C2-2 ID154

LOWER EXTREMITY KINEMATICS OF SKI MOTION ON HILLS

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This research study aimed to collect thre- dimensional joint angles of the lower extremity during a basic ski motion in order to provide more quantitative teaching guide-lines for ski instructors. Eleven infrared cameras were placed to cover the capture volume of three different stopping movements (e.g. “Pflug Fahren”) on hills. Six ski instructors participated in the test. Three trials of each stop were selected for comparison. Based on the results, skiers tended to use the edge of the ski and maintain a wider “V” shape at the shortest stop distance (e.g. 2m) compared to the other stops. Also, each skier had to invert the foot with a less flexed and more abducted knee and hip position as the stopping distance was decreased. This information will be useful for the development of more objective teaching guide-lines for beginner skiers.

KEY WORDS: ski motion, Pflug Fahren, edge angle, ski angle, joint angles.

INTRODUCTION: Biomechanical research on skiing has been actively conducted for the last several decades coinciding with advancement in accurate measurement. However, the interests of these studies mainly focused on high-level skiing techniques such as turning in alpine environments (Mullter & Schwameder, 2003). In addition, high costs and the time-consuming process of biomechanics motion analysis as well as the difficulties of set-up for testing in snowy conditions challenge research activities. To our knowledge, only a few ski studies using three-dimensional research exist because of the complexity involved in carrying out experimental research. Furthermore, a gap between existing skiing research and practitioners in teaching, coaching and training seems to exist compared to other area. Thus, the contribution of a basic ski analysis to the general population would be meaningful but there are no quantitative teaching guidelines and not much biomechanical information for ski instructors or beginners. This research aimed to provide more quantitative information to ski instructors using a three-dimensional analysis of a basic ski motion on hills using infrared high speed cameras and an insole pressure device.
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METHODS: Six certified level II ski instructors (age: 25.3±1.5yrs, height: 169.3±2.9cm mass: 66.2±5.9kg, career: 4.2±2.9yrs, boot size: 265mm) participated in the test. These subjects were selected based on instructors‘ criteria by a highly skilled ski demonstrator among a group of ski instructors and patrols for the test.
Eleven high speed cameras (Oqus 300, Qualiysis, Sweden) with a sampling frequency of 100 Hz were used to capture ski motion on the hill (average temperature: -10°, average slope: 9°-10°, Figure 1). Cameras were placed to cover a capture volume covered an area of 3.5 meters wide by 8 meters long on the hill. Long slip pressure insoles (Novel, Germany) that were designed for high top boots were used at a sampling frequency of 50 Hz. Testing was conducted over three days, the 7th to the 9th of January, 2013. All testing equipment was delivered to the top of the ski hills by research staff using the gondola. Experimental setup was prepared during the day and testing was done in the early evening. The testing area was groomed by ski hill groomers in the morning of all test days. All wires were covered with insulated sealed tubes to protect them from weather damage. A total of eight plastic poles,

which were usually used for ski races, were placed to identify the capture volume (Figure 1). The first pair of poles at the top of the hill was used to show the skier where to start using the ski edge and where to stop at three different distances (e.g. 2m, 4m, and 6m).

Figure 1: Experimental setup on hills.

Forty three reflective markers were attached to the subject. Cluster markers for the whole body were applied to create a 3D model. Four markers (Figure 2 right) on the ski plate, (two markers at the front and two markers at the back of the plate (Rossignol, Frence)) on each side, were attached to calculate edge angle and ski angle during movement. A neutral trial was collected that saw the skier stand on a levelled wooden board in a standard postion (Figure 2. left). A joint coordinate system (x: internal and external rotation axis, y: ab-adduction axes, and z: flex-extension axis) was applied to describe three dimensional joint angles with respect to the neutral angles. Global axis, indicated by x: medial-lateral axis, y: anterior- posterior axis, and z: vertical axis, was set in the middle of the capture volume using an“ L“ shape frame on the levelled wooden board.

Figure 2: Reflective markers on a skier and marker placements on the boot and the ski plate.

The subject was prepared with the attachment of reflective makers on their ski suit (Rossignol, French) before being tested by the research staff. The subject was instructed to perform a run while maintaining a “V“ shape with their skies before stopping, known as “Pflug Fahren (Figure 3)“, at three different stop locations (e.g. 2m, 4m, and 6 m) in the capture area. They performed a few practice runs on the slope as a warm up before testing. The skier started their run 20 meters from the capture area on hills. The speed of the skier before the first line was controlled at 3.5m/sec using timing lights (Seedtech, KOREA). Three trials for each stop distance were averaged for comparison of joint angles between the three conditions. Three dimensional joint angles, ski edge angle of the right leg, and ski angle (the angle between the two skies) were calculated using two software packages (Visual 3D, C-Motion, USA; Matlab, MathWorks, USA). Repeated measures ANOVA with Bonferroni post doc adjustment using a statistical software package (SPSS 18.0, IBM SPSS, USA) were applied at an alpha level of 0.05.

