COORDINATIVE PATTERNS BETWEEN CARVING TURN AND SKIDDING TURN DURING ALPINE SKIING

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The purpose of this study was to investigate the coordinative patterns between segments and ski using the continuous relative phase (CRP) on anteroposterior and vertical axis during carving and skidding turn. Fourteen alpine ski instructors were participated in this study. Eight inertial measurement units were used to collect segment kinematic data. Each skier was asked to perform ten carving turns and ten skidding turns on the groomed 15° slope, respectively. CRP angles between all segments and ski were significantly increased during carving turn on the vertical axis. On the other hand, CRP angles between all segments and ski were significantly increased during skidding turn on anteroposterior axis. Therefore, skiers should perform the anti-phase movements of the lower spine-ski, pelvis-ski, thigh-ski and shank-ski on the vertical axis during the carving turn and the in-phase movements of the lower spine-ski, pelvis-ski, thigh-ski and shank-ski on the anteroposterior axis during skidding turn.

KEY WORDS: alpine ski, carving turn, skidding turn, continuous relative phase

INTRODUCTION: Alpine skiing is a sport in which the body segments repeatedly perform circular movements using external forces to make turns. The circular movement pattern of each segment determines the level of the attack angle and edging angle, thus directly affecting the circular motion of the ski. Therefore, it is very important to investigate the coordinative pattern between segment and ski (Yoon et al., 2017). However, most previous studies on alpine skiing have only shown kinematic analysis of single segments or adjacent segments. Coordination is defined as the relationship between two different segmental movements (Sparrow, 1992). Previous research has suggested that a common coordination pattern exists in skilled performance and the signature patterns are demonstrated as the performance of the technique increases (Temprado, Della-Grast, Farrell & Laurent, 1997; Irwin & Kerwin, 2009). Since the alpine ski racers must turn to a limited radius depending on the type of gates installation, they must select the carving turn and skidding turn (Hébert-Losier, Supej, & Holmberg, 2014). Therefore, the strategic use of both techniques has a direct impact on performance. The purpose of this study was to investigate the coordinative patterns between segments and ski during carving and skidding turn.

METHODS: Fourteen Korean alpine ski racers (age: 29.36±3.85 yrs., 70.18±7.99 kg, 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 collect segment kinematic data 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 under the alpine ski racing suit. One type of skis (HERO ELITE ST RACING, Rossignol, France; length: 167 cm) were 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). 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. Before calculating CRP (continuous relative phase), angular displacement and angular velocity were calculated for the lower spine, pelvis, thigh, shank and ski. CRP angles were calculated between all segments and ski (Irwin & Kerwin, 2007; Smallman, Graham &

Stevenson, 2013). The variables were analyzed during a skiing cycle from the start-point to the end-point of turning. Each point is defined as the end of the turn and the start of the next turn when the orientation angle of the ski on the vertical axis becomes the peak value. The differences of the CRP angle between the carving turn and skidding turn were determined using paired t-test. The level of significance used was p<.05.

RESULTS: On the vertical axis, CRP angle of lower spine-ski, pelvis-ski, thigh-ski and shank-ski were significantly increased during carving turn (Figure 1, Table 1). On the anteroposterior axis, CRP angle of lower spine-ski, pelvis-ski, thigh-ski and shank-ski were significantly increased during skidding turn (Figure 2, Table 2).

