by generating torque inside the direction of turning (LeMaster, 2010, Yoon et al., 2017). Therefore, skiers should increase the shank and thigh angle inward the orientation angle of ski to increase the attack angle of the ski using leg rotation during skidding turn.

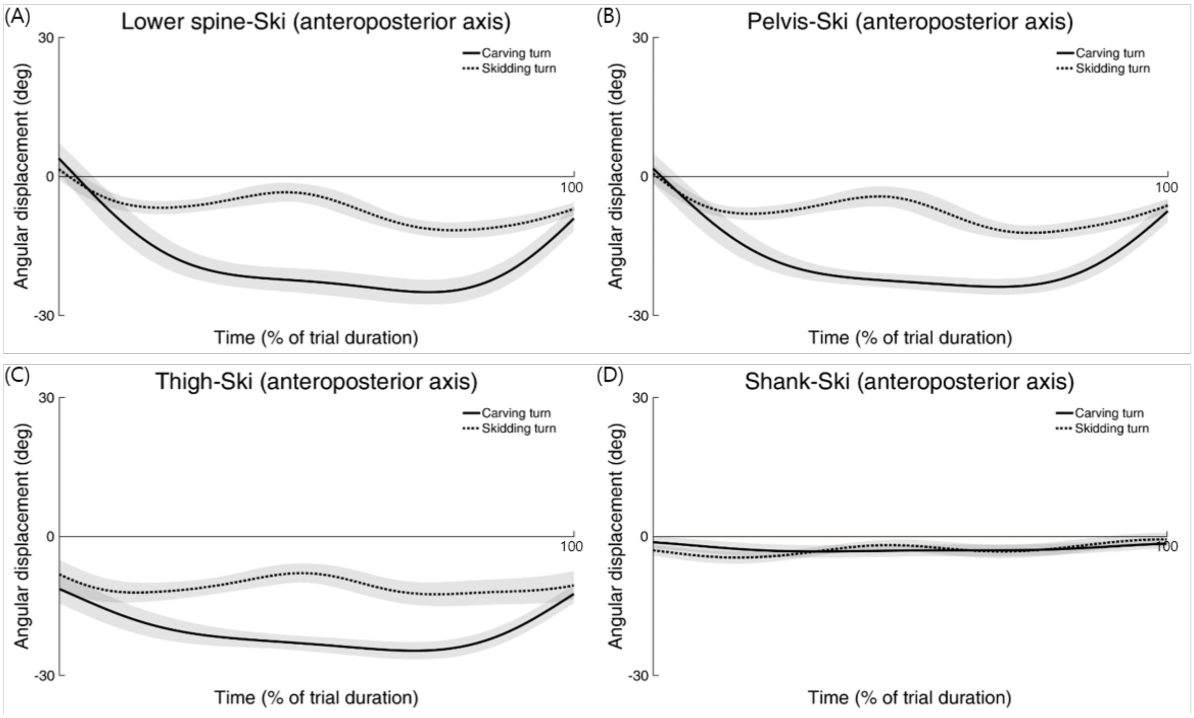

Figure 2: Relative angular displacement between segments and ski on anteroposterior axis during carving turn (solid line) and skidding turn (dot line). Average±standard deviation (gray area) through a skiing cycle (0-100%) for (A) lower spine-ski, (B) pelvis-ski, (C) thigh-ski, (D) shank-ski.

On the other hand, skiers should minimize leg rotation during carving turn to prevent the edge of ski separated from snow surface (Mössner et al., 2014). The knee and the hip angulation play a direct role in increasing the edging angle because it is defined as a projection of the knee and the hip angle to the plane perpendicular to the velocity vector of the center of mass (LeMaster, 2010; Supej, 2010). In general, the knee and the hip angulation must be increased in situations where a large edging angle is required, such as performing a turn at a steep slope with a high acceleration or a turn with a short turning radius. Skiers also increase the knee and the hip angulation because a larger edging angle is required in the turning phase after the fall-line, where the magnitude of centrifugal force is relatively increased (Lind & Sanders, 2004; Supej et al., 2015). The knee and the hip angulation to increase the edging angle appear on the anteroposterior axis of each human segment. Therefore, the skiers are able to continue to increase the edging angle in order to increase the hip angulation using the counter-rotation position and the lower-spine and pelvis should be maintained relatively close to the vertical axis. Also, when performing the carving turn where a larger edging angle is required, the knee angulation should be increased through the internal rotation angle of thigh.