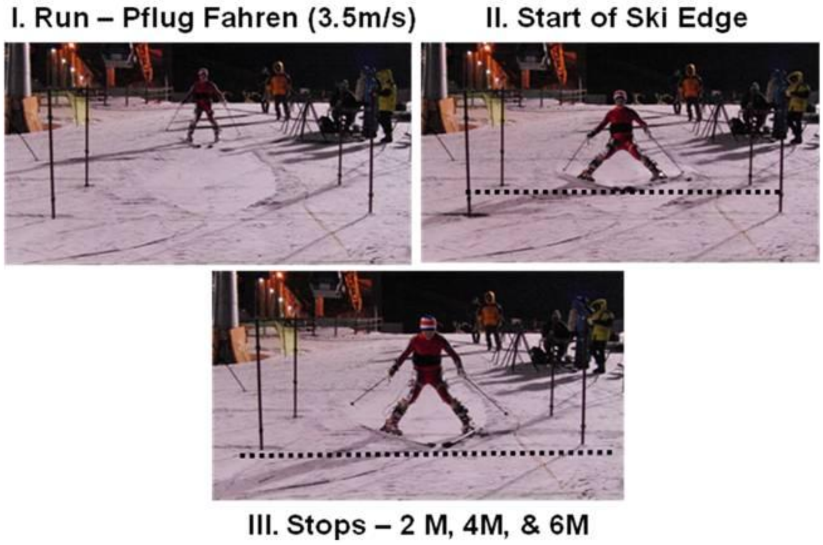

Figure 3: Tested basic movement of skiing known as “Pflug Fahren” on hills.

RESULTS: Figure 4 shows the comparisons in joint angle between the different stops.

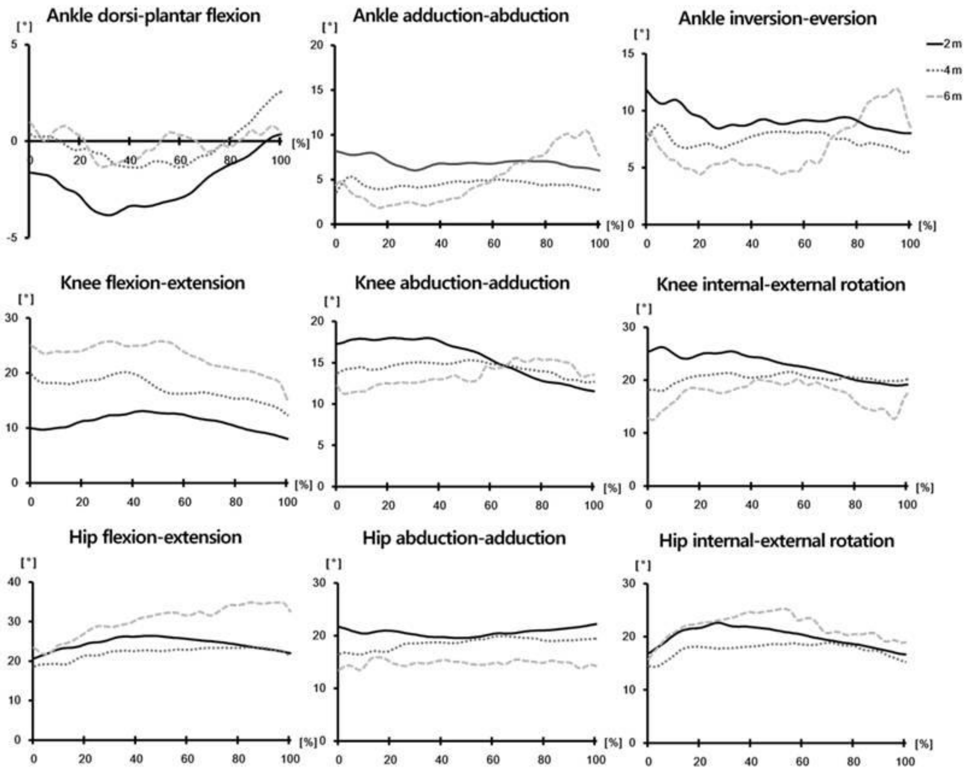

Figure 4: The comparison of 3D joint angles of the right leg between different stop distances in the normalized distance (100%).