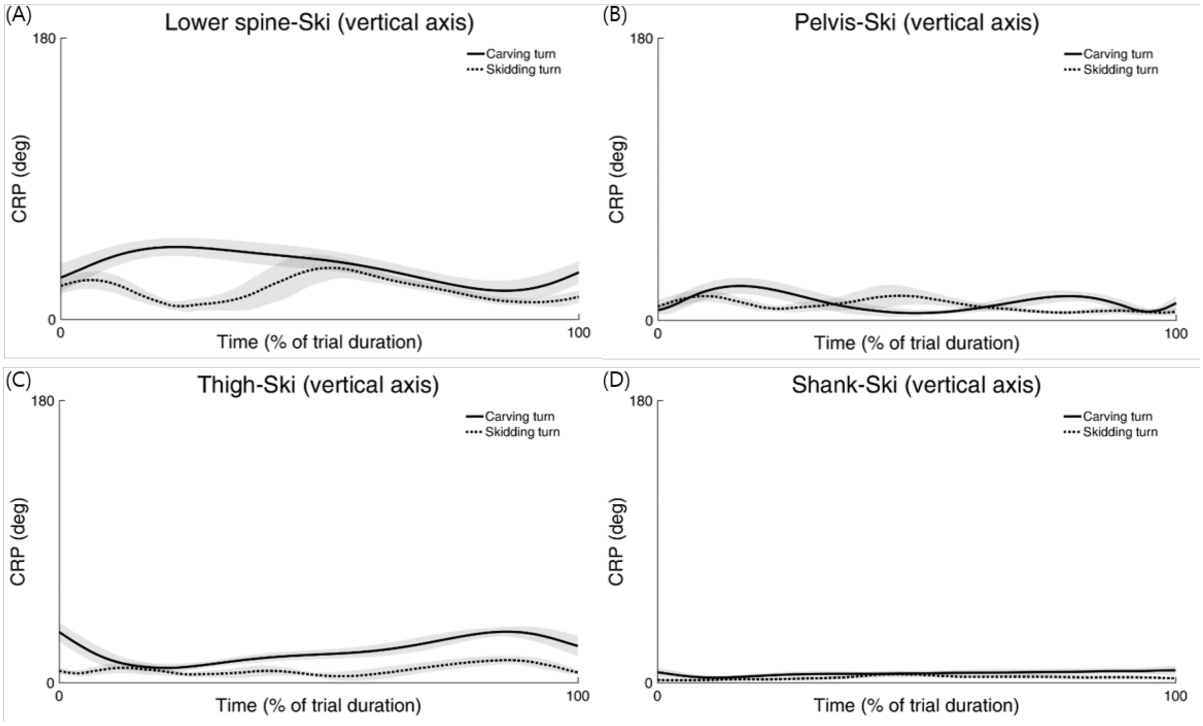

Figure 1: CRP curves between segments and ski on vertical axis during carving turn (solid line) and skidding turn (dot line). Average±standard deviation (gray area) through a skiing cycle (0-100%) for (A) lower spine-ski, (B) pelvis-ski, (C) thigh-ski, (D) shank-ski.

Table 1: CRP angles (degrees) on vertical axis between the carving and skidding turn

Segment Pairing	Mean±SD		Paired t-test results	
	Carving turn	Skidding turn	t-value	*p*-value
Lower spine-ski	33.65±5.66	20.46±5.17	8.008	.000*
Pelvis-ski	11.52±1.66	9.55±1.31	3.728	.003*
Thigh-ski	20.48±2.29	8.21±1.12	18.518	.000*
Shank-ski	5.88±0.90	3.29±0.61	8.158	.000*

Note: *p<.05, significant difference.