CONCLUSION: This study examined relative angular displacement patterns between each segment (lower spine, pelvis, thigh, shank) and ski during alpine skiing. The comparisons were made between skidding turn and carving turn. Significant differences were found in the lower spine-ski and the shank-ski on the vertical axis, and in the lower spine-ski, the pelvis-ski and the thigh-ski on the anteroposterior axis. We, therefore, conclude that these segments movement make a counter rotation position, leg rotation and knee/hip angulation to control the attack angle and the edging angle. It is suggested that skiers should focus on the movement of segment relative to ski when performing the carving turn and the skidding turn. Future studies should examine the muscle activation of trunk and lower extremities and the force between snow surface and ski in various turning skills.

REFERENCES:

Hébert-Losier, K., Supej, M. & Holmberg, H.C. (2014). Biomechanical factors influencing the performance of elite alpine ski racers. *Sports Medicine*, *44*, 519-33.

Kim, J.N., Jeon, H.M., Yoo, S.H., Ha, S.H., Kim, J.H., Ryu, J.S., Park, S.K. & Yoon, S.H. (2014). Comparisons of center of mass and lower extremity kinematic patterns between carved and basic parallel turn during alpine skiing. *Korean Journal of Sport Biomechanics*, 24, 201-7.

Mössner, M., Heinrich, D., Schindelwig, K., Kaps, P., Schretter, H., & Nachbauer, W. (2014). Modeling the ski–snow contact in skiing turns using a hypoplastic vs an elastic force–penetration relation. *Scandinavian Journal of Medicine & Science in Sports*, 24, 577-585.

Müller, E., Bartlett, R., Raschner, C., Schwameder, H., Benko-Bernwick, U., & Lindinger, S. (1998). Comparisons of the ski turn techniques of experienced and intermediate skiers. *Journal of Sports Sciences*, 16, 545-59.

Lindinger. & H. Schwameder (EDs.), *Science and Skiing III* (pp. 172-85). UK: Meyer & Meyer Sport.

LeMaster, R. (2010). Ultimate skiing. Champaign, IL: Human Kinetics.

Lind, D. A., & Sanders, S. (2003). The physics of skiing: skiing at the triple point. New York, NY: Springer-Verlag.

Scheiber, P., Seifert, J. & Müller, E. (2012). Relationships between biomechanics and physiology in older, recreational alpine skiers. *Scandinavian Journal of Medicine & Science in Sports*, 22, 49-57.

Schiefermüller, C., Lindinger, S. & Müller, E. (2005). The skier's centre of gravity as a reference point in movement analyses for different designated systems. In: E. Müller, D. Bacharach, R. Klika, S.

Supej, M. (2010). 3D measurements of alpine skiing with an inertial sensor motion capture suit and GNSS RTK system. *Journal of Sports Sciences*, 28, 759-69.

Supej, M., Hébert-Losier, K., & Holmberg, H. C. (2015). Impact of the steepness of the slope on the biomechanics of world cup slalom skiers. *International Journal of Sports Physiology and Performance*, 10, 361-8.

Vodickova, S., Lufinka, A. & Zubek, T. (2004). The dynamographic and kinematographic method application for a short carving turn. In: E. Müller, D. Bacharach, R. Klika, S. Lindinger. & H. Schwameder (EDs.), *Science and Skiing III* (pp. 247-56). UK: Meyer & Meyer Sport.

Yoneyama, T., Kagawa, H., Unemoto, M., Iizuka, T. & Scott, N.W. (2009). A ski robot system for qualitative modelling of the carved turn. *Sports Engineering*, 11, 131-41.

Yoon, S., Kim, J. H., Park, J. H., Ryu, J., Park, S. K., & Kim, J. N. (2017). Effects of counter-rotation position on knee/hip angulation, center of mass inclination, and edging angle in simulated alpine skiing. *Korean Journal of Sports Biomechanics*, 27, 91-7.

Acknowledgement: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF- 2016S1A5A2A03926063)