Table 1 shows the changes in joint angles depending on the stop distances. Significant differences were found in the mean edge angle (Figure 5, p=0.04), peak ski angle (Figure 5, p=0.01), and mean ski angle (p=0.02) between the 2 m and 4 m stops. Also, the differences in mean ankle plantar flexion were observed between the 2 m and 4 m stops (p=0.01). There were differences in mean knee flexion and abduction angles between the 4 m and 6 m stops (p=0.05, 0.04, respectively). Finally, differences in mean hip abduction were found between the 2 m and 6 m stops (p=0.05).

Table 1
Differences in ski and joint angles of right leg between three different conditions

VARIABLES (°)		PEAK			MEAN		
		2 M	4 M	6 M	2 M	4 M	6 M
SKI	**Edge**	41.45 ±7.08	31.58±5.26	41.46±3.91	34.28±5.37*	25.85±3.66	26.67±1.57
	Plate	75.24±3.62*	65.78±2.57	64.87±3.89	67.22±4.10*	57.73±4.48	56.64±3.67
ANKLE	**D/PFlex**	1.29±3.20	3.21±1.92	3.57±2.83	-2.25±2.80*	-0.26±2.69	-0.08±3.00
	Add/Ab	10.48±5.34	8.64±3.20	14.38±8.14	6.92±3.59	4.49±2.71	5.07±3.64
	Inv/Ev	13.54±5.65	11.27±2.59	14.82±4.65	9.21±3.25	7.45±1.71	6.81±3.83
KNEE	**Flex/Ext**	16.10±10.33	22.88±6.84	28.05±6.15	11.09±10.16	17.14±6.77**	23.07±6.61
	Ab/Add	19.82±6.84	17.75±5.53	19.86±5.42	15.69±5.53	14.36±3.75**	13.47±1.92
	IR/ER	29.39±8.56	25.45±5.26	27.78±4.99	22.86±8.06	20.35±5.51	17.35±2.95
HIP	**Flex/Ext**	28.65±11.11	25.70±11.13	37.40±6.43	24.44±9.97	22.11±10.72	30.33±4.09
	Ab/Add	24.67±1.97	22.32±2.07	20.73±4.55	20.61±3.21	18.59±2.09	14.78±3.47†
	IR/ER	23.79±3.85	20.74±5.80	29.10±3.33	20.02±5.17	17.64±5.20	21.90±4.77

*: Differences between 2M and 4M, **: Differences between 4M and 6M, †: Differences between 2M and 6M.

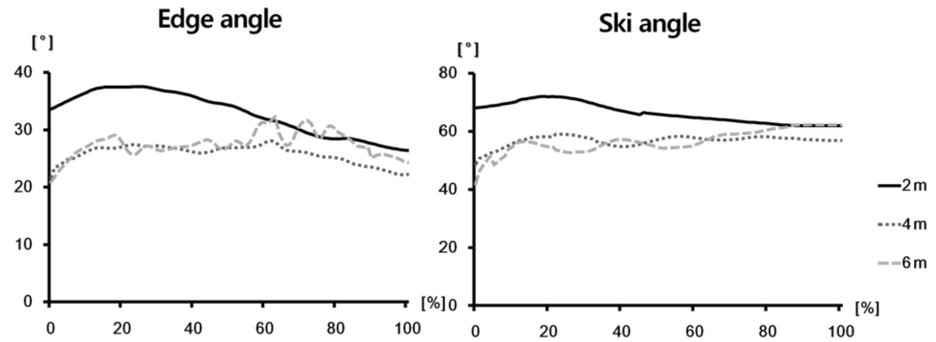

Figure 5: Comparisons in edge and ski angles in different distances.

DISCUSSION: Based on the findings, the skiers tended to increase edge and ski angles especially at the 2 m stop compared to the other two stops. The skiers showed less flexion but a more abducted knee and hip motion during a sudden stop such as the 2 m stop compared to the 4 m and 6 m stops. On the other hand, the foot (or boot and ski when observed as one rigid segment) tends to be more inverted at 2 m stops compared to 4 m and 6 m stops. This result would have been supported by pressure data if the centre of pressure had been located on the lateral side of the foot rather than the medial side.

CONCLUSION: Our data should provide meaningful information for setting up teaching guidelines for ski practitioners. Further analysis will continue to investigate the biomechanical characteristics of other techniques such as turning and jumping, including pressure patterns and muscle activations.

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Acknowledgement

This research project was supported by the Sports Promotion Fund of Seoul Olympic Sports Promotion Foundation from Ministry of Culture, Sports and Tourism.