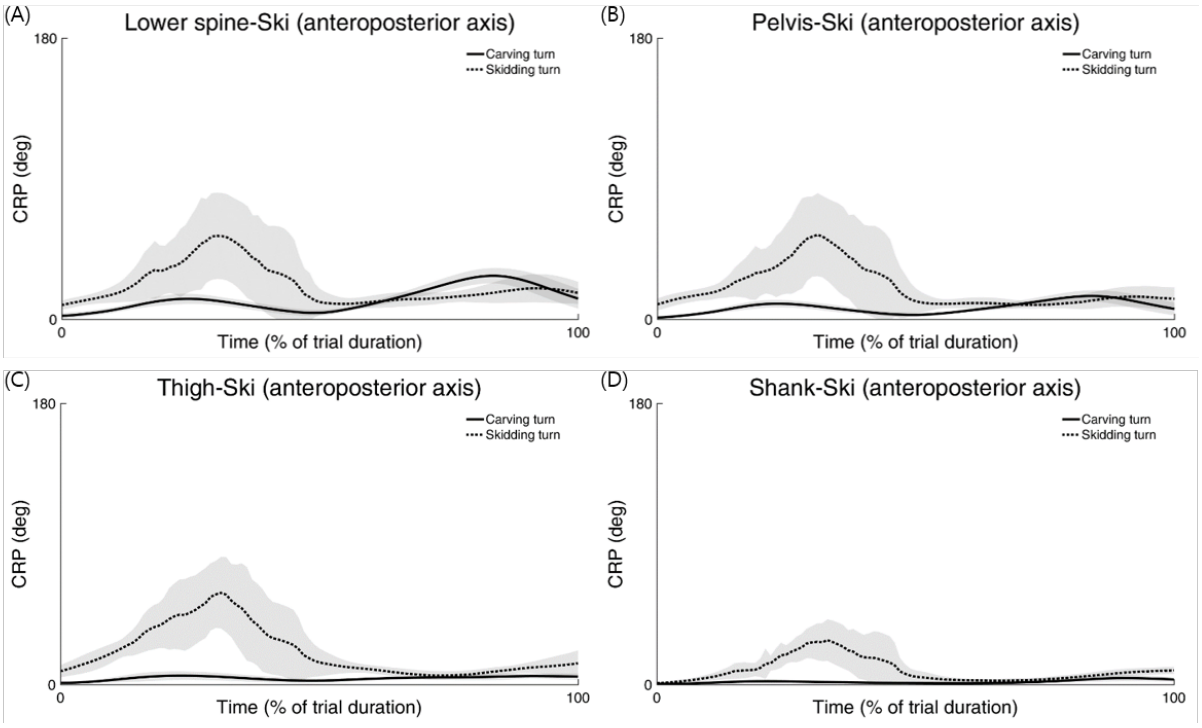

Figure 2: CRP curves between segments and ski on anteroposterior axis during carving turn (solid line) and skidding turn (dot line). Average ± standard deviation (grey area) through a skiing cycle (0-100%) for (A) lower spine-ski, (B) pelvis-ski, (C) thigh-ski, (D) shank-ski.

Table 2: CRP angles (degrees) on anteroposterior axis between the carving and skidding turn

Segment Pairing	Mean±SD		Paired t-test results	
	Carving turn	Skidding turn	t-value	*p*-value
Lower spine-ski	14.51±6.77	22.45±8.85	-3.805	0.022*
Pelvis-ski	7.69±1.19	20.04±7.24	-6.337	0.000*
Thigh-ski	4.08±0.94	20.75±7.26	-8.661	0.000*
Shank-ski	1.82±0.64	9.00±2.08	-12.802	0.000*

Note: *p<.05, significant difference.

DISCUSSION: CRP angle is usually presented as 0° to 180°. 0° indicates that the respective segments are moving in-phase, while 180° indicates the segments are anti-phase. Any angle between these extremes indicates a relative amount of in-phase or anti-phase. In alpine skiing, all the segments rotate in the same direction as the ski is rotating. Therefore, based on the results of this study, the row CRP angle between 2° and 30° showed that the coordinative pattern between segments and ski are in-phase. However, despite the low overall CRP angle, there was a statistically significant difference between the carving turn and the skidding turn. On the vertical axis, the coordinative pattern between all the segment and ski in the carving turn were closer to an anti-phase coupling than in the skidding turn. It seems that the lower spine and pelvis rotate in the opposite direction of the turn relative to the ski, because skiers perform a larger angle of counter rotation position to make larger edging angle in the carving turn than in the skidding turn. The thigh and shank showed a similar movement to ski during the skidding turn, while the opposite movement was observed during the carving turn because the thigh continuously rotates from internal to external at a large angle relative to ski during the whole skiing phase and the shank rotates from external to internal relative to ski. These movements are explained by the knee angulation. Knee angulation is defined as a projection of the knee angle to the plane perpendicular to the

velocity of the center of mass and is the cranking motion of the knee joint without changing the center of mass and used mainly to grip the snow surface (Bere et al., 2011; LeMaster, 2010; Supej, 2010). Therefore, during the carving turn, skiers use a larger angle of the knee angulation to grip the snow surface (to prevent side sliding) than during the skidding.
On the anteroposterior axis, the coordinative patterns between all the segments and the ski in the skidding turn were closer to anti-phase coupling than in the carving turn. Since, the carving turn is dependent only on the bending of the ski compared to the skidding turn, all the segments showed a similar movement to that of the ski. On the other hand, the skidding turn is dependent on the side sliding using the attack angle during the steering phase before the fall-line (steering phase 1) and on the gripping the snow using a reasonably large edging angle to prevent excessive skidding during the steering phase after the fall-line (steering phase 2; Müller et al., 1998). Therefore, all the segment showed an opposite movement to ski during steering phase 1 and a similar movement to ski during steering phase 2.

CONCLUSION: This study examined coordinative patterns between lower spine, pelvis, thigh, shank, and ski using continuous relative phase during alpine skiing. The coordinative pattern on the vertical axis between all the segments and ski were closer to anti-phase coupling in carving turn than in the skidding turn. On the other hand, the coordinative pattern on the anteroposterior axis between all the segments and ski were closer to anti-phase coupling in the skidding turn than in the carving turn. We, therefore, conclude that these coordinative patterns between segments and ski make a counter rotation position, leg rotation and knee/hip angulation to control the attack angle and the edging angle. We suggest that skiers should focus on the coordinative pattern of segments relative to the ski when they perform the carving turn and the skidding turn. Future studies should examine whether the variability of angular kinematic data and coordination are different between turning techniques to demonstrate the stability and the flexibility of turning techniques.

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